Safety of Radioactive Waste Disposal

Proceedings of an International Conference

Tokyo, 3–7 October 2005

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SAFETY OF RADIOACTIVE WASTE DISPOSAL

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FOREWORD

The prevailing opinion of experts in the field of radioactive waste management is that radioactive waste should eventually be isolated from the human environment until it has lost most of its hazard as a result of radioactive decay. The preferred means of achieving this for high level waste and spent fuel is by deep underground disposal. For waste of low activity and short half-life, surface or near surface disposal is the generally preferred approach and it has already been adopted in many countries. Programmes to implement the preferred solution for high level waste and spent fuel have been active in many countries for up to two decades but progress has been slow due to failures to obtain acceptance of proposed disposal sites by local communities. A key issue has been concerned with providing evidence that the proposed radioactive waste repository will be safe and that it will provide protection for future generations living nearby. This is a challenging issue mainly because of the long timescales involved.

With this background, the International Atomic Energy Agency, co-sponsored by the OECD Nuclear Energy Agency, organized an international conference on the Safety of Radioactive Waste Disposal in Tokyo, from 3 to 7 October 2005, to review developments in the field and to promote the exchange of information between experts in its Member States. The conference explored the subject through eight sessions: the global waste safety regime, national strategies to ensure the safe disposal of radioactive waste, the safety case and confidence building, geological disposal facilities, near surface disposal facilities, options for intermediate depth disposal, new facilities, reassessment of existing facilities and decision making on upgrading the safety of radioactive waste disposal facilities, and communicating the safety of radioactive waste disposal facilities. This publication, which constitutes the record of the conference, includes the opening and closing speeches, the invited papers, the summaries of the discussions during the sessions and during the panel sessions and a summary of the conference. A CD-ROM containing the unedited contributed papers to the conference can be found at the back of this book.

Since 2000, the IAEA has organized a series of conferences and symposia on the safety of radioactive waste management. They have addressed the safety of radioactive waste management (Cordoba 2000), issues and trends in radioactive waste management (Vienna 2002) and the disposal of low activity radioactive waste (Cordoba 2004). The Tokyo conference is the latest in the series and the first held in Asia that focuses on the safety of radioactive waste disposal.

The IAEA gratefully acknowledges the support and generous hospitality of the Government of Japan through the Nuclear and Industrial Safety Agency (NISA) of the Ministry of Economy, Trade and Industry (METI), and the support of the Japan Nuclear Energy Safety Organization (JNES).

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SUMMARY

1. BACKGROUND

Radioactive waste disposal continues to be high on the political agenda of many countries, and while considerable experience has been obtained in operating repositories sited near the Earth's surface for low and intermediate level waste, the geological disposal of high level waste and spent fuel has yet to be demonstrated. Nevertheless, tangible progress towards the opening of geological repositories is being made in several countries — such that the first geological repositories can be expected to be operating within the next decade. A key issue in all programmes concerned with repository operation and development is the need to demonstrate long term safety and this was the focus of the international conference held in Tokyo.

Since 2000, the International Atomic Energy Agency (IAEA) has organized a series of conferences and symposia on the safety of radioactive waste management. They have addressed the safety of radioactive waste management (Cordoba, 2000) [1], issues and trends in radioactive waste management (Vienna, 2002) [2] and the disposal of low activity radioactive waste (Cordoba, 2004) [3]. The Tokyo conference was the latest in the series and the first held in Asia that focused on the safety of radioactive waste disposal.

2. GLOBAL RADIOACTIVE WASTE SAFETY REGIME

The entry into force of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management in 2001 was an important step forward in raising the importance of the subject at the international level. By becoming Contracting Parties to the Convention, countries have given legally binding commitments to manage their radioactive waste safely and in accordance with internationally established principles.

Participants at the conference discussed the benefits to be obtained from being part of the Convention and ways in which more countries could be encouraged to join — so that the Convention can become truly global and able to properly fulfil its objectives. The existing Contracting Parties and the IAEA were encouraged to be inventive and flexible in looking for ways to attract new countries.

There has been good progress, in the last year, in the development of international safety standards — with the publication of the long awaited standards addressing the subjects of (a) clearance of materials containing low levels of radionuclides from regulatory control and (b) the safety of geological disposal. It was noted that the ways in which the standards are used by countries varies; some countries use the standards directly and incorporate them into their own regulations, while others use them as a basic reference for developing their regulations. The standards are increasingly seen as representing best practice in the field rather than, as was often the case in the past, the lowest common denominator.

Various regional initiatives were seen as evidence of movement towards a global approach to safety, for example, the information networks established in Asia and Latin America and the increasing use, by countries, of the peer review services of the international organizations. In this regard, the proposal of Japan to expand the Asia Nuclear Safety Network to include radioactive waste management was welcomed by the conference.

3. INTERNATIONAL AND REGIONAL STRATEGIES

The most appropriate disposal solutions for the different types of radioactive waste vary depending on the nature of the waste and range from disposal on, or near, the surface to disposal deep underground. This is reflected in the IAEA's 1994 Classification of Radioactive Waste. However, the 1994 classification is not comprehensive and is scheduled for updating. As described at the conference, an input to this process, a common framework project has been under way for some time at the IAEA. It is aimed at determining, mainly from the perspective of hazard, the most appropriate disposal solution for each major waste type.

Many countries have comparatively small volumes of intermediate and high level radioactive waste. It would be disproportionately costly for each of them to develop its own geological repository. For this reason, studies have been initiated at a regional level, supported by the European Union, to examine the feasibility of a regional repository in which the waste from several countries could be placed. However, no potential site has yet been identified. The issue is sensitive for some countries because it is considered that it might undermine their own national disposal projects. On the other hand, regional repositories could be attractive from nuclear safeguards and security perspectives (and in line with such initiatives at the IAEA). The discussions at the conference reflected the division of opinion on this subject.

4. GEOLOGICAL DISPOSAL

The main popular focus continues to be on the geological disposal of high level waste. The good progress of recent years towards achieving operational geological repositories is continuing in several countries and reports from three of them were made at the conference.

The technical discussions at the conference focused on some of the remaining philosophical difficulties. In the context of geological disposal, because of the long timescales involved, it is not possible to demonstrate safety directly and recourse must be made to other, less direct, evidence. The approaches being used to make the ‘safety case’ for these repositories and to improve confidence in it were discussed.

Providing for protection of the public at long timescales, far beyond the lifetimes of current generations, requires the use of predictive models and stylized scenarios to show compliance with radiological criteria. The subject is difficult and the existing international radiological guidance is being variously interpreted in different countries. The subject would therefore benefit from further international guidance.

5. NEAR SURFACE DISPOSAL

More than one hundred repositories of the near surface type are in existence in the world and they account for the main part, by mass and volume, of the disposed radioactive waste. They are used mainly for the disposal of low and intermediate level waste of short radioactive half-life. They vary in quality and some are currently being upgraded to bring them into compliance with modern standards.

The approach for designing near surface repository systems to achieve safety is well established. For such systems, compliance with the international radiological protection criteria can be achieved by a combination of engineered barriers and institutional controls to prevent inadvertent intrusion into the waste. This contrasts with the situation at the sites at which large volumes of waste from the mining and milling of radioactive ores or from other industries producing waste containing natural radionuclides have been deposited on the Earth’s surface. At these sites, the radiation exposure of local populations is often in excess of radiation protection limits for members of the public. Because of the large volumes, the practical protection measures which can be taken are limited. International guidance on their safe management is not yet adequate and it was recommended that it should be improved based on, in the first instance, the experience described at the conference.

6. INTERMEDIATE DEPTH DISPOSAL

Work on some types of disposal at intermediate depths (typically 50–100 m) was presented. It was emphasized that the safety principles and methods for assessing safety are no different from those used for other types of disposal.

Ongoing international projects to help remove the global problem of disused sealed radiation sources by the technique of borehole disposal were described. Although the approach promises to be much less costly than alternatives, such as near surface and geological disposal, it was stressed that safety would not be compromised and that international standards would be respected. An important next step for general acceptance of the technique is for a borehole system to be licensed and then operated in one or more countries. There was general support for the approach as having the potential to solve a real problem existing in many countries in the world.

7. COMMUNICATING THE SAFETY OF RADIOACTIVE WASTE DISPOSAL

A lesson learned from the early years of radioactive waste disposal is that it is difficult to make progress with the development of repositories, and especially high level radioactive waste repositories, without involving those who may be affected in the decision making process. Several experiences of how the communications with affected parties have been managed in national projects were described during the conference. From these it is clear that it is now generally recognized that openness, trust and participation are all essential in such communication. The importance of using all available approaches and techniques for communication was also emphasized.

The discussions at the conference showed the need for clarity in the language used for the communications between experts in this field but also of a need for a simpler, but accurate, language for communicating with non-experts.

At this conference a first attempt was made to involve the public in an event of this type; the public were allowed to attend in the sub-hall of the conference building and, in addition, the events in the main conference hall were made available ‘live’ on the Internet.

8. THE FUTURE

Demonstrating the long term safety of radioactive waste repositories remains as a challenge but the experience gained in safety studies over the past years in many countries has generated an ever increasing confidence among implementers, regulatory authorities and other stakeholders that the current designs of repositories can safely isolate radioactive waste for the times necessary to provide protection of humans and their environment.

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OPENING SESSION

(Session I)

Chairperson

K. ISHIGURE
Japan

OPENING ADDRESS

K. Hirose
Director General
Nuclear and Industrial Safety Agency,
Tokyo, Japan

On behalf of the Nuclear and Industrial Safety Agency (NISA), I cordially welcome everyone to this international conference on the Safety of Radioactive Waste Disposal. The IAEA conferences in this series have become increasingly acknowledged as important international fora where representatives of regulatory bodies, disposal facility operators and experts come together from around the world to discuss safety issues related to radioactive waste management and disposal. Japan is grateful for the opportunity given to the Nuclear and Industrial Safety Agency to host this conference.

We express our gratitude to the IAEA, the organizer and sponsor of this International Conference and the OECD/NEA, the co-sponsor, as well as to all the members of the Programme Committee who have worked so hard to organize the conference. I would also like to note that the Japan Nuclear Energy Safety Organization (JNES) and other related agencies and entities in Japan have contributed to the staging of this conference.

As a result of the reorganization of governmental agencies in 2001, the Nuclear and Industrial Safety Agency was established as the administrative body responsible for the safety of nuclear facilities ranging from nuclear power plants to nuclear fuel cycle facilities and for industrial safety in the electricity generating industry, the gas industry and the mining industry.

I would like to describe the current status of radioactive waste disposal in Japan, including the problems we have to address, and to set out Japan's basic position on international activities in this area. I would also like to touch upon our expectations for this conference.

A basic policy in Japan is for spent fuel to be reprocessed. Consequently, only vitrified residue canisters, a solidified form of residue resulting from reprocessing, are classified as high level radioactive waste; other types of waste are classified as low level radioactive waste.

The Specified Radioactive Waste Final Disposal Act of 2000, which regulates the disposal of high level radioactive waste, prescribes certain procedures, such as those for establishing an implementing organization, and those for site selection. It established the Nuclear Waste Management Organization (NUMO) as its implementing organization, and NUMO has begun open solicitation for candidate sites. The Specified Radioactive Waste Final Disposal Act calls for the enactment of a law for the disposal of high level radioactive waste that is separate from the law that is now in force for the safe disposal of low level radioactive waste. To that end, the Nuclear and Industrial Safety Agency (NISA), is now considering the legal framework for safety regulations through a committee chaired by K. Ishigure, who also is serving as the President of this conference. NISA is also engaged in research, the results of which are to serve as the basis for future safety reviews and new standards.

Low level radioactive waste generated from the operation of commercial nuclear power plants has been buried at a disposal facility in Rokkasho in the Aomori Prefecture since 1992. The disposal facility and its waste are subject to safety supervision by NISA and the Japan Nuclear Energy Safety Organization (JNES). A technical tour of this facility is scheduled as a side event of this conference. Japan has one commercial nuclear reactor undergoing decommissioning. However, seven of the currently operating commercial nuclear reactors are over 30 years old, and we will eventually face the major challenge of instituting safety regulations for decommissioning and for the waste that may result from dismantling. With regard to the large volumes of waste with a very low radionuclide concentration, including concrete and metal scrap, the Law Regulating Nuclear Source Material, Nuclear Fuel Material and Reactors (the Reactor Regulation Law) has been amended to introduce a clearance scheme whereby such waste can be disposed of, or recycled as normal non-radioactive waste, depending on the results of concentration measurement and evaluation by the operator and by the regulators. The electric utilities are also preparing disposal plans for waste containing relatively high concentrations of radionuclides, such as reactor core internals, channel boxes and burnable poisons.

A reprocessing plant will shortly come on-stream in Japan. There is also a plan being developed to construct a mixed-oxide fuel processing facility. For the waste containing long lived transuranic nuclides (TRU) generated from these facilities, suitable disposal methods have been proposed. There is thus an urgent need for the regulatory agency to develop safety standards appropriate to the proposed disposal methods.

In Japan, limits on radionuclide concentration for disposal and guidelines for safety review have normally been developed for particular waste generating facilities and waste types. However, in view of the future need to dispose of diverse types of radioactive waste, we think it is desirable to establish regulatory limits and standards as part of the process of constructing a common framework for disposal. A detailed study, for this purpose, has been initiated, primarily by the Nuclear Safety Commission (NSC). The agenda of this conference encompasses geological disposal, near surface disposal and intermediate depth disposal, and we anticipate that the discussions about to take place here on these subjects will provide useful information for our study.

Since its creation, the Nuclear and Industrial Safety Agency (NISA) has been represented on OECD/NEA committees, such as the Committee of Nuclear Regulatory Activities (CNRA) and the Radioactive Waste Management Committee (RWMC). It has also participated in the development of international nuclear safety standards through its involvement in the IAEA Commission on Safety Standards (CSS). The outcome of such involvement has been reflected in our national regulations. We will continue these efforts with the aims of attaining a high level of safety internationally and of achieving scientific rationality. In parallel with these efforts, NISA, as a regulatory body of a nation with a large nuclear programme, has also supported the safety enhancing efforts of other Asian countries.

In the field of radioactive waste management, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) is acknowledged as an important mechanism for promoting and encouraging the safety of radioactive waste disposal worldwide. Japan hopes to contribute to the success of the second review meeting scheduled to be held next year.

Aside from the Joint Convention, the Safety Standards now being systematically developed by the IAEA are also considered to play a very important role. The following are examples of the latest international standards adopted into the Japanese regulatory system. With regard to radioactive materials, excluding nuclear fuel materials, the Law for the Prevention of Radiation Hazards due to Radioisotopes, etc. was amended in 2004 to incorporate the exemption levels of the International Basic Safety Standards. When we introduced the concept of clearance this year, the IAEA Safety Guide RS-G-1.7 was used as the basis for the clearance levels now used in Japan. We believe that making the Japanese standards consistent with the international standards will contribute to increasing public confidence in the safety of radioactive waste management in Japan.

For this reason, we have decided to take an active part in the early stages of the development of international standards. In so doing we have in mind our own national circumstances and take account of the fact that the resulting international safety standards are likely to be adopted as part of our national regulations. With the help of this process, Japan will develop the basic principles for safety assurance and the regulatory standards for the disposal of high level radioactive waste and other types of waste.

This is the first time that an IAEA sponsored conference on the subject of radioactive waste disposal safety has been held in Asia. As you may know, Asian countries are implementing many programmes in the field of nuclear power generation and also in the fields of medical, industrial and agricultural applications of radiation. In undertaking these programmes, all of the concerned countries agree that the safe management and disposal of radioactive waste is a critically important issue. It is also true, however, that not all of these countries have had a great deal of experience in radioactive waste management and disposal. One of the reasons why we are hosting this conference in our country is the hope that the information exchange among participants at the conference will encourage improved actions for safe radioactive waste management and disposal in Asian countries.

Japan is a major donor to the IAEA extra-budgetary programme known as the Asian Nuclear Safety Network Programme. This programme is intended to accumulate and share nuclear safety related knowledge and experience in Asia. Its goal is to enhance nuclear safety performance in the region by building an infrastructure for nuclear safety. Since 2004, the Asian Nuclear Safety Network (ANSN) has played a vital role in providing information and human resources. In the fields of education, training, operational safety and safety analysis, beneficial results have been achieved through cooperation, and the scope of such cooperation is expanding further to encompass other fields, such as safety management, including safety culture, a code of conduct and nuclear disaster countermeasures. Prompted by this conference, Japan would like to propose expanding the scope of this ANSN activity, so as to address the issue of radioactive waste management and disposal. We would appreciate having discussions on this proposal at the conference and receiving such useful suggestions as you may make.

In conclusion, I wish to express my best wishes for the success of this five day meeting and hope that all the participants from abroad will thoroughly enjoy their stay in Japan.

OPENING ADDRESS

K. Ishigure
Saitama Institute of Technology,
Saitama, Japan

First of all, let me welcome all participants to this conference, especially those from distant countries. I would like to express my sincere thanks to the IAEA for planning and sponsoring this conference, as well as to the OECD/NEA, for co-sponsoring the event. I would also like to welcome our distinguished guests, IAEA Deputy Director General, Tomihiro Taniguchi and OECD/NEA Deputy Director, Takanori Tanaka. It is a great honour to have the opportunity to preside over such a prestigious and important international conference.

The 'Odaiba region', where this hall is located, has been redeveloped in recent years to become a new town, full of modern buildings. The name 'Odaiba' comes from the 1850s, the late Edo era, when Japan was still adhering to a policy of national isolation. The name came from the fort constructed to protect Edo, the present Tokyo, from the attack of foreign countries, then pressing Japan to abandon her isolationist policy and to open up the country to trade. The first American frigates approached Japan near to this site in 1853. It seems somehow appropriate to be holding this conference here, with many foreign guests attending, and to be dispatching important messages to the world from a site with such historical background.

We expect more than 300 participants from some 60 countries and 3 international organizations to attend this conference, to discuss various global problems concerned with the safety of radioactive waste disposal. Among the foreign participants, there are more than 50 from Asian countries not including Japan, constituting the largest number of participants from any region.

In addition to the invited papers, which will be presented during the sessions of the conference, more than one hundred papers have been submitted from over 40 countries. Among them, about 50 are being exhibited as posters and I hope you visit them, though summaries of them will be reported by the rapporteurs in each session. Panels and information packages from relevant companies and organizations are also on display and I hope that you will find time to visit them.

Needless to say, the disposal of radioactive waste is an issue of vital importance being faced today by every country developing and utilizing nuclear power. A number of transborder initiatives are now under way aimed at executing the basic principles of the safe disposal of radioactive waste. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management entered into force in 2001. This Convention has provided an international framework for attaining high levels of safety in the management and disposal of radioactive waste. At nearly the same time, the IAEA sponsored international conferences held in Cordoba, Spain, in 2000 and in Vienna, in 2002, to exchange information and to discuss the problems of the safe management and disposal of radioactive waste among specialists from various countries. This meeting is intended to provide a view of the future of radioactive waste disposal from an international perspective — from the starting point of the results of the past conferences.

The previous conferences were held in Europe and I would like to note the fact that an IAEA conference on this subject is being held in Asia for the first time. I think this is quite appropriate considering that 20% of the world's nuclear power plants are being operated in this region, and more than half of the nuclear power plants under construction and in planning are concentrated here in Asia. The large number of participants from Asia is an indication of the great interest of these countries in this problem. Asian countries will face their own radioactive waste disposal problems in the very near future and the participants from Asia may see this conference as a good opportunity to share and make use of the experiences of the other countries.

Following the opening session of the conference, there will be keynote speeches and panel discussions on the themes covered by the three main sessions. Though the contents and conclusions of each session will, of course, be described and summarized by the respective chairpersons and participants themselves, I would like to convey my own personal interests and expectations in this regard.

The title given to Session II is 'Disposal Safety — International and National Perspectives'. Here, I look forward to sharing our recognition of the importance of the international framework for the safe management of radioactive waste and of its major components, the Joint Convention and the International Safety Standards. I then foresee discussion on what is to be done at the international and regional levels, particularly in the Asian region, to maintain and develop this framework in the future. Through the exchange of information on the approaches to radioactive waste disposal in the various countries, we expect a deeper understanding and recognition of the need for a common safety rationale to be applied to the diverse methods of radioactive waste disposal and, also, of the contents and role of the safety case.

Session III is entitled 'The Safety of Radioactive Waste Disposal Facilities'. It is composed of three subsessions divided according to types of disposal: 'Geological Disposal Facilities', 'Near Surface Disposal Facilities' and 'Options for Intermediate Depth Disposal'. Here we will be provided with the latest information on disposal programmes in various countries and we expect a lively discussion on the various issues pertaining to the safety of the respective disposal methods and on the measures for resolving them. With regard to geological disposal facilities, some countries are planning to apply for permits to construct facilities within the coming two to three years while other countries are focusing their attention on the experiences of these countries. It will also be interesting to hear the discussions on the rationales and safety arguments for the disposal of various types of radioactive waste at intermediate depths, including the borehole method of disposal that is currently under investigation.

Session IV is concerned with 'Regulatory Control and Communication of Safety Issues'. It will introduce valuable experience on the ways in which countries have dealt with the problems of re-evaluating and improving facilities built in the past. Communication with stakeholders on matters related to radioactive waste disposal is an issue faced by many countries, and the discussion on this may provide useful clues as to how regulatory authorities should respond to this matter.

With regard to the social aspects of the conference, receptions are planned this evening and on Wednesday evening, and I understand that a cultural event has also been arranged to be held during one of the receptions. In addition, thanks to the cooperation of the relevant operators, post-conference technical tours to a nuclear power plant currently being dismantled and to a low level radioactive waste disposal facility are scheduled after the final session of the conference. These events will provide good opportunities for further information exchange among the participants and should help in fostering the building of an international network of personal relationships.

I am sorry to say that due to the large number of participants, far exceeding our expectations for this conference, some participants will inconveniently have to take part via monitor screens in the sub-hall outside the main hall. As a new initiative, the public will be allowed to attend in the sub-hall and, in addition, the sessions in the main conference hall are being relayed live and on demand via the Internet, as a part of our plans for the active dissemination of information.

In conclusion, as President, I will do my utmost to make this conference serve as a forum for disseminating information on radioactive waste disposal safety to the international community, and would like to ask the subsession chairpersons, the keynote speakers, the panellists and all the participants to assist and join with me in this effort.

I would like to suggest that our foreign guests take this opportunity, as far as time permits, to touch upon Japanese culture and art, and to make this visit a truly memorable event.

KEYNOTE ADDRESS

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It is a particular pleasure to welcome you to Tokyo and to the IAEA—OECD/NEA international conference on the Safety of Radioactive Waste Disposal. I would like to thank the Japanese Government for agreeing to host this important meeting.

1. OVERVIEW

This conference could not be held in a more appropriate region of the world or at a more appropriate time. The world is experiencing record high levels of energy prices, economic growth rates in the Asian region and the associated energy demands are at unprecedented levels. Concern continues to grow globally over the rate of emissions to the environment from the burning of fossil fuels for energy generation.

The increasing use of nuclear energy is becoming a reality; the Russian Federation intends to double its nuclear generating capacity by 2020; China plans a near sixfold expansion in capacity by the same date; and India anticipates a tenfold increase by 2022.

Excellent progress has been made in upgrading the safety of nuclear installations and their management since the unfortunate events at Three Mile Island and Chernobyl. So that, in many countries nowadays, nuclear power stations are being accepted as familiar industrial facilities.

Nevertheless, with this increased utilization of nuclear energy comes the increased generation of radioactive waste. The generation of radioactive waste is not a new phenomenon, and the nuclear industry has been managing radioactive waste for over half a century — yet the question continues to be asked by society at large: “*Can radioactive waste be managed and disposed of safely?*”

Concern remains over safety in the management of waste arising from normal operations, in the decommissioning of facilities, as well as in the disposal of waste. These issues continue to give rise to societal concerns that must be addressed before people at large will feel comfortable with the large scale adoption of nuclear power — and so the debate continues.

This conference will explore the question with a view to identifying what needs to be done further, at both national and international levels, to ensure, and to provide assurances to all concerned parties, that the answer to this questions is unequivocally: "*Yes, radioactive waste can be safely managed and disposed of.*"

The conference will address the key questions related to the safety of radioactive waste management:

- International and national perspectives and the Global Waste Safety Regime — the Joint Convention, the International Radioactive Waste Safety Standards, national policies and strategies and their supporting legal and regulatory frameworks, and safety cases. *What is their status, value and benefit? Are they good enough? How can they be improved?*
- Disposal options and their safety — near surface, geological, intermediate depth disposal facilities. *How do we design them and how do we demonstrate their safety? Is this good enough?*
- Regulatory control — setting standards, evaluating safety arguments and safety assessments, establishing conditions of authorization, inspection and enforcement. *Is the evidence available to convince the regulator? Does the regulator have the tools and resources necessary to evaluate the evidence and make good decisions?*
- Communicating safety — engaging stakeholders — academics, politicians, the media, environmental interest groups, and the general public. *What are the successes? What are the lessons from the failures? Is there a universally correct approach?*

Based on the responses to these questions and the findings of the conference on these issues, the IAEA will review its programme of work and revise its action plan in the area of radioactive waste safety.

2. THE GLOBAL NUCLEAR SAFETY REGIME AND THE ROLE OF THE IAEA

Since Chernobyl, the importance of international cooperation in nuclear safety has become generally evident. The IAEA continues to support a global nuclear safety regime based on both binding and non-binding international legal instruments, the IAEA Safety Standards and strong national safety infrastructures.

2.1. Safety Conventions

One of the main roles of the IAEA in support of the global safety regime is in the administration of the international safety conventions. These include the Convention on Nuclear Safety, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention), the Convention on Early Notification of a Nuclear Accident, the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency and the Convention on the Physical Protection of Nuclear Material. The Conventions are formal mechanisms with binding commitments and obligations, but they also provide fora for expert communities to come together to contribute to and enhance the knowledge network on all aspects of nuclear safety, including radioactive waste management.

The last 12 months have seen changes to several of these Conventions. With India's accession to the Convention on Nuclear Safety, all countries operating nuclear power plants, as well as many neighbouring countries, are now parties to that Convention.

The Competent Authorities for the Early Notification and Assistance Conventions met in July and agreed on important improvements, and the Diplomatic Conference on amendments to the Physical Protection Convention has resulted in profound changes, which will provide a solid basis for the future.

More recently, internationally agreed instruments of a legally non-binding nature have been introduced, such as the Code of Conduct on the Safety and Security of Radioactive Sources in 2003, its related guidance on import and export in 2004, and the Code of Conduct on the Safety of Research Reactors in 2004. Due to their non-binding nature, Codes of Conduct may be introduced at a much faster rate than Conventions, as consensus can often be achieved without the prolonged and difficult negotiation process normally associated with the development of binding international conventions. However, if there is political commitment among the countries concerned, a solid scientific basis and an open and transparent process for reaching consensus, by the very character of their voluntary nature, these instruments can be just as effective at improving the level of safety.

The Joint Convention was developed as a sister convention to the Convention on Nuclear Safety. The Chernobyl accident in 1986 had so highlighted the global nature and importance of nuclear safety that countries involved and concerned with the nuclear industry came together, negotiated and agreed the International Convention on Nuclear Safety which came into force in 1994. The Convention represents a commitment to achieve and maintain high levels of safety worldwide through international cooperation.

The countries also agreed that the safety of radioactive waste, because of its potential long term and transnational safety implications, should also be the subject of an international treaty. However, they agreed that such a treaty could not be formulated until there was international consensus on the fundamental safety principles for radioactive waste management. The adoption of the Radioactive Waste Safety Fundamentals in 1995 as one of the top level documents of the International Safety Standards paved the way for such a development and negotiations started in the same year, culminating in the coming into force of the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management (the Joint Convention) in 2001. The Joint Convention calls for a high level of safety to be achieved in the management of radioactive waste and spent nuclear fuel. It calls for safety to be assessed and for the periodic peer review of national programmes of countries that are members of the Convention.

While the Joint Convention is a sister convention to the Convention on Nuclear Safety, with many similarities, there are also some important differences.

Only some of the IAEA Member States have operating nuclear power reactors, but virtually all States generate radioactive waste, which they have to manage safely. This makes the Joint Convention relevant, not only to States generating nuclear energy, but to all States. Contracting Parties are committed to working for improved safety in the management of radioactive waste but also to assisting other countries, particularly developing countries, in all matters related to waste safety. Another important difference is that the Joint Convention makes specific reference to the International Safety Standards and this has brought increasing attention to the waste safety standards as an international point of reference.

2.1.1. The Joint Convention

The Joint Convention:

- Is legally binding but incentive in nature, requiring a commitment to high levels of safety from its Contracting Parties;
- Is concerned with siting, design, development and operation;
- Requires assessment and demonstration of safety — for new and existing facilities;
- Requires national regulatory control and international peer review.

The first Review Meeting of the Joint Convention took place in November 2003 in Vienna and was attended by 350 persons from 33 countries. It revealed a wide variety of long term spent fuel and radioactive waste management policies, also legal and regulatory differences, and concerns over regulatory resources and independence. It also identified some particular areas where additional international standards are needed. Areas were identified by Contracting Parties for improvements in their own waste safety programmes; the areas for improvement included long term strategies, regulations, disposal facilities, control over disused sealed sources, legacy waste and site remediation, storage facilities, and existing disposal facilities.

In November 2005, the Organizational Meeting for the Second Review Meeting of the Joint Convention in May 2006 will be held in Vienna. The meeting will be preceded by an Extraordinary Meeting of the Contracting Parties in order to agree amended rules for the administration of the Convention. This reflects the ongoing efforts of the Contracting Parties to improve the Convention, taking account of areas identified for improvement at the First Review Meeting.

While the Convention is undergoing continuous review to improve its working methods and effectiveness, there is room for concern over the number of countries involved in the Convention. Presently, only 34 countries are Contracting Parties to the Joint Convention, although it is understood that some major nuclear countries are about to become Contracting Parties. This low level of participation is difficult to rationalize since virtually every Member State has radioactive waste to manage and should therefore have an interest in the Convention. I would like to take the opportunity to urge representatives from any countries that are not party to the Convention to discuss with myself or my staff any possible assistance that the IAEA can provide in helping national arrangements towards accession to the Convention Safety Standards.

While the safety conventions provide the overarching commitment by countries to nuclear safety on a global scale, the commitment has to be realized in a coherent and consistent manner by all parties. Even before the advent of the safety conventions, the need for and potential usefulness of international safety standards as a global point of reference was recognized by the countries that established the IAEA and who included in its founding statute a mandate for the IAEA to “establish or adopt … standards of safety for protection of health and minimization of danger to life and property … and to provide for the application of these standards”.

The process of developing safety standards for the management of radioactive waste started in the late 1950s and has evolved and developed continuously since that time. The evolution has reflected developments in the nuclear industry, sociopolitical changes and the increasing sophistication of the underlying philosophies on safety and risk management, together with increasing and improving scientific knowledge and technological development.

The first waste safety standard document published by the IAEA in 1961 was titled Radioactive Waste Disposal into the Sea. Many developments have taken place since that time:

— The world community, through the mechanism of the London Convention, 1972, finally decided to stop the disposal of radioactive waste into the sea at its meeting in 1993 (although a moratorium on ocean disposal had been in place since 1983) — land based disposal was thus confirmed as the reference technological approach.
— More than one hundred near surface radioactive waste disposal facilities for short lived low and intermediate level waste have been developed and operated throughout the world.
— Large amounts of uranium mine tailings have been stabilized on the Earth's surface, often in situ.
— Extensive research and development has taken place into geological disposal as an option for the disposal of long lived and high activity waste and a number of projects to excavate and operate such facilities are underway or in planning. One facility for long lived radioactive waste has been developed and is operating in the United States of America — the WIPP facility.

Of significance in the development of the safety standards, for nuclear, radiation, waste and transport safety, was the rationalization of their structure in the early 1990s. This led to a hierarchy of standards headed by Safety Fundamentals — basic safety principles, Safety Requirements — regulatory imperatives, and Safety Guides — recommended good practice.

In the aftermath of the Chernobyl accident, greater attention was given to the improvement of international safety standards and a more formalized process was adopted for their development and approval. These processes have not been static and, in the past few years, an in-depth review of the standards and their use has been carried out. This has led to a new vision and strategy for their future development and use. The new scheme has been adopted at the highest political level with the IAEA Board of Governors approving the vision and strategy in March 2003.

Achieving international consensus on the safety principles for radioactive waste management proved to be a long and difficult process — nevertheless when agreement was reached and the Radioactive Waste Safety Fundamentals document was adopted in 1995, it led to some developments that were to be of great significance. First and foremost, the Safety Fundamentals provided a logical and coherent basis for the future development of the radioactive waste safety standards — the Safety Requirements and supporting Safety Guides. As previously mentioned, it also enabled the process for establishing the Joint Convention to commence.

The suite of safety standards for the safety of radioactive waste management is well developed but not yet fully complete. A recent achievement in September 2005 was the approval and adoption, by the IAEA Board of Governors, of the Safety Requirements for Geological Disposal and the concurrent approval of the document by the Steering Committee of the OECD/NEA, which co-sponsored this standard.

2.2. Support activities of the IAEA: The international waste safety action plan

The IAEA undertakes a number of activities to assist countries in the use and application of safety standards for radioactive waste safety. Some of these activities provide for the development, expansion and management of knowledge on the safety of radioactive waste management through the establishment of knowledge networks for the expert communities involved. Some activities involve arranging international coordination projects, for example, developing safety assessment methodologies, organizing international conferences, workshops, symposia, seminars and training courses on waste safety, conducting international peer reviews on request and providing other assistance to Member States in support of their radioactive waste safety programmes. International peer reviews of the safety of radioactive waste management activities and facilities provide a powerful tool for giving safety assurance to organizations and the public in Member States. It is a tool that can be employed both by organizations developing and operating facilities and by regulatory authorities.

Throughout the period when the Joint Convention was under negotiation and beyond, the IAEA continued to support related developments in the waste safety area. In 2000 an international conference was convened in Cordoba, Spain, to consider issues that needed to be addressed at an international level pending the Joint Convention coming into force. It was followed by the Vienna Conference in 2002 and the Cordoba Symposium 2004. The conclusions from Cordoba 2000 led to the establishment of an International Radioactive Waste Safety Action Plan, which was endorsed by the General Conference of the IAEA in 2002 and updated in 2003. The Action Plan addresses a number of basic issues, including the need:

- For a common framework — to provide a logical and coherent linkage between all radioactive waste types and disposal options, respecting

international safety standards, technological realities, regulatory requirements and national policies;
- To identify suitable disposal options for disused sealed sources, waste with low levels of activity, long lived non-heat generating waste and waste containing naturally occurring radionuclides;
- To address the implications of the extended storage of radioactive waste — particularly the issues of safety and sustainability;
- To gain international consensus on the safety standards for Geological Disposal of Radioactive Waste (finally achieved in September 2005);
- To develop a structured and systematic way of ensuring worldwide adoption and use of the international safety standards;
- To develop mechanisms to identify and preserve knowledge and information important to the safety of radioactive waste disposal, and to transmit the information to succeeding generations;
- To involve all relevant parties in the decision making processes for the development and operation of waste management facilities.

Another group of activities undertaken by the IAEA in support of the radioactive waste safety standards are the coordinated projects dealing with safety assessment methodology and its application. In the 1990s a number of intercomparisons of safety assessment methodologies were carried out — with widely differing outcomes. As a result, the Improvement of Safety Assessment Methodology (ISAM) project was formulated to develop harmonized approaches to the safety assessment of near surface radioactive waste disposal facilities. Following the successful development of consensus on safety assessment methodology in this area, a follow-up project (Application of Safety Assessment Methodology — ASAM) was started and is presently addressing issues such as the application of safety assessment methodology to heterogeneous waste (including disused sealed sources), mining waste, existing facilities, regulatory review and decision making; in addition, common aspects, such as uncertainty, limited data availability, and performance of engineered barriers, are also being addressed.

3. THE PRESENT SITUATION AND THE FUTURE

Some of the recent positive developments in radioactive waste management can be listed as follows:

- Agreement has been reached on international standards for geological disposal;

— The licence application for Yucca Mountain in the USA is pending;
— The Onkalo geological disposal facility project in Finland is progressing as planned;
— Sweden is moving ahead with its spent fuel encapsulation facility and preparing disposal proposals for consideration in 2008;
— In France, a report is to be made to Parliament in 2006 on options to deal with high level waste;
— Public approval has been gained for the disposal facility at Kincardine in Canada;
— The local community in Bátaapáti, Hungary, has voted in support of a proposed low level waste (LLW) repository at Üveghuta in 2005;
— Australia has identified three potential sites for low and intermediate level waste (LILW) disposal;
— Four local/regional authorities in the Republic of Korea voted to accept LLW siting studies;
— China is accelerating the exploration of geological disposal;
— In Japan NUMO's programme of soliciting sites for geological disposal is continuing — with 2007 remaining the target date for identification of sites.

Nevertheless, for society in general, the question remains: "*Can radioactive waste be safely managed and disposed of?*"

In particular we must consider:

— International/national perspectives and the Global Waste Safety Regime:
  - Joint Convention;
  - International Safety Standards;
  - National policies/strategies;
  - Resources — material, human and knowledge;
  - Legal and regulatory frameworks;
  - Safety cases.

What is their status, value and benefit?
Are they good enough?
How can they be improved?

— Disposal options and their safety:
  - Near surface repositories;
  - Geological repositories;
  - Intermediate depth repositories.

How should we design them?
How do we provide for and demonstrate their safety?
Is this good enough?

— Regulatory control:
  - Setting of standards;
  - Evaluating safety cases and supporting assessments and analysis;
  - Establishing conditions of authorization;
  - Inspection and enforcement;
  - Periodic safety review.

Is the evidence available to convince the regulator?
Does the regulator have the tools and resources necessary to evaluate the evidence and make good decisions?

— Communicating safety:
  - Engaging stakeholders — the general public, academia, environmental interest groups, politicians, the media.

What has led to successes?
What are the lessons from the failures?
How can we judge adequacy?
Are there country specific and universal aspects we must consider?

I hope that we will be able to take away from the conference ideas on what we can do to provide positive answers to all these questions.

The IAEA will give careful consideration to the outcomes and conclusions of the conference and, if necessary, will adjust the focus of its work programmes.

In conclusion, I would like to wish the conference every success. I hope that you also manage to take some time to enjoy my home city Tokyo. I look forward to discussing the outcome and conclusions of the conference with you in the final session.

KEYNOTE ADDRESS

T. Tanaka
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On behalf of the OECD Nuclear Energy Agency (OECD/NEA), I would like to express my thanks to the IAEA and to the Government of Japan for giving us this opportunity to meet here in Tokyo and to address the safety issues of radioactive waste disposal. I also welcome this opportunity to introduce myself as the new OECD/NEA Deputy Director for Safety and Regulation and to welcome you all to my native country. It is a great honour to present, during this opening session, the views of my agency on the safety of radioactive waste disposal.

In recent times there has been good collaboration between the IAEA and the OECD/NEA in this subject area, which has led to the achievement of some significant results. The OECD/NEA, therefore, welcomed the opportunity to co-sponsor this event.

Through the various programmes of work of the OECD/NEA standing technical committee, the Radioactive Waste Management Committee (RWMC), the OECD/NEA has continuously developed its expertise in this field. The RWMC works on key issues related to policy, governance and regulation in long term waste management. In this context, I would like to draw your attention to the participation of M. Federline, the RWMC Chairperson, in this conference.

Radioactive waste management has been a concern of our member States for many years and it has a high priority among OECD/NEA activities. In recent years there has been a shift of emphasis on the technical aspects of waste management; it is now seen that the safety of disposal goes beyond performance analysis and the modelling of repository behaviour. In that regard, we have coined the term ‘safety case for disposal’ and this concept is now used in the IAEA–OECD/NEA Safety Requirements for Geological Disposal of Radioactive Waste. However, there are not only technical aspects to the safety of disposal: consideration has to be given to the concerns of the public and their politicians, in particular with regard to high level waste disposal.

Peer reviews of national studies on the safety of waste disposal — carried out by the OECD/NEA upon requests from member countries — deserve a special mention because they provide strong support to the development and implementation of robust national waste management policies. For example, the peer review of the Japan Nuclear Cycle Project on the establishment of the technical basis of HLW disposal in 1999 helped in making progress towards disposal in Japan.

Now, I would like to share with you some findings from OECD/NEA studies on the various aspects of the safety of waste disposal. There is wide international agreement on the basic principles upon which waste management solutions must be founded. This has been formalized in the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. According to the Joint Convention, solutions are required which, firstly, do not result in undue burdens for future generations and, secondly, whose reasonably predictable impacts are not greater than those allowed for the current generation. The international community and certainly the OECD countries are adhering to the principle, expressed in the Rio Declaration, that those generating the waste — as well as those benefiting from the primary sources — should also provide the appropriate means for managing the waste. This implies providing appropriate policy and regulatory frameworks and relevant institutions at a national level. Disposal of long lived radioactive waste in engineered facilities, or repositories, located deep underground in suitable geological formations with the intention of ultimately closing and sealing them, meets these criteria; thus, such disposal is being widely investigated and developed worldwide as an option to protect both humans and the environment.

For OECD countries, it can be stated that there is wide international agreement on engineered geological disposal as an effective, feasible and promising waste management end point. Repository programmes are being implemented or planned in countries such as Belgium, Finland, France, Germany, Hungary, Japan and the United States of America, for example, as well as in some non-OECD countries. OECD/NEA studies show that geological disposal is seen as a radioactive waste management end point providing security and safety in a manner that does not necessarily require monitoring, maintenance and institutional controls and therefore is sustainable. Geological disposal is also known to be technically feasible and acceptable from an ethical and environmental viewpoint. I would like to stress the word ‘engineering’ because engineered disposal relies not only on natural geology but also on human-made barriers benefiting from human knowledge and know-how, to provide enhanced safety.

While there is no underground repository in operation today for commercial long lived, high level waste, several projects are under way and the commissioning of some sites may be expected around 10–15 years from now. In the meantime, these types of waste are being safely stored, mostly at the reactor sites.

Long lived low and intermediate level waste categories, as well as mixed waste, raise specific technical issues. However, solutions have been developed and implemented in some countries, e.g. WIPP in the USA. Geological repositories and other options, such as borehole disposal, are under consideration for these waste types.

The extensive experience acquired in the disposal of short lived, low and intermediate level waste should not be overlooked and it has provided confidence in the safety of the repositories implemented for these waste categories. Regulatory frameworks and safety standards are in place in this regard and the capacities of existing repositories are adequate to cover the requirements of existing nuclear power plants and fuel cycle facilities.

With many nuclear power plants reaching the end of their technical lifetimes or being shut down for economic or political reasons, large volumes of very low level waste will be generated. The volumes of waste from decommissioning activities will depend on parameters, such as the clearance criteria set by national authorities, and the possibilities for recycling of materials in industries, etc. Nevertheless, there will be an increased demand for repository space/sites. I would like to note the steps forward taken by some countries — Japan, for example — on clearance levels.

Besides technical issues, social aspects have an impact on the requirements for safe radioactive waste management. Society now requires new forms of risk governance in dealing with hazardous activities and new ways of dialogue. The technical assurance and quality of the decision making process are now seen as being as important as the scientific and engineering aspects of waste management safety. Therefore, the ability to communicate and to adapt to the new context has emerged as critical contributors to gaining public confidence. The OECD/NEA Forum on Stakeholder Confidence is at the forefront of developments in these areas.

Ensuring the safety of all radioactive waste disposal is a prerequisite for the future of nuclear energy. It is a challenge facing governments and the industry. Specifically, guaranteeing the integrity of physical barriers and/or the efficacy of institutional controls over periods of time beyond one generation is a major challenge.

International cooperation is essential to address these challenges in the most effective way. The exchange of information and the sharing of experience between countries are means to ensure such cooperation and international events such as the present conference offer unique opportunities for free discussions among experts from all around the world.

I am looking forward to the presentations and discussions of the coming days and I am sure that we will all benefit from lively and stimulating exchanges. I thank you for your attention.

DISPOSAL SAFETY — INTERNATIONAL AND NATIONAL PERSPECTIVES

(Session II)

THE GLOBAL WASTE SAFETY REGIME

(Session IIa)

Chairperson

K. HIGASHI
Japan

Rapporteur

K. RAJ
India

THE JOINT CONVENTION AS A TOOL TO PROMOTE AND FACILITATE THE SAFETY OF SPENT FUEL AND RADIOACTIVE WASTE MANAGEMENT WORLDWIDE

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Abstract

The paper describes the objectives and the main features of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention). It explains how the Joint Convention review process works and the benefits that the countries of the Convention obtain from it. The relationship between the Convention and the international safety standards is also discussed. Some of the important outcomes of the First Review Meeting of the Convention are briefly summarized. Finally, the paper draws attention to the need for more countries to become parties to the Convention and indicates ways in which the review process can be improved.

1. INTRODUCTION

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) has been in force since 18 June 2001. The Joint Convention is a very important process for the improvement of radioactive waste management programmes worldwide. Its origins can be traced back to 1994, when the text of the Convention on Nuclear Safety was finally approved. In its preamble, the Convention on Nuclear Safety recommended that work for a further convention on radioactive waste should be promptly initiated.

The prime objective of the Joint Convention is ‘to achieve and maintain a high level of safety worldwide in spent fuel and radioactive management, through the enhancement of national measures and international cooperation, including, when appropriate, safety-related cooperation’.

2. THE JOINT CONVENTION AND ITS REVIEW PROCESS

To deliver this objective, the Joint Convention, like the Convention on Nuclear Safety, is meant to encourage Contracting Parties to improve their performance, while safety remains a national responsibility. The ‘incentive’ process set up by the Joint Convention is based on two complementary tools:

— National Report, required by Article 32 of the Joint Convention;
— Review Meeting, established by Article 30 of the Joint Convention.

The preparation of the National Report is a major task but it allows the Safety Authority to systematically review all national activities in the field of spent fuel and radioactive waste management and to draw its own conclusions on measures that may have to be taken. Article 32 of the Joint Convention addresses the content of the National Report in detail. The more comprehensive and clear the National Report is on difficulties or good practices, the more useful it can be for the national authorities. It represents a national instrument for the safe(r) management of these materials.

The second purpose of the National Report is to allow for a free exchange of information and discussion between Contracting Parties during the Review Meeting, so that each participant may see where his/her performance could be further improved. The main conclusions and recommendations of the Review Meeting and of the Peer Review process are published in a summary report.

The First Review Meeting took place in November 2003. It is generally acknowledged that the process of preparing a National Report and preparing for review by peers, although time consuming and costly, was beneficial for Contracting Parties. The next review meeting will be held in May 2006.

3. INTERNATIONAL SAFTY STANDARDS

The Safety Standards produced by the IAEA are of great interest for Contracting Parties working at achieving or maintaining a high level of safety in radioactive waste management in the framework of the Joint Convention. As a result of the Action Plan for the development and application of the IAEA Safety Standards undertaken by the IAEA some years ago, most safety standards nowadays tend to reflect an international consensus on what constitutes a high level of safety for protecting people and the environment. In most cases, they represent effective and useful safety assessment tools for application to radioactive waste management facilities, although there is still room for further development and improvement. As an international point of reference, their incorporation into national regulations or practices provides a practical way for Contracting Parties to achieve the main goals of the Joint Convention, keeping in mind that Contracting Parties may also use alternative ways at the national level to achieve these goals.

The International Regulatory Review Team (IRRT) process, supported by the IAEA, is also a part of the international effort to improve and maintain a high level of safety in all nuclear activities, including radioactive waste management; it should be seen by Member States as a way to stimulate the application of the IAEA Safety Standards.

At the European level, the IAEA Standards proved to be very useful as basic reference material when WENRA (Western European Nuclear Regulators Association) started its work on defining harmonized reference levels for the safety of nuclear installations and the management of radioactive waste. It is intended to follow the same approach in developing European harmonized reference safety levels for the deep geological disposal of radioactive waste. A pilot study has already been undertaken on the regulatory review of the safety case related to geological disposal. This harmonization work by the national authorities of Europe is of great interest for France and for all the countries involved.

4. IMPROVING THE EFFECTIVENESS OF THE JOINT CONVENTION

The effectiveness of the Joint Convention in enhancing the global safety of spent fuel and radioactive waste management depends on two key factors:

- The number of Contracting Parties;
- The effectiveness of the review process based around the National Reports and the Review Meeting.

The ratification process for the Joint Convention has been at a much slower rate than that for the Convention of Nuclear Safety (CNS) and it needs to be speeded up. Only 34 States will be Contracting Parties to the Joint Convention at the time of the Second Review Meeting in 2006 compared to the 54 Contracting Parties that attended the Second Review Meeting of the CNS in 2002. The Contracting Parties and the IAEA Secretariat should therefore keep up their current efforts to promote the Joint Convention, which is hoped eventually to include all countries making use of ionizing radiation, i.e. not only countries operating Nuclear Power Plants but, in practice, almost all countries in the world.

Regarding the effectiveness of the review process, the First Review Meeting produced substantial positive results and it gave a real opportunity for participants to focus on spent fuel and radioactive management in both a comprehensive and detailed manner. Contracting Parties clearly demonstrated a strong commitment to the objectives of the Joint Convention and to achieving its objectives. The Review Process worked well but there is room for improvement on two different levels: improvement of the National Reports, and improvement of the Review Meeting.

When elaborating its National Report, a Contracting Party should focus not only on formal (legal) compliance with the obligations of the Joint Convention but should also address the compliance at a practical level, i.e. the implementation of the obligations and the practical activities being carried out to meet the objectives. It should highlight good practices, but also, the difficulties encountered and give consideration to recent past actions and future planned actions to improve the situation. Above all, difficulties should not be kept hidden if it is desired to make progress. If such National Reports could be produced — and there is no reason why they cannot be — the review process during the Review Meeting would be easier and more useful. It would then be possible to get nearer to the original spirit that prevailed during the drafting of the Joint Convention: to provide an opportunity for Contracting Parties to present progress and difficulties in an open and frank manner. For this purpose, the commitment of the Head of each Safety Authority to the production of the National Report and to the exchange of views during the Review Meeting is essential — in order to facilitate the open and frank debates that, ultimately, are for the benefit of all.

From the results of the first Review Meeting, one recommendation seems to reflect the very spirit of the Joint Convention: it is the recommendation to develop and implement integrated decommissioning and radioactive waste management plans. Such plans should be comprehensive and take into account all radioactive waste streams, including the waste arising from decommissioning. For each type of radioactive waste, the plan should present the associated management route (existing or under development) in order to identify possible gaps in the current practices and to enable the preparation of plans and decisions on the ultimate management solutions for all waste streams.

5. CONCLUSION

As a conclusion, the Joint Convention is a major tool for the worldwide improvement of the safety of spent fuel and radioactive waste management programmes. The exchange of information and of views on management solutions allows the conclusion to be drawn that, in more and more countries, spent fuel and radioactive waste are being adequately treated, stored and disposed of.

Let us work to keep the Joint Convention process alive and efficient and to extend the number of Contracting Parties to include all the countries that must face these matters.

DISCUSSION

C. McCOMBIE (Switzerland): It has been stated that one reason why so few countries have become Parties to the Joint Convention is that the preparation of national reports involves a very substantial effort which might be considered excessive by countries with very little in the way of nuclear activities. Could the IAEA do something to ease the reporting burden for such countries?

A.-C. LACOSTE (France): I think there are many explanations for the small number of countries which have become Parties to the Joint Convention as compared with the Convention on Nuclear Safety. For example, the countries with nuclear power programmes were under a kind of ‘social pressure’ to become Parties to the Convention on Nuclear Safety, whereas no such pressure exists in the case of the Joint Convention.

The IAEA recently held a meeting in Ouagadougou, Burkina Faso, for the purpose of informing a number of African countries about the Joint Convention. At that meeting it became clear that the countries in question were aware of the problems associated with radioactive waste, but that they had many higher priorities. It will take a great deal of effort to induce further countries to become Parties to the Joint Convention.

As the Joint Convention is supposed to be an ‘incentive Convention’, perhaps it could be agreed that the first national report of a new party may be a ‘light’ one, in order to launch the reporting process in that country. The new Parties should be welcomed by the long standing ones, which should not judge their early reporting efforts too severely.

T. TANIGUCHI (IAEA): Regarding the question of the small number of Parties to the Joint Convention, my perception is that, for many of the countries which are not Parties, the costs of complying with the Joint Convention look bigger than the benefits. They lack basic knowledge about the Joint Convention.

After the accession of China, the Russian Federation and South Africa, some 90% of the radioactive waste being generated in the world will be covered by the Joint Convention. However, the remaining approximately 10% is very important, for an accident involving radioactive waste will affect public confidence in most countries. I therefore hope that all IAEA Member States which are already Parties to the Joint Convention will promote the Joint Convention and help new Parties to meet the obligations arising out of it, including the obligation to submit national reports.

THE IAEA WASTE SAFETY STANDARDS

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Abstract

The paper provides an overview of the international safety standards on the safety of radioactive waste management by reviewing their history, the standards development process, the new structure of the safety standards, and the existing documents and planned new documents. Finally, it outlines the contents of a newly approved Safety Requirements document on the Geological Disposal of Radioactive Waste.

1. HISTORY

The IAEA has been involved in the management of radioactive waste since its creation in 1957. At that time, the disposal of radioactive waste in the sea was an option being favoured by countries developing nuclear power, and in 1961 the IAEA published Safety Series No. 5, dealing with the establishment of appropriate safety procedures and practices for the disposal of radioactive waste in the sea. In 1965, the IAEA published guidance on radioactive disposal in the ground (Safety Series No. 15).

By the late 1970s, it had become clear that underground disposal was the internationally accepted approach for most types of solid radioactive waste. In 1977, the IAEA outlined a programme for the production of a set of guidance documents on the subject. A review committee was established to oversee the production of the documents. This committee, the Technical Review Committee on Underground Disposal of Radioactive Waste, was set up in 1978 and continued its work until 1988. During this period, it approved the publication of a comprehensive collection of Safety Series documents on underground disposal.

Towards the end of the 1980s, the issue of radioactive waste and its management was becoming increasingly politically important, since it was seen as one of the technically unresolved issues of nuclear electricity generation. The IAEA responded by establishing a high profile family of safety standards, the Radioactive Waste Safety Standards (RADWASS). By this means, the IAEA intended to draw attention to the fact that well established procedures for the safe management of radioactive waste were already in existence. The

RADWASS programme was intended to establish an ordered structure for the safety documents on waste management and to ensure comprehensive coverage of all relevant subject areas.

The initial concept of RADWASS was developed in 1988. The structure, content and scope of the programme were elaborated by international experts in 1990 and work on the programme was started in 1991.

In 1996, the RADWASS programme was amended to broaden its scope by including discharge control and environmental restoration and to reduce the number of planned documents by combining several of the previously planned Safety Guides. RADWASS documents were categorized under four subject areas: discharges, predisposal, disposal and environmental restoration.

In 2003, the IAEA Safety Standards, as a whole, were restructured with the aim of improving coherence and integration of the standards in all areas: nuclear, radiation, waste and transport safety.

2. HIERARCHY OF THE STANDARDS

The IAEA Safety Standards are issued in the IAEA Safety Standards Series, which has three categories, namely, safety fundamentals, safety requirements and safety guides:

— The Safety Fundamentals (with a silver coloured cover) present the objectives, concepts and principles of protection and safety, and provide the basis for the safety requirements. Currently, there are three safety fundamentals: one for nuclear safety, one for radiation safety and one for radioactive waste safety. A single new Safety Fundamentals covering all areas is being developed.
— The Safety Requirements (with a red cover) establish the requirements that must be met to ensure the protection of humans and the environment, both now and in the future. They are governed by the objectives, concepts and principles of the Safety Fundamentals. The requirements are expressed as 'shall' statements and use a regulatory language, which facilitates their incorporation into national laws and regulations.
— Each safety requirements publication is supplemented by a number of safety guides. The Safety Guides (with a green cover) provide recommendations and guidance on how to comply with the safety requirements. The guidance is expressed as 'should' statements. The safety guides represent good practices to help users to achieve high levels of safety.

The IAEA Safety Standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment. They are intended to be implemented within appropriate national regulatory infrastructures.

In addition to the standards, the IAEA produces a wide range of supporting technical publications, including Safety Reports, Technical Reports, and Technical Documents, intended to help States in developing their national standards and infrastructures.

3. DEVELOPMENT PROCESS

The development of a safety standard starts with the drafting of a Document Preparation Profile (DPP). The DPP has to be approved by the Committees involved (NUSSC for nuclear safety, RASSC for radiation safety, TRANSSC for transport safety and WASSC for waste safety) and the Commission on Safety Standards (CSS) before work on the document can start. Each Member State is invited to nominate members of the committees from its safety authorities, for a term of three years. The members of the CSS are senior regulators, selected and appointed, for terms of four years, by the Director General of the IAEA.

The approved DPP justifies the development of a standard; it includes a preliminary table of contents, a listing of interfaces with other standards, a time schedule for the document preparation, and, for cross-cutting documents, a prescription for the involvement committees other than the one with the main responsibility for developing the document.

Following the approval of the DPP, the IAEA Secretariat drafts the safety standard with the help of experts from Member States. When the draft is considered mature enough, it is submitted to the relevant Safety Standards Committee(s) for approval for it to be sent to Member States for comment. At the national level, the lead organization for commenting is the relevant regulatory authority. Member States are given four months to comment; the comments are considered by the Secretariat and are, if appropriate and justified, incorporated into a revised draft. The revised draft is then submitted again to the committees involved, this time, for approval to send it to the Commission on Safety Standards (CSS). After approval by the CSS, the top-level documents, the Safety Fundamentals and the Safety Requirements, require the formal approval of the IAEA Board of Governors as a final step before publication. Safety Guides can be published without this step, after CSS approval, under the authority of the IAEA Director General.

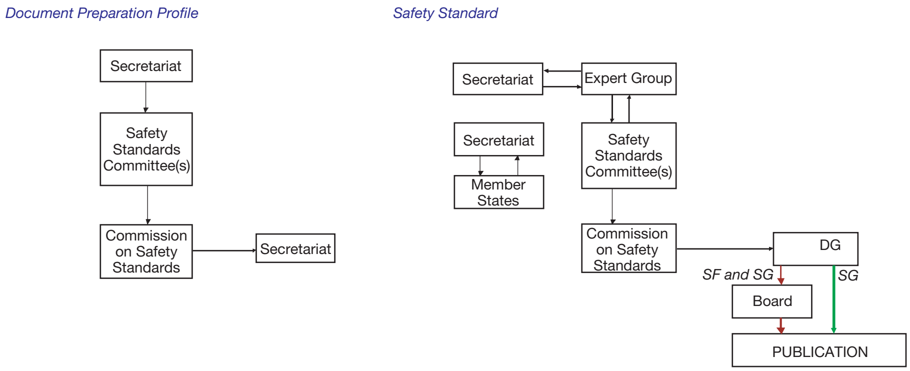

FIG. 1. Development of IAEA Safety Standards.

The development process is illustrated in Fig. 1.

It is the intention, by means of this process, to develop standards that represent the consensus view of IAEA Member States.

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international expert bodies, such as the International Commission on Radiological Protection (ICRP), are taken into account in developing the standards. Some standards are developed in cooperation with other bodies in the United Nations system, such as the International Labour Organization, or other specialized agencies, such as the Nuclear Energy Agency of the OECD.

It is intended to keep the standards up to date and for this purpose they are reviewed at approximately five yearly intervals to determine if revision is necessary. Such revision must take account of any relevant technical developments, information on the use of the standards and other feedback from users. This feedback is important to ensure that the safety standards are meeting the needs of Member States.

4. CURRENT STATUS

The following are the main current safety standards dealing with the safety of radioactive waste management:

— Safety Fundamentals:
  - The Principles of Radioactive Waste Management [1];

— Safety Requirements:
  - Near Surface Disposal of Radioactive Waste [2];

  - Predisposal Management of Radioactive Waste, Including Decommissioning [3];
  - Remediation of Areas Contaminated by Past Activities and Accidents [4];
- Safety Guides:
  - Design and Operation of Radioactive Waste Incineration Facilities [5];
  - Classification of Radioactive Waste [6];
  - Siting of Near Surface Disposal Facilities [7];
  - Siting of Geological Disposal Facilities [8];
  - Safety Assessment for Near Surface Disposal of Radioactive Waste [9];
  - Management of Radioactive Waste from the Mining and Milling of Ores [10];
  - Decommissioning of Nuclear Power Plants and Research Reactors [11];
  - Decommissioning of Medical, Industrial and Research Facilities [12];
  - Regulatory Control of Radioactive Discharges to the Environment [13];
  - Decommissioning of Nuclear Fuel Cycle Facilities [14];
  - Predisposal Management of Low and Intermediate Level Radioactive Waste [15];
  - Predisposal Management of High Level Radioactive Waste [16];
  - Management of Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education [17].

The Safety Requirements on the Geological Disposal of Radioactive Waste [18] (co-sponsored by the OECD/NEA) was approved by the IAEA Board of Governors in September 2005 and will be published shortly. Two other Safety Requirements are under development as part of the restructuring of the Safety Standards (see next section).

Fourteen Safety Guides are currently under development, some of them being revisions of existing older standards (e.g. classification of radioactive waste):

- Implementation of the remediation process for past activities and accidents;
- Safety assessment for nuclear and radiation facilities other than reactors and waste repositories;
- Storage of radioactive waste;
- Release of sites from regulatory control upon termination of practices;
- Geological disposal of radioactive waste;
- Borehole facilities for the disposal of radioactive waste;

- Management systems for the safety of the treatment, handling and storage of radioactive waste;
- Management systems for the safety of radioactive waste disposal;
- Management and storage of radioactive residues from industrial processing;
- Safety assessment of radioactive waste disposal facilities;
- Near surface disposal of radioactive waste;
- Monitoring and surveillance of disposal facilities;
- Safety assessment of decommissioning;
- Classification of radioactive waste.

5. OVERALL STRUCTURE OF THE SAFETY STANDARDS

The Safety Standards cover five areas:

- The safety of nuclear facilities, for which NUSSC is usually the lead committee;
- Radiation protection and the safety of radiation sources, for which RASSC is usually the lead committee;
- Safe management of radioactive waste, for which WASSC is usually the lead committee;
- Safe transport of radioactive material, for which TRANSSC is usually the lead committee;
- General safety (cross-cutting themes), for which the lead committee is determined on a case by case basis.

Few of the draft standards are nowadays reviewed by only one committee.

The safety standards identified in the overall structure are of two types: thematic standards and facility specific standards. Thematic standards provide the overarching principles, policy and requirements that govern the facility specific standards. Facility specific standards are comprehensive ‘stand-alone’ standards that can be applied without the need to consult the thematic standards.

The thematic standards cover:

- Legal and governmental infrastructure;
- Emergency preparedness and response;
- Management systems;
- Assessment and verification;

— Site evaluation;
— Radiation protection;
— Radioactive waste management;
— Decommissioning;
— Rehabilitation of contaminated areas;
— Transport of radioactive material.

The types of facilities considered are:

— Nuclear power plants (two separate groups: design and operation);
— Research reactors;
— Fuel cycle facilities;
— Radiation related facilities and activities;
— Waste treatment and disposal facilities.

In order to implement this new structure in the waste safety area, it is being considered to:

— Replace the three safety fundamentals by a single fundamental;
— Combine the safety requirements for near surface disposal and geological disposal into a single safety requirement;
— Split the Safety Requirements, WS-R-2 (Predisposal Management of Radioactive Waste, including Decommissioning) into two new Safety Requirements: one dealing with waste treatment (predisposal management) and the other with decommissioning.

6. THE SAFETY REQUIREMENTS ON THE GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

At the time of the approval of the new overall structure of the standards in 2003, the development of the Safety Requirements on the Geological Disposal of Radioactive Waste was well advanced and it was decided not to stop its development, since it was felt that there was a great need for such a standard. The development process has now come to an end with the recent approval by the IAEA Board of Governors.

The objective of this standard is to set out the radiation protection objective and safety criteria for geological disposal and the requirements that must be met to ensure the safety of this disposal option.

The radiation protection objective is stated as follows:

> "Geological disposal facilities shall be sited, designed, constructed, operated and closed so that protection in the post closure period is optimized, social and economic factors being taken into account, and a reasonable assurance is provided that doses or risks to members of the public in the long term will not exceed the dose and risk level that was used as a design constraint."

The requirements are set out with a view to ensuring that the radiation protection objective is achieved. They are expressed as 23 discrete 'shall' statements and each statement is supported by an explanatory text, which indicates what is needed to meet the 'shall' statement. This approach is intended to facilitate their application and use generally, as well as to facilitate their use as a basis for peer review processes and assistance services.

The requirements in the new document are grouped according to those relating to the planning phase and those relating to the development, operation and closure of facilities:

Planning of geological disposal facilities

- Legal and organizational framework
  1. Government responsibilities
  2. Regulatory body responsibilities
  3. Operator responsibilities
- Safety approach
  4. Importance of safety in the development process
  5. Passive safety
  6. Adequate understanding and confidence in safety
- Safety design principles
  7. Multiple safety functions
  8. Containment
  9. Isolation

Development, operation and closure of geological disposal facilities

- Framework for geological disposal
  10. Step-by-step development and evaluation
- The safety case and safety assessments
  11. Preparation of the safety case and safety assessment
  12. Scope of the safety case and safety assessment
  13. Documentation of the safety case and safety assessments

Steps in the development, operation and closure of geological disposal facilities

14. Site characterization
15. Geological disposal facility design
16. Geological disposal facility construction
17. Geological disposal facility operation
18. Geological disposal facility closure

Assurance of safety and nuclear safeguards

19. Waste acceptance requirements and criteria
20. Monitoring programmes
21. Post-closure and institutional controls
22. Nuclear safeguards
23. Management systems

7. APPLICATION OF THE STANDARDS

The IAEA statute makes the Safety Standards binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA. Any State wishing to enter into an agreement with the IAEA concerning any form of IAEA assistance is required to comply with the requirements of the Safety Standards that pertain to the activities covered by the agreement.

International conventions contain similar requirements to those in the Safety Standards and make them binding on the Contracting Parties. The Safety Fundamentals for Nuclear Safety were used as the basis for the development of the Convention on Nuclear Safety and the Safety Fundamentals for Waste Safety were used as the basis for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

Safety Standards are not themselves legally binding, except as mentioned above, but States may use the standards for the establishment of a national regulatory framework for radioactive waste management, i.e. as a basis for regulations. It should be noted that the Safety Standards are intended to apply primarily to new facilities and activities. The requirements and recommendations specified in the IAEA Safety Standards might not be fully met at some facilities built to earlier standards and the application of the Standards in such cases is a matter for individual States to decide upon.

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REVIEW OF CONTRIBUTED PAPERS

Session IIa: THE GLOBAL WASTE SAFETY REGIME

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Abstract

An overview is presented of the papers submitted to Session IIa, The Global Waste Safety Regime. In the session, ten papers were contributed by authors from nine countries. The papers cover a wide range of topics including (a) the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, (b) import/export of irradiated fuel and products of reprocessing, (c) national regulation and licensing procedures, (d) international cooperative efforts on waste safety, (e) radioactive waste disposal and (f) safety assessment approaches. The paper summarizes the major technical issues for further review in the conference.

1. MAJOR TOPICS

(a) Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention)

In their paper, Kawakami and Okubo [1] share their experiences in preparing the National Report for presentation to the Joint Convention. The major issues covered are the reporting of uranium mining waste, provisions for decommissioning and environmental impact assessment. A comparison is made of the requirements of the Convention on Nuclear Safety in relation to those of the Joint Convention; the major differences are: (i) the Joint Convention covers diversified facilities due to the variety of categories of waste and their management requirements (in contrast with the relatively well defined and common nuclear reactor facilities), (ii) the safety precautions needed for waste can be optimized in relation to waste amounts and characteristics (in contrast with nuclear reactors), and (iii) a long term perspective is needed in radioactive waste management in view of disposal of long lived waste (in contrast with the finite time for consideration for nuclear reactors). The authors have concluded that the Joint Convention is effective in promoting waste safety and in bringing harmony and conformity in the use of safety standards globally, and that the review meeting of the Joint Convention is a useful platform for sharing information/experience on licensing/regulation, on legal frameworks and on practices in radioactive waste management.

(b) Import/Export of Irradiated Fuel and Products of their Reprocessing

Lavrinovich and Kislov [2] have indicated that the ratification process for the Joint Convention is in progress in the Russian Federation. In their paper, they cover the important topic of import and export of irradiated fuel and the products of reprocessing. The basis for the import of irradiated fuel to the Russian Federation is an annual limit approved jointly by the regulatory bodies, national and local governments with an environmental impact analysis as a precondition. The paper describes two options for irradiated fuel import, namely, (i) temporary storage with subsequent obligatory return to the country of origin, and (ii) temporary storage with planned future reprocessing. The return of the products of reprocessing is also covered; the basis for this is the radioactivity equivalence of the imported fuel assemblies taking natural decay during storage into account.

(c) National Regulations and Licensing Procedures

Three papers describe the formulation of regulatory systems for radioactive waste management in Croatia, Indonesia and Slovakia.

The paper by Kubelka et al. [3] presents the status of spent radiation source management in Croatia. A. The initiative to develop a joint repository and the preparation of regulations for the import/export of radiation sources are described.

Pandi et al. [4] address the present regulation relating to licensing in Indonesia. The paper includes a description of the regulatory system and its licensing documents.

The development of new regulatory requirements for radioactive waste management, necessitated after the recent joining of the European Union by Slovakia, is covered by Konecny and Homola [5]. The authors describe the preparation of new sets of regulations on (i) radioactive waste and spent fuel management, (ii) shipment of radioactive waste, (iii) licensing documentation, (iv) quality management, and (v) periodical assessment of safety. Three acts are being prepared, namely, on environmental impact assessment, including provisions for hearings for citizens in local and neighbouring municipalities, provision of radiation protection and a State fund for decommissioning.

(d) International Cooperative Efforts on Waste Safety

The paper by Kosako et al. [6] presents details of cooperative activities in nine Asian region countries on the safe management of radioactive waste. Australia, China, Indonesia, Japan, Malaysia, the Philippines, Republic of Korea, Thailand and Vietnam are the participating countries. The scope of this initiative covers (i) spent radiation source management, covering the exchange of views on how to respond to problems technically and institutionally and to develop recognition of the importance of spent radiation source management, (ii) management of naturally occurring radioactive materials (NORM), involving the preparation of regulatory guides and the adoption of a graded approach, and (iii) dissemination of information through publications.

(e) Radioactive Waste Disposal

The two papers on this topic cover two entirely different categories of waste, namely, the near surface disposal of conditioned low level waste (LLW) and the geological disposal of high level waste (HLW).

Osmanlioglu [7] presents the current situation in relation to the interim storage of conditioned sealed sources in Turkey. The adopted disposal strategy includes retrievable storage of long lived radionuclides, disposal in vaults/boreholes/large diameter wells located in clay and tuff formations at a depth of 20–80 m.

In a paper on the Japanese HLW programme, the concept of a Requirement Management System (RMS) is described (Sakabe et al. [8]). The necessity for implementation of this tool arises from the long term nature of the programme and includes documentation of fundamental needs and constraints, recording of changes in requirements and the historical record of project decisions and factors that influenced them.

(f) Waste Safety Assessment — Case Studies

Two papers describe approaches adopted in the safety assessment of waste management processes and practices.

In the paper of Oh et. al. of the Republic of Korea [9], the use of treated uranium containing sludge, containing nitrates of Na^+, NH_4^+ and Ca^{++}, as a liquid fertilizer is evaluated. In the proposed process, traditional adsorption and ion-exchange mechanisms are superimposed on a third driving force: the electrical potential on activated carbon fibres.

The paper by Yahaya et. al. [10] describes a study conducted in Malaysia to establish the suitability of using incineration for disposing of NORM contaminated oil sludge waste. The oil sludge contains ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K. Incineration of this oil sludge is carried out in a rotary kiln at 1150°C. The increase in exposure to the workers and the environment due to this practice has been found to be insignificant.

2. CONCLUSION

The papers of Session IIa cover a wide range of topics and issues pertaining to the global waste safety regime. The papers identify many significant topics and issues which could benefit from further review and discussion during the conference, for example, the development and implementation of integrated decommissioning and radioactive waste management plans, the use of IAEA Waste Safety Standards, the import/export of irradiated fuel and products of reprocessing, international cooperative efforts on waste safety and national regulations, and licensing procedures for radioactive waste management, especially for spent radiation sources.

ACKNOWLEDGEMENTS

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PANEL

Session IIa
THE GLOBAL WASTE SAFETY REGIME

Chairperson: **K. Higashi** (Japan)

Members: **A.-C. Lacoste** (France)
L. Baekelandt (Belgium)
K. Raj (India)
Y. Ito (Japan)
M.V. Federline (United States of America)

K. HIGASHI (Japan): Perhaps M.V. Federline, who attended the First Review Meeting of Contracting Parties to the Joint Convention, could give us her views regarding the Joint Convention.

M.V. FEDERLINE (United States of America): I consider the Joint Convention process to be extremely important. I am helping with the preparation of my country's report for the Second Review Meeting, and I have seen how the exercise has brought together agencies which often do not cooperate with one another as closely as they should and has improved our understanding of various radioactive waste management issues.

The Review Meetings enable Contracting Parties to put forward different approaches. This is important since, as was clear from some of the papers summarized by the Rapporteur, K. Raj, different countries have different national strategies, reflecting social, cultural or political differences. At the Review Meetings, we shall be able to consider the strengths and weaknesses of those approaches.

As regards the question of increasing the number of parties to the Joint Convention, in my country the establishment of a geological repository and the control of radioactive sources are currently the two top priority issues. In most other countries there is only one top priority issue — the control of radioactive sources. I believe that, in order to substantially increase the number of parties to the Joint Convention, we must bring that issue to the forefront and seek solutions within the Joint Convention framework.

I also believe that we must be flexible in the Joint Convention process, which must be a 'level playing-field' as between countries with extensive nuclear activities and countries without. The resources required in preparing for Review Meetings can be substantial, but in my view the Joint Convention process can over time evolve so as to enable countries without extensive nuclear activities to participate more easily in and benefit from Review Meetings.

A.-C. LACOSTE (France): I agree with M.V. Federline. If we want to keep the Joint Convention alive, we must be flexible and ensure that its ‘incentive convention’ character is emphasized. We must not impose stringent conditions on newcomers. For example, we must not insist that they endeavour to comply from the very outset with the relevant IAEA Safety Standards. Such insistence would deter many countries from becoming parties to the Joint Convention.

Y. ITO (Japan): I think it is important to introduce greater flexibility into the Joint Convention process through a graded approach as regards the preparation and review of national reports.

I also think that countries which have been parties to the Joint Convention for a considerable time and have experience of the Joint Convention should help newcomers.

K. HIGASHI (Japan): Could A. Lavrinovich tell us about the situation regarding the Joint Convention in his country?

A. LAVRINOVICH (Russian Federation): We signed the Joint Convention some years ago, and I hope that our Parliament will ratify it before the end of this year. The rather long delay between signing and ratification was due to, among other things, difficulties associated with the administrative reform that has been taking place in the Russian Federation.

In the Russian Federation there is a lot of ‘historical’ radioactive waste, and in some cases we are not sure of its location. I hope that in the preparation of our national report for the Second Review Meeting we shall focus successfully on this problem.

As regards the IAEA’s Safety Standards, in developing our nuclear regulatory system we have found them very helpful. We use them a great deal.

A.-C. LACOSTE (France): A. Lavrinovich just spoke of ‘using’ the IAEA’s Safety Standards. I prefer to speak of ‘using’ them rather than ‘applying’ them, for the following reason. There are countries which do not use the standards at all and countries which apply them by incorporating them directly into their regulations, and a wide range of countries somewhere between those two extremes — for example, countries which use the Standards as a reference. It is for each country to decide what it will do with the Standards, and we must bear that in mind.

So far, we have not made much use of the Standards in France, but we recently started using them in an exercise, involving the heads of 17 European regulatory bodies, aimed at the setting of common reference levels for the safety of nuclear power plants and the safety of radioactive waste storage facilities.

L. BAEKELANDT (Belgium): I believe that the IAEA's Secretariat is drawing up a questionnaire based on IAEA Safety Standards to facilitate the preparation of national reports pursuant to the Joint Convention. It has already done something similar in the area of transport safety — on the basis of the IAEA's Regulations for the Safe Transport of Radioactive Material it has drawn up a questionnaire to facilitate the conduct of TranSAS (Transport Safety Appraisal Service) missions to countries requesting the Secretariat to organize such missions.

K. HIGASHI (Japan): In your presentation, you spoke briefly about an IAEA questionnaire exploring the use of the safety standards. Could you expand on what you said earlier?

L. BAEKELANDT (Belgium): It is difficult to give a summary of the results, because not many countries have so far responded and because the questionnaire related to several standards, and the fact that a particular country applies a particular standard does not automatically mean that it is applying all the other standards.

One has to be very careful when interpreting the results. For example, all the responding countries stated that they were using the safety guide on the application of clearance and exemption, but some of them are not making full use of it as they have their own numbers. They probably all use the same radiological criterion, 10 μSv/a, but they do not all use the numbers given in the safety guide.

A.-C. LACOSTE (France): What L. Baekelandt just said shows how careful one must be with the concept of 'application'. The concept of 'use' is more suited to what is a complex situation.

K. RAJ (India): Through my interaction with the IAEA's Waste Safety Standards Committee (WASSC) I have found that many countries are using IAEA Safety Standards in the formulation of their own standards. India is using them in that way, as are more and more other developing countries.

C. PESCATORE (OECD/NEA): I agree with A.-C. Lacoste that one should speak of IAEA Safety Standards being 'used' rather than 'applied'. The replies to the Safety Standards questionnaire show that the regulatory function is closely connected with national policies and national legislation, which reflect the national culture. Given the great diversity of national cultures, even in areas such as stakeholder involvement, it is difficult to bring about the application of internationally harmonized standards by a large number of countries.

A.-C. LACOSTE (France): I hope nobody thought I meant to say that IAEA Safety Standards *should* only be used, not applied. I was simply speaking in light of the actual situation — in most cases they *are* only being used. This is partly due to cultural factors which we should take into account.

L. BAEKELANDT (Belgium): For many countries it is impossible to apply IAEA Safety Standards directly by incorporating them into their national regulations because the Standards are not available in their national official language. In the case of Belgium, they are not available in one of its official languages, so we simply use them as a reference.

Y. ITO (Japan): There are very many IAEA Safety Standards and related documents, and it is therefore important that they be made available in a user friendly manner. I understand that the IAEA Secretariat is looking into how the hierarchy of documents can be presented in a more user friendly form on an IAEA web site. If it is doing so, I hope that it will finish the job soon.

K. HIGASHI (Japan): What role can be played by networking and knowledge sharing in this area?

C. PESCATORE (OECD/NEA): Both my organization and the IAEA provide forums for knowledge sharing. This is important not only for networking but also for advancing the state of the art. In addition, it is important for helping to ensure that there will be future generations of nuclear safety experts.

Ideas evolve over time. We do not now look at nuclear safety in the way we looked at it, say, 15 years ago, which we should bear in mind when talking about IAEA Safety Standards, some of which were drafted a long time ago.

Our two organizations also assist in resolving immediate problems, for example, through IRRT (International Regulatory Review Team) and other peer review missions to requesting countries.

In my view, it is essential not to try imposing detailed procedures on others given the diversity of national cultures to which I referred just now, although harmonization may be possible within a fairly small group of countries — perhaps, for example, the countries whose regulatory bodies belong to the Western European Nuclear Regulators' Association (WENRA).

I think it is particularly important not to try imposing detailed procedures on others in cleanup situations where 'standards' are being developed with the help of local stakeholders. Such 'standards' will differ from place to place, but why not?

There are many ways of promoting the Joint Convention. One way is to provide countries with suitable information. The United States of America made such information available to African countries at the meeting in Ouagadougou, Burkina Faso. That was mentioned earlier — and that information was obtained from documents produced by OECD/NEA and the IAEA.

A.-C. LACOSTE (France): I should like to draw attention to two recent developments.

Firstly, an increasing amount of regional cooperation is taking place through bodies such as WENRA. I welcome that as I believe that, besides cooperation at the global and bilateral levels, there is a need for more regional cooperation.

Secondly, there is an increasing demand for IRRT missions organized by the IAEA. So far, the requests for such missions have been made primarily by what one might call ‘emerging nuclear countries’, but I believe a number of countries very advanced in the nuclear field — for example, Germany, the United Kingdom and the USA — are thinking of making requests. France has already requested an IRRT mission, which will take place early in 2007.

In my view, both these developments will contribute to networking, particularly between the members of IRRT teams and the regulators who host them.

M.V. FEDERLINE (United States of America): Further to what C. Pescatore said about cleanup situations, I would mention that I recently visited Port Hope, Canada, and was very encouraged by what I saw there. Three communities have got together and are conducting a cleanup, developing their own standards in the process. It has worked out very well at Port Hope, and I believe that this is a success story which should be widely publicized.

Y. ITO (Japan): Regarding regional cooperation, I should like to recall the proposal made in the opening address of K. Hirose, Director General of Japan’s Nuclear and Industrial Safety Agency. His proposal was that the Asian Nuclear Safety Network Programme, which was launched by the IAEA in 2001 and of which Japan is a major supporter, be expanded to include the waste management area.

In Asia there are several countries with very active nuclear power programmes and several nuclear power plants under construction, and still more countries where extensive use is also being made of ionizing radiation in medicine, industry and agriculture. These countries attach great importance to safety in the management of radioactive waste, and we believe that expanding the Asian Nuclear Safety Network Programme to include waste management would both help to increase the number of parties to the Joint Convention and promote the use of IAEA Safety Standards. In our view, three activities which might be launched immediately are the exchange of information on the use of the relevant IAEA safety related documents, the development of a database of relevant laws and regulations, and the development of a database for the safety evaluation of disposal facilities.

K. HIGASHI (Japan): Perhaps A. Lavrinovich could say a few words on the subject of regional cooperation.

A. LAVRINOVICH (Russian Federation): I think there is considerable scope for regional cooperation in the field of spent fuel management, with countries which are very advanced as regards nuclear fuel cycle technology helping countries which are less advanced.

The Russian Federation has started taking back spent research reactor fuel which was produced there, and that will be a big contribution to safety.

D. LOUVAT (IAEA): I should like to clear up misunderstandings that have arisen about IAEA Safety Standards and the Joint Convention, about what is and is not legally binding and about what is applied and what is used.

The only obligations under the Joint Convention are an obligation to produce a national report and an obligation to attend the Review Meetings. There is no obligation to apply or use IAEA Safety Standards, which are not the only means of achieving a high level of safety. You can demonstrate that you have achieved a high safety level without the help of those Standards.

IAEA Safety Standards are used, and in the course of being used they are also applied. They may be *used* by any State, but a State which wishes to receive technical assistance through the IAEA must *apply* them. My understanding is that the IAEA Board will not approve a technical assistance project involving the use of a radioactive source in the case of a State which does not have a regulatory infrastructure in place able to control radioactive sources and protect the public from harm due to such sources.

As regards IAEA Safety Standards, there is nothing at the Safety Requirements level which cannot be accommodated by any IAEA Member State, whatever the sociopolitical context.

J.T. GREEVES (United States of America): Under the Joint Convention there is an obligation to produce a national report and an obligation to attend Review Meetings, but there is no obligation to stand up and present one's national report. The production of a short national report — say, one of ten pages — need not be onerous, but defending it in front of an audience can be intimidating. Perhaps it could be agreed that countries which have just acceded to the Joint Convention will not have to defend their national reports in a formal setting — simply present them in a kind of poster session.

Such an approach might raise the number of countries party to the Joint Convention to about the level reached in the case of the Convention on Nuclear Safety.

A.-C. LACOSTE (France): It should be borne in mind that several of the 54 countries party to the Convention on Nuclear Safety are not countries with nuclear power plants but ones situated close to such countries which participate in Review Meetings in order to learn more about possible emergency situations.

As regards the Joint Convention, in order to prepare a national report you need to determine what the radioactive waste issues in your country are, and in many countries that is not easy. It is not easy to find out what has happened in one's hospitals, industrial enterprises and so on. As a first step, you must establish a radioactive waste inventory. Then you have to write a report, which presupposes that there is some kind of radiation protection authority — which is not the case in some countries. Finally, somebody must defend the report at a Review Meeting. This can represent a huge effort.

An approach like the one just suggested by J.T. Greeves might be the answer. Another possibility might be help with the preparation of national reports provided by other countries or by the IAEA. A further possibility might be the preparation of a regional report covering several countries — a process from which the countries new to the Joint Convention could learn.

At all events, what is asked of countries which are thinking about acceding to the Joint Convention must not be too difficult. Otherwise the results of their cost–benefit analysis will be negative and they will decide not to accede.

P. METCALF (IAEA): I think we sometimes forget that the Joint Convention is supposed to be an 'incentive convention' and that review meetings are supposed to help parties to the Joint Convention. Perhaps newcomers would be less intimidated if, before review meetings, groups of parties got together in order to discuss the preparation of national reports.

A.-C. LACOSTE (France): Perhaps one could make it possible for countries to attend review meetings as observers.

I would like to add that I participated in all three review meetings of the Contracting Parties to the Convention on Nuclear Safety that have taken place so far, and I can say that the quality of the reporting at successive meetings has improved enormously.

M.V. FEDERLINE (United States of America): Before the Ouagadougou meeting, the IAEA together with the sponsoring countries, produced a 'tool kit' for the participating countries so that these would understand what they should prepare. Is that 'tool kit' still available?

D. LOUVAT (IAEA): It is available via a link on the IAEA web site to the US Department of Energy web site.

We also have a CD-ROM made at the Ouagadougou meeting which will be made available on request — addressed to K. Hioki in the IAEA's Division of Radiation, Transport and Waste Safety.

L. JOVA SED (IAEA): Regarding the Safety Standards questionnaire referred to earlier, the results obtained with it are very interesting, but it must be borne in mind that the replies came from IAEA Member States which are represented in WASSC — that is to say, mainly from developed countries.

If we had sent the questionnaire to all IAEA Member States, the overall response would probably have been more in favour of the IAEA's Safety Standards as over 90 Member States have participated in the IAEA model projects for strengthening regulatory infrastructures, and most of the experts visiting those countries within the framework of the model projects used the relevant IAEA Safety Standards as reference material.

I.G. CROSSLAND (United Kingdom): There was talk earlier about cleanups in connection with which local stakeholders develop their own safety 'standards'. What do you do, however, if the local stakeholders want the dose levels to be reduced to below what is reasonable or call for retrievability and monitoring at the expense of passive safety or post-closure safety? Surely you need international standards for such situations.

K. RAJ (India): That is a very important point.

DISPOSAL SAFETY — INTERNATIONAL AND NATIONAL PERSPECTIVES

(Session II)

NATIONAL STRATEGIES TO ENSURE THE SAFE DISPOSAL OF RADIOACTIVE WASTE

(Session IIb)

Chairperson

A.J. HOOPER
United Kingdom

Rapporteur

P. LIETAVA
Czech Republic

A COMMON FRAMEWORK FOR THE MANAGEMENT AND DISPOSAL OF RADIOACTIVE WASTE

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Abstract

In order to assist in the development of holistic national strategies for the safe and cost effective management of radioactive waste, the IAEA is supporting the development of an internationally endorsed common framework for the management and disposal of all types of radioactive waste. The framework is intended to be based on clear and justifiable safety arguments for each of the strategies chosen. The paper outlines the logic and essential features of the planned framework.

1. BACKGROUND

Increased attention has been given to the safety aspects of radioactive waste management in recent years as evidenced by the coming into force of the Joint Convention on the Safety of Spent Nuclear Fuel Management and the Safety of Radioactive Waste Management (the Joint Convention) [1], and the greater importance which has been attached to having internationally endorsed safety standards for the management of radioactive waste. These developments have led to a recognition that it would be desirable to have a consistent safety based approach for the management of all types of radioactive waste, taking due account of the relative hazards of the different waste types, the volumes and the radioactive half-lives. Also, bearing in mind the significant costs that radioactive waste management can entail, account has to be taken of the costs and practicality of the different available options. With these objectives in mind, the IAEA is supporting the establishment of an internationally endorsed common framework for the management and disposal of all types of radioactive waste. The essential elements of the approach are outlined in this paper.

2. PRINCIPLES FOR A COMMON FRAMEWORK

All types of radioactive waste need to be safely handled, treated and stored, and eventually disposed of, in appropriate engineered facilities and with appropriate levels of control. What constitutes an appropriate facility and an appropriate level of control depends on the potential of the particular waste type under consideration to give rise to radiation hazards to the public and the environment. The Member States of the IAEA have agreed upon a set of fundamental safety principles that apply to all radioactive waste management activities [2]. These principles form the basis of the Joint Convention [1] and the internationally endorsed safety standards for the management of radioactive waste. One of the nine principles of the Safety Fundamentals document [2], which is also included in the articles of the Joint Convention, is the principle that consideration must be given to the interdependencies between the various steps in radioactive waste generation and management.

In establishing or implementing a radioactive waste management programme it is necessary, for each waste management step or operation that generates waste, that the interdependencies between and implications of the steps are recognized so that, overall, the safety and effectiveness of the radioactive waste management strategy chosen are balanced. This includes taking into account the identification of waste streams, the characterization of the waste, the options for waste treatment and the implications for the handling, storage and transport of radioactive waste. All the management processes have an impact, and have to be considered in the overall radioactive waste management strategy, at facility and at national levels.

A coherent and consistent strategy for radioactive waste management should encompass two independent processes: a decision aiding process which allows the safety of the technical options selected to be demonstrated at the national level and a decision making process which addresses the political, economic and societal aspects of the selected technical options. The decision aiding process should be based on the elements of the so-called Global Safety Regime for Radioactive Waste: the Joint Convention and the International Safety Standards, and on a demonstration of the logic and the coherence of the selection of the technical options chosen to manage the national inventory of radioactive waste.

Logic and coherence in the selection of the various approaches to ensure safe management, have so far generally been made on an ad hoc basis, and have addressed only a part of the total waste inventory, namely, the waste arising from the nuclear fuel cycle. In order to ensure that all radioactive waste is managed in an acceptably safe manner, it is proposed that a ‘common framework’ should be established to provide an approach to ensuring such safe management, and particularly disposal, of all radioactive waste types, in a manner consistent with the internationally accepted safety principles for radioactive waste management. The development of an internationally endorsed common framework for the management and disposal of all radioactive waste types will assist in establishing clear and justifiable safety arguments at the national level for the management and disposal of all types of radioactive waste.

The need for a common framework emerged from the conclusion of the International Conference on the Safety of Radioactive Waste Management, held in Cordoba, Spain, in 2000 [3]. The International Action Plan, which was elaborated from these conclusions had, as a first action, the development of a common framework for the disposal of radioactive waste.

Since that time, a document has been developed containing the outline of a common framework for ensuring the safe management, and particularly disposal, of all radioactive waste types consistent with the international safety principles for radioactive waste management. This framework is intended to provide a basis and logic for the identification of categories of generic waste disposal options appropriate for each waste type and by this means to establish the basis for the classification of waste types. It would also address the means by which the safety of such options can be ensured through the development of storage and disposal systems with suitable characteristics and degrees of robustness, so as to provide an acceptable degree of protection for human health and the environment.

3. LINKING WASTE TYPES TO DISPOSAL OPTIONS

The intent of the common framework is to identify all the waste types that arise in practice, together with the various disposal options available and to create a linkage between them in a manner that is both coherent and consistent with the international safety principles and safety requirements. In reality, realization of this linkage also has to take a number of other elements into consideration, such as the national legal and regulatory system and the technological means available. A schematic view of the common framework is shown in Fig. 1.

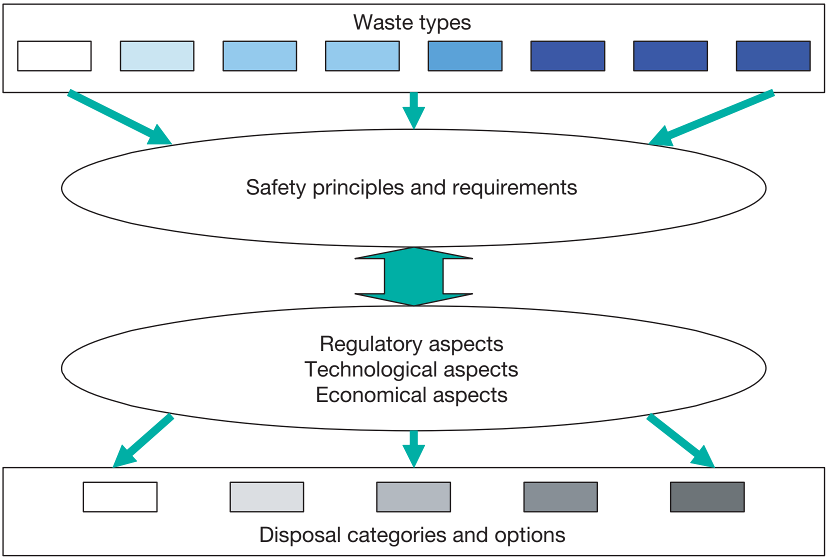

FIG. 1. Outline of the common framework.

4. APPLICATION OF THE COMMON FRAMEWORK

The manner in which the common framework would be applied can be presented in terms of a set of tasks that have to be implemented in order to develop a safe and optimized strategy for radioactive waste management, consistent with the safety principles and the related safety requirements. Those tasks are illustrated schematically in Fig. 2 and explained below.

The first task in the scheme relates to the establishment and maintenance of the national radioactive waste inventory. This includes the identification of sources of radioactive waste and the types of waste from each source, the estimation of the amounts of existing waste and of projected waste arisings, the assessment of the general characteristics and the status of the waste, especially the associated hazard potentials (including non-radiological) and safety features. The second task is concerned with the identification of the generic waste management and disposal options and the corresponding regulatory requirements for each of the various waste types on the basis of national radioactive waste management policy and/or international guidance. The options identified should be such as to ensure that the radioactive waste is managed safely in a manner that is commensurate with the potential hazard presented by the waste and that they are appropriate in terms of national

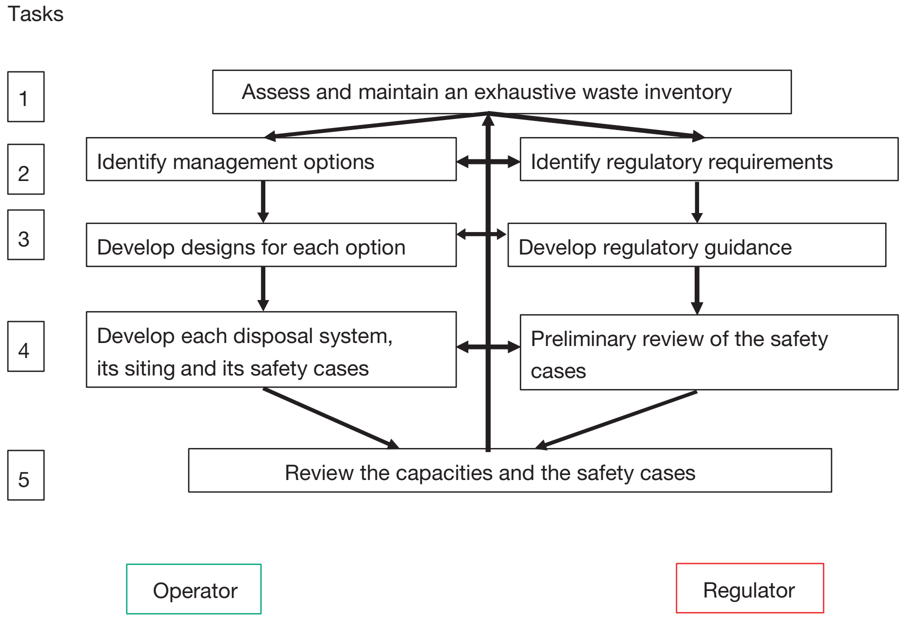

FIG. 2. The application of the common framework.

resources, the national legal system and the available or expected sites. The third task in the scheme is to develop designs and detailed regulatory guidance for each storage and/or disposal system. The fourth task is to develop each storage or disposal system and its corresponding safety case (for the operational and post-operational periods), giving particular consideration to the establishment of appropriate regulatory controls and to siting aspects. The fifth and last task in the scheme is to review the available and planned storage and disposal facilities in relation to the existing and projected arisings of waste and, in particular, to identify any waste types or future waste arisings for which no suitable storage and/or disposal route is available.

5. FUTURE DEVELOPMENTS

The results of the work undertaken to date by the IAEA on the development of a common framework has been discussed in several international fora. The concept has been generally well received, but more work is necessary to ensure consistency and coherence and to develop consensus on its validity and use. The radioactive waste classification scheme is fundamental to the concept and it will be used as a point of reference. The existing Safety Guide on radioactive waste classification [4] is currently being revised and it is intended that the document on the common framework should be developed in such a way as to ensure consistency with the terminology being used in the new Safety Guide on waste classification.

The draft common framework will be presented for consideration and discussion in relevant IAEA meetings, such as the Waste Safety Standards and Waste Technology Advisory Committees (WASSC, WATEC), and in meetings of other interested parties, such as the Radioactive Waste Management Committee (RWMC) of the OECD/NEA.

The document which emerges from this process is intended for the use of Member States in reviewing their national waste management strategies and for the purpose of encouraging further international debate on the linkage between waste types and disposal options. A longer term objective, following the outcome of such experience and debate, is to develop an international standard on the Common Framework.

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THE FRENCH NATIONAL PLAN FOR RADIOACTIVE WASTE AND RECOVERABLE MATERIAL MANAGEMENT

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Presented by R. Cailleton

Abstract

The development of a National Plan for Radioactive Waste and Recoverable Material Management is a priority for the French Nuclear Safety Authority. The main objective is to define a management solution for each type of radioactive waste produced. Radioactive waste without an existing management solution is to be clearly identified and management solutions are to be proposed within a reasonable time frame. The plan should take into account principles being applied for waste in general and also for radiation protection. The Nuclear Safety Authority is overseeing the production of the plan which is submitted periodically to a plenary group in which stakeholders involved in radioactive waste management are represented. A draft of the National Plan for Radioactive Waste and Recoverable Material Management has been available since July 2005 and the plan, in its final version, may become an appendix of the law on high level radioactive waste which is expected to be discussed by Parliament in 2006. The key elements of the plan may also become one of the articles of the law.

1. INTRODUCTION

The need to develop a comprehensive plan for the management of radioactive waste in France was identified a few years ago. One of the objectives of such a plan is to improve transparency, effectiveness and efficiency in the field of radioactive waste management.

Further to a request from the Parliamentary Office for the Assessment of Scientific and Technological Options (OPECST), on the basis of a report produced in 2000 by the Deputy of the Drôme Department, M. Rivasi, the Nuclear Safety Authority (ASN) confirmed that it was in favour of drawing up a national plan for radioactive waste management. During a presentation to the Council of Ministers on 4 June 2003, the Minister for Ecology and Sustainable Development stated her intention to produce such a plan. On behalf of the public authorities, the ASN was given the responsibility for overseeing its production.

The proposal is in conformity with an existing provision in article L.541-11 of the Environment Code (resulting from law 75-633 of 15 July 1975 concerning the disposal of waste and recovery of materials). This article gives the Minister for the Environment the option of drawing up national disposal plans for waste considered to be particularly harmful or requiring special treatment and storage. This option was, for example, used for waste contaminated by polychlorinated biphenyls (PCB).

For radioactive waste, a more global framework appeared to be necessary, to allow for the consistent management of all radioactive waste, guaranteeing safe management and providing for its financing, in particular, for its disposal.

Representatives of the following stakeholders were invited to take part in the work on the National Plan for Radioactive Waste and Recoverable Material Management: the waste producers, the disposal facilities, the National Agency for Radioactive Waste Management (ANDRA), environmental protection associations, elected representatives and the directorates of the ministries concerned.

2. GOALS OF THE NATIONAL PLAN FOR RADIOACTIVE WASTE AND RECOVERABLE MATERIAL MANAGEMENT

The Plan is based on knowledge of the different types of existing radioactive waste described in the reference document National Inventory of Radioactive Waste and Recoverable Material which was published in November 2004 by the National Agency for Radioactive Waste Management (www.andra.fr). This inventory enabled the amounts of waste produced to be estimated for various time frames, including the period 2010–2020. The goals of the National Plan for Radioactive Waste and Recoverable Material Management are presented below:

- Clear definition of the waste to be considered as radioactive, taking account of the existence of materials containing natural radionuclides at variable levels and of certain radioactive materials for which reuse has not been envisaged;
- Identification of management solutions for each category of radioactive waste produced;
- Management of older radioactive waste which has been ‘forgotten’;

- Consideration of the concerns of the public, who rightly or wrongly are worried about the fate of radioactive waste;
- Ensure the consistency of the entire radioactive waste management structure, whatever the level of radioactive concentration or the chemical or infectious toxicity, in particular for waste with an associated ‘mixed’ risk;
- Encourage the waste producers to find optimized waste management solutions: nuclear industry, more conventional industries (in particular those using naturally radioactive substances but for their non-radioactive properties), users of radioactive sources, the medical sector, producers of contaminated earth taken from old polluted sites, the mining industry (uranium mines in particular);
- To achieve consistency in dealing with polluted sites and their reclamation.

The National Plan for Radioactive Waste and Recoverable Material Management does not aim to duplicate the inventory work done by ANDRA. It is possible that the Plan could bring to light the existence of certain waste that does not appear in the inventory, in particular, through a more detailed definition of what is meant by ‘radioactive waste’.

3. PRINCIPLES OF THE NATIONAL PLAN FOR RADIOACTIVE WASTE AND RECOVERABLE MATERIAL MANAGEMENT

The development of a National Plan for Radioactive Waste and Recoverable Material Management is intended to take into account principles regarding waste management and also radiation protection, such as:

- Principles of justification, optimization and limitation required by the radiation protection regulations;
- Minimization of waste production and limitation of the toxicity of the waste;
- Responsibility of the producer until the waste is safely treated and disposed of;
- Informing the public;
- Identification of radioactive waste management routes and prevention of harmful effects on the environment and on human health;
- Minimization of transport;
- Development of solutions for radioactive waste for which no liable producer exists.

4. INTERFACE WITH RESEARCH INTO HIGH LEVEL LONG LIVED WASTE

For high level long lived waste, research into disposal routes is governed by a law (article L.542 of the Environment Code, resulting from the law of 30 December 1991), which requires that a report on the progress of research into the disposal of high level long lived waste be presented to Parliament before the end of 2006, so that a debate can be held on the follow-up to this research.

Producing a National Plan for Radioactive Waste and Recoverable Material Management does not interfere with this process, which concerns only high level long lived waste. The Plan, above all, meets the need to provide ways for managing and disposing of waste which does not fall into this category, such as disused sealed sources, waste containing radium, graphite waste, dismantling waste, and so on. However, its production at the same time as the Government's report requested in article L.542 of the Environment Code will give the political decision making bodies an overview of radioactive waste problems in France and will place the special case of high level long lived waste in a broader context.

5. INITIAL CONCLUSIONS

A first version of the national plan for radioactive waste was presented to the members of the plenary group in September 2004. Revised versions have been examined by the group since that time.

Long term management solutions, or research programmes to establish disposal routes, exist for the main part of the waste. For some waste, such as disused sealed sources, further investigation should be conducted to determine long term management solutions. Application of the principle of justification, that came into force in the Public Health Code, could lead the Government to ask for the removal of a great number of radioactive sources (smoke detectors, lightning conductors) which would then have to be properly managed. Disposal routes for the radioactive waste produced by the decommissioning programme of the first generation of nuclear power plants should be determined, especially for graphite waste. The part of the existing mission of ANDRA concerned with recovering and storing radioactive waste from private individuals or establishments without the resources to dispose of it, should be recognized as a mission of the public utilities. It also seems to be important to review the consistency of the regulatory provisions concerning radioactive waste and to examine the benefit of requiring a declaration from all radioactive waste producers.

6. PROSPECTS

The initiative to produce a National Plan for Radioactive Waste and Recoverable Material Management has been, on the whole, warmly received by the various parties involved, including the representatives of activities not normally considered in this context. It should be noted that internationally, this approach has been seen as a good practice, in particular, within the framework of the First Review Meeting of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, which took place in Vienna from 3 to 14 November 2003. The production of a National Plan for Radioactive Waste Management in each country was a recommendation of the Summary Report issued by the review meeting.

A new version of the National Plan has been available since July 2005 and it can be downloaded from the Nuclear Safety Authority web site (www.asn.gouv.fr). In its report of March 2005 on radioactive waste management, the Parliamentary Office for the Assessment of the Scientific and Technological Options announced that the Plan should be an appendix to the law on the management of high level radioactive waste, which is expected to be debated by the Parliament in 2006. The key elements of the National Plan for Radioactive Waste and Recoverable Material Management could become an article of the law.

The Nuclear Safety Authority considers the development of the National Plan for Radioactive Waste and Recoverable Material Management to be a priority and that it will eventually lead to more open, more thorough and safer management of radioactive waste in France.

Appendix I

RADIOACTIVE WASTE IN FRANCE

TABLE 1. CLASSIFICATION OF RADIOACTIVE WASTE IN FRANCE

Period → activity ↓	Very short lived (half-life <100 days)	Short lived (half-life <30 years)	Long lived (half-life >30 years)
Very low level	Management by radioactive decay	Dedicated surface repository Recycling channels	
Low level waste		Surface disposal (Aube repository) except disused sealed sources (under investigation)	Dedicated subsurface disposal facilities under investigation
Intermediate level waste			Routes under investigation under the terms of article L542 of the Environment Code (law of 30/12/1991)
High level waste			

Appendix II

SUMMARY OF THE SOLUTIONS FOR THE MANAGEMENT OF RADIOACTIVE WASTE IN FRANCE

TABLE 2. SOLUTIONS FOR THE MANAGEMENT OF RADIOACTIVE WASTE IN FRANCE

Existence of the management solution ➔ Level of hazard ➔	Producer/owner of the waste ➔	Existing	Does not exist but research is being conducted (and/or) route under investigation	Does not exist, no research or route under investigation
Low (VLLW)	Aware and solvent	VLLW from operating or dismantling of nuclear installations, included some waste contaminated by tritium Technologically enhanced normally occurring radioactive waste (solvent industry) One part of mining residues Waste and effluent from research sector		
	Not aware, but solvent	Technologically enhanced normally occurring radioactive waste (not identified yet)		Smoke detectors
	Aware and unaware, not solvent	Waste from polluted sites contaminated by radioactive material; one part of waste from mining of uranium ores Technologically enhanced normally occurring radioactive waste from past activities		

TABLE 2. SOLUTIONS FOR THE MANAGEMENT OF RADIOACTIVE WASTE IN FRANCE (cont.)

Existence of the management solution ➔		Existing	Does not exist but research is being conducted (and/or) route under investigation	Does not exist, no research or route under investigation
Level of hazard ➔	Producer/ owner of the waste ➔			
High (>LLW)	Aware, solvent	Waste from operating nuclear installations short lived, ILW and LLW (and waste produced by sectors outside the nuclear energy industry) Some disused sealed sources Short lived radioactive waste from medical and research activities Waste with multiple hazards (radioactive, chemical or biological)	Long lived LLW from nuclear industry (graphite) One part of radium bearing waste Long lived ILW and HLW from nuclear industry (research conducted in compliance with article L.542 of the Code for the Environment) Majority of waste contaminated by tritium Disused sealed sources Liquid organic ILW	
	Not aware, but solvent	Possibly old sources not inventoried (educational uses …)	Old sources not inventoried	One part of radium needles, radium items, lightning conductors containing radium
	Aware or unaware, not solvent	Some waste produced by the cleanup of polluted sites	One part of radium bearing waste	One part of radium needles, radium items, lightning conductors containing radium

RADIOACTIVE WASTE DISPOSAL IN THE UNITED STATES OF AMERICA*

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Abstract

The United States of America has well established national policies for the management and disposal of radioactive waste, which ensure the health and safety of the public, common defence and security, and protection of the environment. These policies call for safe permanent disposal of spent fuel and high level radioactive waste (HLW) in a geological repository and for surface/subsurface land disposal of low level radioactive waste (LLW). They are directed at ensuring long term containment and isolation of waste from the environment. The paper provides an overview of the laws and responsibilities for implementing these policies. The paper also outlines a safety framework, strategies and the open public process for regulating radioactive waste disposal. While carrying out these regulatory responsibilities, the Nuclear Regulatory Commission staff has gained significant experience in developing and implementing regulatory approaches for waste disposal and has enhanced the regulatory process through lessons learned. However, challenges remain, including: (a) making decisions in the face of technical uncertainties over long time periods; (b) developing innovative approaches to public outreach to increase public understanding and involvement in the regulatory process; and (c) knowledge management.

1. INTRODUCTION

In the United States of America, radioactive waste categories are defined largely based on the origin of the waste. There are five main categories of nuclear fuel cycle waste: (1) spent fuel (SF), which is nuclear fuel removed from the reactor after irradiation, the constituent elements of which have not been separated by reprocessing; (2) high level waste (HLW), which is highly

* The opinions and statements documented in this paper are those of the authors and do not necessarily constitute NRC approval or agreement with the information contained herein. Any such interpretation must be obtained in writing from the NRC.

radioactive material resulting from processing spent fuel; (3) transuranic waste (TRU), which is waste that contains more than 4 kBq/g (100 nCi/g) of alpha-emitting radionuclides greater than uranium in atomic weight, with half-lives greater than 20 years, excluding HLW; (4) mill tailings (MT), the tailings or waste produced by extraction or concentration of uranium or thorium from any ore processed primarily for its source material content; and (5) low level waste (LLW), which is defined as “waste that is not spent fuel, HLW, TRU, MT, naturally occurring radioactive material (NORM), nor accelerator produced waste”.

The USA, like other countries, generates significant amounts of technologically enhanced naturally occurring radioactive materials (TENORM). However, this paper focuses on waste from the nuclear fuel cycle, especially spent fuel, and high level and low level radioactive waste. Some nuclear fuel cycle waste is highly radioactive and requires special measures to isolate it from the biosphere. Although disposal technology is well accepted among the technical community, this waste is still of special interest to the public. Regulatory programmes ensure that this waste is safely managed and disposed of through the use of state of the art analyses and technology, as well as robust disposal designs. The programmes for ensuring openness in the regulatory processes are also well developed, given the significant public interest in fuel cycle waste. Similarly, both MT and TRU waste is effectively managed and disposed of — with oversight provided through mature regulatory programmes.

This paper focuses on fuel cycle waste because it provides examples of state of the art management of nuclear waste. For example, geological disposal has been studied for decades around the world and robust technical solutions are currently being evaluated. Also, significant progress has been achieved in public outreach and understanding. However, continual learning for both technical issues and approaches for public outreach is a key issue to ensure further progress. For example, the United States Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC) are addressing both of these elements in the prelicensing programme at Yucca Mountain, the potential site for a geological repository for HLW. Also, the siting of LLW disposal facilities in the USA is being implemented through a state compact process, which continues to pose challenges in public acceptance.

This paper provides an overview of the main policies as well as a framework and strategies for HLW and LLW disposal in the USA. It also addresses the main roles and responsibilities for implementing the policies. In addition, it briefly summarizes the key lessons learned during the past two decades in carrying out responsibilities for regulating radioactive waste from the nuclear fuel cycle.

2. MAIN POLICIES, STATUTES AND REGULATIONS GOVERNING HLW AND LLW DISPOSAL IN THE USA

The policy and regulatory framework governing the disposal of HLW is defined in the Nuclear Waste Policy Act (NWPA) of 1982 [1], as amended, and the Energy Policy Act of 1992 [2]. These acts specify that HLW will be disposed of in a deep geological repository, and that the Yucca Mountain site in Nevada will be the single candidate site for characterization as a potential geological repository. The NWPA established: (a) generic tasks and schedules for siting, construction, and operation of a repository; (b) defined the relationship between Federal, state, affected tribes, and local government agencies with regard to HLW disposal; (c) assigned specific responsibilities for implementation of HLW tasks to the DOE, the Environmental Protection Agency (EPA), and the NRC; and (d) established the 'Nuclear Waste Fund'. The Energy Policy Act of 1992 exempted Yucca Mountain from earlier, generic EPA disposal standards used for the Waste Isolation Pilot Plant and directed EPA to develop new site-specific standards for Yucca Mountain, based on the recommendations of the US National Academy of Sciences. The NRC was directed to develop criteria consistent with EPA standards.

The Low-Level Radioactive Waste Policy Act (LLRWPA) of 1980 [3], as amended in 1985 [4], established the state and Federal responsibilities for the disposal of commercial LLW. The LLRWPA also refers to the NRC classification of LLW in Title 10, Code of Federal Regulations (CFR), Part 61 [5]. In this context, LLW is classified in the commercial sector as Class A, Class B, Class C and Greater-than-Class C (GTCC). This classification system is based essentially on potential LLW hazards and disposal and waste form requirements. Class A LLW contains lower concentrations of radioactive material than Class B LLW which, in turn, has lower concentrations than Class C LLW. Further, in the 1985 LLRWPA Amendment, Congress provided three types of incentive for states to enter into regional compacts for LLW disposal: the Amendment (1) provided any state that did enter into regional compacts with monetary incentives; (2) allowed states hosting disposal sites to impose substantial surcharges for waste disposal on those states that failed to comply; and (3) required a state to take title of its waste and be liable for any damages incurred by the waste generator, if that State were unable to provide for disposal of its waste by 1996. Progress has been slow in implementing this approach.

3. ROLES AND RESPONSIBILITIES OF FEDERAL AGENCIES AND STATES

For HLW, the DOE has the responsibility for developing permanent disposal capacity at Yucca Mountain for SF and other HLW, if the NRC grants a licence. EPA has responsibility for issuing environmental standards for evaluating the safety of a geological repository at Yucca Mountain. The NRC has responsibility for issuing regulations that implement EPA's standards, for deciding whether to authorize construction and operation of the proposed repository, and for ensuring that the DOE, if authorized, safely builds, and later safely operates, the proposed repository. The NRC has engaged the DOE in prelicence application activities. Therefore, through public dialogue with the DOE, the NRC has sought to increase its confidence that a licence application would be of sufficient quality for the NRC to conduct its informed safety review.

EPA issued its Yucca Mountain specific radiation protection standards in 40 CFR Part 197, on 13 June 2001. These standards are designed to protect public health and safety by establishing a maximum acceptable annual dose to a reasonably maximally exposed individual in the accessible environment outside a Yucca Mountain repository. The NRC finalized its Yucca Mountain-specific licensing criteria and published 10 CFR Part 63 on 2 November 2001, incorporating EPA public health and environmental standards. In 2004, these standards and regulations withstood multiple legal challenges — except for the length of time over which the standards for post-closure repository performance must be evaluated. The Court of Appeals for the Washington, D.C. Circuit vacated, in July 2004, the 10 000 year compliance period that was established in EPA's standard and incorporated into the NRC's regulations. Because of the Court's decision, EPA is now proposing to revise the post-closure compliance period.

The DOE's role is to characterize the Yucca Mountain site and determine whether it should be developed as a repository. Based on a recommendation from the DOE, the President notified Congress, on February 15, 2003, that he considered the Yucca Mountain site suitable for a construction authorization application. The State of Nevada (the state where Yucca Mountain is located) was allowed, under current statutes, to raise an objection to the Presidential action. The process allows Congress to overrule the Nevada objection. Congress did overrule Nevada's objection and approved the President's recommendation on 23 July 2003, directing the DOE to prepare an application to build a repository at Yucca Mountain. Once the DOE submits a licence application for Yucca Mountain, the NRC will conduct a safety review and make a decision on whether to deny, approve with conditions, or approve development of a repository at Yucca Mountain.

The role and participation of the 'State and Affected Tribes', regarding disposal of HLW and spent fuel, are codified in the NWPA, as amended in February 1995. The DOE Secretary is required to consult and cooperate with the state regularly so as to provide an orderly process for state review and evaluation for resolving the state and affected Indian tribe's objection at any stage of the planning, siting, development, construction, operation or closure process. This process provides for negotiation, arbitration, or other appropriate mechanisms, including public notification.

The Low Level Radioactive Waste Policy Amendments Act of 1985 gives States the responsibility for the disposal of LLW generated within their borders. For commercial LLW, the disposal facilities must be licensed either by the NRC or Agreement State(s) (AS) in accordance with health and safety requirements (10 CFR Part 61, or AS-compatible safety standards). Currently, there are 10 compacts comprising 42 states, and 10 unaffiliated states (the District of Columbia and Puerto Rico are considered unaffiliated states with regard to LLW disposal compact membership). Under the Atomic Energy Act (AEA) of 1954 [6], the NRC may relinquish to the states a portion of its authority to license and regulate nuclear materials. Currently, 34 of the 50 states have entered into an 'Agreement' with the NRC. Nevertheless, LLW facilities have to be designed, constructed, and operated to meet safety standards (i.e. NRC standards or compatible AS standards). Currently, there are three active licensed LLW disposal facilities: (1) Barnwell, SC (access is authorized for all LLW generators until 2008 but limited to the Atlantic compact after 2008); (2) Hanford, WA (restricted access — only to the Northwest and Rocky Mountain compacts); and (3) Clive, UT (restricted to mostly Class A waste).

In brief, each of the three Federal agencies, i.e. the NRC, the DOE and EPA, as well as the states, have significant roles and responsibilities in regulating radioactive waste disposal activities. Figure 1 provides an overview of the complementary roles and responsibilities of these agencies.

4. FRAMEWORK FOR SUCCESSFULLY MANAGING RADIOACTIVE WASTE

Approaches to the management and disposal of radioactive waste in the USA involve a framework of technical, regulatory and societal elements. Such a framework incorporates the best available science, involves progressive

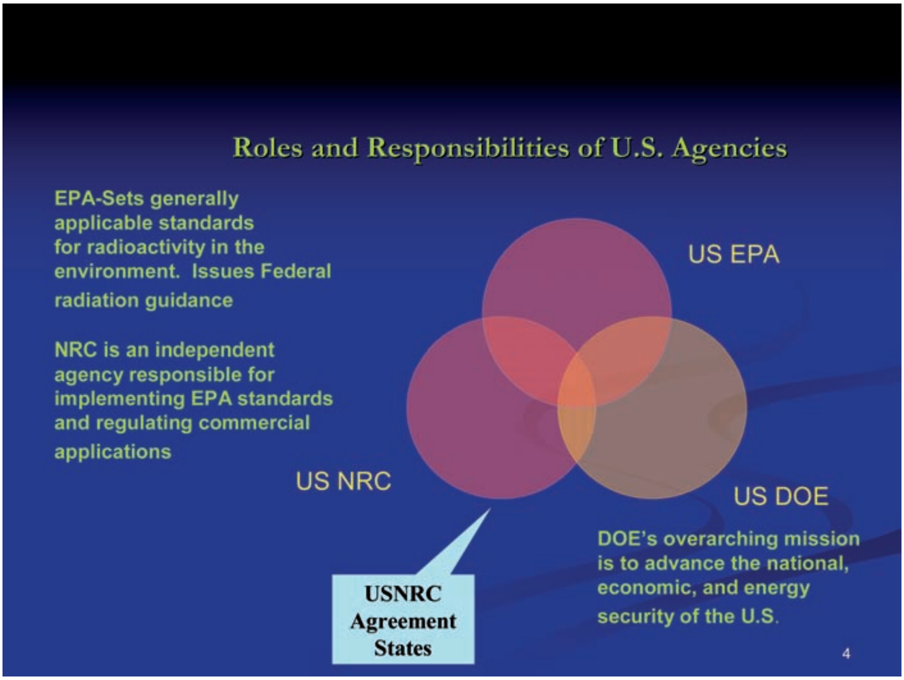

FIG. 1. Roles and responsibilities of US agencies in radioactive waste management and regulations.

regulatory oversight at all stages of the programme, and provides opportunities for the public to be heard in an open process. The fundamental technical element involves a comprehensive safety strategy, which is clear, robust, understandable, and consistent with relevant available data. The safety strategy provides flexibility to allow for incorporation of information from continual learning. A progressive regulatory programme has a clear regulatory structure of rules and guidance, provides for a thorough safety review, provides well defined decision points, allows for broad societal input and critical review and progressively builds confidence in the basis for regulatory decisions. An open process should provide stakeholders with clear and accurate information and a meaningful role in the regulatory process. While all participants may not ultimately agree with the regulatory decision, understanding of how they can participate in the process is imperative. Another critical element of the framework is a clear understanding of roles and responsibilities for protecting health and safety. In the USA, the licensee bears this responsibility; however, as noted in the framework discussion above, the regulator and the public also play important roles.

The NRC, EPA and the states typically develop safety regulations and guidance based on the above framework. Although there are minor differences in safety standards and implementation approaches, all agencies essentially share similar basic principles in establishing and implementing good regulations. The NRC has developed the following principles for conducting its responsibilities:

— *Independence:* Nothing but the highest possible standards of ethical performance and professionalism should influence regulation. However, independence does not imply isolation. For example, the NRC will seek all available facts and opinions openly from licensees and other interested members of the public and consider the diverse perspectives provided through the regulatory process. The NRC strives to base decisions on objective, unbiased assessments of all information and explicitly state its reasons for the decisions;

— *Openness:* Nuclear regulation is the public's business, and it must be transacted publicly and candidly. The public must be informed about, and have the opportunity to participate in, the regulatory processes, as provided by law. Open channels of communication must be maintained with Congress, other government agencies, licensees and the public, as well as with the international nuclear community;

— *Effectiveness and efficiency*: All parties involved in the regulatory process are entitled to the best possible management and administration of regulatory activities. The highest technical and managerial competence is required and must be a constant agency goal. Therefore, the NRC, as an example, must establish means to evaluate and continually upgrade its regulatory capabilities. Regulatory activities should be consistent with the degree of risk reduction they achieve. Where several effective alternatives are available which ensure safety and security, the option that minimizes the use of resources should be adopted. Regulatory decisions should be made without undue delay;

— *Clarity:* Regulations should be coherent, logical and practical. There should be a clear nexus between regulations and agency goals and objectives. Agency positions should be readily understood and easily applied;

— *Reliability:* Regulations should be based on the best available knowledge from technical investigation, research and operational experience. The agency should take into account systems interactions, technological uncertainties and the diversity of licensees and regulatory activities, so that risks are maintained at an acceptably low level. Regulation should be perceived by all stakeholders to be stable and reliable.

These principles are typically implemented through strategic goals, strategic plans, and performance goals and measures.

5. STRATEGIES FOR EFFECTIVE RADIOACTIVE WASTE MANAGEMENT

An operational strategy for implementing waste management policy in the USA involves the minimization of waste by requiring the licensees to reduce the quantity of waste generation from the source and by ensuring efficient and timely decontamination of facilities. Effective disposal strategies involve isolation of waste from the environment for a period of time appropriate for the hazard of the waste. This can be accomplished through appropriate characterization of the waste, adequate design and implementation of disposal technology, and realistic projections of disposal system performance over the period of hazard of the waste. Use of multiple barriers should be used to optimize the system. Also, the concept of defence in depth, consistent with the hazard of the waste, can be used to enhance confidence about the isolation of waste in the face of uncertainty. Passive safety designs for isolation of long lived waste are used, although institutional controls, including the periodic monitoring of on-site and off-site environmental media, such as soil, groundwater and air, are encouraged.

These strategies contribute to meeting the NRC's strategic goal of preventing significant adverse impacts from radioactive waste on the current and future public health and safety and the environment, and promoting common defence and security.

6. CHALLENGES AND LESSONS LEARNED

Over the past decade, significant progress has been made in the disposal of radioactive waste in the USA. Near surface disposal of LLW continues to be a safe and viable option; intermediate level waste is currently being disposed of at the Waste Isolation Pilot Plant; DOE is proceeding toward submitting a HLW licence application to the NRC; and decommissioning of reactors continues without incident. Despite this progress, significant challenges remain in the areas of waste management and disposal. Important challenges remain with respect to making decisions in the face of uncertainty, public acceptance, and knowledge management.

A fundamental aspect of disposal is the estimation of potential radiological exposure in the future and, often, the far future (e.g. 1000 years and longer), based on an understanding of disposal site characteristics and the behaviour of engineered components such as the waste form and package. Uncertainties exist in safety decisions, because of limits on the scientific understanding of the future evolution of the site and engineered components, as well as limitations in the understanding of the behaviour and characteristics of future human exposure scenarios. Although it is generally accepted that specification of a reference biosphere is an acceptable approach for addressing uncertainties in the exposure scenarios, such a stylized approach may not be appropriate for characterizing the complexities and variability of the hazard associated with the evolution of the post-closure environment. Uncertainties in the evolution of the site characteristics and engineered components should be addressed in a structured manner — involving a robust design, quantitative analyses, and monitoring and confirmation activities.

The defence in depth principle has served as a cornerstone of the NRC's deterministic regulatory framework for nuclear reactors, and it provides an important tool for making regulatory decisions, with regard to complex facilities, in the face of significant uncertainties. The NRC also has applied the concept of defence in depth elsewhere in its regulations to ensure safety of licensed facilities through requirements for multiple barriers. For example, regulations for HLW disposal at Yucca Mountain specify that the repository is to be comprised of both natural and engineered barriers. A repository design made up of multiple barriers is expected to be more tolerant of unanticipated failures and external challenges. HLW represents a large potential hazard because of the magnitude of the inventory of long lived radionuclides. It would be expected that the need for defence in depth would vary, consistent with the variation of the level of the hazard and uncertainties over the spectrum of the waste management activities (see Fig. 2). Secondly, quantitative analyses can be used to achieve understanding of the potential effect of uncertainties with respect to overall performance of waste management facilities and the capabilities of safety barriers. Quantitative methods for addressing uncertainties associated with repository performance have matured significantly over the past two decades. Consistent with the level of the hazard and the uncertainties, quantitative methods can be used to evaluate the robustness of facility design and the impact of uncertainty on performance. Finally, the NRC uses its inspection programme as a means to further confirm, to the extent practicable, the safety attributes of the design components and site characteristics.

A second challenge is in the area of public outreach. Difficulties have been encountered in the siting of waste disposal facilities. Acceptance of waste management facilities requires public trust and understanding of the issues. Certainly, the public should expect accurate and timely accessibility to

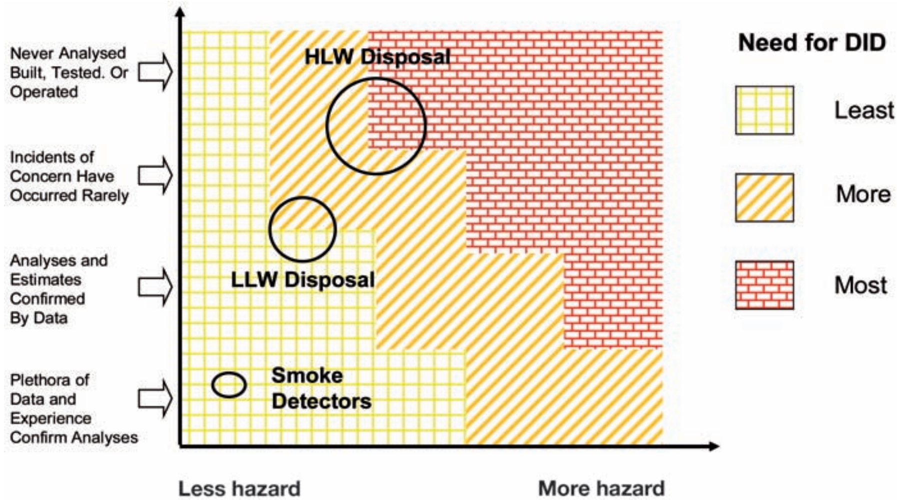

FIG. 2. An example of how the need for defence in depth (DID) can be related to uncertainty and potential hazard.

information about the risks of waste management facilities. Access to information alone will go a long way toward building trust; however, trust alone does not provide for an understanding of the issues. Although scientists' abilities to quantify and evaluate uncertainties have matured, additional improvements are needed in the ability to explain the analyses for all stakeholders. The information should be developed to be understandable to scientists and non-scientists, as well as to individuals outside of the immediate staff of the agencies responsible for developing and regulating the facilities. In this regard, the NRC continues efforts to improve its public outreach programme and communication tools to assist its explanation of risks. For example, a physical model of the potential repository at Yucca Mountain is being developed as a means to explain the behaviour of the repository without the need for charts and graphs, which can be somewhat abstract to many stakeholders with a non-science background. Primary goals of the outreach programme are to present objectively the results of scientific and engineering analyses (both NRC independent analyses as well as the analyses of others) as the basis for scientific judgements.

The NRC has gained significant experience in the development and application of performance assessments of waste management facilities and, more recently, in the development of methods and approaches for the communication of performance assessment concepts and results. A final challenge is the management of this knowledge to ensure that staff benefits from, and will be able to continue to build on, this valuable experience. A minimum requirement is to thoroughly document the technical basis for rules and guidance. In the high level waste programme, the NRC has consistently documented the development of its performance assessment capabilities, including the technical basis for performance assessment models, as well as the sensitivity and uncertainty analyses. Additionally, the NRC has documented technical analyses performed to develop the regulations for Yucca Mountain. The international community provides another approach for enhancing staff knowledge. International peer reviews, research, safety evaluations and cooperative efforts provide opportunities for staff to learn and expand its knowledge of waste management issues and solutions.

7. SUMMARY AND CONCLUSION

Radioactive waste in the USA comprises five main categories, including: SF, HLW, TRU, MT and LLW. The USA has well established policies and regulatory frameworks for radioactive waste disposal; they promote safety and ensure protection of the health and safety of workers, the public, the common defence and security, and the environment. The waste safety programmes maintain robust and effective oversight of large and diversified activities involving the management of spent nuclear fuel and radioactive waste. The policies and roles and responsibilities of the agencies are distinct and codified in a series of policy acts, by-laws, and regulations. The major agencies involved in radioactive waste management and regulatory oversight include: NRC, DOE, EPA and the Agreement States. A framework for the successful management of radioactive waste involves technical, societal and regulatory elements. Robust safety strategies include waste minimization, isolation, periodic monitoring, and defence in depth using multiple barriers.

For the past several years, the NRC, as well as other agencies, has made significant progress and gained extensive experience in regulatory oversight and management of radioactive waste. Lessons have been learned which have resulted in process improvements. However, challenges remain. For example, the NRC staff faces challenges with decision making in the face of uncertainties over long time periods as well as challenges in conducting an effective dialogue with the public on complex technical issues. While addressing these challenges, the NRC benefits from communication and collaboration with the international community. It is believed that continual learning, openness and worldwide cooperation will lead to additional advances in knowledge and public trust for radioactive waste management and disposal.

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DISCUSSION

W. HILDEN (European Commission): Is the radioactive waste resulting from nuclear power plant decommissioning in the United States of America being recycled or disposed of?

M.V. FEDERLINE (United States of America): We have a number of options that allow release, but most of the waste is being disposed of.

SAPIERR — THE IDEA OF EUROPEAN REGIONAL REPOSITORIES IS TAKING SHAPE

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Abstract

The SAPIERR is a project under the 6th Euratom Framework Programme of the European Union. SAPIERR is an acronym for Support Action: Pilot Initiative on European Regional Repository. It was launched on 1 December 2003; its overall duration is two years and so it is close to its end. This project aims to bring together countries in Europe with an interest in investigating the possibilities for shared repositories for spent nuclear fuel/high level radioactive waste, and to present the case for such an option. Twenty-one organizations from 14 countries (Austria, Belgium, Bulgaria, Croatia, Czech Republic, Hungary, Italy, Latvia, Lithuania, Netherlands, Romania, Slovakia, Slovenia and Switzerland) have agreed to take part in the SAPIERR working group. Using the inputs of these working group members, two technical reports were produced — one on inventories of radioactive wastes in the SAPIERR countries and the other on legal aspects of the regional repository — during the first year of the project, and a report on options and scenarios for European regional disposal and on recommendations for future research and development in the European, during the second year. The paper describes the overall project, briefly presents interim results, such as inventories of spent nuclear fuel, high level waste and long lived intermediate level waste and proposed standardization of waste disposal packages.

1. BACKGROUND

Following an initiative of Arius, Switzerland, a consortium, composed of DECOM Slovakia and Arius, submitted a proposal within the Euratom 6th Framework Programme for a pilot study called SAPIERR on a regional approach to radioactive waste disposal. SAPIERR is an acronym for Support Action: Pilot Initiative on European Regional Repository. Its purpose is to

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help the organizations involved to begin to establish the boundaries of the European regional repositories issue, collating and integrating information in sufficient depth to allow concepts for potential regional options and any new research and development needs to be identified. The primary objective of SAPIERR is to bring together those member States of the current and the extended European Union wishing to explore the feasibility of regional European solutions for deep geological disposal. Specific proposals for regional facilities, including potential siting are beyond the scope of this initial pilot study. The development of a geological repository is a very long term project with an overall duration of decades. Given the rapid geopolitical development in Europe, the socio-political reservations concerning multinational repositories that have been expressed by some countries may well have been overcome by the time of actual construction, and the environmental and economic advantages of these solutions may prevail over the political problems.

The proposal for the SAPIERR project was submitted to the European Commission in the first batch of the calls for proposals under the 6th Framework Programme in May 2003. After evaluation of the proposal by independent experts, the project was accepted for funding and launched on 1 December 2003. The planned project duration is two years.

The funding for DECOM's work, as coordinator of the study, is provided through the 6th Euratom Framework Programme managed by the European Commission in Brussels. Under the bilateral arrangements existing at the time of project initiation between Switzerland and the European Union, Arius is supported directly by the Swiss Department of Education and Science. At present, SAPIERR is in its second year. Thus far, all the project objectives have been met and the culminating event — a closing seminar — is planned to be held in Brussels on 9 November 2005.

2. IAEA CONTEXT

The IAEA has been observing the progress of the SAPIERR project since its beginning. The IAEA itself is a promoter of the multinational repositories idea mainly from the safeguards point of view. The IAEA publication IAEA-TECDOC-1413 [1] issued in October 2004 reviews the possibilities for the realization of multinational repositories and is intended to serve as a reference for Member States potentially interested in multinational repository concepts as hosting, partner or third party countries. The report attempts to define the concepts involved in the creation of multinational repositories, to explore the likely scenarios, to examine the conditions for successful implementation, and to point out the benefits and challenges.

3. PROJECT STRUCTURE AND ACHIEVEMENTS

SAPIERR is a pilot project on a small scale. The first year was devoted to gathering inventories data and analysis of the legal aspects of multinational repositories. This was achieved by the establishment of a working group whose members supplied national data for analysis. The objective of the project in its second year is to analyse options for a European regional repository based on the collected data and, finally, to suggest areas for further research and development in this area.

3.1. Data on inventories and legal aspects

The consortium has collated and documented the data and views from European countries interested in regional solutions. This has been done interactively with the working group participants. These data have been complemented by a review of the existing information from the European Commission and from IAEA databases. The issues examined comprise:

— For each country, the amounts, types and times of arising waste that might be a candidate for disposal in a regional disposal facility;
— The nature of legal issues concerning waste transfer, liability and waste transport, export/import;
— National political and organizational views and policy and European radioactive waste policy;
— Economic aspects of shared facilities (nationally and in the European Union).

The above information was collected from the working group participants by means of two questionnaires: on inventories and on legal aspects. The questionnaires were prepared by the consortium and further discussed and refined at the working group kick-off meeting. The kick-off meeting took place in Piestany, Slovakia on 19–20 February 2004: 21 organizations from 14 countries (Austria, Belgium, Bulgaria, Croatia, Czech Republic, Hungary, Italy, Latvia, Lithuania, Netherlands, Romania, Slovakia, Slovenia, Switzerland) agreed to take part in the SAPIERR working group. It must be noted that the organizations involved in the project represent only themselves and not the official views of the respective countries.

The consortium reviewed the above questionnaires and consulted with the working group participants when necessary. When additional data were needed, other published data were used and the source was referenced. Similarly, data for non-SAPIERR European Union countries have been derived from published documents. Subsequently, two technical reports have been compiled on the basis of the gathered information:

— Legal Aspects [2];
— Inventory of Radioactive Waste [3].

These reports were submitted for comment to all working group participants and later to the European Commission.

The Legal Aspects report attempts to document the current legal framework related to the option of a regional solution for storage and disposal of long lived radioactive wastes. An overview of the status of national and international legislation regarding waste transport and transfer, export and import is given and the radioactive waste management programmes, including the competent authorities, funding and waste policies of the countries covered in the study, are described and summarized. The legal framework on liability management, which also plays an important role in connection with internationally shared repositories, was excluded from the present study but will have to be examined in subsequent studies.

The Inventory of Radioactive Waste Report presents the status of nuclear power in Europe and assumptions on its future development, surveys of waste management policies in the SAPIERR countries, and estimates of radioactive waste amounts arising in the SAPIERR countries. An attempt is made to assess the cumulative inventories of spent nuclear fuel, high level radioactive waste and other long-lived waste from all SAPIERR countries and its growth in time (see Fig. 1).

Comparisons are made between the size of nuclear power programmes in individual SAPIERR countries and other European Union countries and between the inventory of spent fuel in the SAPIERR countries and other countries with large nuclear programmes.

The graph in Fig. 2 shows a comparison of the total installed power in all SAPIERR countries and countries intending to construct national deep geological repositories. It can be seen that the total installed power in all SAPIERR countries is still less than that of France. This is one factor prompting the 11 SAPIERR countries owning nuclear power plants (plus three countries owning only research reactors) to examine the possibilities for

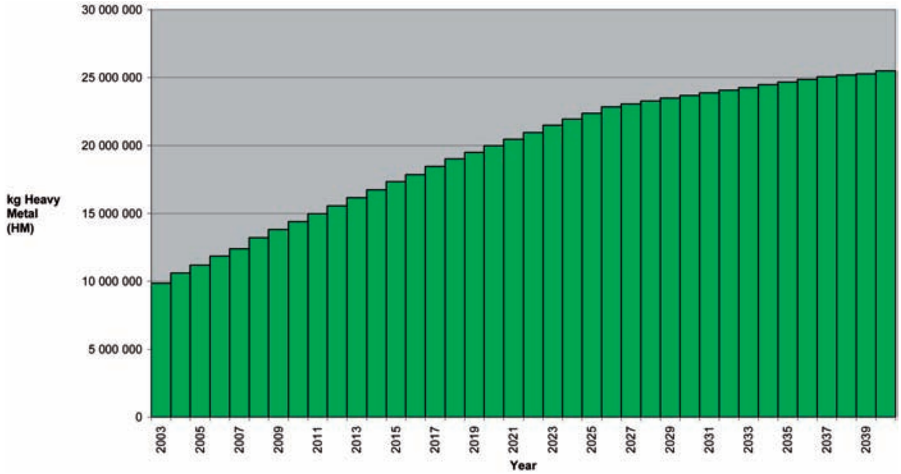

FIG. 1. The cumulative amount of spent fuel destined for disposal from all SAPIERR countries.

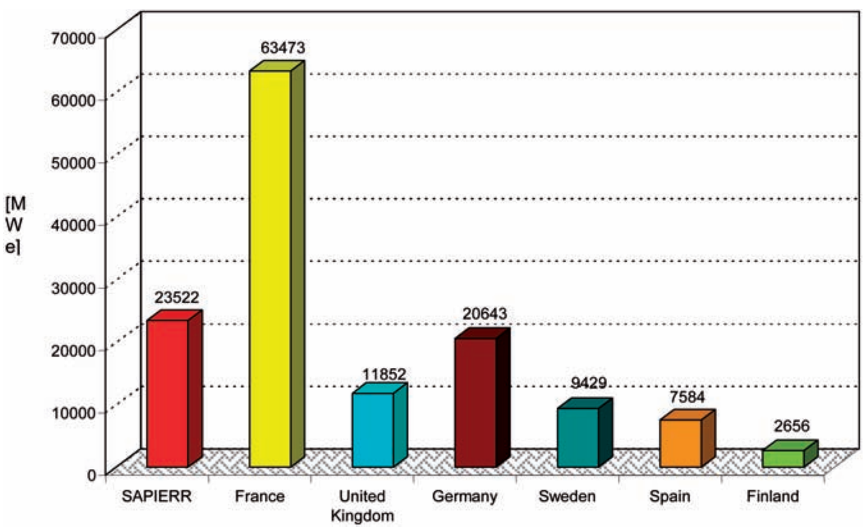

FIG. 2. A comparison of size of nuclear power industry in terms of installed power in all SAPIERR countries and countries intending to construct national deep geological repositories.

construction of a shared deep geological repository instead of 14 separate facilities.

More specifically, the SAPIERR countries' spent fuel inventory can be compared to the inventories of the countries with large nuclear programmes, for example, France or Germany. At the end of 2002, about 7200 t of French fuel was stored at La Hague and 3600 t in EDF's nuclear power plants. An estimate of the amount of spent nuclear fuel generated in Germany is that 9000 t will have been generated by around 2020. The total amount of 10 800 t of French spent fuel is 10% larger than the current inventory of spent fuel in all SAPIERR countries. Taking into account the policies of individual SAPIERR countries described in the Inventory Report, it can be expected that in 2040 the spent fuel inventory of all SAPIERR countries together will still be less than the spent fuel inventory of France alone and will be only about twice that of the spent fuel inventory of Germany.

Another good example of a large size deep geological repository for spent fuel is the planned Yucca Mountain repository in the USA. The US Department of Energy is currently preparing to submit a licence application to the Nuclear Regulatory Commission for repository construction authorization. The US legislation limits the emplacement of waste at the first geological repository to 70 000 tHM until such time as a second repository is in operation. The materials that may be disposed at Yucca Mountain include about 63 000 tHM of commercial spent fuel; about 2333 tHM of defence programme spent fuel; and about 4667 tHM of defence programme high level radioactive waste. From the above figures it can be seen that all of the SAPIERR reference spent fuel could fit into a single repository smaller than that which France or the USA will need, but that the quantities are high enough to suggest that it could still be economical to implement more than one repository for regional use.

Other issues, such as storage capacities, national repository programmes, and costs of the repositories development have been also addressed in the study.

3.2. Options and scenarios

Current work is examining the scenarios and possible concepts for European regional disposal. Three types of standard disposal containers have been proposed for all spent fuel for disposal from the SAPIERR countries. Such standardization is an important cost saver and may be the first and easiest step towards the development of the European regional repository. Figure 3 shows how many containers of each size would be produced, assuming a uniform cooling time of 50 years for the spent fuel before conditioning.

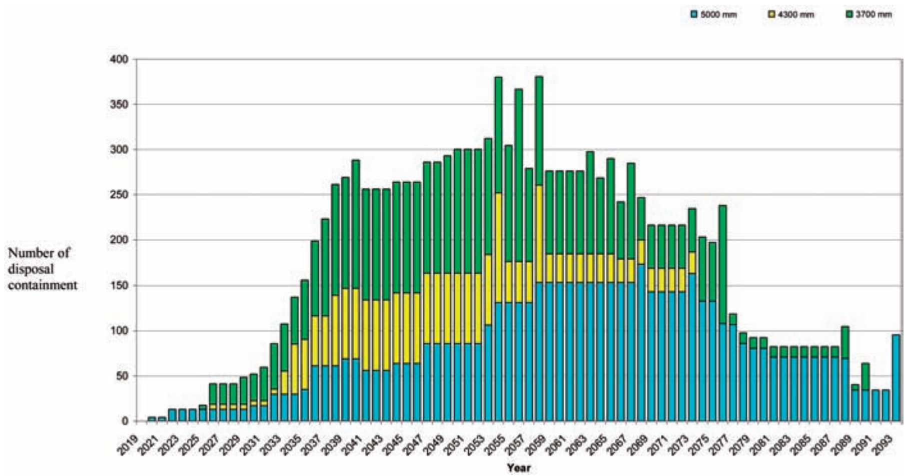

FIG. 3. Production of the disposal packages with spent fuel from the SAPIERR countries.

With similar standardization of packages for HLW and partially also for ILW, the options for (a) a single repository for all the waste, and (b) separate repositories for spent fuel and ILW, are being analysed in terms of optimum point in time when they need to be available and the required sizes and costs.

The study on options and scenarios will be complemented by the identification of requirements on transnational research and development to be carried out in the future. SAPIERR will clarify the research and development requirements to address unresolved safety, governance, and economics aspects of a potential European regional repository. More specifically, it will also propose mechanisms for developing strategy options and research and development needs in future European Union programmes.

4. CLOSING SEMINAR

The working group participants will meet again, towards the end of the project, at an open international seminar in Brussels on 9 November 2005. The objective of the seminar will be to review and disseminate the results of the project to a wide audience and to record views on the most effective subsequent steps on the way towards a European Regional Repository. Regional repositories are also of interest outside Europe but have been little studied. SAPIERR and its concluding seminar will hopefully put the European

Union in a leading position to provide advice and, possibly, services to other countries.

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[2] BOUTELLIER, C., McCOMBIE, C., Legal Aspects, Technical Report of the SAPIERR project, Deliverable D2, European Commission, Brussels (2004).

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DISCUSSION

W. HILDEN (European Commission): If a non-SAPIERR country offered to accept and dispose of radioactive waste from the SAPIERR countries, would these countries — or some of them — not be tempted to export their waste to the non-SAPIERR country?

V. ŠTEFULA (Slovakia): I cannot speak for individual SAPIERR countries. In the scenarios on which we have focused, one or more SAPIERR countries would accept the radioactive waste of other SAPIERR countries. We have not considered such an 'add-on' scenario.

W. BREWITZ (Germany): Have you taken account of transport costs? With 14 participating countries, they could be substantial.

V. ŠTEFULA (Slovakia): We are aware that there could be substantial transport costs, but we have not quantified them.

A. ZURKINDEN (Switzerland): You spoke of a total inventory of 350 m^3 of high level waste (HLW) and 31 000 m^3 of low and intermediate level waste (LILW) in addition to 25 000 t of uranium.

Where would the HLW and LILW come from — and would it all be disposed of in a single repository?

V. ŠTEFULA (Slovakia): The HLW would be from the reprocessing of spent fuel, mainly from Italy and the Netherlands, and there would be 31 000 m^3 of long lived waste from the decommissioning of nuclear power plants and research reactors.

It is assumed that the HLW would be disposed of together with spent fuel. As to the decommissioning waste, two options have been examined — a single repository for the spent fuel plus the HLW and the LILW, and separate repositories for the spent fuel plus HLW and for the LILW.

L.W. CAMPER (United States of America): Given the number of countries involved in the SAPIERR project, what was the basis for the assumption that no further nuclear power plants would be built and there would be no plant life extensions?

V. ŠTEFULA (Slovakia): We made that assumption for the sake of simplicity — we wanted a single base case.

REVIEW OF CONTRIBUTED PAPERS

Session IIb: NATIONAL STRATEGIES TO ENSURE THE SAFE DISPOSAL OF RADIOACTIVE WASTE

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Abstract

The paper identifies and summarizes the main issues arising from the 32 contributed papers to the session. The main topics covered are addressed under the headings: national strategies, waste processing, storage, disposal and clearance. The paper concludes by summarizing the main common issues arising from the papers.

1. INTRODUCTION

There is a broad interest among countries in the safe disposal of radioactive waste; 32 papers on the subject were contributed to this session from around the world as shown in Fig. 1.

Radioactive waste management issues of concern vary between countries depending mainly on whether or not nuclear power is being utilized in the country. The following issues were addressed by two or more papers:

— National strategies for radioactive waste management;
— Waste processing;
— Management of stored waste;
— Disposal of waste in national and international repositories;
— Use of clearance levels for the release of materials from regulatory control;
— Management of contaminated sites.

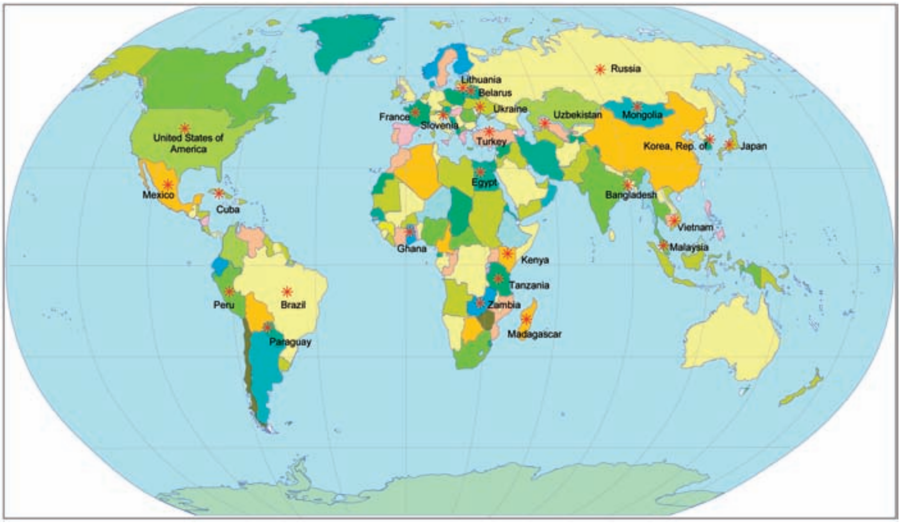

FIG. 1. Distribution of countries contributing papers to Session IIb.

2. NATIONAL STRATEGIES

Most contributed papers described the preparation of national radioactive waste management strategies. In general, the main objectives of the strategies cover the creation of the infrastructure of the national management system, the preparation of an effective legal framework and the definition of clear, unambiguous responsibilities for regulators, waste generators and operators management installations.

These strategies are under development by responsible governmental bodies or dedicated committees. The following trends are apparent:

— The establishment of centralized radioactive waste management facilities seems to be an urgent matter in both developed and developing countries. Some of these facilities are, or have been, built with the help of other countries or the IAEA and are at commissioning stage or are already in operation;
— The dilute and disperse approach is a preferred practice in the management of liquid radioactive waste;
— There is a need for the development of very low level waste (VLLW) disposal facilities to accommodate the large volumes of radioactive waste

with activity concentrations just exceeding the clearance limits, e.g. from the decommissioning of nuclear power plants;

- Several disposal options are under consideration. In developing countries, where the inventory of radioactive waste consists mainly of disused sealed sources, the borehole disposal concept is becoming a preferred option or is considered to be as satisfactory as near surface disposal. In countries with large nuclear installations, such as nuclear power plants and reprocessing facilities, the construction of different types of repository to cover all waste types is under consideration. Two main disposal concepts are being considered — surface or near surface engineered facilities and mined rock caverns;
- Among the developed countries, waste classification schemes vary and do not necessarily conform to the IAEA classification scheme;
- Some developing countries expressed their interest in establishing a mechanism for the acceptance of their waste (mainly sealed sources) in existing repositories in developed countries.

3. RADIOACTIVE WASTE PROCESSING

Several contributed papers described national experiences with radioactive waste processing. From these it is obvious that the processing of liquid waste presents more problems than the management of solid waste. Liquid waste is usually stored in tanks awaiting appropriate conditioning. The construction of treatment and storage facilities is in progress in some countries to deal with the large volumes of liquid waste from the operation of nuclear power plants.

For developing countries with extensive mining activities, the management of waste containing naturally occurring radioactive material (NORM) is at least as important as the management of other radioactive waste types.

4. MANAGEMENT OF STORED WASTE

For countries without a disposal facility, the storage of radioactive waste is, temporarily, the last step in the management process. The need for national centralized storage facilities to provide safe storage until a national repository is constructed was expressed in several papers. Some existing storage facilities have been reconstructed and safety assessments for the derivation of operational limits and conditions were described.

5. DISPOSAL IN NATIONAL AND INTERNATIONAL REPOSITORIES

Several contributed papers provided details on planned or operating disposal systems:

— The safety assessment methodologies used for disposal facilities generally conform to the methodology developed in the IAEA's Improvement of Safety Assessment Methodology (ISAM) project, however, it is noted that intrusion scenarios have not normally been considered in the assessments;
— One developed country provided information on a new low level waste classification scheme for waste of different origin and type (operational, institutional, TRU and U waste), which is being used as a decision making tool for the determination of the most suitable repository concept;
— Several countries described the design of planned or operating near surface repositories;
— The need to establish safety guidelines for the planned subsurface disposal facilities with engineered barriers at the depth of 50 to 100 m below the surface was expressed.

Interest in the multinational disposal concept was not only expressed in the invited paper on the European regional repository project, SAPPIER, but also in a contributed paper prepared by specialists from five Latin American countries (Cuba, Costa Rica, Guatemala, Panama, Venezuela). The benefits of joint efforts for the development of regional repositories were clearly identified from the perspectives of both host country and countries shipping their waste to the regional repository. In contrast to the SAPPIER project, the inventory of the proposed Latin American regional repository would mainly consist of disused sealed sources. The development of a regional repository would have the potential for a near surface or borehole disposal facility to be shared by almost 30 Latin American countries. However, the paper also addressed several challenges:

— The need to identify countries in the region interested in using such a facility;
— The need to achieve consensus among the involved countries for implementing a regional Latin American repository;
— Possible issues with national laws on waste import and export.

6. USE OF CLEARANCE LEVELS

The derivation and verification of clearance levels for solid waste and waste oil generated by the operation of nuclear power plants and for decommissioning waste was the main subject of several of the papers from developed countries.

Clearance levels were derived using several scenarios (landfill disposal, incineration, recycling) for a wide range of short lived radionuclides and compared with the values published in different IAEA documents. The calculated values of the clearance levels are comparable with the values listed in IAEA Safety Guide RS-G-1.7 and are generally lower than other reference values. These values will be used in the revision of clearance related regulations. The procedure for verification of clearance levels used in one developed country was also described.

The management of large contaminated sites is an issue that was addressed in contributed papers from two Eastern European countries. This contamination is a result of a major accident and military and civil activities on the coastal areas. One paper focused on the conditioning of radioactive contamination in the soil while the other was concerned with the radiological classification of contaminated areas.

7. CONCLUSIONS

From the contributed and invited papers the following issues were identified:

- Disused sealed sources;
  - Borehole disposal concept as a preferred disposal option for disused sealed sources in developing countries;
  - Prospects of a multinational regional repository for disused sealed sources, benefits and challenges;
- Disposal of low and intermediate level waste;
  - Development of subsurface disposal facilities at intermediate depth;
  - Safety case for disposal facilities;
  - Acceptance of radioactive waste of foreign origin for disposal;
- Geological disposal of spent fuel and/or high level waste (HLW);
  - Alternatives to geological disposal of spent fuel and/or HLW;
  - Prospects for a regional geological repository;

— Regulation of radioactive waste management activities;
  - The role and involvement of regulatory authorities in the site selection process and in the definition of siting criteria for different types of disposal facilities;
  - Roles and responsibilities of national agencies involved in the regulations of radioactive waste management activities;
— Centralized waste management facilities;
— Country specific classification schemes for radioactive waste;
— Acceptance of waste management facilities by the public;
— Internationally derived versus case by case clearance levels;
— Management of large amounts of contaminated material from decommissioning and site restoration activities.

PANEL

Session IIb
NATIONAL STRATEGIES TO ENSURE THE SAFE DISPOSAL OF RADIOACTIVE WASTE

Chairperson: **A.J. Hooper** (United Kingdom)

Members: **R. Cailleton** (France)
M.V. Federline (United States of America)
V. Štefula (Slovakia)
P. Lietava (Czech Republic)
T. Kosako (Japan)
C. McCombie (Switzerland)
M.J. Song (Republic of Korea)
D. Louvat (IAEA)

A.J. HOOPER (United Kingdom): From the presentations made earlier in this session it is clear that there is a 'common framework' within which we can think about what long term management solutions exist for radioactive waste. However, R. Cailleton's presentation seemed to indicate that even in a country which has made great strides in the field of radioactive waste policy development there are some waste types for which the long term management solution is not very well defined. Perhaps R. Cailleton could clarify that point.

R. CAILLETON (France): With the law of 30 December 1991 we acquired a legal framework for seeking a long term management solution for high level waste. Then, in the 1990s, we developed a management framework for low and intermediate level waste and for very low level waste. Now, in developing the National Plan for Radioactive Waste Management we are trying to cover all categories of radioactive waste.

For some waste categories there are at present no long term management solutions, but the National Plan places the responsibility on waste producers for finding solutions and requires actions within a reasonable timescale.

T. KOSAKO (Japan): Regarding the 'common framework', within ICRP we have been discussing similar questions for over ten years. The inclusion of NORM presents different problems from those encountered in managing normal nuclear fuel cycle waste. The situations in which we encounter NORM are not usually like conventional 'practice' situations; they can be better described as ‘intervention’ situations — in the sense that they have often not been planned and are a legacy from the past. It is not possible to use the dose limits and constraints designed for the control of practices; a different type of thinking is necessary. The most relevant ICRP publication on this topic is ICRP Publication 82.

In this context, the Japanese Radiation Council has already set guidance levels for NORM and TENORM.

It is important that NORM is included in the discussion of a common framework.

C. McCOMBIE (Switzerland): Technical people need a common framework, and the public needs a common framework. Without it we would not be credible.

What bothers me is that we tend to talk about a common framework that is commensurate with the hazard. But some elements have been left out — the volumes and the economics. Either the standards themselves or the approaches used have got to take account of volumes and economics. Standards might differ, because we might guarantee 0.1 mSv/a for 10 000 years into the future for a deep geological repository, but it is very difficult, if not impossible, to guarantee achieving such safety criteria for a near surface facility with long lived waste in it. Using the same example, you can try to build your deep repository in such a way that you do not have to have institutional control forever but you cannot achieve the required degree of safety for mining waste on the surface without institutional control. In my view, therefore, ‘commensurate with the hazard’ has to be qualified with an ALARA-type qualification on the lines of ‘social and economic considerations being taken into account’. Otherwise, we shall again not be credible in a technical and a societal sense.

M.J. SONG (Republic of Korea): I would like to talk briefly about the common framework for the management of long lived intermediate level waste. At the beginning of the session, D. Louvat mentioned the linkages between waste classification and the disposal options, and after him R. Cailleton made a presentation about the French strategies. I think the French classification system and the actual and proposed disposal options are in close compliance with what the IAEA suggests, except in a few areas, such as NORM and TENORM, as T. Kosako mentioned. The other areas are tritium-bearing waste and sealed sources, as R. Cailleton mentioned. However, the grey area is the long lived intermediate level waste. For this waste, I think you can either have a separate repository or you can sink boreholes near the surface repository or the deep geological repository, whichever is possible. So I would like to ask D. Louvat whether it is possible to make clear recommendations for this kind of waste.

D. LOUVAT (IAEA): The last three interventions were very much linked.

I agree with T. Kosako that ICRP Publication 82 is an excellent reference document, and I also agree with him that bringing NORM into the decision aiding process for radioactive waste management is a challenge. It is a challenge we are confronting at the IAEA, and we have several standards on NORM under development or about to be developed — but the solution will not be straightforward.

However, there is also a history. Most NORM waste is legacy waste. We have to realize also that what resulted from the past is sometimes very close to an intervention situation as defined in ICRP Publication 82.

We must do something. We cannot leave the situation as it was in the past. This is the reason for taking NORM into consideration.

Some countries have already taken a decision, and we want to show that it is possible also for other IAEA Member States.

I disagree with C. McCombie about bringing economics and other factors into the equation. Behind the safety standards there is this very first principle that you should manage waste to protect the public, and everything should be done in accordance with this principle.

You may have noticed that with the type of framework we have proposed there is an acceptable solution and an unacceptable solution, and, in between, an inappropriate solution. What does 'inappropriate' mean? Does it mean inappropriate from a safety point of view but possibly appropriate when you are considering the local situation in terms of economics and other factors? Are we going to provide some clear indication in this document? That is the expectation, and I would say that it will depend on all of us. Once we start distributing the draft, we are willing to accept any comments and any suggestions for improvement.

Finally, I think that the point made by T. Kosako is very important. All the underlying reasoning is based on very sound and still very useful documents like ICRP Publication 82.

T. KOSAKO (Japan): C. McCombie said that the economic situation is also important. But let us consider the situation regarding NORM, which appears everywhere, not only in legacy situations but also in present activities — coal fly ash in power generation, scale in the oil industry, monazite and so on.

For application to these cases the intervention level will be decided by thinking not only in terms of the ideal but also in terms of the economic balance and social activities.

C. McCOMBIE (Switzerland): I would not like the word 'economics' to be taken too seriously. I am not saying that, if it is too expensive, we cannot make it safe. For ‘economics’ read ‘practicality’. We should not promise things that we cannot do. In the United States of America, and in some other countries, there was a promise made to clean up legacy sites to ‘green field’ status. If you had thought about it, you would have realized that it is not just a question of cost but of practicality. We lose credibility every time we say that we can do things that we end up not being able to do.

In the cases we have been hearing about, practicality is very closely tied to economics. You cannot take the whole surface of Hanford or Sellafield and dispose of it deep underground, which is probably what you would have to do if you wanted to maintain exactly the same standards.

A.J. HOOPER (United Kingdom): Perhaps we could now talk about stakeholder or public acceptance in the formulation of national policies or strategies. In the United Kingdom, we were intrigued by what happened recently in Canada where, with the involvement of a local community, it was decided that waste which — according to D. Louvat’s framework — ought probably to remain near the surface, should be placed in a deep geological repository.

In her presentation, M.V. Federline hinted that such matters are influential in United States policy. Perhaps she would like to comment on the role of public and stakeholder acceptance in the formulation of national strategies.

M.V. FEDERLINE (United States of America): Over time, we have developed our standards and requirements with public involvement, but how do we know when we get it right? I talked about defence in depth, and from a scientist’s standpoint I can convince myself that defence in depth addresses uncertainties. D. Louvat talked about putting material at a particular depth. What about the public that says “keep it open and monitor it at depth for a good number of years — that will convince me that this is the right thing to do”? What should we do? Should we listen to the scientists, should we listen to the public, or should we do both?

M.J. SONG (Republic of Korea): We have quite a long history of public involvement, especially with regard to low level waste disposal sites. We have experienced several serious failures in trying to establish candidate sites even for low level waste. Now we are about to establish one candidate site, possibly in November.

M.V. Federline emphasized the importance of the management of knowledge, but my experience indicates that it is not a matter of knowledge management; it is rather about public perception. The public tends to listen to what the environmentalists and the anti-nuclear groups are saying rather than to what the licensee and the government are saying. So the more important factor for us is how to cope with the environmentalists and the anti-nuclear groups and how to change the perception of the public.

R. CAILLETON (France): I should like to speak briefly about the way in which the French National Plan for Radioactive Waste Management was developed.

At the very outset, the safety authority invited all stakeholders to take part in a working group in order to help develop a draft plan. This included the waste producers environmental protection associations, Members of Parliament and also local representatives in order to have a diversity of points of view on the subject.

The fundamentals are the principles of safety and radiation protection, but inside this technical framework there is room for debate. That is why, from the very beginning, all kinds of stakeholders were invited to participate in the formulation of the draft plan. From July to the end of 2005 the draft plan will be available on a web site and open to public comment. After this period, the working group will discuss the comments and produce the final version of the plan.

A further comment — the plan to be issued at the end of 2005 or next year will not be definitive; it will not provide long term management solutions for all kinds of radioactive waste. It will be a step, and a few years later we will have to review the plan in order to determine whether we made real progress with the actions which were decided upon in 2005–2006 and then to set new priorities for the following years. So this is a step by step process.

A.J. HOOPER (United Kingdom): Perhaps we could now turn to the issue of regional repositories.

V. ŠTEFULA (Slovakia): When I talk about the SAPIERR project, I am often asked which country would be the host country.

There are some success stories connected with the volunteering approach for the siting of national repositories, for example, in the Republic of Korea, Finland, Belgium and Slovenia. In my view, if you are able to persuade the local public that the waste you are going to dispose of in their ‘backyard’ will be safe for a duration that exceeds the whole length of human civilization, then it is no problem for the public to accept the waste whether it is from a hospital or a nuclear reactor and regardless of the country of origin.

P. LIETAVA (Czech Republic): I am a little more sceptical. In my country, we tried to identify an appropriate site for a national deep geological repository but the exercise had to be stopped because of public opposition.

In relation to regional repositories, I think that we need to move from discussions to binding political decisions. That will be very difficult because, if you have a meeting where people from several countries are present, every country supports the idea of a regional repository if it is not going to be within its territory. So, the meeting ends and everyone goes home. In my view, we must therefore now find a way of moving forward — of transforming our knowledge about the advantages of regional repositories into binding political decisions by governments which agree not only to support the project but also to host the repository. That is a big task, and I do not know whether it is a task for the IAEA or for some other international organization.

D. LOUVAT (IAEA): I do not know whose task it should be. In my view, the process is a political decision making one which should be handled by the governments of the States concerned.

People often quote the IAEA's Director General regarding regional solutions. But the Director General sees regional solutions as a way to ensure, in the first place, non-proliferation and security.

C. McCOMBIE (Switzerland): It is easy to say that, in a meeting of people from different countries, no country will volunteer to host the repository. If you bring together people from different parts of a single country and say that a radioactive waste repository is going to be built and ask who is prepared to host it, you get the same result. It is not a different issue. The last thing you should do is start a national programme or a multinational programme by trying to decide on the site at the very outset. The way to do it in the case of a multinational programme is exactly the same as in the case of a national programme. First the participants must agree on the need for the facility. If they do not agree that there is a common need, you will not arrive at a common solution. After you agree that there is a need for a common solution, then you can talk about the attributes, the choices. It is the same logical path as for a national facility.

I would hate to interpret the mind of my boss, but when the IAEA's Director General is quoted he is quoted as also recognizing the economic and environmental benefits — not just the non-proliferation and security benefits.

It is a myth that the SAPIERR project is not realistic if there is no site. If that is the definition of 'realism', then there are about three realistic programmes under way in the world.

M.J. SONG (Republic of Korea): I am very much in favour of regional solutions. This issue is very important for small countries which have large nuclear power programmes — for example, my country and Taiwan, Province of China — and for countries which are big users of long lived radioisotopes.

Not only the general public, but also some scientists working in other fields are not confident about the safety of the disposal of radioactive waste, so I think it is a good idea to minimize the total number of repositories in the world.

I therefore favour a regional approach, especially in Asia. Japan is thinking about establishing a high level waste repository, but I do not think it has been very successful so far. However, its programme will continue. As a backup it might be a good idea for it to participate in a multinational repository programme for high level waste disposal.

T. KOSAKO (Japan): There is a question of equity concerning regional repositories. For example, we in Tokyo are benefiting from nuclear power generation taking place elsewhere in Japan while the people living near the nuclear power plants are exposed to a certain risk. Where is the equity? Similarly, if one country receives the radioactive waste of another country, where is the equity?

V. ŠTEFULA (Slovakia): It is interesting that people never challenge the fact that, when you produce uranium from ore, you leave the mill tailings in the country where the ore was mined and export the uranium to be used in other countries. People are never worried about a lack of equity in this case.

C. McCOMBIE (Switzerland): It has been suggested that the establishment of a multinational repository could be a national strategy. In my view, however, it would be foolish to have only that as your national strategy, because you would not know whether the multinational repository was ever going to materialize.

At the present stage of development of multinational facilities and of national facilities in 90% of the world, you can afford to keep both options open. Nobody will be disposing of high level waste and spent fuel for decades probably, so you do not have to decide now for or against one or the other. If you can keep your options open, keep them open.

A.-C. LACOSTE (France): Regarding the question of regional solutions, I should like to say a few words about the situation in France.

It is quite possible that early next year our Parliament will give the green light for the construction of a deep geological disposal facility for high level waste. If it does so, I think it will specify that the facility may not accept any radioactive waste from outside France (which would be in line with the present legal position in France).

I can imagine that many countries with smaller nuclear power programmes than France's or with no nuclear power programme at all will be unhappy about that precondition; from their point of view, it is absurd to imagine that each of them will one day construct a deep geological disposal facility. While understanding their concern, however, I think they should realize that, if they start dreaming too obviously about a regional solution, that may block the path to a national solution for France; if those countries are not cautious, many people in France will say: "The regional approach sounds fine. What about not having a national facility and relying on a regional one in, say, Slovenia or Slovakia?"

J.-M. POTIER (IAEA): Also regarding the question of regional solutions, I would say that for several countries to get together for the purpose of establishing a shared facility there must be a strong driving force. One driving force is economies of scale, particularly in the case of a geological repository, as the construction costs are very high.

However, there may be other solutions which can be implemented nationally and adapted to the size of a small nuclear programme. For example, if you look at the disposal facilities for low level waste, there are none which are shared, the reason being that they are fairly modular and can easily be adapted to the size of a nuclear programme and every country is able to implement a facility of its own.

At the IAEA, we are trying to help countries with small nuclear programmes where the radioactive waste consists essentially of disused sources. We are looking at the borehole disposal approach which, assuming that it can be implemented safely, would be a cost effective solution for such countries. The facilities are modular, so that there is no need for a number of countries to get together. The solution can be implemented nationally at a very reasonable cost.

F. BESNUS (France): What is the position of organizations like the IAEA regarding multinational versus national solutions from the point of view of safety rather than cost?

D. LOUVAT (IAEA): As I indicated earlier, the IAEA position regarding the multinational approach is based mainly on security considerations. If the events of 11 September 2001 had not occurred, it is unlikely the IAEA have the current level of interest in that approach. That approach is so far being discussed within the IAEA Secretariat and between it and Member States primarily with reference to the front-end of the fuel cycle.

I do not see any difference between a multinational facility and a national one from the safety point of view. Both will have to meet the same safety criteria, probably with the same safety case and the same licensing process. The only differences relate to the transport of the waste and to the safeguards provisions — an issue which could, in my view, easily be resolved by legal experts.

C. McCOMBIE (Switzerland): Regarding the question of multinational versus national facilities from the safety point of view, I agree with D. Louvat that there is no difference.

In my view, virtually every country could create a safe disposal facility — even a safe geological disposal facility; it would be more difficult in some countries than in others, but not impossible. So, you cannot say that you are going to pursue the regional approach because it is safer. On the other hand, you are not allowed to advocate the multinational approach on the grounds that someone else will do things more cheaply. No country should export its radioactive waste to another country unless it is convinced that the waste is going to be handled there with the same regard for safety that it would have itself.

As far as I know, only one country has shown any interest in accepting other countries' radioactive waste for disposal: the Russian Federation. If a facility was made available there for radioactive waste from other countries, I think all the potential users of the facility would have to be satisfied that the facility was as safe and well controlled as any other facility in the world. That is where an international organization like the IAEA might have an important role to play.

J. WANG (China): Technically, the establishment of regional repositories is possible. However, a repository for high level waste has not only technical aspects but also social, economic, environmental and — above all — political ones. So the driving force must come from the politicians.

P. LIETAVA (Czech Republic): We all know that multinational repositories are the most reasonable option from the economic and safety points of view but politically the most difficult one to realize. The question is who among us can sell the idea of multinational repositories to the politicians.

T. TANIGUCHI (IAEA): With regard to the IAEA Director General's proposal for a multinational approach, D. Louvat indicated that it was prompted by concerns about proliferation and security. Initially, the discussion focused on the most sensitive areas: enrichment and reprocessing. During the discussion, however, the multinational approach came to be regarded as more promising in the case of spent fuel and radioactive waste management than in that of enrichment and reprocessing. In my view, when considering multinational approaches to the nuclear fuel cycle we would do well to focus on spent fuel and radioactive waste management — that is the area where the driving force is most likely to come from.

L.W. CAMPER (United States of America): M.V. Federline has asked whether decisions should be taken by the public or by the scientific community. A question I would ask in response is: "Who is the public?" Environmentalists and anti-nuclear groups have been mentioned in this connection.

In my view, we as scientists have an obligation to explain to decision makers what risk really is and that ever lower numbers — particularly in the range that we talk about — do not necessarily represent a commensurate risk reduction. After all, the money available for public health and safety measures is not unlimited. If money were no object, we could make the numbers lower and lower, but that is not a realistic solution.

C. PESCATORE (OECD/NEA): In response to what has been said by M.V. Federline and L.W. Camper, I would recall what was said by R. Cailleton.

Talking about France's national radioactive waste management plan, he showed that decisions can be taken jointly by the officials and the interested publics, including the scientists, if there is dialogue from the outset.

W. BREWITZ (Germany): Regarding deep underground disposal, I would mention that each year in Germany we dispose of some 50 000 t of highly toxic chemical waste in a deep underground repository. This waste arises not just in Germany but also in Sweden, Finland, the Czech Republic and several other countries, including even countries as far away as the USA, so one can say that the facility in question is a multinational repository.

With that in mind, I would say that as technical people we in the radioactive waste management area have done our job and it is now up to the politicians.

A.-C. LACOSTE (France): Reverting to the question of public opinion, I would mention that in France we are currently preparing a radioactive waste management bill which will probably be submitted to our Parliament early in 2006. The focus will be on high level waste. A great deal of work has been done by the Parliamentary Office for the Assessment of Scientific and Technological Options (OPECST), and that body was quite ready for the parliamentary debate. Then the Government decided to launch a national public debate involving many meetings in different parts of France. The congressmen, congresswomen and senators who have been working on the preparation of the bill are not happy about the fact that a national public debate is taking place outside Parliament. In their view, the national public debate should be conducted in Parliament, by the public's elected representatives. They argue that it is a question of the legitimacy of Parliament — when Parliament has reached the point where it is ready to vote on something, there is no need for more public debate.

This is clearly an example of the dichotomy between elected representatives of the public and another form of democracy — a kind of direct democracy without much history so far. Let us wait and see what the outcome will be.

DISPOSAL SAFETY —
INTERNATIONAL AND NATIONAL PERSPECTIVES

(Session II)

THE SAFETY CASE AND CONFIDENCE BUILDING

(Session IIc)

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United States of America

THE SAFETY CASE FOR RADIOACTIVE WASTE DISPOSAL FACILITIES
A brief discussion of key issues

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Abstract

Performance assessment and the resulting safety case are of key importance in the step-wise approach to repository implementation. Over the years, much progress has been made and today the methodology for developing a safety case is at an advanced stage. In the paper, the history of the safety case concept development is briefly reviewed and the purpose and content as well as the development of a safety case are discussed.

1. INTRODUCTION

Post-closure safety is an issue of key importance in the establishment of geological repositories and safety analyses have been conducted for many years. Preliminary assessments of a rather generic nature were performed in the 1970s and early 1980s (e.g. Refs [1–3]); these were followed by assessments of the basic feasibility of deep geological disposal in a number of countries, e.g. Belgium (SAFIR [4]), Finland (TVO-85 [5, 6]), Germany (PSE [7]), Japan (H-3 [8]), Netherlands (OPLA-1 [9]), Sweden (KBS 3 [10]), Switzerland (Projekt Gewähr [11]), etc. After these first assessments, more detailed assessments were made (e.g. SR-97 [12], H-12 [13], SAFIR-2 [14], Project Opalinus Clay [15], TSPA-VA [16]). Some of these evolved into studies that were part of the basis for important site-specific decisions (TILA-99 [17], TSPA-SR [18]). This clearly shows the importance of safety assessments and indicates their level of maturity.

All of these safety assessment studies are concerned with safety after the closure of the repository and are aimed at demonstrating that the repository is safe over very long periods of time. They do not consider other important aspects of repository implementation, such as construction of the facility, non-nuclear issues, etc. These issues are considered in environmental impact assessments (EIAs), which are very broad in content and sometimes also include the post-closure safety aspects. Such comprehensive EIAs provide an excellent platform for interaction with the different stakeholders and often include a comparison of different options (e.g. Refs [19, 20]).

The scope and methodology of safety analyses are continuously developing and today, safety analyses are more rigorous in their methodology and broader in their content than they were 10–15 years ago.

Nowadays, the term ‘safety case’ is often used and, for the purpose of this paper, the term safety case is defined as follows:

> ‘The safety case is the set of arguments and analyses used to justify the conclusion that a specific repository system will be safe. It includes, in particular, a presentation of evidence that all relevant regulatory safety criteria can be met. It includes also a series of documents that describe the system design and safety functions, illustrate the performance, present the evidence that supports the arguments and analyses, and that discuss the significance of any uncertainties or open questions in the context of decision making for further repository development.’

The safety case and its broader framework are discussed in detail in several OECD/NEA ([21, 22]) and IAEA publications ([23]). The author of this paper has profited very much from his involvement in developing these documents and the many discussions with colleagues in the course of that work.

2. PURPOSE AND CONTENT OF THE SAFETY CASE

Most programmes are nowadays committed to a step-wise or adapted staging approach. The safety case is an integral element of this approach and thus, normally, a system is assessed by a series of safety cases that will gradually change their nature and level of detail and ambition. At each decision point, the safety case has to provide the safety related information that allows a judgement on the adequacy of the decision proposed; this has to include an evaluation of the expected levels of safety but also an evaluation of the significance and implications of uncertainties and open questions. A safety case has to serve several purposes. These depend upon the phase and maturity of the repository development programme. In the very early phase of concept development, the safety case is, for example, concerned with the assessment of the broad geological possibilities for repository siting that a country offers. This is often combined with an assessment of the design concept chosen. Formally, these safety assessments are sometimes connected to the ‘demonstration’ of the basic feasibility of safe geological disposal. The results of these assessments normally constitute one of the key elements that are used to direct the programme (what host rocks and geological situations to concentrate upon, what design concepts to further develop, etc.). As the programme progresses, the safety case will become more focused on the specific system under consideration and will eventually be an important element for licensing decisions. Although the relative importance of the following elements will change as the programme progresses, the safety case is always concerned with the following broad issues:

— The assessment of the level of safety that is provided by the repository system under consideration;
— The identification of the strengths and weaknesses of the system under consideration in order to ensure that the refinement of the repository design is focused on the important issues. This also includes input for the future research and development programme;
— The justification of decisions on how to proceed with the programme. In the later stages, this also includes licensing decisions and – once a repository is in operation – recertification and eventually, the decision to close and seal the facility.

In a broad sense, the safety case evaluates whether or not the overall (safety) strategy is adequate, that is: (a) if the system chosen (site, design) is sufficiently promising to continue; and (b) if the information available and the level of understanding is adequate to proceed to the next phase. Furthermore, the safety case may give guidance on the development of both the system (site and design) and the information basis (e.g. through further focused research and development).

To fulfil its role, a safety case has to be rather broad and should include:

— A description of the purpose and context of the safety case. This may also include a compilation of a broad set of ‘objectives, criteria and principles’ to be used for assessing the quality of the system and the quality of information/understanding.
— A description of the understanding of the system — which also contains an evaluation of the corresponding uncertainties.
— A discussion of the features of the system most important for safety (both those that provide safety and also those that have the potential to severely undermine safety). The safety case has to provide the evidence available that gives confidence in the proper functioning of these features of the system (e.g. reliance on fundamental laws of science, independent nature observations, natural analogues, etc.).

— An assessment of the quality of the system both in a quantitative and qualitative manner. Such an assessment has to examine explicitly the effects of uncertainties and to discuss any open questions of relevance to the decision at hand.
— An overall synthesis of the broad findings of the safety case in relation to the decision at hand. This may also include a discussion of future work to resolve any open issues.

To discuss the quality of the system, both quantitative and qualitative arguments are used. The quantitative assessment includes an analysis of the performance of the total system (e.g. calculation of dose or risk) but may also contain an assessment of the performance of individual components or subsystems (e.g. see Ref. [15]). Besides the quantitative assessment, more qualitative types of arguments are also used; these are considered to be equally as important as the quantitative assessment. They may include a phenomenological analysis (e.g. see Refs [24, 25]) that contains both qualitative and quantitative arguments. Also the evaluation of so-called safety functions makes use of qualitative arguments and discusses (qualitatively and quantitatively) the contribution of the different repository features to the different safety functions (e.g. see Refs [14, 15]). This results in a ‘safety concept’ that clearly describes the key features of the repository system and its functioning.

The analysis has to include an evaluation of the impact of uncertainties. This includes identifying the possible alternative behaviour of key features of the repository system which, in turn, may lead to alternative evolutions of the system. This process is an essential part of the development of the set of calculated cases used for the quantitative assessment of the performance and safety of the repository system.

The assessment of the quality of the system must be made against criteria. These are, at least partially, provided by the regulatory framework, but it may also be appropriate for the regulatory criteria to be complemented by additional criteria. Besides the most common quantitative criteria, such as dose and risk, complementary safety indicators (e.g. radionuclide/radiotoxicity fluxes, evolution of concentrations, etc.; see Ref. [26]) may be used. The quantitative criteria are complemented by qualitative criteria and may include design requirements. In the regulatory framework, the qualitative criteria are often expressed in the form of principles or concepts (e.g. multibarrier principle, robustness, essentially complete containment for a specified period of time, etc.).

A safety case for a satisfactory repository may result in a set of arguments as follows:

— The basic repository concept is adequate and there is ample evidence of the intrinsic quality of the site and the design chosen.
— Sufficient safety is to be expected both in relation to compliance with regulatory dose and risk criteria and safety indicators complementary to dose and risk. This also includes 'compliance' with more qualitative objectives and principles.
— Existing uncertainties and open questions do not jeopardize the prospects of achieving a safe repository and with the help of adequate measures it is very likely that the critical technical issues can be resolved.

Because of its importance in providing the technical basis for decision making, a safety case will have a spectrum of different audiences: the implementer, the regulator, the decision makers, the general public, etc. This needs to be considered in developing the documentation and, often, a range of different documents may be developed that differ in their level of detail, but are consistent in the underlying basis and in the key messages.

3. THE DEVELOPMENT OF A SAFETY CASE

The process of developing a safety case is often called 'performance assessment'. Performance assessment (PA) serves as a platform for collecting, integrating and evaluating all the information and for putting it into context (the synthesis). In developing a strong safety case, it is essential to consider the following points:

— For compiling the information needed, the PA specialists only act as moderators; key scientific technical information has to come from, and be justified by, the corresponding scientific experts. As moderators, the PA specialists have to ensure that the full spectrum of understanding of the different issues is made available (also to obtain the full picture of the existing uncertainties) and that this information is compiled and presented in an unbiased manner. It is important that the scientific basis contains neither overly optimistic assumptions nor 'hidden' safety factors. Several possibilities exist for achieving this goal, including formal expert elicitation methods.
— It is then the task of the PA specialists to process this information in a structured, transparent and traceable manner. In this process, it is important to keep the scientific experts involved to ensure that the information originally provided by them is properly integrated and adequate for the context. Here, it is important to recognize that PA often

relies on simplified models. However, these build upon and are justified by the results of the more detailed process models.

— A key element in the process is an adequate treatment of uncertainties. Although very cumbersome, long features, events and processes (FEP) lists continue to be an essential part of the analysis of uncertainties (see Ref. [27]). These FEP lists are not an aim in themselves, but serve a number of purposes: (a) to ensure that no important aspects are overlooked — this is achieved by a rigorous comparison with other relevant FEP lists (e.g. [28]); (b) to confirm that the spectrum of calculated cases is broad enough and includes all relevant FEPs and their associated uncertainties; (c) to confirm that the relevant FEPs are modelled using adequate tools; (d) to demonstrate that the possible interactions between FEPs have been adequately considered.
— The performance assessment process also serves to set priorities; not all the issues need to be known at the same level of detail. Sometimes it may be adequate to use conservative assumptions for some of the aspects that are not known in detail. The issue of sufficiency in understanding also depends upon the decision at hand. In the earlier phases simplified and conservative assumptions as well as bounding types of analyses are often used, whereas at later stages, more detailed and realistic approaches are applied. However, in all phases it is important that the PA specialists stay open-minded, and that they are prepared for the ‘unexpected’ and able to consider seriously all inputs by the scientific experts.
— Reviews, including the regulatory review, are an integral part of performance assessment. Such reviews are needed during the iterative process of developing the safety case — but also, at the end, to cover the completed safety case.

To ensure quality and traceability, it is beneficial to develop and document the full process of PA (i.e. the methodology for compiling, processing and evaluating the scientific information and corresponding uncertainties). This also includes the definition of adequate QA measures.

When defining such a methodology, it may be appropriate to define different organizational functions. In a recent PA study by Nagra ([15]), different roles were explicitly defined: (a) management (has to keep the work focused on the project goals and has to be responsive to new findings); (b) scientists (have to develop and evaluate the scientific basis for the assessment); (c) PA specialists (have to process and evaluate all the information and to compile the safety case); (d) bias auditors (have to ensure that the scientific basis is sufficiently complete and adequately documented and exploited in the assessment). This concept has proven to be very effective.

Documenting the safety case in a transparent and traceable manner is of key importance. In addition to being convincing (easy readability, not too long), the documentation should be sufficiently comprehensive to allow the calculated results to be independently reproduced (all the assumptions must be clear and the data retrievable). This requires the documentation to be structured in a logical and hierarchical manner. Despite considerable efforts, it is still very difficult to ensure completeness and, at the same time, to maintain an adequate level of reader friendliness.

4. CONCLUSIONS

— Performance assessment and the resulting safety case are of key importance in the step-wise approach of repository implementation. A high quality safety case is expected to provide an adequate basis for well informed decisions about post-closure safety. Thus, the safety case has to include the collation of a broad range of evidence and arguments that will provide confidence in the feasibility and safety of the proposed repository system. The safety case has also to address the adequacy of the depth of understanding and the technical information available to support the decision to move to the next phase.

— Over the years, considerable progress has been made and, today, the methodology for developing a safety case is at an advanced stage. The scope of a currently developed safety case is much broader than it was 10–15 years ago. The evolution of safety case development is also reflected in the regulatory context; substantial discussions on a broad range of issues related to the safety case are currently taking place at the international level (IAEA, OECD/NEA, European Commission, etc.).

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CONFIDENCE AND CONFIDENCE BUILDING IN THE CONTEXT OF RADIOACTIVE WASTE DISPOSAL

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Abstract

'Confidence' and 'confidence building' are concepts of high relevance in connection with the preparation and review of a modern, long term safety case for disposal. They are recent concepts that arose from the technical debates held in the 1990s around the issue of validation in the context of geological disposal. The paper explains how they arose, and how they can be, or have been, used in the actual preparation and review of a disposal safety case. Confidence can be seen as the complementary concept to uncertainty, just as risk is complementary to safety. On the other hand, confidence requires more than only uncertainty analysis; it is about communicating quality and demonstrating inclusiveness at the same time. The potential resistance towards utilizing confidence and confidence building, either as words or as concepts, is also commented upon.

1. INTRODUCTION

'Confidence' and 'confidence building' are concepts of high relevance in connection with the preparation and review of modern, long term safety cases for disposal. They arose from the technical debates held in the 1990s around the issue of 'validation', and entered the waste management vocabulary for technical and managerial reasons rather than for purposes of addressing the needs of the public and society (see Pescatore in Refs [1, 3]). In order to demonstrate how they arose in the technical world and their relevance when preparing a technical safety case for disposal, the paper is organized in four parts:

— In Part 1, some definitions are given and illustrated in order to help frame the issues. This first section of the paper ends with the preliminary conclusion of the centrality of the concept of confidence building.
— In Part 2, a review is provided of how things came to be as they are today. It describes the shift from validation to confidence and from Performance

Assessment to Safety Case in the context of decision making. Confidence building is shown to be a central concept for the preparer and reviewer of a safety case.

— In Part 3, a description is provided of how confidence building can be implemented in the practice of preparing a safety case. The case is made that confidence and confidence building are technical concepts that are important for situations such as final disposal where safety is achieved through passive means rather than by active control. An illustration of their actual utilization is given. The connection between confidence and uncertainty is discussed.

— Part 4 provides some overall conclusions.

2. RELEVANT DEFINITIONS AND THEIR IMPLICATIONS

2.1. Disposal

According to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention):

— ‘Disposal means the emplacement of spent fuel or radioactive waste in an appropriate facility without the intention of retrieval.’

The Joint Convention definition is appealing in that it is wide and covers sites whose safety is guaranteed both through the exercise of active controls — such as mill tailings and some surface facilities — and through passive provisions. Another advantage is that the word ‘disposal’ is used in a way that reflects common usage among the English speaking public. The disadvantage is that a ‘dump’ or low grade facility could also qualify as a disposal facility, for the Convention does not mention what is an ‘appropriate facility’. Presumably, ‘appropriate’ means ‘appropriate to achieve safety’. An alternative definition adapted from [2] and connecting disposal to safety is as follows:

— ‘Disposal is the radioactive waste management end-point meant to provide security and safety in a manner that does not require monitoring, maintenance and institutional control.’

This is a narrower definition than that of the Joint Convention. It was conceived in the context of geological disposal of long lived waste and would not apply to sites whose safety rests on active controls. However, it makes it clear why that kind of disposal was proposed by society, namely, to protect future generations through means not requiring the direct presence of humans. The difference in the two definitions raises the question about whether disposal is not too generic a term, and whether its use should not be qualified by, at least, the use of proper attributes, such as ‘monitored disposal’, ‘long term, monitored disposal’, ‘final, engineered disposal’, etc. in the way it is done in some non-English speaking countries. Indeed, surface repositories, mill tailings stabilization, or geological repositories for spent fuel entail very different disposal technologies and issues. Clear definitions — even different terms — would enhance communications among specialists and also help avoid misunderstandings when communicating with the general public, who must be assured that ‘disposal’ is not synonymous, in any circumstances, with ‘dumping’.

2.2. Safety

Surprisingly, while safety[1] is the topic that unites a large number of efforts in the field of disposal, there is, to this author’s knowledge, no definition of safety applicable to the waste disposal field. For instance, the Joint Convention glossary does not define this term. In the absence of an agreed definition, the following one, taken from ongoing discussions within the OECD/NEA, is proposed:

— ‘Safety is an intrinsic property of a system. It represents its tendency not to cause (physical) harm. The “system”, in turn, is the ensemble of technical and administrative arrangements conceived to make it work over a given period of time.’

Ancillary observations related to safety are as follows:

— Over any defined time period, a system will or will not be safe regardless of our modelling capabilities. Namely, safety is not the result of modelling but of a series of provisions and technical arrangements that will also include modelling.

[1] In this paper ‘safety’ in the technical sense is discussed. The paper by F. King — see these proceedings — examines ‘safety’ from the point of view of the local, host communities and societal decision making.

— The way safety will be argued and documented (safety case) will raise (or not) our level of confidence (conviction) that safety is attainable under the conditions that have been described.

2.3. Confidence

According to Ref. [3]: 'Confidence is to have reached a positive judgement that a given set of conclusions are well supported.' Confidence building is then about the ways to enable a positive judgement to be reached that a given set of conclusions are well supported.

Because there is no one depository of the truth, there must be shared confidence among the main actors that are involved in decision making that the safety case for the decision at hand is a quality one. The best way to proceed is thus for all actors to develop factual and transparent ways to build confidence, namely, to evaluate and communicate their own confidence, in order to favour dialogue and quality in the decisions to be taken. Confidence is thus not a 'trust me' affair, but a 'see what I did and judge for yourself' affair and a 'I am ready to have you test it' affair.

Confidence must be shared in order for it to have any impact. A parallel to science can be made: a finding becomes a scientific fact and a part of science when many — and not just a single thinker — share the same positive view on the validity of the finding at hand.

It can be observed that in the case of (final) disposal, it will not be possible to validate one's own confidence and provisions must be made to take account of the fact that, in the long term, society may lose the ability to verify that our judgement was right. An additional, important concept in this context is trust.

2.4. Trust

'Trust is about accepting the transfer of control'.The granting of a licence for definitive closure of a repository containing long lived radioactive waste involves accepting that control has to be given up. It actually involves an act of trust in the technology and the legal and regulatory arrangements implemented by the current generation on behalf of future generations. The connection between trust and confidence is that trust is the result of a long chain of confidence building actions. Trust is gained slowly but can be lost rapidly.

2.5. Conclusions

‘Confidence’, ‘confidence building’, ‘trust’, and ‘control’ are fundamental concepts when preparing or judging a long term safety case for which safety does not rest on active controls. Confidence has to be shared for it to have an impact. Confidence building is what enables confidence to be gained and shared. In time, it will lead to trust.

3. HISTORICAL OVERVIEW

The modern concept of the safety case was formulated in the late 1990s [3]. It substituted and enlarged upon the concept of performance assessment (PA) that was used in the 1980s and early to mid-1990s [4].

Rightly, the safety case emphasizes a focus on safety rather than on performance, and on sufficiency for decision making rather than on performance in its own right. The earlier focus on performance assessment: (a) implied that safety comes from numerical analysis; (b) promoted a ‘science tells us that’ attitude that could be easily challenged as no validation of the results of the long term analysis of repository performance is scientifically possible; (c) promoted an ‘us versus them attitude’ that reduces the space for dialogue.

In the 1990s it became clear that:

— Decision making is the goal;
— The context is that repository development proceeds in stages;
— The depth of understanding and technical information available to support decisions will vary from stage to stage.

Decision making requires only:

— Confidence to support the decision at hand;
— Confidence that a workable strategy exists to deal, at later stages, with any uncertainties that have the potential to compromise safety.

A safety case should provide confidence to support the decision at hand, and include a strategy in which there is confidence to deal, at later stages, with any uncertainties that have the potential to compromise safety [3]. Confidence building should be a central concept, both for the preparer and the reviewer of a safety case.

Conclusions from the 1990s

A safety study is performed explicitly to enable a decision to be made. Society is interested in safety more than in performance. A safety case is what society wants for making decisions at each stage. A safety case is a platform for dialogue for a multiplicity of actors.

4. CONFIDENCE AND CONFIDENCE BUILDING IN THE PRACTICE OF PREPARING AND REVIEWING A SAFETY CASE

Confidence building implies awareness which, in turn, must rely on a deliberate set of actions/procedures intended to achieve confidence for taking a specific decision under a specified context or set of constraints. A frame needs to be established in which confidence can be evaluated, communicated, enhanced. Confidence building is, thus, both a technical and a managerial concept.

We can start by asking ourselves what are the bases for technical confidence in the safety case that is being prepared or reviewed. Figure 1 identifies the several components of a safety case, and from this, it appears that overall confidence in the safety case rests on:

— Confidence in the robustness of the system concept;
— Confidence in the quality of the assessment basis and the reliability of its application in performance assessment [3].

4.1. Confidence building criteria

The two main components of confidence identified above rest ultimately on confidence in other sub-elements of the safety case. For each of these elements, a series of criteria can be formulated in order to check one's own level of confidence and, if needed, to improve on it. Examples are developed in Refs [3, 5]. An enlarged set of about 40 criteria has been made in Ref. [5] to support OECD/NEA-sponsored peer reviews of disposal safety studies. Examples are provided in the following:

— Strategy for achieving safety, i.e. a robust system concept:
  - Have we, through the choice of site and design, avoided or forced to low probability or consequences most phenomena and uncertainties that could be detrimental to safety and to its evaluation?

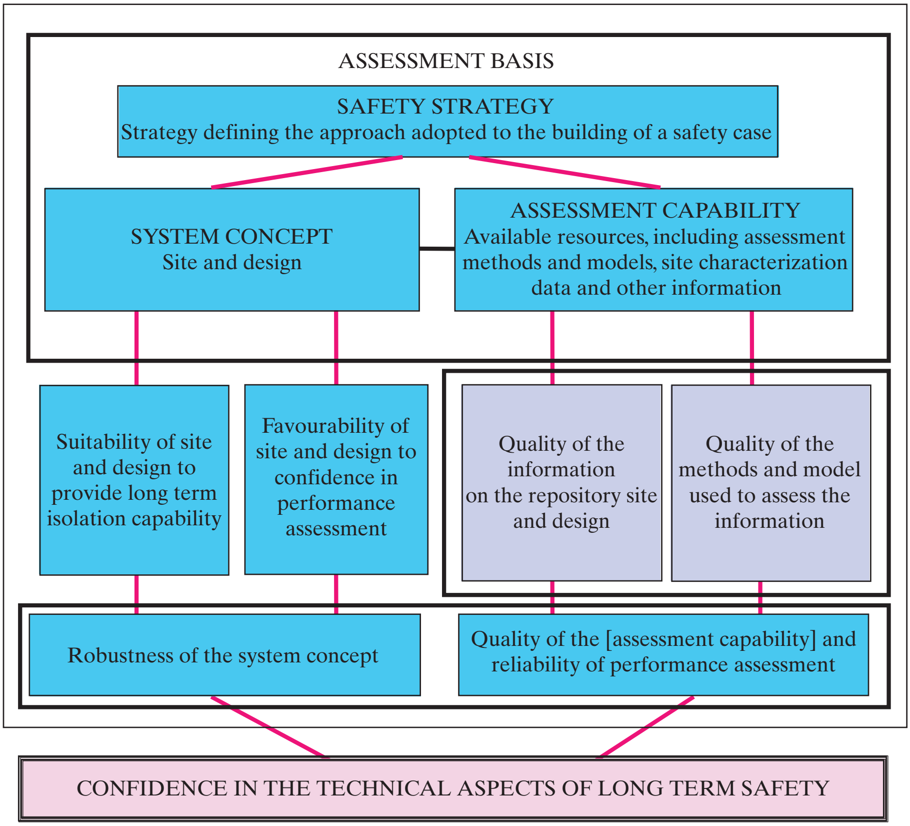

FIG. 1. The several elements of a safety case and their relation to confidence in long term safety [3].

— Strategy for ‘proving’ safety, i.e. for arriving at a good assessment basis:
  - Are we describing a confinement and containment approach rather than a disperse-and-dilute one?
  - Do we have the concept of safety functions right and are we using it properly?
  - Are we viewing the different timescales realistically?
  - Have we acquired relevant information for the system concept?
  - Have we developed and applied methods and models to assess this information, including the identification of assessment cases?

— Assessment basis: a good assessment basis improves reliability of performance assessment (PA):
  - Have we acquired relevant information for the system concept?

  - Have we developed and applied methods and models to assess this information, including the identification of assessment cases?
- The robustness of the system concept:
  - Have we provided arguments for robustness by confirming that appropriate criteria and procedures have been observed?
  - Have we provided arguments for robustness by using PA as a test across a range of scenarios, in order to identify/exclude sensitivities?
- Quality of PA methods and models:
  - Have we provided arguments for the chosen PA approach?
  - What is the level of understanding of safety relevant features events and processes (FEPs)?
  - What is the availability of the conceptual and computational tools?
- Quality of information on site and design:
  - Have we provided arguments for data degree of support and quality?
- Reliability of the application of methods, models and data in PA:
  - Quality assurance (QA) procedures;
  - Independent evidence;
  - Have we demonstrated broad understanding through use of simplified models, etc.?

These criteria are a basis for checking one's own confidence in an actual safety case from the perspective of both the provider and the reviewer or external user of that safety case. An example of how the above criteria have been used in the context of a peer review is documented in the literature (see Ref. [6]). Additional criteria may be deduced from the Safety Requirements for Geological Disposal of Radioactive Waste (see Ref. [7]).

4.2. Confidence statement

Ideally a safety case should include a statement of confidence [8] in the quality of the product and its applicability to the decision at hand. Conducting and documenting a check of the identified criteria, such as those described in Section 4.1, would help in preparing a statement indicating that, in the context of the given programme stage:

- Principles, previous guidance, programme constraints and safety strategy have been respected;
- All relevant data and information, and their uncertainties, have been considered;
- All models have been tested adequately;
- A rational assessment procedure has been followed;

— Results have been fully disclosed, and subjected to QA and review procedures;
— The safety strategy is appropriate to handle remaining, incompletely resolved safety related issues at future stages.

The rigour and discipline implied are, by themselves, factors of confidence in the quality of the safety case.

4.3. Potential resistance to the use of the confidence word or concept

There may be resistance to using the word ‘confidence’ because in some languages the concepts of confidence and trust cannot be easily distinguished, as the same word is used for both concepts.[2] In these cases, a useful synonym of ‘confidence’ is ‘conviction’.

The provider of the safety case may be reticent to talk of his/her own confidence for fear that this would convey an impression of arrogance. At the same time, the reviewer of the safety case may not want to use the word confidence, for fear of being seen as being partial to the party being being reviewed.

Reticence may also come from a technical mindset that is focused on uncertainty and uncertainty analysis and which is not used to the application of the more inclusive concept of confidence. Within this technical mindset, it is difficult to recognize that, for the long term, the concepts of ‘uncertainty’, ‘dose’ and other indicators of safety (or of lack of safety) are not the same as the concepts that one learns routinely in school and that are applicable to relatively short term projects. It should be useful, in this case, to reflect on the links between confidence and uncertainty in the context of decision making.

4.4. Confidence versus uncertainty in the context of decision making

Uncertainty will exist in any human endeavour. Decision making has always to take uncertainty into account. The real issue for decision making is that of confidence. Decision making is hardly ever based only on numerical values for uncertainty:

[2] Just as in some languages where ‘uncertain’ and ‘unsafe’ are translated with the same word even if they are different concepts.

— Even if probabilistic assessments of the safety of nuclear power plants have been in use for many years, no nuclear power plant has ever been licensed on the result of only a probabilistic number.
— Confidence does require a demonstration that uncertainties have been dealt with, and there are means to deal with scientific uncertainty, i.e. those techniques typically applied in data analysis and model testing. However, when it comes to long term predictions, there are special issues to deal with.
— A mixture of quantitative and qualitative arguments will have to be provided to engender confidence both in the provider and the reviewer.

On the one hand, confidence can be seen as the complementary concept to uncertainty, just as risk is complementary to safety. On the other hand, building confidence requires more than just uncertainty analysis; it is about communicating quality and demonstrating inclusiveness at the same time.

4.5. Conclusions

Confidence and confidence building are important technical and managerial concepts to achieve and define the quality of a modern safety case. Confidence building is a management tool for preparing and reviewing a modern safety case. A set of criteria has been developed to help in building confidence, i.e. in achieving, evaluating and communicating confidence. One distinctive feature of the safety case is the provision of a confidence statement in order to enable dialogue and provide improved support to the decision at hand.

5. OVERALL CONCLUSIONS

Confidence and confidence building are technical and managerial concepts of high relevance in connection with the preparation and review of modern, long term safety cases for disposal. They arose from the technical debates held in the 1990s around the issue of validation, and entered the waste management vocabulary for technical and managerial reasons rather than for purposes of addressing the concerns of the public and society at large.

Uncertainty will exist in any human endeavour. Decision making has always to take uncertainty into account. The real issue for decision making is that of confidence. Decision making requires only (a) confidence to support the decision at hand, and (b) a strategy, in which there is confidence, to deal at later stages with any uncertainties that have the potential to compromise safety.

Importantly, confidence has decision making value only once it is shared. Therefore, aiming for confidence implies, at the same time, a policy of transparency and openness to all the actors involved in decision making.

On the one hand, confidence can be seen as the complementary concept to uncertainty, just as risk is complementary to safety. On the other hand, confidence requires more than just uncertainty analysis: it is about communicating quality and demonstrating inclusiveness at the same time.

Confidence is not the same as trust, and confidence building implies explaining the means by which confidence was acquired. This explanation presupposes clarity of purpose and discipline. There exist proven methods that help in building confidence, i.e. in achieving, evaluating and communicating confidence.

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DISCUSSION

T. TANIGUCHI (IAEA): At the beginning of your presentation, you defined ‘disposal’ as the waste management end point providing safety and security, and you juxtaposed safety and security and gave the impression that they have comparable weight.

Is it your view that such security includes security against malicious acts?

Also, how is security linked to the safety case?

C. PESCATORE (OECD/NEA): That definition of ‘disposal’ indicates that putting things away in a geological repository also helps to avoid malicious intrusion. It will provide protection against security breaches.

Modern safety cases do not talk much about security. In fact, I do not think that security is directly mentioned in safety cases by itself — only together with safeguards.

T. TANIGUCHI (IAEA): I was wondering what the approach to this issue should be in the future.

C. PESCATORE (OECD/NEA): When giving definitions, it is important to understand what they mean. To me, the first one — from the Joint Convention — is not a very effective definition when we are talking about long term problems.

REVIEW OF CONTRIBUTED PAPERS

Session IIc: THE SAFETY CASE AND CONFIDENCE BUILDING

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Abstract

The paper presents an overview of the contributed papers submitted to Session IIc on The Safety Case and Confidence Building; 11 papers were contributed on a wide range of topics including: (a) key components for safety, (b) regulatory compliance, (c) discussion of relevant scenarios, (d) treatment of uncertainty, and (e) use of the volunteer process to develop confidence in selection of repositories. The paper presents some conclusions and recommendations based on a review of these contributed papers.

1. INTRODUCTION

The following key points were identified in the review of 11 papers from a diverse group of authors: (a) identification of key components for the safety case; (b) treatment of regulatory requirements and compliance; (c) a staged development or phased process for repository development; (d) identification and definition of scenarios; (e) treatment of parameter uncertainty (using deterministic and probabilistic methods); (f) confidence building; and (g) IAEA support for its Member States. A discussion of each of these key points is provided below to provide some context for the discussion during the panel session for Session IIc.

2. IDENTIFICATION OF KEY COMPONENTS FOR THE SAFETY CASE

Several papers dealt with the safety case for a new near surface repository. One paper analysed the basic elements of confidence in safety assessment as confidence in the safety assessment methodology and confidence in the safety assessment approach.

It is generally agreed that to enhance confidence in the safety assessment results, a good understanding of the phenomena, mathematical models and numerical methods involved in the safety assessment is required. One author noted that, while technical merit and an ability to perform the technical components of the programme to the required standard are essential, ‘artistic impression’ is equally important in influencing people to ‘vote’ in favour of a proposal — and this is where programmes often fall short.

3. TREATMENT OF REGULATORY REQUIREMENTS AND COMPLIANCE

Confidence in the results of safety assessments can be enhanced by demonstrating compliance with regulatory requirements. To increase confidence in the results and to demonstrate compliance with regulatory requirements, some authors employed different assessment techniques in a complementary manner. For example, some authors preferred a high degree of conservatism in scenarios, mathematical models and data with the aim of demonstrating compliance with regulatory requirements. One author examined the technical elements of carrying out safety assessments into the distant future and noted the need for a stylized approach for the period beyond 10 000 years. One author noted the benefit of using a Regulatory Guideline and Regulatory Assessment Principles safety evaluation. The safety evaluation report resulted in recommendations to issue a licence subject to compliance with a certain standard and eight special licence conditions, specific to criticality, safety and emergency arrangements. It is noted that a variety of radiological criteria were used by the different authors varying from 0.15 to 1 mSv/a.

4. A STAGED DEVELOPMENT OR PHASED PROCESS FOR REPOSITORY DEVELOPMENT

Some authors indicated that it is preferable that a separate safety case is produced for each stage of repository development to demonstrate the safety of that stage before it commences. Governmental policy in Japan has determined that the site selection for a high level waste (HLW) repository should be a phased process. The process begins with the identification of Preliminary Investigation Areas (PIAs), from which Detailed Investigation Areas (DIAs) are selected before moving to full characterization of a preferred site. Law in Japan also specifies that the Nuclear Waste Management Organization (NUMO) must work transparently in all its activities. On this basis, and having observed that failures in siting programmes worldwide are more often due to societal problems than to technical issues, NUMO has chosen an ‘open solicitation’ approach for finding candidate sites. NUMO has invited municipalities from throughout the country to consider volunteering as candidate areas for exploring the feasibility of hosting a final repository for HLW. This open approach is extremely dependent on NUMO’s ability to establish sufficient trust and confidence in itself. A number of authors indicated that confidence building is a process that needs to be followed through all stages of safety assessment and the value of international experience in this context was emphasized.

5. IDENTIFICATION AND DEFINITION OF SCENARIOS

Several authors agreed that the development and justification of scenarios, the formulation and implementation of models, and the analysis based on the scenarios, was critical to developing a credible safety case. Some authors stressed the importance of a systematic approach for defining scenarios, and all relevant features, effects and processes (FEPs) that could influence the performance of the disposal system. To estimate long term repository performance, a number of authors analysed the resident farmer scenario. This scenario, in which a family constructs a home on the site and raises an appreciable fraction of its food there, is considered to be a credible bounding scenario because on-site residents receive a dose that is at least as large as the dose to off-site residents, and is generally larger. For events that may occur in the far future one author called for the use of a stylized scenario for inadvertent human intrusion that establishes the processes and exposure pathways to be considered in the scenario. It was noted that a number of European programmes consider near surface processes to be so uncertain beyond 10 000 years that they have moved away from dose or risk criteria to other indirect indicators of system safety.

Scenario uncertainty was considered in a number of papers. Frequently, deterministic calculations are used to address scenario uncertainties. Scenarios, which were evaluated in this way included: the normal evolution scenario with progressive engineered barrier system degradation; the cap failure scenario; the instant failure of all engineered barriers; the climate change scenario; the inadvertent human intrusion scenario.

A paper from the Czech Republic addressed the need for new licences for operating repositories. This process had to be supported by updated safety assessments that reflected an improved knowledge of the disposal systems performance and in some cases included a wider range of scenarios than those evaluated previously.

6. TREATMENT OF PARAMETER UNCERTAINTY

The treatment of parameter uncertainty using the deterministic and probabilistic methods was discussed in some papers. Using a deterministic approach, the behaviour of the disposal system under various conditions can be evaluated by analysing a suite of variants where alternative parameter combinations are used. Sensitivity analysis can be used to rank the most influential parameters in the assessment. Data/parameter uncertainties can be treated through sensitivity analysis (single parameter variation — deterministic) and multiparameter variation (stochastic calculations), using all available data.

7. CONFIDENCE BUILDING

A number of authors agree that confidence building is a process that needs to be followed through all stages of the safety assessment. To increase confidence in the results, and to demonstrate compliance with regulatory requirements, different assessment techniques were used in a complementary manner. A number of authors focused on confidence building concerning the treatment of uncertainty in the post-closure assessment. Building confidence in the safety of geological disposal is a challenge faced by all waste management programmes. It is recognized that confidence building measures are needed for interacting with the technical community, and also with the general public. Early on, the tendency was to simply announce the results of discussions, with important decisions, such as the definition of the disposal concept, being suddenly introduced into the public domain with no prediscussion. The public had no access to, and no influence on, the decision making process. Since that time, a number of countries (for example, NUMO of Japan) have opted to use an approach based on complete reliance transparency in all aspects and a volunteer process.

NUMO faces the challenge of initiating one of the largest HLW disposal programmes in the world. It has chosen to tackle the key challenge of identifying potential repository sites by using a completely transparent volunteering approach. The paper described the measures that NUMO has taken to establish its scientific credibility at home and abroad. Observing that failures in siting programmes worldwide are more often due to societal problems rather than to technical issues, NUMO has selected an 'open solicitation' approach for finding candidate sites. NUMO has invited municipalities throughout the country to consider volunteering as candidate areas for exploring the feasibility of hosting a final repository for HLW. This open approach is extremely dependent on NUMO's ability to establish sufficient trust and confidence in itself. The NUMO open volunteering process implies (a) that the communities must have confidence in the technical capabilities of NUMO as well as in its openness and honesty, and (b) that a very wide range of geological settings could require to be characterized and matched to suitable, safe repository design concepts.

Building confidence in the feasibility of implementing safe deep geological repositories is a challenge facing all HLW disposal programmes. Successfully achieving this objective in public and political circles is certainly a bigger task than doing so in the technical community. However, sufficient confidence in the technical community is a necessary (though not sufficient) condition for wider trust. NUMO has taken specific steps to establish that it is a credible organization, that it manages its work using the best advice from external experts, and that it has a transparent long term programme against which its progress can be judged.

8. IAEA SUPPORT FOR ITS MEMBER STATES

A number of papers indicated the results of IAEA support, and its positive influence on the decision process in Member States. For example, in June 2004, in Budapest, the IAEA hosted the first workshop dedicated to safety case development for near surface waste disposal facilities. The IAEA efforts helped Member States analyse the basic elements of confidence in safety assessment. In another example, the Slovenian Agency for Radwaste Management has founded and developed a performance assessment team, which has been provided with training and other help from the IAEA to perform performance assessment calculations for the repository safety case. In addition, the IAEA has supported the creation of an International Centre for Spent Nuclear Fuel Storage in the Russian Federation.

9. CONCLUSIONS AND RECOMMENDATIONS

The review of the contributed papers has identified a list of key points: (a) there are a variety of dose limits being used by various authors and it is not clear which approach is preferable; (b) the language used to present the safety case is not as clear and transparent to some stakeholders as it could be for effective confidence building; (c) a more transparent and clear discussion of the benefits of using either deterministic or probabilistic approaches would be helpful; (d) identifying some success stories regarding confidence building through a volunteer process would give confidence to other programmes; and (e) the programmes of the international organizations have helped the international community to make progress in developing and presenting safety cases.

The absence of any papers that address the use of international peer review processes was noted. Independent reviews of safety cases are valuable and necessary to provide credibility and to help build trust in the process. Several such reviews have been conducted in the past few years and a paper which addressed the results of these reviews would be a good addition to a future conference or workshop on this subject.

PANEL

Session IIc
THE SAFETY CASE AND CONFIDENCE BUILDING

Chairperson: **T. Pather** (South Africa)

Members: **P. Zuidema** (Switzerland)
C. Pescatore (OECD/NEA)
J.T. Greeves (United States of America)
H. Umeki (Japan)
M.W. Kozak (United States of America)
J. Repussard (France)

M.W. KOZAK (United States of America): The papers we heard this morning largely represent the views of the geological disposal community. There is another community of radioactive waste professionals who is dealing with near surface disposal problems, however, and in my view many of the issues discussed in those papers have been dealt with by the near surface disposal community; some of the wording is different, but you will find a parallel line of publications in the literature which come up with the same concepts independently — the shift away from validation towards confidence building, for instance. That shift probably happened in the near surface disposal community earlier than in the geological disposal community, largely because the near surface disposal community has to put waste into the ground immediately, so there were very imminent problems which had to be solved — we had to move to decision making very rapidly and in a very concrete way.

The second point I wanted to make is that there is a significant new approach in a regulation that has been proposed in the United States of America. It is a two-tier system recognizing that analyses will need to be more stylized in the far distant future than in the near distant future. The two tiers are an acknowledgement that, with uncertainty growing as you move into the future, there may be a need to specify a different dose limit or a different dose constraint as you move into the distant future. That is what the US Environmental Protection Agency (EPA) recently proposed for use at Yucca Mountain.

H. UMEKI (Japan): Actually, the definition of ‘safety case’ is still under discussion. To me, there is no universal definition at present. However, the presentations this morning made it clear that the ‘safety case’ is much more than a safety case in the traditional sense.

The safety case should be reviewed and updated throughout the disposal programme. In this regard, confidence should be increased continuously as the programme is developed; to aid this process, research and development should be carried out continuously to support the safety case development.

How should the level of confidence in the safety case be evaluated? Implementers have their own views about the confidence associated with the safety case they have provided; the regulators have their own views. This could be discussed by the panel.

J. REPUSSARD (France): I should like to make three points in order to start the discussion.

First, it seems that there is a general consensus that there is a need for a step by step approach, allowing a lot of time — many years — from the start of an idea to the eventual decision to create a geological repository. This means that the safety case is not just a document that exists at some moment in time in order to satisfy the safety authorities. It is more like a vehicle for dialogue between all those involved, including stakeholders, politicians, scientists, research people and practitioners.

The second point is linked to that — it is that the quality of the safety case is not just a matter of science; it has to be diverse and robust enough to be reviewed by people from different countries, by experts who have not been taking part in the development itself, and by experts hired by local communities. Confidence will emerge from this variety or plurality of views and actors. Information on the safety case has to be available, and not just on paper — it must be comprehensible and accessible. Messages have to be conveyed to ordinary people since, at the end of the day, ordinary people will influence politicians, who will take the decision, or not take the decision, as the case may be.

The last point I would like to make is about the important issue of security. Between the moment when the repository starts working and the moment when it is closed there will be a 20–70 year period during which time the site will have to be designed to allow access, ventilation and to provide safety for workers. Therefore, the issue of security, which sometimes comes into conflict with safety, has to be reviewed. I believe there has not been enough international thinking about it, and I am glad that T. Taniguchi raised the subject this morning.

C. McCOMBIE (Switzerland): I would like to revert to the question of definition. I agree that words are important, but we should not get lost in a semantic fog. To illustrate my point, I shall use two examples from the work of the OECD/NEA.

One is the example which C. Pescatore gave for disposal. We had two alternative definitions of ‘disposal’. One of them is understandable to a real person and the other is not. You cannot define ‘disposal’ as being the management option which gives safety and security without doing anything, because if you do, you rule out the questions which the man in the street asks: “Is disposal safe? Is it secure?” You cannot tautologically define it into the concept. In my view, the Joint Convention’s definition is much clearer.

The other example is safety assessment itself. In the brochure mentioned here (Post-Closure Safety Case for Geological Repositories, NEA No. 3679, (2004)), ‘safety assessment’ has two definitions. The OECD/NEA definition describes ‘safety assessment’ as ‘the process of showing that something will remain safe for a prolonged period’ whereas the IAEA’s definition says that safety assessment is a process of systematically analysing the hazards. Again, the OECD/NEA definition has defined the answer into the question. Safety assessment does not prove that something is safe. Safety assessment shows how safe it is. My feeling is that the IAEA process (and I come to the specific point) of review of its documents is somewhat wider than the OECD/NEA review, which is a very specialist production group and a specialist audience, and my guess is that some of these items would be cleared up by having a wider review process of the actual wording in the way that the IAEA does — yesterday we heard that the IAEA has a very extensive review process. So we must make sure that we are not caught up by our own specific insider definitions, which are very different from what the man in the street would understand.

P. ZUIDEMA (Switzerland): I should like to make two remarks about that.

First, the difficulty with wording is that, for many of us in this room, English is not our mother tongue. That clearly creates the need for all of us, in our reports, to clearly define the terms we use. That is what we have done, because there are sometimes also differences between the cultural or legal framework you are operating in.

So I agree with C. McCombie — one has to be very careful about the wording. On the other hand, I think that, at the moment, it is still necessary that each country is careful about whether it agrees with definitions of the IAEA, OECD/NEA or whoever or, if not, to define them itself, so that it is really clear.

T. PATHER (South Africa): In a lot of cases, it is more the semantics — different choices or different terminologies — and I think this is one of the major roles that the IAEA Safety Standards committees can play. As the current Chairperson of Waste Safety Standards Committee (WASSC), I focus very much on trying to ensure that we have a coherent system — something that we can all use confidently when we communicate with one another. At the last two WASSC meetings we discussed the IAEA safety glossary, which currently exists as a working document on the Internet, and the need to give it more visibility and to publish it as a safety document.

J.T. GREEVES (United States of America): One positive thing I got out of my review of the Contributed Papers is that these safety case concepts are actually being used out there. The examples that I found were for near surface disposal. So, the work that WASSC and the OECD/NEA are doing is having some pay-off. I was very heartened to see that.

M.W. KOZAK (United States of America): I would like to take up one of the points which C. McCombie made. I think it is a good one: the wording that we use should not prejudge the outcome of the result. The wording that we saw earlier today did that. It said: “We are going to demonstrate safety.” By such a process, we could be demonstrating safety when it is not safe. I think that in communications with the public, it is important to show that we will admit it if we are wrong.

P. ZUIDEMA (Switzerland): Clearly, one cannot disagree with what you say. On the other hand, I really wonder whether this community would propose projects that are unsafe. If, in the process of making your analysis, you were to find out that the system is not good, are you going to make a safety case for this system? In my view, if you did that you would lose all credibility.

M.W. KOZAK (United States of America): Here again I must come back to the experience of the near surface community where there are several examples of submissions having been rejected by the regulator. It is not so much necessarily that the system is unsafe, but that the demonstration has not been adequate. As long as the process works and allows for a rejection if the case has not been made appropriately, I think that is a value — not a detriment.

M.V. FEDERLINE (United States of America): I would like to follow up on what M.W. Kozak said about the ICRP work.

When we discuss these long time periods, of the order of a million years, is the public really going to believe that it is credible that we can demonstrate compliance with dose limits of the order of 25–30 mrem? I really wonder if that is possible.

I prefer to think of the performance assessment as a test of outcomes. In other words, there is a reasonable set of outcomes that could occur over a million years, and performance assessment allows us to test those outcomes and make reasonable arguments to the public. We can then have a dialogue with the stakeholders and the regulators and others, and decide whether they make sense over time. But trying to convince ourselves and others that we are going to be able to demonstrate with certainty over a million years that we meet 25–30 mrem, I think that is going to be a hard test.

P. ZUIDEMA (Switzerland): M.V. Federline made a very good point. I think we should be very careful.

What we actually do is a design process, and the whole performance assessment or safety analysis or safety case is only a help us to end up with a good design. We do the best we can, but we cannot make a real demonstration in the legal sense. We should be very clear that we are only doing a design process.

On the other hand, I still think that, although these timescales are very long — in our framework one million years is nothing extraordinary — many geological formations are hundreds of millions of years old. There are, therefore, good reasons why we can make the case for stability over very long timescales.

F. BESNUS (France): Regarding the content of the safety case, there was a lot of focus in the presentations on safety assessment as being a kind of calculation exercise that has to meet some given radiological criteria. But there is much more to it than that. The purpose should be to build confidence. If you take near surface disposal as an example — and I will take the Centre de l'Aube case — if you look at that facility, I think you will realize what defence in depth means. Why? Because it is not just a 'dump' where you leave waste. It is an industrial facility. It has several barriers — you can see them. It has a monitoring system — you can see that everything is controlled. So I think it is a very strong vehicle for creating confidence. It is not only the calculation that creates confidence.

J.T. GREEVES (United States of America): The low level waste sites have that advantage — you can see the results quickly.

C. PESCATORE (OECD/NEA): You cannot see the results quickly. That is the problem.

J.T. GREEVES (United States of America): I can show you sites in the USA where we have contamination. We know that it has come out and what those processes that have caused it. That is very familiar to us.

C. PESCATORE (OECD/NEA): I am sorry, but you do not know who will be around after 500 years. You may not have institutional control any more. Perhaps it is perfectly safe, but you cannot say that you know.

M.W. KOZAK (United States of America): I think you are talking about two different things. Let me intercede, because in my view there is nothing to argue about. I do not think J.T. Greeves was implying that you can see the results in the sense of radionuclide migration, but the fact that it is a concrete facility where — as F. Besnus said — you can see the quality of the construction, you can, to some extent, test the quality of the construction. If it is a facility that is not yet developed and will not be developed for 20–50 years, that is a more abstract thing. So, in that sense, once it is constructed and is in front of you and there is a physical entity that you can look at and test, that gives you more confidence because you can actually look at it.

But I agree — the difficulties of demonstrating the quality of the safety assessment or the radionuclide migration analyses or any of the other defence in depth arguments are similar for geological disposal and near surface disposal.

R. LOJK (Canada): What we have not done is to explain the safety case to the public in a common sense manner. We are using all sorts of different interpretations, different words and making assumptions. Clarity is sometimes more important than content. You should tell people what they need to know and keep the rest of the semantics out of it in order to get a clear message. If they ask more questions, you can go to greater depth, but as technocrats we have a very hard time explaining things to people in a simple manner. We cannot even agree here how to explain it, so it is a problem of communication more than anything else.

H. UMEKI (Japan): I think everyone knows the difficulty of future prediction. If we were to say that we could predict far into the future, we would lose our credibility. But we have to take a decision on this problem and the safety case is a concept to help us provide a more convincing argument to society. This is a very important point, I think, because the traditional safety assessment provides only ‘calculational’ results, to be compared with the safety criteria and that is not enough for confidence building.

C. PESCATORE (OECD/NEA): I think semantics is necessary for specialists. They have to have a certain specialized vocabulary. Aircraft builders have to understand how the aircraft system works and, therefore, they have their own vocabulary. But not everyone needs to know this vocabulary to be convinced of the safety of aircraft. It is the same with radioactive waste repositories. Not everyone needs to know the details of what we are discussing today in order to be convinced of the safety of the repository system.

P. ZUIDEMA (Switzerland): I think we should be careful and not say that the safety assessment and the safety case are the same thing. What is also important — as M.V. Federline said — is that the safety case should provide the arguments that will lead to a suitably safe solution. So, the safety case is somehow the basis for the design process. If the safety analysis reveals a mistake in the system, the safety case should indicate where the mistake is and what has to be changed. In that sense, I think it is very important that you distinguish between these two things.

Another point is that there will not be one document that serves all purposes with respect to the audiences. There are different audiences with different needs, and we have to acknowledge that. Different documents are needed but they should have the same basis and the same key messages and the same key conclusions, and they must be consistent with one another. It is clear that the regulator would not be satisfied with just qualitative arguments. The regulator would want the quantitative basis and all of the details. The public, on the other hand, would probably be confused by all the details. So, I think we must acknowledge that we cannot put everything into one document.

J. REPUSSARD (France): On words and terminology — I think that we should combine our efforts to work through international agencies to reach agreement on words. We should commit ourselves, when these words have been finally tuned up and reviewed by appropriate processes, to use the words to the exclusion of others. Lack of trust also comes from the fact that people are not quite sure if you are using difference words or nuances — which they cannot understand — as a way to hide things.

So I would strongly call for a unification of vocabulary under the IAEA's auspices.

J. KOTRA (United States of America): What is missing for me in this discussion about choice of words is the fact that you have to listen to the community that you are speaking with and understand what it is that they want to know from you. That will dictate the words or the terms that you use. I do not think that we can presume that we are going to train the public to know the latest terminology that we have come up with. I will give you an example. We have worked very hard to develop plain language materials to explain some of the more difficult technical concepts in the regulation of a potential repository — Yucca Mountain. We developed a poster on what performance assessment is, and we used the term 'it is an iterative process'. Most of us in this room know what an iterative process is — it comes tripping off the tongue very easily. But, one of our secretaries said: "What does that mean?" I thought about it and realized that we were failing to communicate something very fundamental. When we said: "It's a learning process", not only did we reach a larger number of people, we conveyed the idea that we are open to learning — if new information comes forward, this analysis is not closed, we are open to learn about things as we go along. That is a confidence building issue, and it ties in with the question we just heard.

I have talked for ten years about an engineered facility with opportunities for quality assurance, for monitoring and so on, but when I arrived recently in a district of Nevada, the local newspaper contained an article discussing 'the dump'. That is, in fact, how the people see it, and you have to respond to those views and listen to their concerns and respond in a way that has meaning for them. So, I think that the language which we use among ourselves may be appropriate to a conference like this one, but we must bear in mind that there are different ways of communicating with a broader audience.

R. LOJK (Canada): I am glad somebody has spoken about 'the dump'. Contrary to what C. Pescatore implied, we are not building aircraft. We are not near that complexity. We are building dumps — deep dumps, shallow dumps, surface dumps depending on what the matter is, and the public should be told that that is what they are getting — they are not getting some complex facility with a lot of computers in it — they are getting a hole in the ground. Our technology is complex in one way and simple in another. Talking about iterative processes for something that means that when we make mistakes we shall be able to fix it because the door is open — is less than honest to the people that we serve. This is not done for us — it is for our clients, and the customer is always right, and the customer wants to know that we are looking after them and that there is a reason for why we are doing the things that we are doing, and we owe it to them to be clear about what we are providing to them. If it is a dump, we can use another word to describe it, but the reality is that that is what is in their minds. We have to make sure that they understand that they may have one but that it is well taken care of.

C. PESCATORE (OECD/NEA): We must not talk in such terms — we should not tell people that they are getting a 'dump'. In France, they take the job very seriously and it is not a dump that they are going to build. Probably they can meet the concerns about irreversibility and also long term safety. They have done the same thing in Switzerland — they took seriously the fact that they wanted to build something which is long lasting, which allows for monitoring and so on — they call it differently, but it is their own irreversible concept. They are certainly not 'dumps'.

J.T. GREEVES (United States of America): There are a number of intervention situations that countries are going to come to the Joint Convention to talk about — including waste 'dumps' that have leaked. Not all of these require action — a safety case and an analysis may show that you should do nothing. These situations have to be talked about and, in the same way as for repository safety cases, trust and confidence has to be built up through the experience of the cases that have been looked at.

P. ZUIDEMA (Switzerland): I would re-emphasize that we should not expect that we can meet the needs of all audiences with one report. I think the aircraft analogy is a good one. When I flew here, I was confident that we would not crash, and I did not have that confidence through reading all the manuals about how the aircraft was built. It was through something else. In our field, part of the safety case is addressed to the regulator or to ourselves as a design instrument to end up with a good system. This has all the details. It is certainly not suitable for the public, but nevertheless it is important and it is absolutely essential also for the public to know that it exists so that they know that we do a good job. But it is a different thing to explain to the public how the repository works and what the ingredients are that make it safe. I think we simply have to accept that we cannot use the same document for everything.

F. KING (Canada): Undoubtedly a good safety case is important for confidence building, but I think that, in reality, it is only a small part of it. I shall be speaking in Session IVb, about the experience which we have had recently in siting a deep geological repository in Kincardine, Ontario (Canada), where we ended up with a host community voting to accept the repository. In that process, confidence building and safety were central to getting that community to accept the facility, but the safety case itself was just a small part. In my presentation, I shall speak about the other things that we also did in order to gain the confidence of the community.

E. VOMVORIS (Switzerland): One of the ingredients of confidence is the independent review. In the past, the OECD/NEA has played this role by providing independent review bodies, but then you also have to do that in your own country. In this context, is there a definition of who is independent?

C. McCOMBIE (Switzerland): I would like to point out the difference between inventing new words and inventing new processes. Sometimes we create confusion by that. Actually, we did not invent the expression 'safety case'. Safety cases were being used in transport studies ten years before we started using them. But we started using the words, and I sometimes feel that there is too little acknowledgement that there is nothing in what P. Zuidema described, for example, that is not somehow referred to in many previous analyses. If you read the old rules of the Nuclear Regulatory Commission, all of the concepts are in there — 'reasonable assurance', 'independent lines of evidence' and so on. So, I think that taking over the term 'safety case' was a good thing, because it shone light on the idea that we are looking at an entire system. But we should be careful that we do not, at the same time, imply that there is a totally new way of doing things. It is an improved, more structured way, but all of the elements were there before. I think that has caused confusion in some places.

C. PESCATORE (OECD/NEA): Regarding independent reviews, we call them 'peer reviews'. In the case of the OECD/NEA, we do not tell the world that this was well done and that was not well done. It is done just to help the organization receiving it to do better next time. In fact we use experts who are usually aware of all ongoing work in the field and perhaps also aware of the work that is being done in the country that requests the peer review.

Behind this idea of 'independence' there is also the idea of 'trusting' — mutual accountability of different organizations; regulators and implementers are trying to be accountable to one another by doing such peer reviews.

J. REPUSSARD (France): I think we would all agree that confidence is not the sole object of the safety case. Obviously, confidence comes also from many other things.

With regard to the question of independence, I think it is a false word. It does not really exist. What you can do is allow a pluralistic approach — that means that you open up your files and agree to discuss with people in the terms they choose — let them ask the questions they want to ask, and they will judge whether you have convincing answers or not — and if various actors give coherent answers or not. People can judge that quite well. That is what should be done in fact. So, the plurality of actors is a way to create confidence — to create a situation where there is a plurality of actors active in examining the evidence.

Another thing I wanted to mention is that people can also observe the behaviour of people, notably operators. For example, a company that is unable to transmit knowledge from one generation to the next of its own employees is not going to be trusted with a project that needs to be demonstrably safe for the next ten thousand years. There is a mismatch there. The social behaviour of a company locally with its own people, its own employees, tells a lot, although it is not technical, about the trust you can place in that company.

J.T. GREEVES (United States of America): Regarding the question of independence, I was a regulator for a long time, and I think that you have to set up a body that has not invested in the outcome — that must be able to reject the application. Not only must they be able to do that, they must have the competence to do the analysis. You can have an independent regulator, but if it does not have competent staff, it can't do the job. Peer review is an adjunct to that process. I encourage the use of peer reviews, but alone they are not enough. You really must have an independent regulatory process.

M.W. KOZAK (United States of America): I would like to add one thing. J.T. Greeves brought up the need to have a strong regulatory body and strong competence. But the ability and funding to do independent analyses which P. Zuidema brought up in his presentation — is not present in many smaller countries. I cannot emphasize enough the necessity for the regulator to be able to carry out independent analyses, because it is only then that you really find where the gaps are.

T. PATHER (South Africa): What is the real role that the regulator should be playing in terms of confidence building? An independent regulator is supposed to be neither for the project nor against it. It is supposed to be promoting the interests of the public — to ensure that they are kept safe. How should it do it when the moment it says that a particular concept is good, its independence comes under question. What is the role that the regulator is supposed to be playing?

P. ZUIDEMA (Switzerland): There is not just the regulator. There is also the policy maker, and I think we should bear that in mind because, at least in some countries, it is the policy maker who plays a very important role. So, I think it is the four groups: the implementer, the regulator, the policy maker and the — probably — nervous public.

M.W. KOZAK (United States of America): That is a very good point. It is not generally acknowledged that, at some point in the process, the regulator changes sides, and ultimately, assuming that there is a positive finding on the licence application, the regulator, in the view of the public, becomes an advocate. It has made a decision, and has to defend that decision before the public. It becomes an advocate for the system. So, it is incumbent on it to make sure that the licence applicant has done a good job.

When that happens, their role fundamentally changes, and that is not generally recognized.

C. PESCATORE (OECD/NEA): In the end, confidence is to be shared for things to go ahead. I think it is normal that, first of all, the regulator has to say how it built its confidence that the system will work. The confidence of others should follow from this.

M.V. FEDERLINE (United States of America): I see confidence building as an extended societal process. It started about 25 years ago in the USA. We have had a series of congressional decisions. We have a Nuclear Waste Technical Review Board. We have an independent regulator. We have a developer. And we have stakeholders. So, to me the confidence building process is societal and involves the roles of each of these organizations. To me, a regulator is an independent body that guarantees involvement in the process to the people who are interested in the decision that is being made.

In Session IIb, in my presentation, I said that there is no guarantee of any outcome. And, as a matter of fact, probably 95% of the people do not like the decisions of the Nuclear Regulatory Commission. But it is important for the regulator to build confidence that we are independent. That does not mean isolated; it just means independent of the decision that is being made. To me, it is the credibility of the regulator that adds to that confidence building process.

L.W. CAMPER (United States of America): If we are going to inspire confidence, we have to be able to communicate with the local elected officials. Unless we can convince the mayors, the legislators, the town councilmen and women, the delegates and so on of what we are doing in terms and concepts that they can understand, so that they can then impart to their constituents in church on Sunday morning or at dinner on Friday night at the local restaurant, we will not succeed.

That is difficult for us to accept, because we communicate with each other in terms and mathematical concepts that we understand. It does not work out there for the typical populace, particularly those who believe they are going to have to host an engineered facility for waste disposal.

J.T. GREEVES (United States of America): This idea of changing sides is interesting. In this context, I think it is important for there to be discipline in the process. It must be clear in advance how the application will be reviewed. The process must be published in a national standard; it should be a standard process applicable to all facilities. The regulatory staff working on the evaluation should not be allowed to invent anything along the way — their analysis must be done according to a standard review plan. Finally, the regulator should be required to write a safety evaluation report. It is important for the other stakeholders to know that the regulator has previously rejected cases because they did not measure up. If the accusation comes that the regulator is changing sides, the response can then be that a well established procedure was followed — known in advance — and that there is no question of taking sides. Unfortunately, not everyone can afford to do what we do in the USA.

C. McCOMBIE (Switzerland): We are talking about establishing confidence, but for the regulator the important question is: “Confidence in what?” I agree with M.W. Kozak: the regulator’s role changes. I think the regulator first has to establish confidence in the science. That is important for everybody, so that it is possible to judge the safety. That is the first thing that the regulator should be interested in having public confidence in. Secondly, the regulator should then be interested in having the confidence of the public that it (the regulator) is able to judge the safety — in other words, confidence in the regulator itself being able to do the job. Lastly, once the decision has been made, the regulator has to be involved in establishing confidence that the decision was right. (I think the ‘changing sides’ concept is a rather extreme view.) At that stage, it means establishing confidence that the facility is safe. So there is a gradual transition in the object of confidence.

P.E. METCALF (IAEA): I think one thing to think about is the safety culture concept — the attitude of always questioning things — keeping a constant eye on the review, re-reviews and so on. I think that is one of the regulator’s responsibilities — not really to become an advocate of the facility — but rather to always question the safety and to question the assurance of safety. He must keep that independent objectiveness and continually question the safety case and the assumptions and examine whether they are all valid after ten years, after 50 years and so on.

A.-C. LACOSTE (France): We are talking mainly about deep geological repositories. It is a kind of mystery, because the official title of the panel has nothing to do with deep geological repositories. We should be talking about repositories in general, and I think that something quite astonishing is the fact that nobody is taking into account the experience feedback coming from surface disposal. The question we are discussing has been dealt with, for better or worse, for other kinds of repository. Sometimes I have the feeling that we are reinventing the wheel.

Of course, the safety authority must remain neutral, as usual, but I think there are two difficulties about this topic for regulatory bodies. The first one could come from the fact that the regulatory body thinks that there is a need for a geological repository. It is a kind of bias. If you think that there is a need for a deep geological repository, you could be seen to be in favour of such a facility. In relation to the second difficulty, I will make a reference to the position of the French regulatory body. In France, there was a law passed by Parliament in 1991 saying that there would be 15 years of research especially about deep geological repositories. That means that the National Waste Management Agency (ANDRA) has made studies for 15 years, and for 15 years the French regulatory body has supervised these studies. Let us imagine that the green light is given by Parliament for a deep geological repository. That probably means an application around 2015 for a possible licence about 2020–2025. By that time, the French regulatory body will have worked for 35 years on the issue. How can it stay in a neutral position when it has worked for 35 years on a particular application? I think this is the real issue — how not to become a part of the application, how not to take the side of the applicant. I think this is a real topic for each regulatory body, but it is not specific to deep geological repositories, it is specific to any kind of long term project.

T. PATHER (South Africa): One of the last issues I would like us to look at is the confidence statement. What is a confidence statement, and in arriving at it how do we address the unresolved issues that C. Pescatore spoke about? How do we look at some of the conservative or generic type calculations that we have and bring all that together into a confidence statement?

M.W. KOZAK (United States of America): In the USA it is done in a legal sense, because there is a licensing hearing and a judge will put his stamp of approval on it. That is a very decisive statement of confidence in a legal sense. In other countries it is not done in such a legalistic way. I think the form that it takes will depend on the local conditions, on what the legal system is and what the regulatory system looks like. So, I do not think there is a general way in which you can define what that confidence statement should look like.

P. ZUIDEMA (Switzerland): I think that C. Pescatore was talking about the confidence statement more in the context of the stepwise approach, where it is acknowledged that, early in the process, not everything is known or needs to be known. That means that the confidence statement should just say something about the envisaged way forward — what are the prospects that eventually you will end up with a suitable situation and also, in case of doubt, what are the alternatives and what flexibility do you have. I think the confidence statement should only say that there are good chances that we can resolve the issues and, if not, that we have a way out. So, in that sense, I think that in the early stages, it is absolutely acceptable that not everything is resolved and that we have open issues in the confidence statement.

C. PESCATORE (OECD/NEA): I agree, but there should be a first part to the statement. We have put together all sorts of arrangements, so that the arguments developed up to now are good arguments, because we have done a certain number of things, because we have used certain procedures — so we have a disciplined process. So, we feel that this part of the job is relatively well accomplished and we are ready to move on and then again explain why we are ready to move on and why there are good chances for the next step also to be successful. So, in my opinion there are two parts to the confidence statement.

H. UMEKI (Japan): I think that a possible way to state confidence is to check the contents of the safety case against the major components of the safety case — for example, that the purpose and the context and the safety strategy have been well defined and the assessment basis is well provided and so on. The confidence statement is closely related to checking — one by one — these major components of the safety case.

M.W. KOZAK (United States of America): We heard that one of the key elements was confidence in a regulator and the regulators have been in business for a long time and that they develop confidence over a long period of time. Well, for most of the States represented here that is not true. We have a lot of young regulatory authorities that are in the midst of changing, and a lot of them are actively working on licensing near surface repositories, and, if we really need to have 35 years' worth of confidence in our regulator, we have problems in a lot of these countries.

A.-C. LACOSTE (France): I do not claim to be speaking on behalf of any country except France. On the subject of confidence in deep geological disposal, if you start talking to people, whoever they are, about just high level waste and deep geological repositories, of course they are afraid. If you can say to them: "You know, there is a national organization for radioactive waste management (ANDRA), it is a public organization, it has been approved by Parliament, it has been operating for years, you can go and visit a surface repository which is being operated by ANDRA, and it has been successful up to now. We have a particular issue, which is high level waste and, on that, we have been working for a long time, and there have been a lot of national debates on that the subject."

I think that is a way to gain confidence, because you are not just, all of a sudden, asking the people for their confidence. You can show them that there has been substantial long term planning. They have been participating in it, and the deep geological repository is just a consequence of that general planning. But it presupposes a lot of preliminary work, and this is exactly the work we are trying to do in France. In Session IIb, R. Cailleton described the general planning for waste management, and high level waste is just a part of it.

Obviously, the situation is not the same in other countries, and I share your views about the difficulty of such issues in quite a number of other countries.

A. KOTENG (Kenya): As a regulator, I have licensed things like medical isotope facilities, but now we have the challenge of the mining of mineral sands. We have no experience of this kind of operation. Is the operation safe? Someone has produced an environmental impact assessment, and economically the project is good for the country, but there may be radiation related issues. We are concerned about the safety of the public and of the workers and, as we have no relevant experience, the question of confidence simply does not arise. All we can say is that this kind of mining has been done in Australia, India and South Africa, and it has been done safely.

THE SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES

(Session III)

GEOLOGICAL DISPOSAL FACILITIES

(Session IIIa)

Chairperson

F. BESNUS
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HIGH LEVEL RADIOACTIVE WASTE MANAGEMENT
Research and development challenges for repository design and implementation

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Abstract

The Japanese high level waste (HLW) disposal programme involves a volunteering approach to siting, which results in special challenges for those involved in designing repositories and planning their eventual implementation. The National Waste Management Organization of Japan (NUMO) has documented a flexible approach to developing repository concepts tailored to the characteristics of volunteer sites, allowing some of the main research and development challenges for repository design and development over the next three to five decades (or even longer) to be identified. These challenges are reflected in the Japan Nuclear Cycle Development Institute's (JNC) research and development programme, which is being refocused to ensure that key information — and experienced 'manpower' — is available as and when required by the repository implementer, the regulatory bodies and other relevant stakeholders. When viewed from an international perspective, this refocusing seems very much in line with international trends and, indeed, many of the specific technical issues are common to other programmes and represent areas where information exchange or collaborative projects could be mutually beneficial.

1. INTRODUCTION

During the latter half of the 20th century, major progress in the development of deep geological disposal concepts for high level radioactive waste (HLW) was evident. There is now a broad consensus that safe disposal is possible in a wide range of different geological settings, with the required isolation being assured by various combinations of natural and engineered barriers. Despite large investments in supporting research and development, however, progress towards the implementation of repositories has been generally much slower than originally planned in national programmes (with the possible exception of Finland). The factor contributing most to such delays has been the growth of public opposition to these (and, indeed, most other major industrial) projects. Consequently, national programmes and international activities include not only effort invested in scientific and technical issues, but also increasing focus on societal, legal and economic aspects that affect public acceptance of geological disposal projects.

In Japan, the technical foundation for geological disposal of HLW was documented by the H3 [1] and H12 [2] projects. Based largely on the platform provided by H12, the implementation phase for HLW disposal was initiated in the year 2000; the law regulating implementation ("the Final Disposal Act") was passed and the HLW implementer, the Nuclear Waste Management Organization of Japan (NUMO), was established. Discussions on establishing safety regulations have been also initiated by the Nuclear Safety Commission (NSC) and the Nuclear and Industrial Safety Agency (NISA). In accordance with the research and development framework specified by the Atomic Energy Commission of Japan in 2000 for the implementing phase of HLW disposal, the Japan Nuclear Cycle Development Institute (JNC) has been actively promoting technical research and development with a view to contributing to both the implementation of disposal and the formulation of safety regulations.

The H12 generic safety assessment illustrated the basic feasibility of siting a safe repository in the Japanese archipelago. Based on this, NUMO decided to adopt a novel 'volunteering' approach to siting, which acknowledges the great importance of acceptance — particularly by local communities [3].

This volunteering process presents a unique challenge to those responsible for developing repository concepts. Although the key initial step involves solicitation of volunteers, NUMO's subsequent plans for stepwise site selection, involving increasing characterization of the sites carried through to each successive phase, are similar to those in other national programmes. However, the process for comparison and ranking of sites is intended to be open and transparent, which requires that the appropriate repository concepts (including associated safety cases) are developed in a clear manner. This is quite different to other programmes where the basic repository concept is defined in advance of — or in parallel with — the initiation of the site selection process.

2. TAILORING REPOSITORY DESIGN AND ENGINEERING TO SPECIFIC SITE CONDITIONS

2.1. Key research and development challenges in repository concept development during site selection

NUMO has a rather wide definition of the term ‘repository concept’, which includes not only the design of all surface and underground repository structures (tailored to a given siting environment) along with a description of how they would be constructed, operated and closed, but also an evaluation of operational and long term safety, ease of retrievability and the required level of monitoring, as well as an assessment of environmental impact and socioeconomic aspects [4].

When volunteers come forward, the initial requirement is to determine if construction of a repository is feasible at that site. Although locations that are inherently unsuitable with regard to long term safety will be screened out by exclusion criteria, sites may remain which would not be suitable for the very idealized designs presented in H12. One or more concepts thus need to be developed and evaluated in a rigorous and transparent manner — particularly if choices need to be made of which sites are to be carried forward to a characterization phase; this will inevitably be costly in terms of resources and ‘manpower’. As the stepwise programme proceeds, such concepts will be further developed to support decision making and eventually to form the basis of licensing applications.

The challenges can thus be identified as defining a process of repository concept development which is appropriate and accepted by all stakeholders and ensuring that the knowledge base required to support it is available in an accessible and timely manner.

NUMO has already [4] examined various top-down and bottom-up approaches to developing site-specific repository concepts. For a comparison of options and/or sites, a multi-attribute analysis (MAA) approach has been found to be useful. Indeed, as similar approaches are being increasingly used by partner organizations, this might be a good focus for collaboration. To date, however, the attributes included often involve surrogates and the scoring models used are extremely simplistic — in many cases effectively representing expert opinion. Further development of this methodology may thus be justified.

Development of the supporting knowledge base requires considerably more effort. Studies carried out over the last two decades have shown that, under the boundary conditions set by various national programmes, many different combinations of waste type/engineered structures and geological settings can provide high levels of safety. Nevertheless, to make the task manageable, focus in Japan is being placed on the primary engineered barrier materials and the alternatives identified in the H12 project. Their behaviour and evolution with time is well supported by extensive laboratory studies, mechanistic modelling and natural analogues, at least on a generic basis.

Even restricting consideration to engineered barrier systems (EBSs) based on a steel overpack and a bentonite-based buffer/backfill, a very wide range of designs and layouts of the underground structures can be derived to respond to the geological environment encountered and the requirements of stakeholders [4]. Nevertheless, in order to build confidence in derived design concepts, the robustness of key safety functions of the EBS, such as physical containment by the overpack and retention of radionuclides in the bentonite buffer, have to be assured for specific siting environments, e.g. the saline groundwater expected at coastal sites.

An area which is currently less well defined is the practicality of construction of such an EBS under strict quality assurance controls in an operational repository environment, considering underground conditions of restricted space, humidity, emplacement rate, remote handling, operational safety, robustness to perturbations, etc. When viewed from such a perspective, there are clearly a number of aspects of the EBS designs that need to be revised or, at least, analysed in greater detail. These are mainly associated with the emplacement of the bentonite-based buffer, which plays many important roles in the associated safety case, e.g. colloid filter, hydraulic barrier, plastic mechanical buffer, chemical buffer, and providing for radionuclide sorption. To ensure that these roles are performed for relevant time periods, the buffer needs to be emplaced in a strictly quality assured manner and its mineralogical/ structural stability must not be degraded by other engineered barrier materials under the expected hydrogeological and thermal conditions.

Demonstration of buffer emplacement methods to meet defined quality levels (e.g. density, homogeneity), when implemented with appropriate remotely operated procedures, could be particularly challenging in the geological environment, where potential host rocks are likely to be rather wet. The handling of highly compacted bentonite is known to be difficult under high humidity conditions and its entire practicality/quality assurance becomes questionable if significant liquid water is present. Nevertheless, there are certainly ways to engineer around this problem, such as the use of prefabricated EBS modules but, in the interim, it is being increasingly studied based on experience gained in full scale tests [5].

This is very much in line with recent international trends, which place increasing emphasis on site-specific tailoring of the rather simple concepts used originally for feasibility demonstration to improve operational practicality, robustness and safety. Apart from conventional laboratory studies, there seems to be much that could be gained from large scale, long term demonstration projects in underground test facilities which, in the past, have clearly illustrated the difference between a design that is possible to implement and one that is truly practical under the boundary conditions of a working repository. Extensive resources and the experienced, multidisciplinary teams are required for such projects, and they can, therefore, often be implemented efficiently as multinational collaborations. Such projects can also play a valuable role in communicating design concepts to non-technical audiences.

In this context, a further international trend is the increasing general acceptance of the idea that enhanced retrievability/reversibility may need to be built into repository designs, to increase acceptance but also to allow flexibility by keeping options open for future societies to be able to make use of possible technical advances in waste management and materials technologies. There has been little research on the extent to which such enhanced retrieval provisions — such as delaying the placement of repository isolation barriers — could have negative impacts on safety. Again, long term demonstration experiments in situ could be useful.

2.2. Special challenges associated with implementation

As the stepwise process moves closer to identification of the final repository site, the details of implementation will need to be more clearly specified. Even though this is expected to be three decades from now, in Japan, it is recognized that some of the requirements for implementation have long lead times and hence need to be considered now. These requirements can be subdivided into structures and 'manpower'.

Initially, repository concept development focuses on the primary engineered barriers, even though a number of other repository structures may have barrier roles, e.g. tunnel liners, borehole caps, backfilling materials, plugs and seals for tunnels, ramps and shafts. Particularly when considering the safety and practicality of construction and operation, such features may play critical roles. As yet, however, there has been relatively little detailed study of the performance of such structures and their possible long term interactions with each other (and the primary EBS). For example, managing groundwater inflow might involve the use of high quality tunnel (or borehole) liners. Indeed, the use of some form of liner may be required for mechanical stability/operational safety, as increasingly recognized internationally, even in programmes focusing on strong, hard rock. Designs of such liners tend to be focused on the use of concrete, which raises questions with regard to the long term degradation of bentonite. In fact, similar concerns arise from all uses of cementitious materials in repositories — including floors, plugs, seals, grouts, etc. As noted elsewhere [6], there are several possible approaches to solving (or avoiding) this problem but, as yet, they have not been assessed in a rigorous manner.

Current concepts envisage that the main emplacement operations in a repository will involve some kind of remote operation, although this has not yet been shown to be feasible with existing technology. The special difficulties of handling radioactive materials underground and the need to be able to recover from any perturbations which might arise during the decades of operation lead to a requirement for robustness which, realistically, will require several cycles of iterative design and testing; as cycle lengths could be around 5–10 years, the need to initiate work now is clear.

Implementation will allow considerable potential for optimization and some areas where design improvements are possible have already been identified, e.g. prefabricating the main components of the EBS, placing several vitrified waste packages in a single overpack. These conceptual options do, however, need considerable study to bring understanding up to the level of more conventional approaches and to clarify any consequences for post-closure safety. For example, optimization resulting in higher emplacement densities leads, inevitably, to higher thermal loading and a potentially significant increase in both the maximum temperatures within the EBS and the duration of the thermal transient which could, in turn, have a large impact on kinetically controlled chemical interactions. The technical background needed to carry out a rigorous cost–benefit analysis within an optimization study would require a considerable extension of present-day knowledge.

In terms of ‘manpower’, it is clear that an HLW repository project will require significant numbers of widely experienced staff, particularly at the time around the initiation of operations. Recruitment of highly qualified staff is recognized to be a problem throughout the nuclear industry and hence an active programme of ‘manpower’ development is needed. An HLW repository will be a ‘first of its kind’ facility in Japan and, even if a few repositories are operational by this time in other countries, the extent to which experience can be directly transferred will be limited. The multidisciplinary experience needed cannot be gained in conventional projects and, hence, this is seen to be a key role of underground research laboratories (URLs). This is an area with great potential for international collaboration, especially when there are clear links between URL experiments, laboratory experiments, process modelling and data gathering [7]. As previously noted, URL experiments are valuable in their own right for demonstrating the functioning of repository components under realistic conditions and for developing, testing and demonstrating engineering standards and quality assurance methods; this complements their training role.

In accordance with the new framework specified by the Atomic Energy Commission of Japan in 2000 [8], JNC continues to be responsible for the research and development activities supporting the HLW programme. Given the importance of in situ work as identified above, a particular feature of JNC research and development activities in this implementation phase is to promote two purpose-built generic URL projects — one at Mizunami in crystalline rock and the other at Horonobe in sedimentary rock [9]. Given the degree of international interest in large scale demonstration projects, this is an area where Japan, with its strong engineering base, could take a lead and attract other national programmes into shared, long term, high profile tests and demonstrations of repository engineering technology.

3. INTEGRATION OF TECHNICAL UNDERSTANDING WITHIN A KNOWLEDGE BASE

In order to develop optimized designs for specific sites, it is important not only to have an integrated database of the information from site characterization and supporting research and development, but also a formal mechanism for supporting and documenting decisions. At present, several implementing organizations (including NUMO) are investigating variants of 'Requirements Management' for this purpose [10]. Ideally, this tool can be integrated with the development of the information database (Knowledge Management) and assurance that required quality levels are maintained (Quality Management) [11]. Both the information and quality databases should be completely objective and therefore should be compiled and managed by an independent third party (e.g. JNC). They would then form a valuable resource for both the implementer and regulator.

Through the surface based investigations in the Mizunami and Horonobe projects (phase 1), integration of work from different disciplines into a 'geosynthesis' has been illustrated and is planned to be developed further in the underground facilities at these sites. These projects also serve to develop and test the tools and methodologies required for site characterization. Further 'know-how' will be gained through participation in foreign underground laboratory projects, the transfer of experience from these projects to Japan and the tailoring of the information to Japanese conditions and requirements. This experience represents an important knowledge base for assessing how key site characteristics are derived and for determining the uncertainties associated with this process. This provides an input for subsequent repository design studies and the associated safety assessment. In turn, safety assessment has an important role to play in guiding site investigations and repository design activities by quantifying key sensitivities and uncertainties. An integrated programme in which these topics are developed iteratively is planned; this will create experienced multidisciplinary project teams with the wide perspective provided by participation in multinational projects and familiarity with other national HLW programmes.

To facilitate programme integration and the sharing of technical information between the site investigation, repository design and safety assessment teams, JNC is also developing an archive system, in which a database stores technical information in the form of a structured flow chart that systematically represents the structure of research activities. Such a structured knowledge base will provide the basis for a formal knowledge management system for geological disposal.

4. CONCLUSIONS

The Japanese HLW disposal programme involves a stepwise approach with an iterative process of site characterization, repository design and safety assessment, which is consistent with that internationally accepted and implemented in other national programmes. Through this approach, repository concepts will be tailored to siting environments, taking account, not only of long term and operational safety, but also of engineering practicality, retrievability and monitoring, as well as environmental impact and socioeconomic aspects. The selected volunteering approach to siting does, however, create rather unique boundary conditions for this process.

Key research and development challenges are associated with ensuring a clear and transparent process of repository development for volunteer sites, which includes continually tailoring the design to site conditions in order to support the decisions leading to final site selection. Additional issues are associated with increasing the reliability and robustness of the repository concept and extending the assessment of operational practicality — both of which may benefit from in situ engineering demonstration on a large or full scale. A closely related area is the development of the knowledge base to support optimization during implementation. Substantial numbers of experienced persons will be required to construct and operate such a facility in Japan. Again, large projects in underground research laboratories can play important roles in these areas.

In order to develop an optimized design and a safety assessment basis for specific sites, variants of the Requirements Management system, which could be integrated with the development of knowledge management and quality management systems, are being considered. Development of a quality assured knowledge base and a structured approach to managing technical knowledge on geological disposal is critical in this regard, preserving a valuable legacy of intellectual property in the HLW disposal programme.

The challenges identified are recognized to be common to many national programmes and hence could be a focus for future collaboration. In addition to the benefits of sharing the resource and 'manpower' costs of projects, such collaborations also serve the valuable role of facilitating transfer of experience between programmes and of helping to build confidence among the general public.

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DISCUSSION

P.E. METCALF (IAEA): You said that the repository concept would be discussed with the regulator, but you did not say that the safety case would be discussed. Would the repository concept not be part of the safety case, which should be considered by the regulator?

H. ISHIKAWA (Japan): Basically, the safety case is provided by the implementer. Japan's Nuclear Waste Management Organization (NUMO), the implementer, has provided some repository concepts, but they have not been reviewed by the regulator.

A. MATHUR (India): On the basis of what factors did you select a depth of 1000 m for the underground repository laboratory?

H. ISHIKAWA (Japan): On the basis of geological features such as the temperature gradient underground and mechanical stability.

THE SITING OF RADIOACTIVE WASTE DISPOSAL FACILITIES

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Abstract

The goal of any siting process is the selection of a site that allows the development of a repository project fulfilling the safety and environmental requirements necessary for licensing and for which political approval and local, regional and national acceptance is achieved. However, until that goal is reached, many obstacles have to be overcome. The paper identifies and discusses some of these challenges and, based on a large body of experience from a number of countries, indicates ways in which they may be overcome.

1. INTRODUCTION

The successful siting of a radioactive waste disposal facility requires that the corresponding project fulfils two groups of criteria: (1) technical/scientific (primarily safety criteria, but also criteria regarding technical feasibility, land use planning, etc.) and (2) public acceptance. In the past, the application of a systematic technical screening process on its own, using geological and other data, has in many cases not led to successful siting. The approach did not fail on every occasion that it was applied, but it failed whenever it was used in a way such that a siting project was *imposed* on a locality. It follows that successful siting strategies should explicitly acknowledge the importance of winning public acceptance, which requires real public involvement. Experience suggests that meaningful public involvement, that is sustained over the required period (several years), can only be achieved if the public feels that it can influence the outcome of the decision process and that it perceives the process as fair, structured, open and transparent. In Switzerland, recognizing that a legally binding site selection procedure that is widely accepted would be beneficial, the recently revised Swiss Nuclear Energy Law [1] and the corresponding Ordinance [2], both of which entered into force on 1 February 2005, require that such a process must be defined by the Government; the procedure and the corresponding criteria are currently under development (*Sachplan geologische*

Tiefenlager). Another important element influencing public acceptance is the perception, by the public, of the net socioeconomic impact of a disposal facility. Such (perceived) impacts can be both detrimental, e.g. decrease in property values, or beneficial, e.g. generation of work, financial compensation to the affected communities.

A large body of experience on the siting of radioactive waste disposal facilities is available from a number of countries; in the present paper the focus is on the so-called EDRAM countries. EDRAM is the International Association for Environmentally Safe Disposal of Radioactive Materials; a society of executives or chairpersons of radioactive waste management organizations that provides a forum for the promotion of exchange of knowledge, experience and information among members. Members include ANDRA (France), BfS and DBE (Germany), ENRESA (Spain), Nagra (Switzerland), NIREX (UK), NUMO (Japan), OCRWM (USA), ONDRAF (Belgium), OPG (Canada), POSIVA (Finland) and SKB (Sweden).

2. STAGES OF THE SITING PROCESS

Despite differences in the approaches taken by different countries, the siting process is usually divided into four stages (see, for example, Refs [3, 4]):

(1) *Conceptual and planning stage.* During this stage, potentially important siting factors, potential host rocks and possible siting areas are identified, and investigation objectives and investigation programmes are defined. It typically includes factors such as the development of the safety concept, i.e. how the system is expected to provide long term safety, including identification of potential host rocks, the definition of the conceptual design, the establishment of a strategy to develop the required technical basis (RD and D), and the identification and allocation of responsibilities, including the role of the regulator.

(2) *Area survey stage.* In this stage, one or more potential sites are identified for further investigations (preliminary investigation areas) based on regional studies. This may be done by a systematic survey of potentially suitable sites, either for all suitable host rock types or only for a preferred host rock type. In such a survey approach, the narrowing down to one or a few sites for further investigation is typically done using predefined criteria. Alternatively, the area survey may be limited to sites that appear desirable for a number of different reasons, e.g. because they have been volunteered by communities or because preference is given to already existing nuclear sites.

(3) *Site characterization stage.* During this stage, the potential site(s) identified at the area survey stage are studied with surface based techniques to identify the preferred site(s) for confirmation (detailed investigation area(s)). It is at this point that a single preferred site might be designated if investigations have been made on multiple sites. The extent to which multiple sites are characterized will vary between countries and will depend on the requirements for different radioactive waste types, on the availability of different host rock types or on political reasons.

(4) *Site confirmation stage.* In this stage, the preferred site(s) are characterized through detailed underground studies to confirm acceptability from the point of view of long term safety. Site confirmation may continue through the construction and operation phases of the repository and may be extended to include a monitoring phase.

3. CRITERIA FOR SITE SELECTION

For the purpose of further discussion, the criteria used for site selection are divided into three categories:

(1) *Scientific/technical issues.* This includes both safety related issues as well as issues related to the technical feasibility of implementing the chosen design concept. Key siting factors include the geological environment, the hydrogeological and geochemical properties of the host rock at that site and the potential for human intrusion. Experience shows that different possibilities exist for achieving a safe system (varying geologies with the engineered barrier systems adapted to the geological conditions). After the considerable developments in performance assessment methodology over the past 10–15 years, tools exist to allow the reliable assessment of the safety of different repository designs in different geological environments.

(2) *Environmental impact issues and land use planning.* Environmental impact issues are concerned with the impact of repository construction and operation, e.g. associated with the transportation and disposal of excavated material, the transportation of radioactive waste. Directly connected to this is land use planning. In Switzerland, for example, the Nuclear Energy Ordinance [2] requires that, in addition to the safety report (with all the auxiliary reports), an Environmental Impact Assessment report and a report on land use planning are submitted as a part of the documentation supporting an application for a General

Licence (i.e. the step that defines the site). Finally, it is noted that Environmental Impact Assessments can provide a useful framework for the involvement of the public (see also Section 4).

(3) *Socioeconomic issues.* Although studies on the possible impact of a repository project on the local and regional economy are not always required by legislation, they may form an important part of the basis for the discussion with the stakeholders. In fact, experience suggests that for those stakeholders who are convinced of the technical feasibility of a specific repository project, the decision on whether or not they accept a repository 'in their backyard' may depend on the (perceived) socioeconomic impacts. Such impacts can be both detrimental, e.g. property values may decrease temporarily, or beneficial, e.g. jobs may be created, the affected communities may receive compensation, to the local and regional economy. It is the purpose of socioeconomic studies to evaluate and illustrate the net impact of repository projects under a range of assumptions.

The relative weight and level of detail to which these three categories of criteria are considered depends on the stage of the siting process, but may also vary from country to country. However, the selected site has to provide an adequate level of safety, irrespective of how well the other criteria, (2) and (3), are met.

4. INVOLVEMENT OF THE PUBLIC

Over the last decade, awareness of the need for better communication related to nuclear waste programmes has increased worldwide (see also Section 5.1). In recognition of this fact, the OECD/NEA's Radioactive Waste Management Committee (RWMC) created the Forum on Stakeholder Confidence (FSC) in 2000, to facilitate the sharing of international experience in addressing the societal dimension of radioactive waste management (see, for example, Ref. [5]). The FSC explores the means of ensuring an effective dialogue among all stakeholders, and considers ways to strengthen confidence in the decision making process.

Some key findings of the FSC relevant to the siting process include:

— Environmental impact assessments can provide a useful framework for the involvement of the public.

— Local communities and municipalities can play an important role in radioactive waste management decision making; this needs to be recognized, encouraged and facilitated.
— The municipalities already hosting nuclear sites have a special interest in solutions being found for the disposal of radioactive waste; they are especially receptive to dialogue.
— Sufficient time and resources must be devoted to the stakeholder participation process.
— A range of tools is needed for involving different sectors of the public.
— Stakeholders should be allowed to participate from the very early stages of the siting process.
— Public interest in participation can be maintained only if stakeholders believe they can influence key decisions.
— Information on management options and alternatives is needed to ensure properly balanced deliberation by the stakeholders.
— Not all participation is alike. Different levels of stakeholder participation or involvement are provided by different techniques. One approach may be simply to transmit information to a passive stakeholder audience, while at the other end of the scale, stakeholders may be significantly empowered in the decision making process.
— There is a need for implementing organizations to clarify the level of involvement and communication that the participants can expect. Once this has been defined, it should communicated to the potential stakeholders as early as possible in the process.

5. EXPERIENCE

5.1. Overview of approaches to site selection

Over the past decades, there has been an evolution in the approach for selecting potential sites for waste management facilities. In the early days of nuclear technology, sites for nuclear facilities were commonly chosen to be remote, often simply to minimize the numbers of directly affected persons. Subsequently, additional facilities were often sited adjacent to existing installations. The necessary infrastructure was available and public acceptance was easier, because of the prior familiarity of the local population with nuclear technology.

With time, new locations were needed for nuclear facilities, such as waste repositories, for which there are additional, very site-specific requirements. This was the period when 'expert judgement' was often exercised, however, the process took place ‘behind closed doors’. Groups, primarily of technical specialists, would, in good conscience, gather together in order to select specific sites and they would plan how best to ‘decide, announce and defend’ their decisions. This procedure was not successful. Following this period, hope was placed on a procedure intended to be logical and traceable, that would result in single sites being identified and recognized by everyone as ‘logical best choices’. This kind of approach was described in international documents, e.g. those of the IAEA, produced through the 1980s. It would, of course, have been an ideal solution for decision makers who would have had the perfect defence for their siting choices. However, the approach is problematic; the degree of subjective judgement in narrowing the options is high enough to fuel disputes even among the experts. Moreover, the proposed approach neglected key societal aspects.

Another proposed approach involves the use of multi-attribute analysis. In this technique, all criteria influencing the choice of options are identified, the extent to which each option matches the criteria is evaluated, and then the scores are combined, using appropriate weighting factors, to give a ranking of preferences. The scores, and especially the weightings, can be allocated by different stakeholder groups, which allows for the inclusion of the wider non-technical issues. A variant on this approach starts with options that are suitable from a technical point of view and which may be the result of the application of a technical screening procedure. This approach is promising — provided that there is full transparency concerning the parameters and also the weighting factors that are employed when combining judgements on the individual parameters.

Another approach is to select potential sites by soliciting volunteer communities. Current siting guidelines from the IAEA [3] recognize the validity of the volunteering approach with one key provision, namely, that ‘the selected site provides an adequate level of safety’.

In summary, the approaches used for site selection have varied from rigid technological procedures through to totally open volunteering that emphasizes social consensus. A recent report from the US National Research Council [6] suggests the ‘adaptive management’ approach for arriving at socially and technically acceptable waste management solutions and it could also be applied at the siting stage. The report also points out that a direct technological approach may be more justified if there are urgent concerns with, for example, the security of spent nuclear fuel.

5.2. Some examples from EDRAM countries

In practice, all of the approaches mentioned have been tried; some examples are given in the following discussion:

- *National concerns as the driving force in repository development.* An example of a successful project in this category is the WIPP deep repository for long lived (primarily military) transuranic wastes (TRU) in New Mexico, USA, that has been in operation for some years now. The large number of TRU surface interim storage sites dispersed over the country was a national situation that was considered to be unsatisfactory.
- *Familiarity of the local population with nuclear technology.* Examples of successful siting projects, where familiarity of the local population with nuclear issues may have been a factor, include the Olkiluoto project in Finland, the WIPP repository in the USA, the low and intermediate level waste repository at Forsmark in Sweden and the Kincardine project for a low and intermediate level waste repository in Canada.
- *Public involvement in decision making.* Examples here include the Swedish and Finnish programmes for the development of repositories for spent nuclear fuel. In Sweden, following a wide volunteer solicitation process that led to little success, SKB identified promising sites to host a spent fuel repository, but made commencement of a site characterization programme contingent upon receiving the consent of the local community. This approach has been successful in identifying two potential sites — Simpevarp and Forsmark — where the site investigations are well underway. In Finland, after a cautious staged approach in which various options were investigated, attention was focused on two communities, which then competed to host the repository. For one of these sites, Olkiluoto, a general licence for a repository for spent nuclear fuel has been granted and underground exploration is underway.
- *Importance of public acceptance.* The selection of Wellenberg as the Swiss site for low and intermediate level waste (L/ILW) in 1993 was made by the implementer through qualitative comparison with three other short listed potential sites. In spite of widespread agreement (including by the regulator) on the technical merits of the site, the project subsequently failed, due to lack of sufficient public support. In the 1970s, technical experts, in closed session, selected a single site at Gorleben in Germany for HLW disposal; today the legitimacy of the process is still being challenged. Later, in the 1990s, a similar approach in the United Kingdom led to the selection of Sellafield as a preferred site for a geological

repository for ILW but this subsequently failed to receive planning permission.

— *Role of environmental impact assessments in the siting process.* An example to illustrate the role of environmental impact assessment in providing a framework for discussion with the public on all aspects of a disposal project is provided by the Finnish programme for the development of a repository for spent fuel. It is interesting to note that the relevant national report explicitly states that "… an important part of the environmental impact assessment of the project was the involvement of various parties in the EIA procedure. Public involvement aimed at generating interaction between the parties responsible for planning the final disposal facility and those participating in the EIA procedure. The candidate municipalities played the main role." [7].

— *Multi-attribute analysis.* In the USA, technical multi-attribute analyses yielded three potential sites for a repository for high level waste (HLW) and spent fuel, and from these a political decision by Congress identified the Yucca Mountain site. Although there is continued opposition at state level to the project, the US Department of Energy (USDOE) is currently preparing a licence application for repository implementation at the site.

— *Voluntary approach.* Japan has embarked upon a very wide solicitation process for volunteers, with comprehensive data packs being distributed to over 3000 communities. The results of this approach are awaited with interest.

6. SUMMARY AND FUTURE CHALLENGES

In summary, technological solutions to the safe disposal of radioactive waste exist, but public acceptance and political support for the siting process are critical elements in many countries. The most critical single requirement for successful repository implementation in a country is the political support needed to make people aware that the existing arrangements of interim waste storage (which may evolve, by default, into indefinite storage) should be changed towards the construction of repositories. Once such support is at an adequate level, the disposal concept, the siting process and the siting criteria can be defined, e.g. by national governments, but with adequate involvement of all stakeholders (all stakeholders should have the possibility to 'help to make the rules'). The rules should be settled before the actual process starts. The siting process itself should be structured, open and transparent and it should be seen as being fair, with the possibility for local and regional stakeholders to participate and to influence decisions. A staged decision process, in which (initially) alternatives exist and that foresees the possibility of reversing decisions, may be helpful in this respect. Even an optimal siting process will not be able to identify the 'safest' site; this is neither possible nor necessary. However, it should be demonstrated that different options and/or regions have been considered. Another factor that is considered helpful in the siting process is a strong and independent regulatory body that plays an active role by defining the safety criteria and critically reviewing the technical part of the implementer's work and that takes part in discussions with the local and regional stakeholders ('expert of the public'). Regarding siting criteria, all stakeholders should recognize the overriding importance of the safety criteria, even though in practice, socioeconomic issues (and environmental impact issues) may play a more important role in influencing public acceptance.

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DISCUSSION

M. TAKEUCHI (Japan): What are your views regarding the attitudes of communities that are neighbours to a future host community?

H. ISSLER (Switzerland): That is a sensitive issue. Neighbouring communities can be affected both during the construction phase and later, by waste transport operations. The environmental impact assessment and socioeconomic studies should take account of the affected neighbouring communities. Difficulties can arise particularly when affected neighbouring communities are not participating in a financial compensation scheme. Experience has shown that it is helpful if the future host community and the neighbouring communities establish a working group to coordinate their positions.

UNITED STATES DEPARTMENT OF ENERGY EXPERIENCE IN CREATING AND COMMUNICATING THE CASE FOR THE SAFETY OF A POTENTIAL YUCCA MOUNTAIN REPOSITORY

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Abstract

The experience gained by the United States Department of Energy (DOE) in making the recommendation for the development of the Yucca Mountain site as the United States of America's first high level waste and spent nuclear fuel repository is useful for creating documents to support the next phase in the repository programme, the licensing phase. The experience that supported the successful site recommendation process involved a three-tiered approach. The first step involved making a highly technical case for regulatory compliance; the second involved making a broader case for safety in an Environmental Impact Statement; and the third involved producing plain language brochures, made available to the public in hard copy and on the Internet, to explain the DOE's action and its legal and scientific bases. The paper reviews lessons learned from this process, and makes suggestions for the next stage of the repository programme: the licensing phase.

1. INTRODUCTION

On 23 July 2002, the President of the United States of America signed into law House Joint Resolution 87 — a Bill passed by both houses of Congress. The law designated the Yucca Mountain site as the nation's first spent nuclear fuel and high level radioactive waste repository, and allowed the process to move forward into the licensing phase. Reaching this milestone required the characterization of the Yucca Mountain site, the study of materials to be used in building the repository, an appropriate level of design, and a host of other scientific, engineering, computer analysis and document preparation work. The next challenge, the licensing process, will be very demanding on both the United States Department of Energy (DOE) and its regulator, the Nuclear Regulatory Commission (NRC).

One of the lessons learned in the process leading to the successful site recommendation to the President is that we need to be able to show that the work done in supporting a claim for repository safety is competent and credible. This needs to be done to satisfy the very technical audience from the regulatory and oversight body. This audience is empowered by law to stand in judgement of the project and to evaluate whether or not there is sufficient confidence in the safety argument to allow the project to move forward to its next phase. There are, however, other audiences, including the general public, elected officials, and the non-participant scientific and engineering communities from which the DOE's experts are drawn. Without general support from at least some of these important segments of society, it may be difficult to move forward with this technical, but Congressionally controlled programme.

This paper discusses what was done for these various audiences in preparation for the site recommendation decision, and it suggests that the DOE's approaches and actions might be improved upon, and might usefully be emulated, to some extent, by repository programmes in other countries. It is recognized that each country has a cultural and legal/regulatory setting that makes it unique. However, the need to communicate very technical materials at several levels for audiences differing in scientific or technical expertise is universal.

This paper explores the lessons learned from the site recommendation process and suggests applications of those lessons during the licensing process. It makes suggestions, not policy. The first priority for the DOE is to produce a comprehensive, high quality licence application for the Nuclear Regulatory Commission to review. But the need exists to explain the content of this application, and the process of which it is a part, to a variety of other, non-regulatory, audiences.

2. THE 2002 CASE FOR YUCCA MOUNTAIN SAFETY

2.1. The tiers of documents supporting the site recommendation decision

A highly technical document was produced that demonstrated that the applicable regulation, the DOE's Siting Guidelines, published in the Code of Federal Regulations as Title 10 Part 963 (hereafter 10 CFR 963), was met [1]. This regulatory compliance document is the Yucca Mountain Site Suitability Evaluation [2]. In turn, this document was supported by a more comprehensive document, the Yucca Mountain Science and Engineering Report [3] giving the scientific foundations for its compliance arguments. Thus, two documents were prepared. One was to show compliance, the other to show the science underlying that compliance. The Yucca Mountain Science and Engineering Report was supported by many analysis and model reports. There are too many to list here, but they are generally available on the Internet (www.ocrwm.doe.gov/technical/index.shtml).

A third document, required by law, was a Final Environmental Impact Statement [4]. It is a comprehensive discussion of safety and other potential impact items as required by the National Environmental Policy Act (NEPA). It is intended to be read by non-specialists, with more detailed treatments of certain issues, and discussions of data and calculations, contained in technical appendices. In addition, it has a 'Readers Guide' and a 'Summary' document, both of which are designed to be read by non-specialists.

Finally, to convey the decision being made (the site recommendation to the President) and to give an indication of its basis to the general public, a two-part brochure was produced and made available on the Internet [5]. The first part is "Why Yucca Mountain?", the second part is "Why Yucca Mountain? Frequently Asked Questions".

The indications are that these documents have served their various purposes. A recommendation was made to the President, by the Secretary of Energy, via a letter [6]. In that letter, mention is made of a peer review by an international group of experts with IAEA involvement. A more substantial explanation of the Secretary's decision to recommend the site is contained in [7] which makes it clear that the OECD/NEA–IAEA review referred to in the letter is the joint review performed by the OECD/Nuclear Energy Agency (NEA) and the IAEA [8].

2.2. Making the case for long term repository safety

The OECD/NEA–IAEA review, in Section 2.5, indicated that the safety evaluations that were the subject of the review were found to be "soundly based and implemented in a competent manner" and provided "an adequate basis for supporting a statement on likely compliance within the regulatory period of 10 000 years, and, accordingly, for the site recommendation decision". However, the OECD/NEA–IAEA review also made critical observations about the work being too narrowly focused on regulatory compliance and not making a broad enough case for showing the level of understanding reflected in the safety evaluations. The review made a number of observations about the approach being conservative in some key respects, and of not making a case for the intrinsic robustness of the proposed repository system. In Section 3.1 the review makes clear that what was looked for and found wanting was a 'safety case':

"A Safety Case should be developed as a higher level document, and include the articulation of a strategy to achieve safety as distinct from the strategy for demonstrating compliance, with an emphasis on obtaining and communicating understanding and facilitating dialogue with the relevant stakeholders."

The tiers of documentation described above, taken as a whole, make a comprehensive case for safety and demonstrate understanding of the system to a wide range of potential stakeholder audiences (interpreted to mean all interested parties including the public). However, they do not quite answer all of the suggestions for improvement made in the OECD/NEA–IAEA review. Making a comprehensive case for system safety is not a trivial undertaking, and the definition of what a safety case is has changed since 2002.

2.3. The safety case as a concept

The IAEA and OECD/NEA are jointly promulgating an international Safety Standard entitled Geological Disposal of Radioactive Waste [9] that defines the safety case as "an integration of arguments and evidence that describe, quantify and substantiate the safety, and the level of confidence in the safety, of the geological disposal facility". That publication contains a figure that explains the safety case concept (Fig. 1).

It is the DOE's contention that the tiered document structure created to support the site recommendation process collectively addresses all of the elements of a safety case mentioned in Fig. 1. Whether a hierarchy of documents is the best way to make a case for multiple audiences for safety is not entirely clear. The Swiss National Cooperative for the Disposal of Radioactive Waste (Nagra) is receiving international praise for its Project Opalinus Clay Safety Report [11], a single volume English language report addressing every aspect of a safety case as defined by the IAEA and the OECD/NEA. However, the Swiss authorities are receiving three documents from Nagra, two comprehensive technical reports synthesizing the geological investigations and engineering underlying the safety assessment cited above. So, a hierarchy of documents may be necessary even when a comprehensive single volume safety argument has been produced.

The Nagra Project Opalinus Clay Safety Report is an exemplary multi-audience, one volume case for safety, suitable to the stage of the Swiss repository programme (the feasibility of siting stage, in this case). Creating a similar document for the DOE's licensing phase would be challenging, but

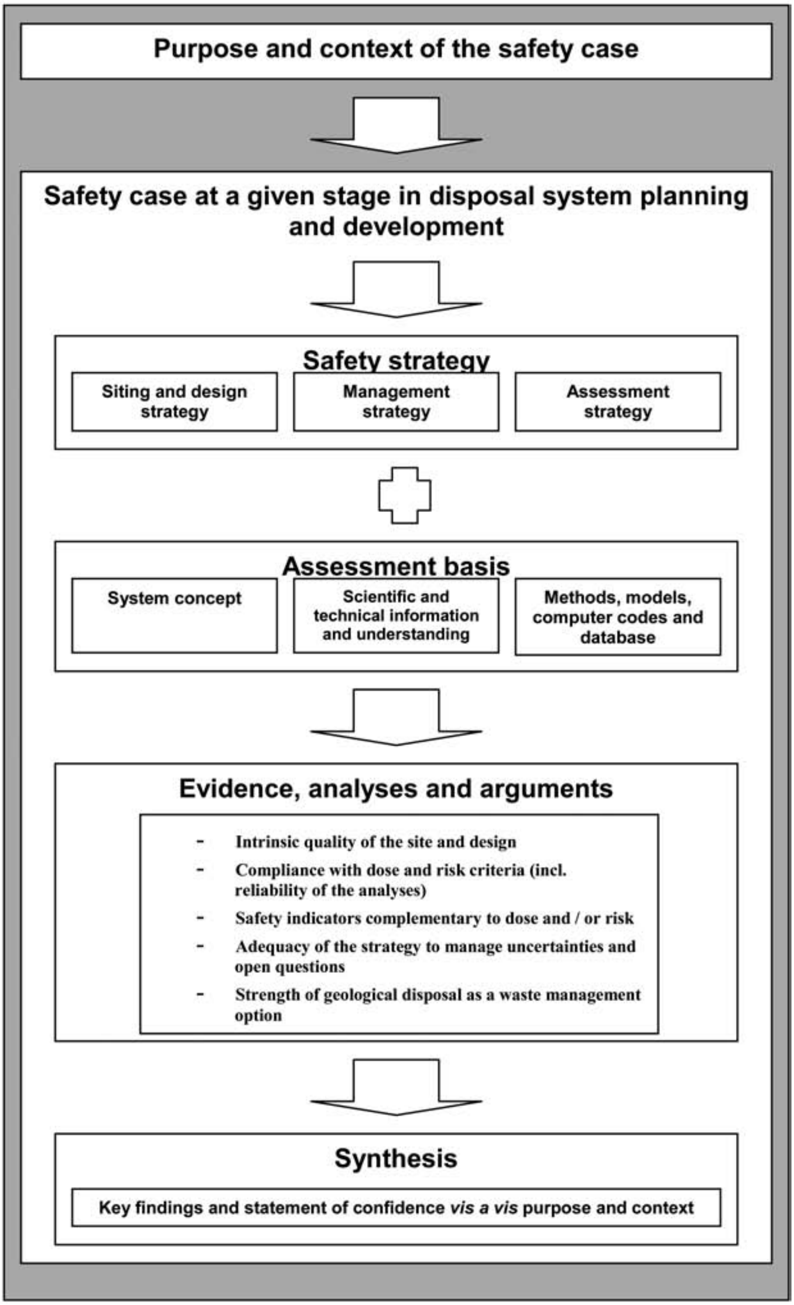

FIG. 1. An overview of the relationship between the different elements of a safety case [10].

worthwhile in terms of being able to explain the content of the massive, highly focused licence application to more general (non-specialist but still technically astute) audiences. Producing such a multi-audience document is under consideration.

3. CRITICAL OBSERVATIONS ON THE 2002 YUCCA MOUNTAIN SAFETY EVALUATION AND A CHALLENGE TO THE REGULATIONS

3.1. An administrative challenge to the Nuclear Regulatory Commission's regulation

The State of Nevada sought to reopen the regulation to be addressed by the DOE in its Yucca Mountain licence application by requesting a formal rulemaking to change the NRC's regulation in several ways [12]. One portion of the request is for the NRC to address the OECD/NEA–IAEA review observations on the DOE's interpretation of the NRC's (then draft) regulation [8] in its conduct of the safety assessment supporting the site recommendation. The NRC pointed to the words of the OECD/NEA–IAEA review in supporting its denial of the request [13].

The OECD/NEA–IAEA review suggested, in its Sections 2.1 and 2.2, that the DOE was too focused on showing quantitative regulatory compliance with the NRC's regulation (as it was in turn reflected in the DOE's own regulation, the 'Siting Guidelines' [1]). This observation from the review was overlooking the fact that the regulation also requires demonstration of understanding in support of the compliance calculation, and that the regulation left the approach to showing compliance to the DOE. The OECD/NEA–IAEA review also suggested that the DOE ought to construct a safety case within which to place the regulation driven safety assessment.

The State of Nevada challenged the NRC regulation, in part, to request it explicitly include a requirement for the DOE to do as the OECD/NEA–IAEA review suggested: to construct a comprehensive safety case within which to place its safety evaluation.

The NRC denied this particular request on the grounds that the DOE is free to construct a case for the repository in the way it may wish, and that the requirement already exists to show understanding as part of the basis for compliance (quotations selected from pages 32 and 33 of Attachment 2) [13]:

> "Petitioner [State of Nevada] believes that DOE must be required to present 'an affirmative safety case' which demonstrates an understanding

of repository performance. To ensure demonstration of an affirmative safety case, petitioner has proposed a new regulation (proposed § 63.21(c), supra) which is based on, but not identical to, recommendations made by the Peer Review with respect to DOE's TSPA-SR. Although the Peer Review focused on DOE's TSPA-SR, it did make a few observations on NRC's proposed Part 63:

> The regulations require that a risk-informed approach should be adopted in demonstrating compliance with the dose limit, in recognition of the uncertainties inherent in making assessments over long time frames in the future. It is also required that the assessment should reveal an understanding of the relationship between the performance of the repository sub-systems and the total system performance. Nevertheless despite the prescriptive nature of the regulations, the I[nternational] R[eview] T[eam] notes that the proposed licensing regulation 10 CFR 63 states that 'consistent with a performance based philosophy, the Commission (NRC) proposes to permit DOE the flexibility to select the approach for demonstrating this relationship that is most appropriate to its analysis.'"

The NRC then cites two paragraphs from the OECD/NEA–IAEA review and observes (pages 33–35 of [13]):

> "Thus, the Peer Review acknowledged the importance of DOE presenting, in its TSPA, an in-depth understanding of the performance of the repository system and recognized that demonstration of safety is more than numerical compliance with the proposed regulatory requirements. As a matter of record, a similar concern was raised during the public comment period on the proposed regulation (i.e. can performance assessment be relied on as the sole quantitative technique for evaluating compliance with the postclosure safety requirements). The Commission, in response to this concern, explained that the regulations contained a number of requirements directed at DOE's demonstrating an in-depth understanding of the repository system:
>
> Although repository postclosure performance is evaluated with respect to a single performance measure for individual protection, the NRC considers a broad range of information in arriving at a licensing decision. In the case of the proposed repository at Yucca Mountain, Part 63 contains a number of requirements (e.g. qualitative requirements for data and other information, the consideration and treatment of uncertainties, the demonstration of multiple barriers, performance confirmation

program, and QA program) designed to increase confidence that the postclosure performance objective is satisfied.

The Commission will rely on the performance assessment as well as DOE's compliance with these other requirements in making a decision, if DOE submits a license application for disposal of HLW at Yucca Mountain."

The NRC response continues, but the important point is that, in essence, the NRC agrees with the OECD/NEA–IAEA review and says that it is up to the DOE to demonstrate that it knows its system and has evaluated its uncertainties. Whether or not this broad demonstration of understanding, evaluation of uncertainty, and demonstration of compliance is called a safety case is up to the DOE to determine.

4. CONSTRUCTING THE CASE FOR REPOSITORY SAFETY FOR THE LICENCE APPLICATION

4.1. Documents in preparation to support the licence application

As in the case of the site recommendation process, the licensing process is being approached in a multitiered fashion. Two tiers are currently being developed. The lower tier provides the technical and scientific basis for the data, and the models used to interpret that data at the detailed, as well as subsystem and system levels. The higher tier is the licence application itself, which refers to the lower tier of documents, as needed, and makes the case for compliance, shows understanding of the system, evaluates uncertainty, and lays out plans for continuing or new investigations, as part of a Performance Confirmation Plan.

4.2. The safety evaluation, the heart of the licence application

Designs and scientific information are brought together in an evaluation of the way the total system performs after final closure. That evaluation is called the Total System Performance Assessment (TSPA) and it constitutes the heart of the case for safety as well as the central exhibit in the compliance demonstration. The OECD/NEA–IAEA review observed, concerning the 10 000 year compliance calculations required in regulations at that time (page 24 of [8]):

> "Finally, it is noted that the U.S. regulations are currently the subject of legal challenges. Thus it would be prudent to ensure that any TSPA is robust to possible regulatory changes, such as the 10 000-year compliance period."

The US Circuit Court of Appeals in Washington, D.C. did, in fact, invalidate just that part of the regulations applicable to Yucca Mountain [14], and the US Environmental Protection Agency (EPA) is revising its standard, to be followed by the implementing regulation being revised by the NRC. In particular, the court addressed the lack of specific compliance criteria for peak dose. The regulations considered in the court case required that the calculations be taken to the time of peak dose, or up to the period of geological stability, which is considered to be a million years by the EPA [15], citing the National Academy of Sciences [16]. The results were to be described and reported in the Environmental Impact Statement. However, the TSPA that was critiqued by the OECD/NEA–IAEA reviewers did not have a longer term component; it aimed only at showing compliance with the 10 000 year regulation, as has been noted.

The proposed revised draft EPA standard [17] currently out for comment as part of the formal rulemaking process, lets the 10 000 year portions of the former Part 197 standard [15] stand and gives a preferred approach and several options for the standard that is to be addressed for a time period beyond 10 000 years and up to a million years. Regardless of the outcome of the rulemaking process, the work that the DOE needs to do to show compliance will involve extending calculations out to times at which the previously EPA standard characterized projections as being very uncertain [15]:

> ". . . the peak dose within 10 000 years after disposal must comply with the individual protection standard. In addition, we require calculation of the peak dose within the period of geologic stability. The intent of examining the disposal system's performance after 10 000 years is to project its longer-term performance. We require DOE to include the results and bases of the additional analyses in the EIS for Yucca Mountain as an indicator of the future performance of the disposal system. The rule does not, however, require that DOE meet a specific dose limit after 10 000 years. We have concerns regarding the uncertainties associated with such projections, and whether very long-term projections can be considered meaningful; however, existing performance assessment results indicate that the peak dose may occur beyond 10 000 years . . . . Such results may, therefore, give a more complete description of repository behavior. We acknowledge, however, that these results, because of the

inherent uncertainties associated with such long-term projections, are not likely to be of the quality necessary to support regulatory decisions based upon a quantitative analysis and thus need to be considered cautiously. In any case, these very long-term projections will provide more complete information on disposal system performance."

In its proposed draft standard, the EPA acknowledges that it still believes this. However, given the decision by the US Circuit Court of Appeals, the proposed longer term standard accommodates the higher uncertainty that goes with calculating for the longer term by specifying a higher numerical limit for the assigned performance measure, and specifying that for these longer term calculations, the median, rather than the mean, is to be used. Its numerical performance goal is a number shown to be safe from a population dose perspective, based on regional differences in background radiation. That number, based on the difference between background doses near the proposed repository and Colorado, is a median dose of 3.5 milliSieverts (350 millirem) per year. This is a larger value than the 0.15 milliSievert (15 millirem) per year mean dose specified for the 10 000 year portion of the standard, when uncertainties also exist, but are generally significantly less.

This is an approach very similar to what is being considered or followed elsewhere in the world and is, in the DOE's opinion, in harmony with the new Safety Standard of the IAEA and the OECD/NEA [9]. The EPA makes clear in its discussions that it has given careful consideration to international precedents for its new approach. The DOE will submit comments and suggestions on the details, as is proper for any stakeholder or interested party under the legally defined rulemaking process. According to law, there needs to be an NRC rulemaking to revise its 10 CFR Part 63 regulation to incorporate new requirements added to the EPA standard through the EPA's rulemaking process. It is currently not clear at what point the DOE will be able to address the new 10 CFR 63 in a licence application.

4.3. The supporting science and engineering documents: the circulatory system of the case for safety in the licence application

If the TSPA is the heart, the scientific and engineering/design supporting documents are the circulatory system. Without feeds from that body of technical work the heart has nothing to bring to the discussion of safety. The best models in the world cannot yield credible output results unless they are firmly and properly based on science and engineering. For a long term (whether 10 000 years or a million years) calculation to have credibility, it has to reflect and be consistent with what is known.

Some parts of the models reflect what is known, because some models are calibrated against data and observations pertinent to the system being analysed. However, to build a degree of confidence in the modelling, comparisons are also made against (a) data that are not used in the calibration process, (b) analogue systems, if any are available, and (c) advance predictions of new tests, if appropriate. Peer technical reviews of data and models also play an important part in the process of showing that there is a basis for having confidence that the modelling that is done is fit for its intended purpose.

The purpose is to show that the planned system is expected to be safe. However, whether the demonstration of safety is sufficient or not at a given point in time may well depend on the stage or phase of the repository programme. The licensing phase being entered into by the DOE is one for which an authorization from the NRC to construct a repository is sought. Then, before the repository can receive waste and be operated, the NRC will have to make another finding that it is appropriate. Prior to allowing final repository closure, and undoubtedly at some points during the operational phase, other safety demonstrations will be required to show that all that was found to be important to safety is as it was assumed to be in the earlier safety assessments or has been properly evaluated.

Systems that are important to safety and efficiency during construction, operations and at closure will be re-evaluated through continuing scientific and engineering activities. Upgrading of the operational system in response to pertinent advances in technology may be expected, and should certainly not be precluded, during the decades of the operational phase. At final closure, the efficacy of the sealing programme will receive greater focus than in earlier stages.

This overview of the repository programme underlines the fact that such programmes are very long term, active and demanding societal commitments. The case for safety is to be periodically re-evaluated throughout the long programme length. This means that the level of confidence needed to support a decision can be time phased. For example, the question may be whether or not to go forward into a new phase (in the transitions from site selection to licensing, or in the transition from operations to closure, as two examples), to reverse a phase (retrieval of waste after the start of emplacement, for example), or to continue the current phase after new information has been obtained for which the safety case had to be re-evaluated.

Not everything needs to be known at the start of a repository programme. However, there should be a sufficient argument at the transition of one phase to the next to give participants, stakeholders and the public confidence that safety is very likely to be assured by carrying out the planned work. This point is made quite firmly in the NRC's Yucca Mountain Review Plan [18], which states in detail what will be looked for in a licence application to allow the start of repository construction at Yucca Mountain.

5. A REPOSITORY AT YUCCA MOUNTAIN: WHAT IS BEING PROPOSED?

5.1. Surface and subsurface facilities proposed for a Yucca Mountain repository

The Yucca Mountain repository is to receive waste by rail, preferably, and also by truck. Spent fuel will be stored, as necessary, on the surface prior to repackaging for disposal. At the storage facility, fuel being placed into waste packages will be thermally blended so as to achieve the desired thermal output from each waste package. Spent fuel assemblies and high level waste canisters will be placed into waste packages, and sealed by welding. The waste packages will then be moved underground and placed in emplacement drifts, end to end, with little separation. As a drift is filled, it will be isolated from the rest of the repository.

Figure 2 shows the general layout of the repository and the planned location of surface facilities (to be presented in the licence application). Figure 3 shows a schematic diagram of the proposed surface facilities and gives an indication of the process from waste acceptance to disposal. Figure 4 shows a larger version of a schematic cutaway of waste packages in a drift also shown in Fig. 3. Figure 4 also shows the emplacement of the ‘drip shield’ over the containers in this drift. The purpose of the drip shield is to guard against both rockfalls and dripping water. Rockfalls are expected in response to the cooling of the repository after the thermal period, with or without effects of earthquakes.

The waste packages (Fig. 5) are double-layered metal containers with a highly corrosion resistant alloy on their surfaces, and stainless steel on their interiors to give strength to the whole structure. Different sized packages are designed to accommodate the different types of expected waste forms.

5.2. An estimate of the long term radiological impact of the proposed Yucca Mountain repository

The Yucca Mountain repository will be able to contain its radioactive inventory for many tens of thousands of years. Thereafter, the rate of waste

FIG. 2. General layout of repository excavations. The surface facilities for handling and packaging waste would be located at the end of the current North Ramp (drift length for disposal is 65 km).

package failure, together with the natural attributes of the system, will assure that public safety is maintained even into the very distant future.

The re-evaluation of the TSPA that is to support the licence application is not yet complete. However, it is likely that its results will be roughly comparable to those published in the Final Environmental Impact Statement (FEIS) [4] that accompanied the Site Recommendation documents. The FEIS results suggested that, over a million year time span, the highest potential radiation doses from a Yucca Mountain repository would come at about a half million years after waste emplacement. The FEIS also showed that, if the recent dosimetry and approach of the International Commission on Radiological Protection (ICRP) (and as applied by the IAEA in its safety guides) are used, the peak dose to the hypothetical individual defined by regulation as the potential receptor might be of the order of 0.3–0.4 mSv/a (30–40 mrem/a).

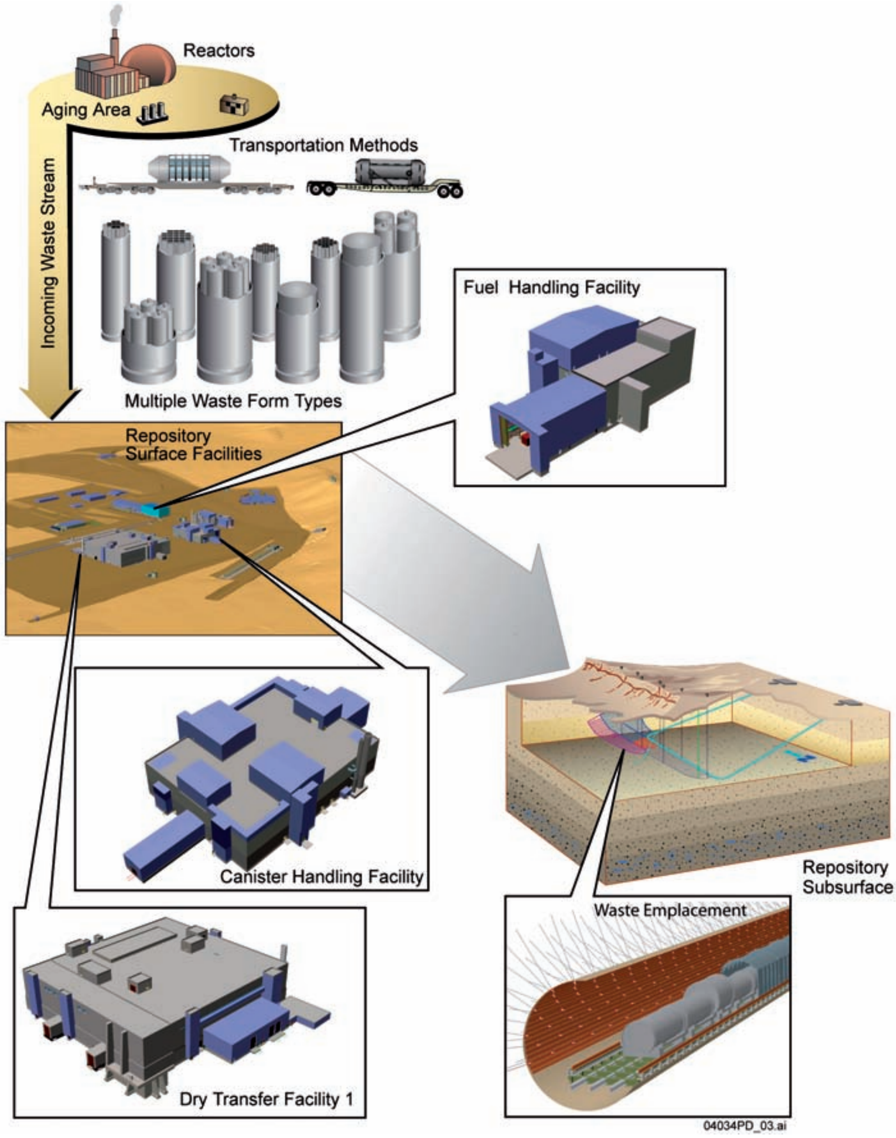

FIG. 3. Schematic diagram of proposed waste forms, waste handling, packaging and disposal facilities.

This is a small fraction of background radiation levels in the USA and in the local area from all sources, (about 3.6 mSv/a or 360 mrem/a), and poses no concern in terms of significant adverse health impacts. The doses calculated at 10 000 years, and shown in the FEIS as well as in the Yucca Mountain Site

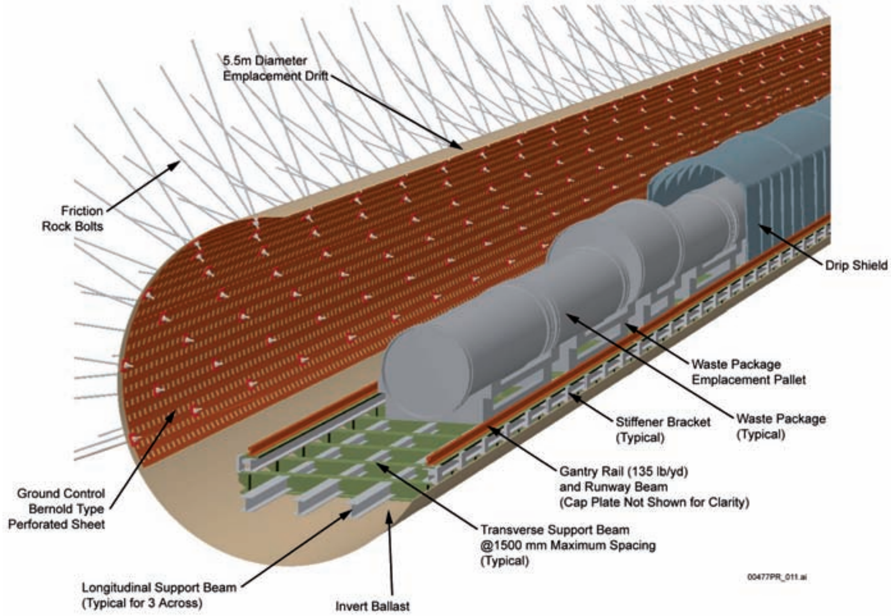

FIG. 4. Schematic diagram of the emplacement drift with drip shields over a portion of the waste packages (ground-support rock-bolts are shown radiating from drifts).

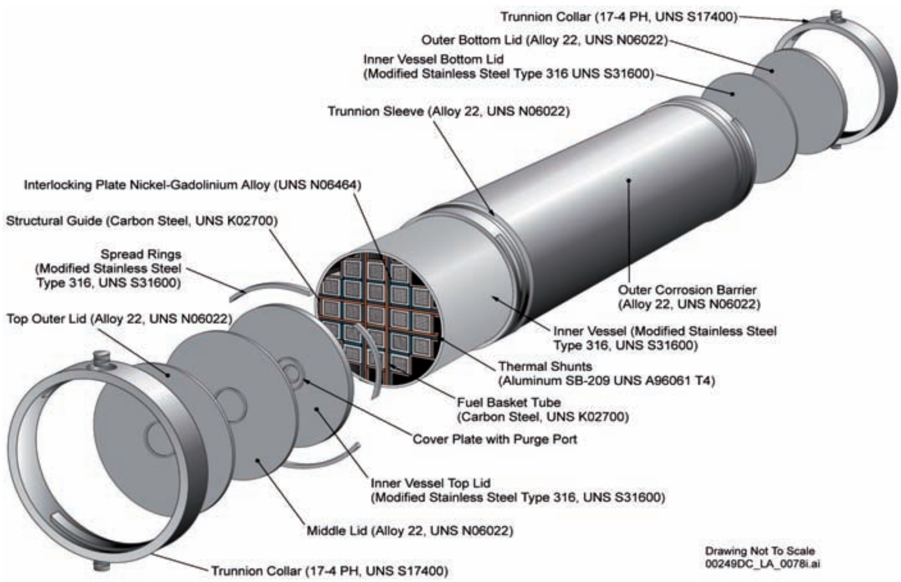

FIG. 5. Schematic diagram of the proposed spent nuclear fuel waste package.

Suitability Evaluation [2], are a very small fraction of the allowable 0.15 mSv/a (15 mrem/a) to this same hypothetical dose receptor.

6. CONCLUSIONS

With robust waste packages, stable drifts, little water, and a mild chemical environment at depth, waste packages will last for a long time within Yucca Mountain and will fail only after a very long time. At that point, the rate of waste package failure together with the physical and geochemical characteristics of the host formation will continue to assure safety into the very distant future.

Worker safety will be assured throughout the construction and operational phases by following industry safety practices and specifications as well as site-, facility-, and even process-specific operating procedures. The NRC will have on-site inspectors at the Yucca Mountain facility to assure compliance with operational safety requirements.

The main risks to the public from the proposed Yucca Mountain repository are expected to be non-radiological. Shipping the waste, according to the FEIS, presents the greatest risk of all the risks evaluated for the system. Accidents are possible, but radiological releases from such traffic accidents are very unlikely.

Suggested improvements based on reviews of earlier Yucca Mountain safety evaluations, such as those provided on the TSPA supporting the site recommendation process by the OECD/IAEA–NEA, have led to changes in the work being done to demonstrate that safety is likely to be achieved by a Yucca Mountain repository in the very long term. Direct support of the licence application safety case is provided through nearly 100 technical documents. In addition, to give a broader overview of aspects of the scientific work described in these documents, two overview reports were prepared. One integrates all that is known about the site into a Yucca Mountain Site Description [19], the other integrates what was learned from various natural analogue studies concerning processes potentially operative in Yucca Mountain into a Natural Analogue Synthesis Report [20]. For a similar reason, 14 focused integrated scientific discussion documents were produced. These are intended to be readable by scientific experts who may not be specialists in repository development [21]. Finally, as the licensing process begins, it will be important to prepare materials that explain the nature of this process, and the nature of the case being made for safety, to a very broad audience.

ACKNOWLEDGEMENTS

This paper reflects work done by the many persons who have contributed to the Yucca Mountain repository programme of the United States DOE's Office of Civilian Radioactive Waste Management. Their contributions are gratefully acknowledged.

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DOSSIER 2005
Assessing the feasibility of a repository in clay

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Abstract

The paper describes the preparation and the content of the set of reports that ANDRA, the French National Agency for the Management of Radioactive Waste, submitted to its supervisory ministries in June 2005 concerning the feasibility of a reversible radioactive waste repository in a Callovo-Oxfordian clay formation located in eastern France. The document is also known in French as Dossier 2005 Argile. The paper focuses on certain methodological aspects and illustrates them with various examples. It addresses, in particular, the management of uncertainties, geological characterization and reversibility.

1. INTRODUCTION

The French law requires ANDRA (the French National Agency for the Management of Radioactive Waste) to assess the feasibility of an underground repository for high and intermediate level long lived radioactive waste by the end of 2005. Although ANDRA has worked on both clay and granite as host media, this paper focuses on the studies on clay, which rely on the data from the Meuse Haute-Marne underground laboratory.

The preparation phase of Dossier 2005 was marked by a preliminary review of possible approaches to follow — consistent with the following guidelines:

— The need to collect advance comments from ANDRA's advisors (regulators, scientific assessors) on the approach to be adopted to prepare its report. In order to achieve that goal, a first methodological report was prepared a few years ago, known as Dossier 2001 [1]. This step provided ANDRA with significant experience feedback and is recommended for future exercises;

— The decision to expand the research programme at the international level by taking advantage of the feedback of experience from ANDRA's counterparts and to be open to cooperation;
— The adoption of state of the art techniques, sometimes derived from industrial sectors not directly associated with radioactive waste management in order to help in the collection of information;
— The intention to make Dossier 2005 a true integration exercise by structuring its different sections on engineering, data collection, modelling and safety within a consistent format.

The main components of Dossier 2005 are available in French on ANDRA's web site [2].

2. BACKGROUND

The French Law of 30 December 1991 [3] is the first, and only one so far, dealing specifically with the management of radioactive waste. It prescribes a certain number of requirements, including the following:

— A moratorium on the disposal of radioactive waste in deep geological formations;
— The description of three research areas for the management of high level radioactive waste: partitioning/transmutation, reversible or irreversible disposal in deep geological formations, and long term storage;
— The institution of the National Review Board (Commission nationale d'évaluation — CNE) as an autonomous organization responsible for the periodic assessment of the progress of research work in three the different areas;
— The creation of ANDRA as an agency independent from waste producers and responsible for disposing of low level and intermediate level short lived radioactive waste in surface facilities, and for the conduct of investigations on disposal systems in deep geological formations and for informing the public on all matters involving radioactive waste.

The same Law prescribed that a parliamentary debate should be held in 2006 in order to take stock of the results and to determine future directions.

In parallel with the procedure that led to the adoption of the Law, the French Nuclear Safety Authority (Autorité de sûreté nucléaire — ASN) published, in June 1991, a list of recommendations contained in a basic safety rule (règle fondamentale de sûreté), called RFS III.2.f, with a view to ensuring the safety of a deep geological repository [4].

A procedure was then started to find candidate sites for an underground laboratory. Among the sites for which ANDRA had submitted an application, only the Bure site, located in a clay formation in the Meuse Department at the border with the Haute-Marne Department, was approved in 1998. At the time of that decision, the Government confirmed its belief in reversible disposal and indicated its determination to identify a second site in a granite formation. For this purpose, a special project was initiated in 2000, but it did not result in a site being identified.

The Meuse Haute-Marne Site, enclosed within the Paris Basin, contains a Callovo-Oxfordian formation made up of argillites. It meets the criteria prescribed by RFS III.2.f, such as geodynamic stability, depth, suitability for excavation, and absence of significant natural resources. Studies on the feasibility of siting a repository within this formation led to a first report, Dossier 2001*,* which was submitted to the National Review Board, the Nuclear Safety Authority and to an international peer review organized by the OECD/NEA [5]. The conclusions of these different reviews and assessments were taken into account in the drafting of Dossier 2005*,* which was published in June 2005. The final version of Dossier 2005 is expected later in December 2005 and will incorporate the latest results achieved in the underground laboratory.

FIG. 1. Aerial view of the Meuse/Haute-Marne Research Laboratory.

3. PERFORMANCE APPRAISAL AND DATA INTEGRATION

ANDRA took into account the discussions of the IAEA and the OECD/Nuclear Energy Agency (NEA) on the topic of 'safety case' (see Refs [6, 7]), in the preparation of Dossier 2005. In preparing its safety case, ANDRA intends to use the experience feedback from its previous exercise, Dossier 2001. The first experience feedback came from experts working on the project, the safety engineers and scientific experts. The second experience feedback came from the conclusions of different external reviews, especially the OECD/NEA review.

Dossier 2001 highlighted a relative weakness in the method being used to formalize and to explain the transition between the collection of data, the understanding of the prevailing phenomena during the long term evolution of a repository, and their representation in performance calculations. Dossier 2001 may have led to the belief that the safety assessment relies only on impact calculations and that it does not take account of other arguments, such as, the robustness of the repository design, and the quality of the scientific arguments.

It was therefore decided to structure Dossier 2005 differently. The Dossier is now divided into three volumes: the first volume is dedicated to engineering topics, construction approaches, as well as the reversible operation and closure of the repository [8]; the second volume deals with scientific information on the initial state of the geological environment, its long term evolution and its interactions with the repository [9] and the third volume contains the safety assessment [10]. Special care was taken in the development of an overall safety approach that goes beyond performance appraisals and impact calculations.

The volume containing the safety assessment is preceded by an introduction on the structure of the approach, the quality management system adopted for Dossier 2005, the control of exchanges between scientific experts and safety or design engineers, the organization of internal reviews for making important decisions on options, and document verification procedures using external editors from the academic world and/or the international community. Procedures for conducting feasibility studies on the deep underground repository have been audited on a regular basis by an independent firm, Bureau Veritas Qualité International ever since ANDRA was granted the double ISO-9001 and ISO-140001 certification.

3.1. Safety functions as a common link

Presenting the Dossier in three volumes, with each intended for a different readership, does not imply that the safety approach addresses engineering, scientific studies and safety studies separately. On the contrary, it results from the experience feedback on Dossier 2001 and the integration of the three disciplines has led to the setting of clear priorities and ensuring the quality of the overall work. 'Safety functions' proved to be a very useful tool for facilitating that integration. The concept of safety function is the common link throughout the entire set of stages.

Three safety functions are identified for limiting radionuclide transfers through water: 'limiting water circulation', 'preventing radionuclide releases and immobilizing them within the repository' and 'delaying and mitigating radionuclide releases'. They serve as basic requirements for defining repository structures and for setting the research programme and all acquired data. They are also used as guidelines for interpreting the results of performance calculations presented as outputs in relation to the three safety functions.

Each of the three volumes of the Dossier constitutes a separate entity and is designed to respond to the concerns of a specific type of readership. During the review of Dossier 2001, it was observed that the assessors of the National Review Board responsible for checking the scientific quality of the work and for safety issues, had varying concerns and wished to address the topics relating to the evolution of the repository from different perspectives. In order to produce Dossier 2005, the organization of ANDRA itself had to be modified on the basis of the experience feedback from Dossier 2001. The focus of comment on the linkage between scientific information and safety assessment led to the creation of a Scientific Integration Unit. The existence of such a unit has proved useful in facilitating the dialogue among scientists and safety engineers. The unit was entrusted with the task of preparing specific documents. At the early stages of the preparation of Dossier 2005, it conducted the drafting of an analysis of repository studies, which contains a synthesis of scientific studies and provides a chronological and spatial overview of the evolution of repository components in support of engineering studies and repository modelling. At a later stage, the work involved developing conceptual models for the purpose of providing safety engineers with a selection of parameter models and values together with a description of related uncertainties in each case. Based on this, safety engineers are able to make their choices with a full knowledge of the facts.

3.2. Uncertainty management

Special attention was also paid to the management and control of uncertainties in safety assessments. The results are presented in the volume dedicated to safety assessment. Uncertainties and their relative impact on

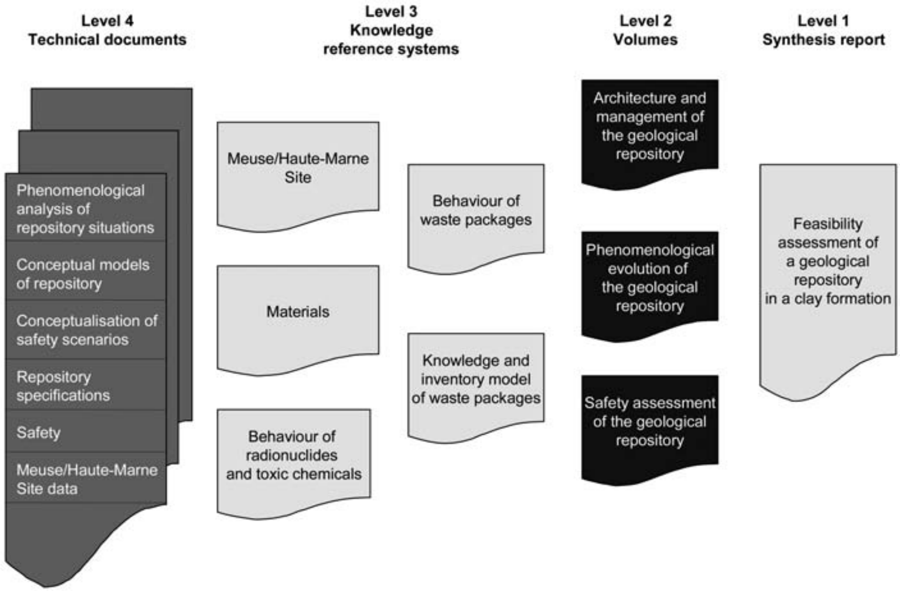

FIG. 2. Structure of Dossier 2005.

performance appraisals are addressed not only by using deterministic or probabilistic numerical tools, but also qualitatively in order to define the major types of situations to which may lead the evolution of the repository, whether normal or accidental conditions are involved. The decision to gather qualitative and quantitative arguments is related to the concept of multiple lines of evidence [6]. ANDRA has applied the concept very systematically, not only in the specific volume on safety, but also throughout its scientific documents. It is important to identify systematically the uncertainties that may affect the acquisition of knowledge and to ensure that they are properly addressed in the Dossier — either through the selection of suitable repository structures to counter them, through performance calculations carried out with conservative parameters and models or, if need be, through the representation of an alternative to the normal-evolution model, in order to reflect the deficiencies that could result from an erroneous integration of uncertainties. Managing uncertainties by means of design options is one of the major principles of Dossier 2005. In fact, performance appraisals show that, in all situations, the geological environment and its characteristics constitute the dominant factors in determining the impact of a repository. Engineered components have more of a role of managing uncertainties about the behaviour of the rock, and of complementing its performance. Hence, the isolation role of containers may appear to be of minor significance; however, those containers are expected to be useful in preventing radionuclide releases under high heat conditions, due to uncertainties on release and transport modes at temperatures exceeding 50°C. For obvious reasons, such a conclusion would depend on the rock and the repository structures under study and should not be automatically extrapolated to all situations.

A pending issue is to reconcile two different safety approaches: first, the more conventional safety approach based on the quantification of the repository impact; and second, a more qualitative method, that promotes confidence in the assessment and provides sound arguments in support of the robustness of the repository. In this field, know-how is being gained at a slow pace, but will increase as more countries produce their own safety cases or documents based on a similar approach.

In the following sections a first illustration is given of the concepts mentioned above: multiple lines of evidence, the role of safety functions, and the integration of data acquisition and safety assessment — through the various activities conducted in the geological environment.

4. GEOLOGICAL CHARACTERIZATION AND ROLE OF THE LABORATORY

4.1. Objectives of characterization work

Deep clay media, such as the 155 million year old Callovo-Oxfordian formation of the Meuse/Haute-Marne Site, have favourable intrinsic properties for the study of a deep geological repository for high level and long lived waste, such as:

— Water circulation, representing the major factor likely to alter waste packages and to dissolve and transport radionuclides, is low;
— The chemistry of the environment remains stable over time, irrespective of the disturbances due to the degradation of the materials used in repository structures, thus guaranteeing that the isolating properties of the clays are maintained;
— The mechanical behaviour of the formations limits the disturbances (microfissures, fracturing) induced by the opening of underground installations and due to increases in permeability in the immediate vicinity of the drifts.

In addition, the geological environment of the Meuse/Haute-Marne Site provides:

— Long term stability because it is only slightly active geodynamically (especially low seismicity) and due to the depth of the layer (500 m), thus protecting it from the impact of surface processes (erosion and climate changes);
— Homogeneity of the clay layer due to the very stable environment of the deposit and to a geological history that has been only very slightly disturbed by tectonic movements and by interactions between fluids and the rock.

Investigations conducted in the geological environment focus on its characterization as a suitable safety related component for the repository. They must address possible safety questions that could be raised about the behaviour of the environment and its reaction to the disturbances induced by the repository. RFS III.2.f [3] was the first guide to be used in order to set the experimental programme. Published by an external entity to ANDRA, the document provided additional legitimacy in the sense that it was not the product of the organization responsible for assessing the feasibility of the repository.

“Investigations to be conducted in the underground laboratory (RFS III.2.f) [3] (excerpts)

2.1. The objectives of the underground laboratory include:

— *to take measurements in the in-situ rock or in fluids as undisturbed as possible by the experimental conditions, in order to have a better understanding of the parameters already assessed during the reconnaissance programme conducted from the surface;*
— *as an equivalent method to more thorough experiments, to determine the behaviour of the different rocks and fluids, by taking into account natural phenomena and the changes resulting from the construction of the repository;*
— *to explore the geological environment, especially in terms of its variability in space (…);*
— *to determine relevant excavation, back-filling and sealing methods.*

2.2. Measurements in situ and on samples:

Measurements shall be made in the laboratory in order to confirm or to clarify parameter values and to assess their anisotropy, their spatial distribution and their scale effects. Among investigations to be conducted are included the following:

- *assessing the life-scale permeability of the environment;*
- *specifying, notably through measurements taken at the bottom, the hydraulic role of aquifer faults or fractures, if any*
- *determining and monitoring over time the geochemical properties of waters and gases encountered during the opening of drifts and the drilling of boreholes from the bottom, in order to locate the exact connections between the more or less permeable zones being intersected;*
- *assessing the tensor of initial stresses;*
- *assessing the drillibality of the rock in the cavities opened in the underground laboratory and its behaviour on their walls (scaling risk for hard rocks, convergence for plastic rocks);*
- *measuring deferred mechanical effects (relaxation, creep);*
- *specifying the geochemical properties that may affect radionuclide migration and especially refining the water-rock exchange coefficients as measured on cores."*

RFS III.2.f describes the geological environment as a barrier against radionuclide migration. However, ANDRA wished to clarify the expected role of the rock in relation to the safety objective, which is to protect human beings and the environment, through a series of safety functions to which the geological environment contributes in various ways. The safety function concepts are not explicitly present in the definition of the experimental programme which was established at an earlier stage, although they are implicitly included. However, they prove useful as a tool for verifying the thoroughness of the programme and as a simple means for communicating the objectives of the programme and its overall consistency. Table 1, taken from the synthesis intended for the public, illustrates such a use of the safety functions.

Beyond their role in providing information on the objectives of the safety case, safety functions also support the safety assessment of Dossier 2005, since they maintain the link between the scientific data and the performance appraisals of the repository. Uncertainties relating to the data may derive from an uncertainty on the performance of a specific function, and to the identification of possible failure modes of the repository.

TABLE 1. REPOSITORY CHARACTERISTICS ASSOCIATED WITH SAFETY FUNCTIONS

Functions		Period	Safety related characteristics involved
Prevention of water circulation		After closure	Low permeability
Limiting radionuclide releases and immobilizing them in the repository			
Type-B waste	Protecting metal caste against corrosion	After closure	Low permeability
	Protecting the coating bitumen (bituminized waste) against temperature, deformations, pH	All	Low permeability, capability to buffer disturbances
Type-C vitrified waste	Preventing water seepages on the glass during the thermal phase	Thermal phase	Low permeability
	Limiting the transport of dissolved species close to glass packages	After closure	Slow diffusion rate of dissolved elements
Spent fuel	Preventing water seepages on assemblies during the thermal phase	Thermal phase	Low permeability
	Limiting the transport of dissolved species in the vicinity	After closure	Slow diffusion rate of dissolved elements
Limiting radionuclide dissolution and ensuring reducing chemical conditions			Low permeability, capability to buffer disturbances
Filtering colloids			Small pores
Delaying and mitigating radionuclide migration			
Controlling migration by diffusion, retention, dispersion in the host formation		After closure	Slow diffusion rate of dissolved elements

4.2. Behaviour of the formation: Qualitative and quantitative arguments

The acquisition of data on the geological environment of the Meuse/ Haute-Marne sector (Callovo-Oxfordian host formation and surrounding Dogger, Oxfordian and Kimmeridgian formations) is structured around several complementary approaches, as follows:

— As many as 27 deep boreholes of several hundred metres in depth, in situ 2D (1994–1996) and 3D (early 2000) seismic campaigns, field studies to observe formation outcrops, both at the laboratory and sector scales, in order to understand the major features of the geological environment and to collect samples;
— Laboratory analyses and experiments, particularly at Mol, Belgium, and at Mont Terri, Switzerland, with a view not only to testing methods and tools, but also to validate models;
— Shaft sinking operations starting in 2000 in order to observe the formation in situ and to assess its full scale behaviour;
— Drift opening operations at a depth of 445 m, starting in 2004, and at a depth of 490 m, starting in 2005, together with associated experiments.

The properties of the formation and its homogeneity is an important topic of Dossier 2005. In fact, the performance appraisal of the safety functions relies on three specific factors: (1) the low capability of the formation of allowing water circulation; (2) the prevailing diffusive-transport regime within cells; and (3) favourable geochemical characteristics for reducing the migration of harmful elements (radionuclides and toxic chemicals).

These properties are a good illustration of the notion of 'multiple lines of evidence'. In this respect, Dossier 2005 describes the characteristics of the formation (low permeability, good homogeneity) on the basis of several arguments:

— The deposit conditions of the formation within a calm marine environment, thus contributing to its lateral homogeneity;
— Borehole measurements for which an important data acquisition programme was launched;
— Porosity distribution measurements demonstrating the small size of existing pores;
— Salinity differences between the upper and lower surrounding formations, thus proving the barrier role played by the host formation;
— The existence of hydraulic overpressure within the formation, which is typical of low permeability media;

— Consistency with the results achieved by counterparts in similar environments.

During the review of Dossier 2001, the issue of the existence of possible geological structures providing preferred hydraulic transfer pathways was raised. From seismic measurements in situ, traces of potential, but undetermined, structures were detected in the underlying Dogger formation. By reprocessing 3D-seismic data by means of state of the art techniques, it was possible to clarify the nature of the signals. Through a deviated borehole campaign, which had never been used before at the Meuse/Haute-Marne Laboratory, but similar to techniques used by the oil industry, it was verified that the zones did not contain any particular discontinuity. The seismic signals do not correspond to faults, but most likely to blocks of fossil coral similar to those already observed on some regional outcrops.

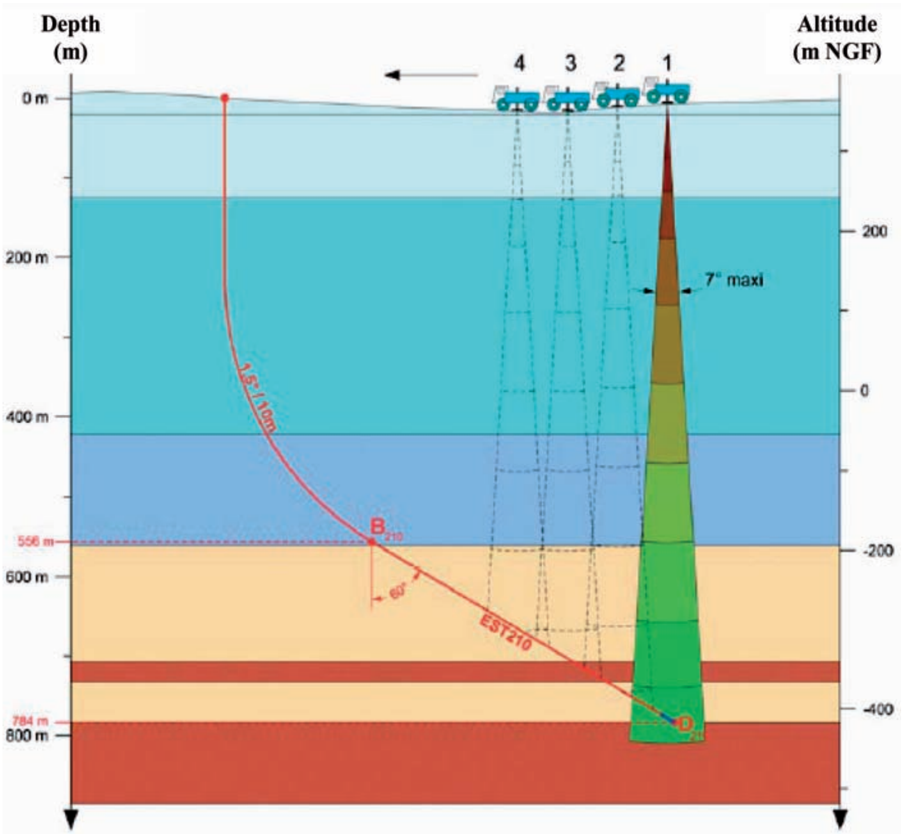

FIG. 3. A geophysical survey by deviated boreholes and geophysical measurements.

Consistency with the work of similar organizations also represents a strong point of the safety case. That consistency may be considered to be methodological, if it is demonstrated that experimental or methodological approaches are similar to another case already assessed independently. It may even go as far as the data acquisition itself, if the transposition is justified. Such is the case for the Meuse/Haute-Marne Laboratory cooperation with the Mont Terri Laboratory (see Box 1).

Within the context of a national safety case, the use of experiments and observations made in different contexts raises two possible issues:

— First, the transposability of experiments, with its potential intrinsic limitations. ANDRA has documented the analogies it may have established between the Bure argillites and Opalinus clay [11]. The transposition may be limited to methodological aspects and it does not remove the need to carry out in situ experiments at a later stage of the programme. Thus, the ongoing KEY experiment at the Meuse/Haute-Marne Laboratory dealing with the implementation of an anchoring key is a continuation of the EZ-A experiment performed at Mont Terri;
— Second, it is not only necessary that results achieved in foreign laboratories be published and distributed, but also, that all stakeholders share a common interpretation of them. Since the results are used as arguments within the safety case, it is important that all contributors (designers, regulators, technical suppliers) to the safety case share the same view about the research results.

5. ENGINEERING AND REVERSIBILITY

This section deals with integration between engineering and safety through the specific example of reversibility.

5.1. Selected reversibility approach

With regard to the feasibility of a reversible repository, the purpose of Dossier 2005 is to propose various options for robust, but simple, structures in order to serve as an assessment base and to apply solutions that do not require any major innovations. For the purpose of this paper, it was decided to focus on the concept of reversibility and how it is reflected in repository structures. Although reversibility is often presented as being nation specific, since the requirements for a reversible repository vary from country to country, it has

Box 1. Cooperation with other laboratories

In order to optimize the research programme and to take into account the fact that, during its first phase, access to the host formation would not be possible due to shaft sinking operations, ANDRA decided to rely on the support of its counterparts' laboratories to finalize its experimental programme and, to the extent that results would be transposable from one laboratory to the other, draw an initial set of experimental conclusions to be confirmed by in situ observations during the second phase.

As early as 1996, ANDRA started developing the experimental programme of the Meuse/Haute-Marne Laboratory in anticipation of the authorization it hoped to receive to implement and operate such a facility, since previous experiments conducted at the Mol Laboratory, Belgium, had shown that the development of specific equipment and of experimental protocols were very time consuming.

Hence, ANDRA joined in the project to create an international consortium designed to carry out in situ experiments in the Mont Terri Highway Tunnel, Republic and Canton of Jura, Switzerland: the schedule coincided with ANDRA's own plans, the proposed experiment programme corresponded in part to its own experimental programme and the characteristics of the Mont-Terri argillites (called "Opalinus clay") to be investigated were similar to the Callovo-Oxfordian argillites at Bure. Experiments are conducted by several partners, which allows for a distribution of activities, a better exchange of ideas, an improved synthesis of the acquired information and a much appreciated saving of time in the preparation of experiments.

- The first activities (1996–1997) involved the testing of tools or methods: collecting porewater samples from in situ boreholes drilled through Opalinus clay, measuring porewater pressure in the formation, optimizing borehole drilling methods, etc.
- Since 1998, cooperation has been expanded to eight partners from seven different countries and is focusing more on experiments designed to acquire scientific data on the processes governing the behaviour of clays, such as tests involving the diffusion of chemical elements in the rock, etc.
- Since 2002, a special programme has been established to validate, on a large scale, the models defined on the basis of the experimental data resulting from the diffusion, gas-characterization, geochemical and heat tests performed in the Meuse/Haute-Marne Underground Laboratory in order to assess the geomechanical behaviour of the rock. The programme also includes full scale engineering tests concerning drift opening and ventilation, the implementation of engineered barriers and the incision of special cuts to stop the excavation-disturbed zone and to restore the continuity of the geological environment.

been the subject of intensive discussions at the international level from which ANDRA has benefited.

ANDRA's approach to reversibility goes beyond the technological capability to remove waste packages and may be defined rather as the capability to ensure a progressive and flexible control of the repository. The objective is to be able to incorporate experience feedback and technical advances into the management of the repository and, more generally, to ensure that future generations maintain the freedom to decide how radioactive waste should continue to be managed.

ANDRA has decided not to adopt a pre-established reversibility period, but rather to use reversibility levels. In doing so, ANDRA wishes to provide the broadest flexibility possible in the management of each step, thus ensuring the possibility of maintaining a status quo before deciding to move ahead to the next step or to return to the previous one. Consequently, the disposal process is designed as a succession of steps for which no predetermined period is prescribed. The transition from one step to the next is neither final nor imposed by any specific operational scheme. On the contrary, various choices are involved at every step, including returning to the previous state, maintaining the facility as it is or moving on to a lesser level of reversibility. The design of the repository is aimed at guaranteeing that choices remain as open as possible.

All decisions concerning the management of the repository rely on an understanding of the evolution of the repository over a timescale spreading over several centuries. In situ observation and measurement devices help to monitor the evolution of the different structures and of their environment in order to ensure their durability. Observations also serve to highlight the need for intervention, if appropriate, with a view to preserving management choices, whether it involves maintaining a structure as it is for a certain amount of time, moving to the next step by sealing the structure or returning to the previous step by restoring access to the structure. In addition, observations also provide experience feedback and serve as a base for improving the design and management of the repository.

Furthermore, observations provide useful information to help understand the conditions for the potential recovery of waste packages. In broader terms, observations also help to ensure that operations remain consistent with forecasts and to improve the behaviour models of the repository on the basis of the acquired data. Observation and measurement devices (deformations, temperatures, porewater pressures, etc.) as well as data transmission networks are installed in a few reference disposal cells for Type-B, Type-C and spent fuel waste, as well as in shafts and drifts, as soon as these structures are built, in order to study their evolution before and after sealing throughout the operation of the facility. A much larger number of other cells may also be instrumented with lighter devices with a view to confirming the behaviour observed in the reference cells and to transposing those results to the overall disposal zone.

The study of the sensor devices used in other industrial sectors, notably in civil engineering, as well as the experience feedback from the Centre de l'Aube Disposal Facility, managed by ANDRA, also proved to be very useful tools in the definition of the monitoring programme.

5.2. Contribution of the international discussions

In parallel with the work conducted in France, the topic of reversibility has also been addressed at the international level.

In the framework of the work supported by the European Union, a joint effort was initiated on the topic of reversibility [12]. The initiative only addressed the concept of waste retrievability without using the term reversibility. It also introduced the idea of dividing the life of the repository into several time phases in order to facilitate the retrievability analysis. In addition, the joint initiative adopted, as its basis, the stepwise approach that several national programmes were already following. This approach is in line with the sociopolitical process involved in decision making and provides sufficient management flexibility to facilitate any decision to return to a previous stage and, if necessary, to retrieve packages. It also allowed the comparison of the various retrievability schemes proposed in the different disposal studies throughout Europe.

A European Commission study on repository monitoring throughout the various steps in the implementation of the facility was carried out and completed in 2004 [13]. The study highlights the advantages of monitoring, among other things, for validating long term safety models, improving scientific and technical knowledge, and for nurturing decision making processes. The activities are in line with IAEA-TECDOC-1208 [14] on monitoring in which the role of monitoring in the decision making process is discussed.

The OECD Nuclear Energy Agency (NEA) also produced documents on the topic of reversibility in 1999 [15] and 2002 [16]. The 2002 document introduces a clear distinction between retrievability and reversibility, and shows how the scope of reversibility is broader than that of retrievability. More particularly, it details the relationship between reversibility and the stepwise approach. In parallel to the work conducted in Europe, investigations were carried out in the United States of America on the design of a multiphase repository [17]. The 'adaptive staging' proposed by the US National Research Council is quite similar to ANDRA's approach, according to which, at each step, decision makers are able to make choices.

The projects to which ANDRA has contributed not only directly in France and in Europe, but also indirectly in the USA, provided feedback for its own review of reversibility and helped it to derive a technical solution.

5.3. Correlation with safety

The impact of reversibility on safety is not viewed as a separate issue, but rather safety is optimized for a specific reversible structure. The integration of engineering and safety approaches helps to resolve potential conflicts.

Safety should always prevail in considerations of reversibility concepts. Serious conflicts between reversibility and safety have not occurred so far in our investigations. However, specific technical solutions for safety purposes are being considered in a reversible context. For example, the possibility of installing wireless devices in order to monitor disposal cells without affecting the safety functions of the various components guaranteeing its watertightness is being investigated.

In terms of safety assessment, the main consequence of reversibility is to generate an unknown factor concerning the operational phase of the repository. In this context, reversibility is an uncertainty in the sequence of planned management steps. An open question concerns the extrapolation of physicochemical phenomena associated with a repository remaining open (oxidizing disturbance, desaturation maintained by ventilation, rock creep on supports, etc.) to longer timescales than initially forecast. Provided that the phenomena do not undergo drastic changes, experience shows that the safety assessment of a repository implemented in the Callovo-Oxfordian formation may include multisecular reversibility periods without any noticeable impact.

6. CONCLUSIONS AND PROSPECTS

For ANDRA, Dossier 2005 marks a significant advance. The evolution described in the document is the result of a deeper consideration of work at the international level and of an internal review of working methods and document production. Progress has also been made through a number of advances, particularly with regard to geological characterization and to the definition of reversible structures and of the associated monitoring programme.

Informing the public at large about the results became a sensitive issue once the French Government had decided to launch a public debate on radioactive waste management. ANDRA has prepared itself to explain the results by preparing specific summaries for non-specialists. The opening of the debate was the first opportunity for ANDRA to test its capability to present detailed results with full transparency.

Depending on the decisions to be made by French Parliament, ANDRA's future activities may involve the characterization of a larger area of the Meuse/Haute-Marne region, the continuation of current experiments and further technical implementation.

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DEMONSTRATING THE SAFETY OF GEOLOGICAL DISPOSAL FACILITIES

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Abstract

The demonstration of the safety of a geological disposal facility is a long lasting and incremental process; it starts at the early conceptual planning phase and may continue until the permanent closure of the facility. The safety case and the related regulatory review have a central role in the demonstration of safety. The safety case should be a living document that is updated and reviewed regularly as the disposal programme proceeds and research data increase. The long term safety case involves major uncertainties mainly related to the long term evolution of the disposal system. Absolute proof of the long term safety of geological disposal is not possible but the judgement should be based on the concepts of reasonable assurance and multiple lines of evidence. The robust design of the disposal system ensures that safety is not seriously jeopardized even if pessimistic scenarios are realized.

1. INTRODUCTION

Geological disposal means the emplacement of solid radioactive waste in a facility located in a stable geological formation at the depth of hundreds of metres. The aim is to provide long term containment and isolation of radionuclides in the waste from the biosphere and to provide security of waste from accidental or unauthorized interference by humans. Disposal at the depth of a stable geological formation also mitigates the effects of climatic and other above ground processes.

Geological disposal facilities are designed to provide operational and post-closure (or long term) safety. Operational safety is provided by means of engineered features and operational controls. Long term safety is provided by means of robust engineered and geological barriers, without reliance on active controls after the facility is closed.

A geological repository does not have a significant potential for catastrophic events and, accordingly, confidence in the operational safety of a geological disposal facility is fairly good. Long term safety, on the other hand, has continuously raised intense debates. This is mostly due to some unusual features of the safety case of geological repositories: one is the very long time scales to be considered and the other is the difficulty in characterizing the geological host medium.

A geological disposal facility can only be implemented through a step-wise process. Such an approach allows interaction with the stakeholders, i.e. regulators, decision makers and the public, and provides opportunities for the review of decisions on whether to move forward or to modify or reverse the process.

The demonstration of the safety of a geological disposal facility is a part of the incremental repository development process. It starts at the early conceptual planning phase, proceeds through the siting, construction and operational phases and terminates with the permanent closure and sealing of the repository. Important elements of the process are the technical design and testing of facilities and barriers, the site characterization, the safety case development and the regulatory process.

This paper discusses the demonstration of the safety of a geological disposal facility in its various phases. The discussion is limited to scientific and technical issues, i.e. societal issues, including approaches for gaining public confidence in the repository development process, are outside the scope of this paper.

2. LONG TERM SAFETY CASE

The safety case and the related regulatory review have central roles in the demonstration of safety. The safety case is a synthesis of evidence, analyses and arguments that quantify and substantiate the safety, and the level of expert confidence in the safety, of a geological disposal facility for radioactive waste [1, 2]. The backbone of a safety case is quantitative safety assessment, in which the ability of the disposal facility to comply with the safety requirements is systematically analysed. In a safety case, the scope is broadened to include the collation of more qualitative evidence and arguments that complement and support the reliability of the outcome of safety assessment. Such complementary considerations may include, e.g. scoping or bounding assessments, complementary safety indicators, evidence from natural analogues or palaeo-geosciences and expert elicitation processes.

The long term evolution of a disposal system is driven by both internal processes in the repository and by interactions between the repository and its surroundings. The evolution should be described systematically, e.g. in the form of stated variables and the physical processes affecting them, as in Ref. [3]. The processes should be modelled as far as practicable. However, the potential changes and/or their timing are not predictable enough to be described as processes; such changes are normally dealt with as scenarios, i.e. as postulated alterations of the disposal system. Scenarios are also used for testing the robustness of the disposal system (the ‘what if’ scenarios).

A long term safety case involves uncertainties, which are due to incompleteness of considered processes and scenarios, lack of model validation, or inaccuracy or stochastic variation in parameter values. Such uncertainties can be addressed in the safety case in different ways, e.g. by applying the principle of conservatism, sensitivity analyses or probabilistic assessments. As the repository development proceeds, the uncertainties will decrease but some ‘inherent’ uncertainties will remain. It is widely accepted in the scientific community that an absolute proof of the long term safety of geological disposal is not required or even possible, but that a reasonable assurance of safety is enough for proceeding with the repository development process.

An important issue to be addressed in the long term safety case for a geological disposal facility is the role of various safety functions in different time frames. For example, the following time periods can be considered:

— *Containment period*, during which the engineered barriers should provide practically complete containment of the radionuclides. For spent fuel or vitrified high level waste, the length of the containment period is one thousand to several thousands of years in order to allow substantial radioactive decay and normalization of the host rock temperature. The focus in the safety assessment in this period is on the behaviour of the engineered barrier system.
— *Solation period*, during which substantial degradation of the engineered barriers cannot be ruled out. However, the engineered and natural barriers will effectively delay and limit the release and transport of radionuclides. The focus of the safety assessment in this period is on those processes. The peak of the radiological impact on the public generally falls in this region.
— *Naturalization period*, during which the radioactivity or radiotoxicity of disposed waste will be less than that in natural uranium deposits and the host geological medium is likely to ensure adequate isolation of the waste. For spent fuel, the beginning of this period is at a few hundred thousand to one million years and for high level vitrified waste or other long lived waste it is significantly less. Because of the large uncertainties, it may not be appropriate to extend rigorous safety assessments to this period, rather, the safety can be justified on the basis of complementary considerations mentioned above.

Another issue is disruptive events, which have a low frequency of occurrence but may cause radiation doses well above the radiation dose constraint. Examples of such events are human intrusion, rock displacement intersecting the repository and volcanic eruption in the disposal area. As the timing of such incidents is randomly distributed over long timescales, the annual individual risk can be low despite the significant consequences. The 'concentrate and contain' concept implies that, while the protection of the public at large is very good, a few people in future may receive elevated doses, e.g. close to radiological intervention levels. From society's perspective this may be acceptable but it may not be from the perspective of the individuals who may be at risk. The issue is a philosophical one and, ultimately, the regulator has to determine the fundamental protection goal and to decide to what extent the averaging of risk in time (risk dilution) is permitted in the safety case.

The regulator should issue guidance on how the safety case is to be structured in order to comply with the safety goals. The guidance should include, as a minimum, the main protection goal, e.g. in the form of a dose or risk constraint, but it may also contain other criteria or principles for guiding the safety case, such as those related to the definition of reference biospheres, the treatment of unlikely disruptive events, the use of safety indicators in different timescales, criteria for judging site suitability and the treatment of uncertainties. It should be kept in mind that demonstrating compliance with the regulatory requirements cannot simply be based on the comparison of the outcomes of analyses with numerical criteria but must be based on a broader judgement based on multiple lines of evidence.

3. PHASED DEMONSTRATION OF SAFETY

3.1. Conceptual planning phase

The conceptual planning phase includes the preliminary definition of the disposal concept, i.e. the waste to be disposed of, the type of host formation and an outline of the repository and the engineered barrier system. The conceptual planning phase is generally part of a feasibility study which also incorporates a safety case. It may involve field investigations in representative host formations and in rock laboratories. In the feasibility studies, the analyses are based on rather generic modelling and data.

The feasibility study aims at the justification of the proposed disposal concept, i.e. demonstrating that the concept is likely to meet the relevant regulatory criteria. The feasibility study will normally be subject to a formal regulatory review. (In many cases, the national regulatory review process has been supported by an international peer review.)

During the past 25 years, several feasibility studies on geological disposal have been published and reviewed, e.g. the Swedish KBS-3, SKB-91 and SR-97, the Swiss Gewaehr-85, Kristallin-I and Opalinus Clay Project, the Canadian AECL/EIS Study and the Japanese H-12 Project.

3.2. Siting and design phase

In the siting phase, the focus is on the characterization of potential sites, site nomination and confirmation of the suitability of the site. Siting strategies vary: some countries have performed a systematic countrywide site screening while others have selected directly one site or a few potential sites with seemingly favourable geological or other characteristics.

Surface based investigations, including deep drillings, are first made at the selected potential site or sites. At this stage, design studies for the refinement of the engineered barrier system and the repository structure and layout are also carried out. A site can be nominated for more detailed investigations when sufficient information has been gained from the surface to justify the decision.

The site confirmation stage includes construction of access ways (shaft or ramp) at the planned disposal depth and underground characterization of the host rock. The repository design is adapted to the geological structures and other characteristics of the host rock and excavation and construction techniques are tested.

The site-specific safety case can be elaborated during the siting phase by utilizing the vast amount of data collected from the site characterization activities. It includes geological, geohydrological, geochemical and geomechanical models of the site to support the conceptual modelling of the degradation of engineered barriers, and of radionuclide release and transport. Stochastic modelling of geoprocesses is justified in this phase because of the heterogeneity of the host rock. Examples of site-specific safety cases are: TSPA (Yucca Mountain, USA), Dossier 2001 Argile (Bure, France), TILA-99 (Olkiluoto, Finland) and Safir-2 (Mol, Belgium).

The siting phase involves regulatory processes in which the key issues are judging the suitability of the candidate site or sites and the continuation of the siting process. In some countries, e.g. USA and Finland, the nuclear legislation defines specific authorization processes for the selection of the disposal site. In most countries, the Environmental Impact Assessment process is conducted during the siting phase.

3.3. Construction phase

In most countries, the nuclear legislation defines the construction licence process for disposal facilities. It involves the regulatory review and the approval of the technical plans and the safety case for the repository. It may also include the review and approval of a waste encapsulation or other conditioning facility, particularly if it is co-located with the disposal facility.

The operational safety of the disposal facility should be demonstrated with high confidence during the construction licence stage in order to avoid the need for later modifications to the designs or operational procedures. This should not be problematic because the disposal operations are relatively simple and do not involve major hazard potentials.

The long term safety case, however, involves major uncertainties at the construction licence stage. Some of these uncertainties relate to the properties of the host rock and decrease as the construction of the repository proceeds. Some others pertain to the long term evolution of the engineered barriers and the site and are more difficult to eliminate.

In the case of geological repositories, the interval between construction and operating licences may be relatively short, because some parts of the repository, e.g. the underground rock characterization facility, may have been constructed prior to the construction licence and the construction of the disposal facility may take place in a phased manner, parallel to its operation.

So far only two deep repositories, both intended for non-heat generating long lived waste, have passed the construction licence phase: the WIPP facility in the USA and the Konrad facility in Germany. Thus, the current experience of licensing of geological disposal facilities is quite limited.

3.4. Operational phase

In the operating licence application, the technical plans and operational safety case of a geological disposal facility should be updated to correspond with the actual design of the facility. This concerns also the waste encapsulation or other conditioning facility if such is included in the licence application. The operational safety functions should be demonstrated during the commissioning tests as far as practicable.

The long term safety case should be updated for the operating licence application, taking into account the new investigation and research data collected during the construction period. If that period remains short for the reasons described above, the assurance level in the safety case may not be enhanced significantly.

The operational period of a geological repository may be very long, up to more than a hundred years, depending on the nuclear energy programme. The safety related research and investigations should be continued during the operational period, e.g. by means of a performance monitoring programme. It is also possible that a small pilot or demonstration repository, e.g. one disposal tunnel, with readily retrievable waste canisters, will be established to validate the near field processes, e.g. saturation effects, corrosion processes and geomechanical impacts. The long term safety case should be regularly updated on the basis of new research data and it is expected that, as a result, the assurance level in the safety case will be increased significantly during the operational period. This concerns particularly the first deep repositories; the later ones will gain from the experiences from earlier repositories in similar rock formations.

3.5. Closure phase

Partial closure of a geological repository may take place in parallel with the operational phase. Particularly in the case of saturated host media, the disposal tunnels should be backfilled as soon as practicable in order to minimize geomechanical and geochemical disturbances. Even whole segments of the repository may be closed and sealed if the operational period is long. It is also possible that after all the emplacement operations have been completed, some shafts and main tunnels of the repository may be kept open in order to allow extended performance monitoring of the repository or investigations in its demonstration compartment.

Partial closure of the disposal facility prior to the completion of the safety demonstration can be done provided that the waste packages are retrievable. Such a closure of the repository should be subject to regulatory review and approval.

Permanent closure of the repository is another licensing step. The safety case should then be finalized and after regulatory approval, all underground spaces should be backfilled and sealed. Demonstration of the safety of the disposal facility has then been completed.

3.6. Post-closure phase

It is possible that after the permanent closure of a geological disposal facility, some monitoring at the site will be performed. Such monitoring should not be regarded as an element of safety demonstration but rather as a contribution to the social acceptability of disposal. In the case of spent fuel disposal, monitoring may also be performed for the purpose of nuclear safeguards.

Post-closure monitoring of a geological repository, if implemented, should be based on relevant, reliable methods which do not disturb the repository. Monitoring of surface waters may provide public reassurance but it is a poor indicator of the performance of the containment and isolation system. Monitoring using instruments in the repository itself are not sufficiently reliable given the time frame of concern of tens to hundreds of years. Groundwater samples in boreholes in a downstream direction from the repository is a potential method, provided that the impact on safety of forgotten open boreholes is not significant.

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REVIEW OF CONTRIBUTED PAPERS

Session IIIa: GEOLOGICAL DISPOSAL FACILITIES

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Abstract

National geological disposal programmes for high level and long lived waste are facing a double challenge: to develop technically sound and safe solutions for the long term management of the waste and to obtain a sufficiently broad societal and political base for the decisions leading to facility siting, construction, operation and closure. There is a general awareness that the challenges cannot be dealt with in an isolated manner. This rapporteur's review introduces and discusses some of the major issues and achievements in the national disposal programmes and in the international discussions, as identified from the papers in this session and other sources of information. The aim of the paper is to provide elements for further discussion in the panel discussion of Session IIIa.

1. INTRODUCTION

For more than 30 years research and development work has been conducted on the final disposal of radioactive waste. While the disposal of low and intermediate level short lived waste is an industrially mature practice, with operational facilities available in many countries, progress in the disposal programmes for high level and long lived waste has been much slower. This rapporteur's review for the session on geological disposal facilities describes some of the major achievements and remaining issues. The intention of the paper is to stimulate the panel discussion for Session IIIa of the conference.

2. GENERAL PROGRESS IN GEOLOGICAL DISPOSAL PROGRAMMES

Although important decisional steps have been taken or are in preparation in some countries (Sweden, Finland, United States of America, France, Switzerland), it remains difficult to move forward towards repository implementation.

Measured in terms of accumulating knowledge, growing technical consensus and available mature tools, there has been clear progress at the international level and in national programmes. This is illustrated for some major elements below.

2.1. Safety cases

There is a broad consensus on the central role and nature of safety cases in disposal programmes (this is evidenced through the recently published safety cases in Japan, USA, Switzerland, France or in preparation in Sweden and Finland). A safety case brings together, in a structured way, all the arguments for safety and is used to support key decisions in the disposal programme. The stepwise and flexible approaches followed in these national programmes will allow further improvements to be made, where and when needed, in the successive safety cases, based on continuing programme research, accumulated practical experience, on technology advancements, on regular peer reviews and on regular assessments by the regulator and other stakeholders.

A safety case is an important tool and driver for the systematic integration of the design work, of system understanding and of safety assessments. The safety arguments presented do not solely come from the quantitative results of safety assessment calculations, but also, and maybe more importantly, from the demonstrable quality of the system (favourable and robust characteristics of site and design) and from the demonstrable quality of system understanding and system assessment (data, models and methodologies). An essential element of the latter is the systematic and transparent treatment and management of uncertainties in the safety case and the programme: this includes design modification responses to uncertainties, the treatment of uncertainties in safety assessments, as well as the identification of research and development priorities.

An evolution from a multibarrier approach to a multifunction approach can be observed in safety case arguments. This is also reflected in the IAEA's new Safety Requirements for Geological Disposal [1]. A multifunctional approach provides the basis for a more detailed description and assessment of system and subsystem functioning, and also provides a useful communication tool.

Challenges for future safety cases:

- Transparent and traceable information integration, e.g. abstraction of detailed process models, with identification of critical processes and parameters, extrapolation in time and space of observed, measured or calculated system characteristics and evolutions;
- Uncertainty management, in order to be able to deal with the different types of uncertainties affecting the safety of the system in the different timescales and to be able to decide on the strategy to reduce uncertainties where required;
- Communication and involvement of stakeholders:
  - How to communicate on the technical aspects of a safety case?
  - How to involve stakeholders in the process of safety case development and in the interactions between regulator and applicant?
  - How to give the stakeholders the opportunity to understand and influence a safety case ?

2.2. Technical feasibility and system reliability

Although progress in the stepwise decision process is often slow, many national programmes are reaching the phase of implementation of the designed system. This creates a shift in priorities from conceptual and methodological studies and preliminary site characterization work to demonstration of technical feasibility and system and component reliability on a relevant scale, to construction and operation issues, with the associated need to develop the required quality assurance and management procedures for construction and operation, and also to site confirmation activities.

Positive decisions with respect to the technical feasibility of the studied or proposed system imply that the remaining uncertainties can be adequately dealt with in the next phases of the programme. Although such decisions will largely depend on the specificities of the national decisional process (including the regulatory aspects), international collaboration and possibly general guidance, on the assessment of the technical feasibility could be beneficial for most national programmes.

After a positive decision on disposal feasibility, the nature of the programme and the safety case will evolve towards:

- An enhanced emphasis on the demonstration of crucial aspects of construction, operation and closure;
- Observations on site and system specific conditions (e.g. long term material degradation or radionuclide migration experiments);

— Evaluation of the detailed interactions between the successive phases of repository construction, operation and closure, and their impact on post-closure safety.

2.3. Reversibility/retrievability and monitoring

In the discussion of retrievability/reversibility, the challenge is mainly on the technical and practical way to accommodate this in the design, the construction, the operation and closure of a repository. Consideration has therefore to be given to determining what is possible, from an engineering and feasibility point of view, without a significant degradation in the safety of the system.

The technical answers to the societal and political requirement of reversibility lead, in practice, to an increase in the flexibility of repository operation and closure, such that, at each step, a sufficient number of decisional options or possibilities are available. This approach is illustrated in detail in ANDRA's Dossier 2005 [2].

Although technical answers are available and can be further developed, a more global view on the potential implications of the reversibility requirement is still needed. This implies thinking about the institutional, regulatory and organizational framework, as well as the possible financial and juridical implications and responsibilities in the long term.

Monitoring activities are seen as one element among others for guiding the decisions to be taken to move forward, or not, in the process. Monitoring activities and provisions should not significantly degrade the safety of the system and the passive safety of the system should not depend on monitoring over a long time. Future generations should, however, have the freedom and possibility to continue monitoring activities for as long as they see a need. Solutions in which most of the repository is 'lightly' monitored and a small part of it more intensively monitored are being developed in some countries. And also here, the question of available technologies and engineering solutions becomes more important.

2.4. Choice of host geological medium and site of implementation

There is a general recognition that site selection is a key step in the implementation process; siting decisions are crucial and difficult, because the technical, political and societal factors of safety and acceptance are intimately intertwined.

Over the last two decades, an evolution from a siting process mainly or solely based on geological criteria towards a siting process based on a system approach and on a participatory interaction with stakeholders can be observed. In the interaction with stakeholders, the perception of the process as being fair, with the possibility of choices between options and the possibility for stakeholders to influence the outcome of decisions, seems to be of overriding importance, compared with, for example, technical arguments for a 'best' site.

In this constrained context of siting (candidate sites rather than a possible choice among a large group of potential sites), it is important to tailor the design to the specificities of the site in order to develop a safe system. There is a growing awareness of the flexibility that is offered by different possible combinations of engineered barrier systems and geological settings to obtain a safe system.

A multifunctional approach provides a valuable instrument to explore the abovementioned flexibility and to integrate site and design characteristics. The choice of a host formation determines, to a very large extent, the general functioning of the system. For disposal in granite, the stable chemical and mechanical host rock creates the required favourable conditions for a robust engineered barrier system that can ensure long term containment (see the Finnish and Swedish examples). For disposal in clay, the natural clay host medium as a transport barrier to radionuclide releases from the system is the main contributor to the containment and isolation safety functions.

3. REGULATORY ISSUES

Operational safety is not seen as a major issue, although the potential or direct influence of preclosure activities on post-closure safety requires further attention. Postclosure (or long term) safety is very specific for geological disposal, and is mainly related to the long timescales and to the passive nature of a closed disposal systems, with an important role for the geological host medium to provide long term isolation and containment.

A major challenge is how to provide for the long term protection of humans and the environment, given the growing uncertainties when assessing the system over long time periods. It is the responsibility of the regulator to issue safety standards and to provide general or specific guidance on how to demonstrate compliance with long term safety standards (see, for example, OECD/NEA work on timescales in Ref. [3] and long term protection criteria, and European Commission and IAEA work on safety indicators complementary to dose and risk, Refs [4, 5]). Linked to this is the issue of stylization of approaches and scenarios in a safety case, for example, for the biosphere, human intrusion and protection in the very far future. Also, the prominent place of qualitative arguments in a safety case, such as the quality of site and design and multiple lines of arguing, makes the compliance demonstration and its judgement a challenging exercise.

There is a general consensus that the overall performance of the system is what matters, and not necessarily the functioning of isolated subsystem or components. This gives the implementer flexibility within his responsibility to design and optimize the system. However, regular discussions and the presentation of opinions and arguments between regulator and implementer are required to avoid far-reaching divergent views. It was with this aim in mind that ANDRA submitted Dossier 2001 to the safety authorities prior to the development of Dossier 2005.

Another challenge for both implementer and regulator is how to evaluate uncertainties in the successive steps of repository development and their influence on the regulatory decisions to move to the next phase of the programme. The implementer's safety case has to address the question of uncertainties and the regulator can agree, or not, with the judgement on which uncertainties can be transferred to the next phase of the programme. As research and development work will continue even during repository construction and operation, this requires careful consideration.

Finally, the regulator can have an important role in discussions on the balance between technical safety requirements (such as a passive robust system that is not disturbed by a long open phase) and societal considerations (maintaining an open, actively controlled and monitored system for retrievability reasons).

4. KNOWLEDGE AND KNOW-HOW PRESERVATION OVER LONG PERIODS

A challenge for all national programmes is how to organize knowledge management and preservation of information and know-how over long periods of time (centuries). Two aspects can be distinguished:

(a) The efficient use of information and know-how within the programme to support programme decisions at all levels;
(b) Archiving of relevant information to enable future generations to take informed decisions.

Besides providing protection to future generations by means of a passively safe system, another important ethical consideration is the transfer of information to future generations that will be confronted with the results of our decisions. This transferred information should allow them to make informed decisions with respect to the repository (duration and extent of monitoring, land use and developments in the vicinity of the repository, and interventions). A record of the programme decisions on widely varying levels (from detailed experiments and use of the results obtained up to safety statements and strategic decisions) is certainly part of the information that could be transferred.

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PANEL

Session IIIa
GEOLOGICAL DISPOSAL FACILITIES

Chairperson: **F. Besnus** (France)

Members: **H. Ishikawa** (Japan)
H. Issler (Switzerland)
W. Boyle (United States of America)
A. Grévoz (France)
E. Ruokola (Finland)
P. De Preter (Belgium)
T. Tsuboya (Japan)
K. Mathur (India)
J. Wang (China)

F. BESNUS (France): I think it would be interesting to hear the views of the panellists about looking for a suitable site, as opposed to the best site, for a radioactive waste disposal facility.

J. WANG (China): In radioactive waste disposal, it would be nice to find the best site, but it is not usually possible to find the best site. One has to settle for a suitable site.

Different countries have different natural host rock conditions, and therefore they have to set different criteria. There are no internationally accepted criteria for repositories. For example, in Japan there are many active faults, and the criteria relating to them may be inappropriate in other countries. In Canada and Australia, on the other hand, the crust has been very stable, so you have other criteria.

In China, which is a huge country, we have the Gobi Desert, huge forests and also some fairly developed areas. So, if we set a single set of selection criteria for the whole of China, it might be very difficult for us to find a suitable site.

If we decide to look for a suitable site in the west of China, for example, in the Gobi desert area — because there are not many people there and there is not much vegetation, perhaps the criteria could be relaxed a little.

K. MATHUR (India): In India, the siting process is going ahead, and some candidate sites have been selected. Our concept is similar to the concepts of Japan, Finland and other countries. The remaining issues include that of site characterization. Out of ten possible sites we shall select one site or so, but the main issue remains whether we can characterize the host rock mass. Techniques are available for doing that but we would not like the host rock to be punctured and extensively weakened by borehole drilling. So, high resolution geophysical techniques will be used, so that we can characterize the rock mass from the surface without drilling much — we can then build an underground repository laboratory and carry out in situ experiments.

Everybody knows that the main thing in characterization is the hydrogeology of the area. We must predict how, in the long term, the micro joins and fractures will behave, how the permeability and porosity of the rock mass will be in the coming thousands of years.

T. TSUBOYA (Japan): I would like to draw attention to two issues. One is a legal issue and the other is a technical one.

Japan has a Specified Radioactive Waste Final Disposal Act which was enacted in 2000. The Act specifies stepwise site selection processes with three steps. The first step is the preliminary investigation of areas based on the literature, not through access to the candidate sites. The goal of selecting preliminary investigation areas is to exclude areas that would be unsuitable as a repository site.

The Act also specifies the geological conditions necessary for each site selection step. For example, for the selection of preliminary investigation areas, the Act requires an evaluation of the long term stability of the geological media with account taken of natural phenomena, such as significant movement due to earthquakes or fault activity, igneous activity, uplift and erosion.

On the basis of the Act, the Nuclear Safety Commission published guidelines regarding geological environment requirements for the selection of preliminary investigation areas in 2002.

As to the technical issue, what is the key characterization objective when assessing geological media performance? It is to provide information about long term geological stability for the performance assessment of multibarrier systems and for repository design. Various survey methods will be used in the investigation areas for acquiring data. The geological information will be obtained by data analysis and interpretation, conceptualization, modelling and so on. Understanding the geological environment of the candidate site will be one of the most important matters for the development of the safety case.

The site investigation process will require a lot of resources and a lot of time — two to three decades. Accordingly, the information about the site investigation should be transparent and accessible for all stakeholders through good communication.

E. RUOKOLA (Finland): In my country, the siting process for a spent fuel repository took 15 years. It started in 1985, when the site screening report was published, and it ended up with a siting decision in 2000.

It was not stated explicitly, but I think that the target was then to select a geologically superior site. Many geologists were of that opinion. What was the outcome? I would say that the chosen site is a societally acceptable site which is also geologically adequate. There was clearly a shift in the target and also in attitudes. There were several reasons for that. In the first place, the whole siting process was a learning process — we learned a lot about geology, and also about the safety concept for disposal.

Regarding the minimum requirements for a site, H. Issler gave a list of about six site suitability criteria. I do not think that we can go much further, because geological media are so different, but if granitic sites were to be selected, we could give much more specific site suitability criteria.

H. ISSLER (Switzerland): I agree with what was said. Also, from my implementer point of view, we should not have minimum requirements or quantitative criteria. If you say, for example, that there should be a distance from populated areas of ‘x’ kilometres in one country, this may cause problems in other countries. So, we should start with generally accepted geological requirements. At a later stage, a set of criteria should be prescribed — very specific to the site and to the host rock — which have to be met in the final characterization phase.

I would then like to say a few words about volunteering to host a facility. I believe that in many programmes it is a combination of volunteering to host the facility and having the facility imposed on one. The question is what weight you give to a volunteering process. Many countries are trying to have maybe two site options open for a long time, hoping that one or both of the communities in question will volunteer. In Japan and — I think — in France, a volunteering process was introduced at quite an early stage, but before you start a volunteering process you should define the selection criteria. If you have a volunteering process, you should have more than one volunteer — there should be several volunteers to start with.

Experience has shown that there is some risk associated with the volunteering process. The council of a local community makes a positive statement, and this may be overturned later by a negative vote when it comes to a referendum at the local level. That was twice the case in Sweden.

Another issue is that with the volunteering process it may be necessary to provide quite an attractive financial compensation scheme. This has to be carefully balanced with the tradition in each country.

It is important at what stage you introduce the volunteering process, but the final goal should be a suitable site which has public acceptance — and many roads lead to Rome!

P. DE PRETER (Belgium): I think there is value in a stepwise approach. As a first step, based on very general qualitative criteria, the selection of a host formation or suitable host formations can be made. After selection, the volunteering aspect can be brought into the programme.

Why is there value in this approach? Because then you can develop specific systems for the selected host formations, and these specific systems will lead to specific criteria for selecting specific sites within these host formations. In that way one avoids starting on the volunteering process too early, when volunteering could lead to the selection of a host formation for which one has to say at a certain moment that it is not suitable.

P.E. METCALF (IAEA): When we were developing the geological disposal safety requirements (Safety Standards Series No. WS-R-4), in the discussion on siting and what the requirements should be, there was much opposition to having siting criteria or siting requirements. The safety requirements document talks about characterizing the site in such a way that will enable you to carry out the safety assessment, and the real criterion is the safety of the facility. Yet I still hear a lot of people talking about siting criteria, and 'national criteria'. I had the impression that it is inappropriate to talk about such criteria.

F. BESNUS (France): I think the point raised by P.E. Metcalf is that it is very difficult for an international agency to specify generic criteria, because different countries have different geologies and different approaches, and it is probably very difficult to have quantitative and even stringent qualitative criteria that would suit most countries' specificities.

C. McCOMBIE (Switzerland): Regarding the staged development of a repository, I am interested in how much site characterization you have to do in order to make the decisions at each stage. Very specifically, can I make a definitive siting decision when I have only been on the surface? If not, I have to go underground — and how much time and effort do I have to spend underground before I can make a decison?

I know that before it depends on the host rock, but you have three sets of host rock that are almost the same, plus some crystalline rocks. So, I would be interested in a quantitative assessment of the time that you need from being on the surface to having a definitive licensing case underground.

W. BOYLE (United States of America): I do not know whether it is possible to give quantitative answers to C. McCombie's question. I think it is host rock dependent. In the United States of America there is WIPP in salt, and the implementers spent a lot of time getting to a point where they thought they had enough knowledge to move ahead and then had to convince someone else, which is — I believe — where we find ourselves at Yucca Mountain. We have moved through the site recommendation phase, where we thought that we had enough knowledge and managed to convince Congress and the President, and at the next stage we will have to convince the independent regulator, the Nuclear Regulatory Commission, in order to obtain the construction authorization. With this staged approach, before we can receive and take possession of the waste, we will yet again have to go back to the regulator and convince it again that we are ready to move to the next step. So, I do not think it is possible, a priori, to say how much time you need to spend on each step or how much work you need to do at each step. In my view, what is more important is the realization that before you move to the next step you will have to convince someone else that it is appropriate to move to that step.

A. GRÉVOZ (France): I will not give a quantitative period either because it is really difficult to say.

In our programme, where the characterization of clay is concerned we had reached a point where we had — thanks to colleagues in other countries — access to quite a lot of samples from the surface through boreholes and to models of the large scale behaviour of the host rocks. Also, we had access to a host rock that is fairly similar to ours. If we had not had access to the host formation, that might have been sufficient — provided we had made very conservative assumptions in our safety assessments to account for uncertainties. But I think that from a psychological point of view it was good to have seen the host formation on a large scale and to have been able to say that we were inside it before releasing the feasibility report, because that is something that people will expect. So, I do not think it would have been very reasonable to claim feasibility if we had not drilled into the host formation.

As for the time that it will take to reach something that looks like a preliminary safety report, we think that, if there are only technical delays, it could be five to ten years from now, but that is a very preliminary estimate and there are a lot of assumptions behind it — we might get some surprises while performing experiments in the laboratory that would lead us to change the estimate.

A. ZURKINDEN (Switzerland): Regarding the Yucca Mountain repository project, I heard somewhere that there are already more than a million pages of documentation on it. If that is so, how does one maintain an overview of the documentation?

W. BOYLE (United States of America): I can only guess where the estimate of a million pages comes from. I know that the post-closure analyses run into the tens of thousands of pages — but not a million. I expect A. Zurkinden is referring to an estimate that has to do with the Licensing

Support Network (LSN), which is a legal requirement so that all parties to the judicatory process will have knowledge of all documents submitted. The LSN is available for anyone to look at.

W. BREWITZ (Germany): I am rather unhappy about what has been said regarding the site selection process. We are now overemphasizing the bottom-up process and we may be conveying a misleading message to the public.

In fact it is also a top-down approach, an inductive one. We should also give people the idea that it can work the other way around — if we have a good scientific understanding of the geology we are looking at, we can then find an appropriate site. This was the way in which the Konrad repository in Germany was selected, and I can assure you that it is a very good site, not least because it has survived several governments.

F. BESNUS (France): Site characterization cannot be isolated from developing a project and having a safety approach. The safety analysis should be the guideline for site characterization.

So, this brings us to the problem of safety approaches — how to implement them for various purposes. We have the old debate of probabilistic safety assessment versus the deterministic approach. Is it such an issue? Are they that different? For what purposes do you use them?

We must, as P. De Preter said, address uncertainties, and especially the very long term ones or those which are not accessible to our knowledge, like human intrusion. Should we make calculations again and again or try to agree on some generic stylized approach that would at least lead to a consensus, on problems that are not really accessible to true science?

The safety assessment is of course a sort of guideline — it has to be backed up by a demonstration programme, and a demonstration programme is quite time consuming and costly. So, how does one develop, step by step, a demonstration programme that backs up the safety assessment? In particular, what is its use and when do you use underground repository laboratories?

W. BOYLE (United States of America): I would like to follow up on the discussion of this morning about deterministic versus probabilistic. I think that, in the end, deterministic approaches and probabilistic approaches are not mutually exclusive — they are just different manifestations of the same thing.

For example, if you do a Monte Carlo simulation probabilistically, every realization you generate is completely deterministic. In order to do the calculation, every variable has a fixed value for that calculation, and at the end, by doing enough realizations, you have a probabilistic calculation. But what do people do next? They go deterministic again! They say "What is the mean value? What is the median value? What is the 95th percentile?" From that point of view the probabilistic approach is deterministic in large part.

Also, when you take the determinist route — for example, at Yucca Mountain — since more rainfall is bad for performance you tend to choose deliberately high values, which then are criticized for being unrealistic. So, then the deterministic proponents start asking for sensitivity studies to provide insight — and, in a sense, by doing a lot of sensitivity studies with the deterministic approach, you are again developing a probabilistic understanding.

So, to my mind they are not mutually exclusive — they are related to each other, and I think the way in which the Nuclear Regulatory Commission has written the regulation is appropriate. P. Zuidema showed a slide today that acknowledges the same thing — that the bulk of the calculation should be probabilistic, but for those cases where it makes sense, if you need to put in a bounding assumption or a conservatism, it should be allowable, particularly if you know why you are doing it and can explain why you are doing it.

A. GRÉVOZ (France): We have just had a statement from the most probabilistic country in the world, so I think I should add something from the most deterministic country in the world.

In my opinion, when one discusses probabilistic versus deterministic there are two different aspects. The first is regulatory compliance and what type of criteria should be imposed. This is really a matter of national sensitivities; regulations are expressed sometimes in deterministic terms and sometimes in probabilistic ones. I think this is something that cannot be harmonized, because it relates to two cultural habits. But as far as the technique of safety analysis is concerned, we all acknowledge nowadays that, even if we call it ‘deterministic’ or ‘probabilistic’, it is always a mixture of the two. You cannot do a purely deterministic risk analysis. When you analyse the risk qualitatively, you always have to think about what is probable and what is improbable, what may happen to safety functions in terms of a probabilistic approach. As far as numerical tools are concerned, for quite a long time we at ANDRA refused to use probabilistic calculation tools so as not to induce any misunderstanding with our safety authority. But this year we tried a probabilistic calculation that does not aim at any regulatory compliance; we wanted to gain access, through this probabilistic calculation, to information that we could not obtain with deterministic calculation tools.

So, in terms of tools and approaches, it is always a mixture of the two, and I think it is rather different from regulatory compliance.

F. BESNUS (France): Perhaps we could now hear views about the question of demonstration tools and experiments — a challenge for tomorrow, especially as regards the long term extrapolation of human-made barrier performances.

H. ISHIKAWA (Japan): Regarding demonstration, we have started the excavation of the two underground repository laboratories. We think it is important to predict long term behaviour, not only for the natural barriers but also for the engineered barrier system. For example, the simulated degradation of buffer materials under high pH conditions is being carried out on a laboratory scale, but it is necessary to carry out the full scale simulations.

Also, we think it is important not only to conduct experiments in underground repository laboratories but also to combine them with laboratory-scale experiments. We can identify more detailed behaviour with a combination of laboratory-scale and underground repository laboratory work.

P. DE PRETER (Belgium): In my view, one should always ask what is the added value in testing in an underground facility compared with testing at the surface. Of course, if you test underground there is the advantage of the site-specific conditions being stable over long time periods. There is the possibility of conducting better long term tests, also interaction tests, degradation tests and so on. But there are also disadvantages. One disadvantage is cost and also sometimes the difficulty if interpreting the information. I think these are considerations to be borne in mind when one is deciding on the type of demonstration experiment. Should it be done underground or at the surface?

J. WANG (China): Regarding uncertainty, I think it is a very important issue related to safety cases. I think uncertainties can be classified in three categories. First is the uncertainty relating to the engineered barrier system. This can be modelled or predicted in a relatively precise manner. The second uncertainty relates to the natural system. For example, seismic effects are the most difficult to predict. But the evolution of a rock mass and also a geological medium is relatively easy to predict. The third uncertainty relates to the evolution of human society. This is a very difficult thing to predict. For example, a few thousand years ago there were no people in North America, and just think about the changes which have taken place in Japan and elsewhere in this part of the world since the Second World War.

So, when we talk about uncertainty, we should think in terms of the different kinds of uncertainty.

T. TSUBOYA (Japan): It is important to demonstrate how to encapsulate waste in an overpack. In Japan a proposed overpack material is carbon steel, and for ensuring long term safety appropriate welding technology is very important. Other issues are how to emplace overpack and buffer materials underground.

We are studying how to demonstrate the feasibility of industrial-scale barrier technologies to ensure the long term safety of repository systems.

The choice of appropriate technical options for barriers is very important and we must be ready with answers when facing questions from stakeholders.

K. RAJ (India): Regarding the selection of the overpack. What is the basis for the selection either of the material or of the thickness? What is the expected performance — for how many years will it contain the waste?

T. TSUBOYA (Japan): We have not yet selected the overpack material. However, it is clear that the choice of overpack material is very important. We wish to provide containment so as to take advantage of the significant decrease in the activity concentration of the waste during the first thousand years. One of our guidelines for developing such a long term isolation capability through the use of overpacks is a containment time of about a thousand years, and our research is directed towards this objective.

K. RAJ (India): How was the figure of one thousand years arrived at?

H. ISHIKAWA (Japan): One thousand years is the minimum requirement in Japan, because we have not yet decided on the candidate site — and therefore have not decided on the candidate water chemistry. At first, we considered a very broad spectrum of water chemistries. If the water conditions are good at the selected site, we can aim for a longer period, for example, 10 000 or 100 000 years. But in Japan we have many kinds of water chemistry — fresh, saline and high sulphate content, so it is difficult to select one best material.

P. DE PRETER (Belgium): This is very much linked to the system and the host formation. I think this is the main difference in terms of containment function between systems based on sedimentary types of low permeability — formations like clay and argillite — and systems based on granite. In the case of systems in clay — sedimentary low permeability formations — the host material prevents migration of activity during the thermal phase of the system and during the transient phases of the system. In the case of systems in granite, much more emphasis is placed on containment, and the containment requirements are much longer than a thousand years.

V. NYS (Belgium): I agree that determining the lifetime of the barriers is an issue. In some cases it cannot be based on experience alone — it must also be based on numerical estimates, especially for geochemistry. So it is not only a question of experience, but also of determining the lifetime of a buffer component through numerical calculations.

F. BESNUS (France): Essentially you are asking whether one can base performance on numerical estimates? My answer would be probably not.

A. GRÉVOZ (France): I agree that, when you can carry out experiments, that it is best, but sometimes you cannot because the kinetics of the processes are very long. If you think of the degradation of engineered bentonite barriers by iron or by alkaline plumes, some modelling is necessary because you cannot exclude some reactions that would be so slow that you cannot see them by experiments. But these models are not without any kind of validation, because you can find natural analogues of such very slow reactions that will help you to validate your model.

M. JENSEN (Sweden): I am interested in the philosophy of regulation regarding the issue of long timescales. ICRP Publication 46 states that waste management is not a free-standing operation in need of its own justification — the justification comes with the process that generates the waste. So, in this respect I would advise against regulation for very long timescales, because there are many inevitable things which will happen in a million years and which cannot really be regulated. And regulation is not the right way. If you really do not like to have uranium in your rock, you should not start with nuclear power production at all, or you should do something else with the uranium. So, the regulator should see this limitation and not try to regulate over cosmological timescales.

F. BESNUS (France): Can one solve the problem by regulating on time frames?

M. JENSEN (Sweden): I think it is a good principle to try to describe what will happen in the long term, but I do not think it is realistic for the regulator to reject a repository because he foresees problems arising after 500 000 years.

E. VOMVORIS (Switzerland): Regarding requirements or criteria, it has been said that different countries might have different criteria. In my view, it is important that, when the requirements or criteria are decided upon, the rationale or thinking behind them is clearly documented. I think requirements management is something one could propose as one way of having transparency and of recording the history of the programme.

J. WANG (China): Nowadays there is a lot of talk about retrievability. Ten years ago nobody was talking about it. Theoretically anything at any depth can be retrieved, if you have enough money. Oil companies recover oil from depths of the order of 8 km and mineral deposits at depths of about 1200 m can be mined. Retrievability has to be connected with economics; if you 'over-insist' that the waste should be retrievable, you will place a big burden on the waste management organization.

F. BESNUS (France): Are you in favour of retrievability or not in favour?

J. WANG (China): It is hard to say. If you do not consider retrievability when you design your system, it will be easier from the engineering point of view.

NEAR SURFACE DISPOSAL FACILITIES

(Session IIIb)

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DESIGN AND DEVELOPMENT OF NEAR SURFACE DISPOSAL FACILITIES FOR RADIOACTIVE WASTE

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Abstract

The paper describes the development of near surface disposal facilities, including facilities intended for different categories of low activity waste (short lived, long lived, very low activity). Emphasis is given to the design aspects, especially the first steps of the design process, where choices have to be made between a number of options and criteria. It contains examples of technical options and design criteria for different solutions.

1. INTRODUCTION

Near surface disposal facilities are the most commonly used solution for the final disposal of different categories of low activity radioactive waste.

The aim of this paper is to give a broad view of the issues related to various types of near surface disposal facilities. It provides a general overview of the available technical options, the potential reasons and limitations for the adoption of a given option, taking into account technical aspects and other aspects, such as public acceptance or cost. This is reviewed for three cases: the disposal of low and intermediate level waste; very low activity waste disposal; and the disposal of large volumes of very low activity long lived residual materials.

2. TECHNICAL OPTIONS

There are a number of different designs that can be classified into two general types [1]: (1) surface or shallow disposal facilities, including vaults, trenches, etc. with simpler or more sophisticated engineered isolation systems; and (2) subsurface caverns some tens of metres under the surface.

The first group may require more stringent post-closure surveillance and institutional control to prevent inadvertent intrusion. The assumptions made in different countries related to inadvertent intrusion may vary and the resulting limitation of the radioactive material concentration or content may be different.

Figures 1 and 2 show different concrete vault solutions built on the surface or at shallow depth (Centre de l'Aube, France; Rokasho Mura, Japan). Figure 3 shows a facility for where the isolation barriers are based on clay and/or plastic films such as high density polyethylene (HDPE), intended for lower activity waste (Envirocare Utah, USA). Figure 4 shows a solution in underground caverns (SFR, Sweden).

3. DESIGN BASIS: PRINCIPLES, REGULATORY REQUIREMENTS, SAFETY GOALS

The general principles for the development of this type of disposal facility are those applied to radioactive waste management in general. The following principles taken from the International IAEA's Safety Fundamentals on the Principles of Radioactive Waste Management [2] are relevant: Principle 1 (protection of human health), Principle 2 (protection of the environment),

Fig. 1. L'Aube (France).

Fig. 2. Rekasho Muro (Japan).

Fig. 3. Disposal cell at Envirocare (Utah, USA).

Fig. 4. SFR (Sweden).

Principle 4 (protection of future generations), Principle 5 (burden on future generations) and Principle 9 (safety of facilities).

Regulatory requirements often include obligations on administrative and procedural aspects, but technical requirements may vary from country to country. For instance, in some cases there are activity limits for surface disposal, not always related to the safety case of the facility. More often they are very general and are based on radiological protection requirements.

In the case of near surface facilities, the major safety objective may be stated as the protection now and in the future of humankind and the environment. A radiation dose constraint to provide protection to individual members of the public is the usual criterion used in respect of this safety objective. For surface facilities, the need to assume inadvertent intrusion in assessing safety after a certain period after closure of the repository may also be considered as a basic safety requirement.

To fulfil these basic objectives, the main design basis is the isolation of waste, mainly from surface and underground water, and minimization of the risk of human intrusion. The need for an appropriate assessment of the facility performance may also be considered as part of the design basis.

4. INTERRELATION WITH PERFORMANCE ASSESSMENT

It is important, from the very beginning of the development, to ensure a good coordination between the design and the performance assessment teams in order to be sure that the hypotheses adopted in the performance assessment are coherent with the specifications and drawings. Theoretically, feedback from the performance assessment exercises might show an overdesign and allow for a simpler (cheaper) solution. However, the intrinsic uncertainties associated with future predictions, even if technically and scientifically well supported [3], indicate the desirability of erring on the side of safety in the design.

5. INPUT DATA: SITE AND WASTE CHARACTERISTICS

Together with waste activity and other waste packages characteristics, the site characteristics are very important as input data for the selection of a technical option. In general, two situations can be foreseen: an existing or preferred site or a site selection process. In the first case, the characteristics of the site may condition the option and the main design criteria. The design option should provide enough isolation from water transport and allow an appropriate assessment of the facility performance taking into account the site hydrology. The design option should allow for good stability of the disposal system in the periods considered and taking account of the natural risks foreseeable at the site. Other factors, such as the existence of clay or other isolating materials may also have great influence in deciding on an option and establishing design criteria. When the development includes a site selection programme, the early definition of a conceptual or basic design may help in the screening process.

Near surface disposal facilities are intended for low activity, low level or low and intermediate level waste, but there is not a common definition of this waste category nor a generally accepted activity limit for surface disposal. Even in the same country different objectives and activity limits can be observed for some residual materials containing long lived radionuclides but existing in large quantities. Perhaps these differences can be justified through optimization considerations. Sometimes, the maximum authorized activity is regulated, based on generic impact studies [4], or it is set in the specific facility permits [5]. Generally the specified maximum alpha content is around 4000 Bq/g. Beta-gamma emitters activity may have a total activity limit or a radionuclide specific limit. In some cases, waste containing only long lived radionuclides is not allowed, even if it would be acceptable if mixed with waste containing short lived radionuclides. For waste with higher contents of alpha-emitting or other long lived radionuclides, other solutions at depths of tens of metres have been proposed.

6. DESIGN CRITERIA: TECHNICAL AND PUBLIC CONFIDENCE CONSIDERATIONS

For surface disposal facilities of the vault type, design criteria to respect the safety goals mentioned above vary from country to country and for different facilities. Isolation of waste from water and humans is accomplished through the adoption of a multibarrier system. A conventional division into three barriers (site, engineered barriers and waste packages) is usually adopted and, at least theoretically, a balance between the properties of the different components can be considered in order to achieve the required safety level. Overlapping of the different barriers functions is intended to provide for a good confinement even in the case of failure of one component. The main functions of the engineered barriers may be defined as minimization of water flow, collection of infiltered water to facilitate monitoring, and minimization of the intrusion risk. Isolation from water may be achieved by means of different designs, taking into account the placement of the vaults. Some designs specify placement above a certain maximum flooding level; in others, the vaults are constructed below the maximum level of the water table. The detailed aspects of the design are also important (materials specifications, slopes, joints, etc.). Diversion of rainfall and area seepage has to be thoroughly addressed. Some designs include collection ponds to monitor the rainfall collected or special provisions, such as percolated water collection and monitoring systems and inspections galleries beneath or around the vaults. The structural design and selection of materials should take into account the need for maintenance of structural integrity, the provision of support to other components of the disposal system, and resistance to natural events such as earthquakes.

The definition of very low activity waste may also vary significantly. In some cases, under this term, materials candidate for clearance and free release are included. For the purpose of this paper, consideration is restricted to materials not subject to clearance and release from the nuclear regulated field but whose activity limits are of internationally accepted exemption values. This category is of particular interest in waste management in relation to the decommissioning of nuclear installations, from which large volumes of materials with very low activity concentrations can be expected. Very low level radioactive waste disposal can be of special interest where the clearance of waste from nuclear installations is not permitted. It is also compatible with an active clearance policy, in order to have an alternative solution for waste whose potential risk is small and where sophisticated and expensive disposal solutions might not be justified. In this case, materials with activities lower than established clearance values may also be managed as very low activity waste because the uncertainties and difficulties involved in measurement may justify their direct disposal. Very low activity disposal facilities may require less stringent design requirements to fulfil the same safety goals. As an example, the French Morvilliers facility design criteria are based on the requirements for hazardous waste contained in the European Directive on waste disposal [6]. In Spain, this directive has also been followed, and the use of clay and high density polyethylene have been proposed as barrier materials for the very low activity disposal cells.

Long lived residual materials with low activities but large volumes have specific needs. Often in situ management is the best solution, as in the case of uranium mill tailings. For the Spanish Andújar uranium mill decommissioning project, the US UMTRAP requirements were taken as a reference [7]. A service life objective of 1000 years was adopted. The main safety functions in this case included the limitation of water percolation and a limit on radon emission of 750 mBq/m^2, and an overall exposure limit of 0.1 mSv/a. Resistance to the design earthquake and to erosion after a potential breakdown of dams in the river up-stream are important design criteria. Figure 5 shows a section of the engineered cap design.

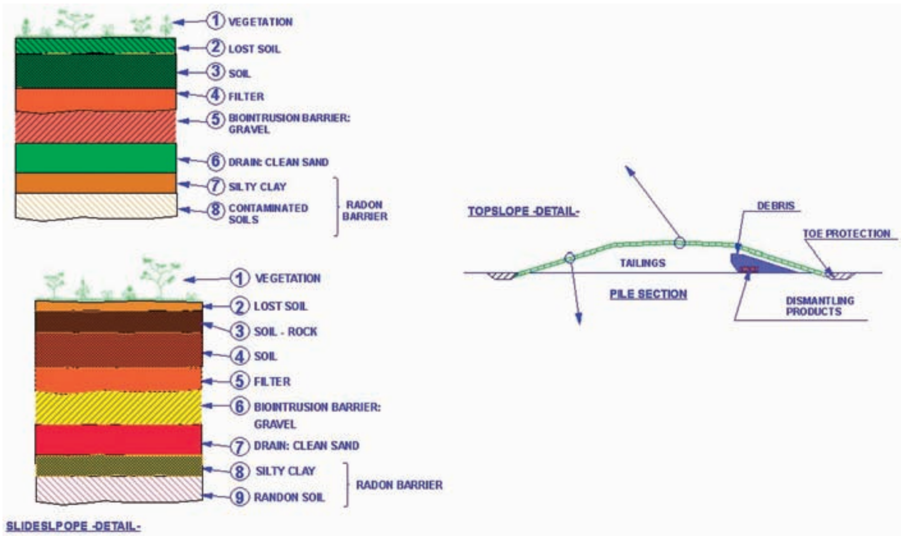

FIG. 5. Final design of cap (FUA).

7. DESIGN PROCESS

The design process usually includes conceptual design, basic design and detailed design steps, which relate to different levels of safety assessment [1]. As in any other multidisciplinary project, the organization and management aspects are important. Quality assurance in the design, construction, waste acceptance and operation of the facility is of paramount importance both in giving confidence to the authorities and the public. The necessity of auxiliary installations and buildings has to be considered from an early stage. These may include buildings for monitoring services and for administration and security, workshops, and waste treatment and conditioning, facilities, and they may be more costly than the disposal facility itself. Cost effectiveness, although difficult to measure, should also be included as a general principle. However, the cost of the engineered barriers is only a small fraction of the total investment cost of the facility or the total waste management cost, especially for facilities of a limited size or waste reception rate. Common costs, such as those for technical studies or general infrastructures, as well as the need for ancillary facilities, such as laboratories, workshops, etc., represent larger costs, and the operation and surveillance costs may represent a large proportion of the management cost. The cost of the El Cabril facility in Spain was €100 million in 1992. That figure can roughly be split into 20% for the excavation and construction of the

100 000 m^3 internal volume vaults, 25% for design and technical support studies, 25% for general infrastructure and services buildings, and 30% for treatment facilities, laboratories and storage buildings.

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DEMONSTRATING THE SAFETY OF NEAR SURFACE DISPOSAL FACILITIES

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Abstract

The characteristics of the radioactive waste intended for near surface disposal are such that an emplacement near the biosphere can be permitted. This waste can be described as low level and short lived radioactive waste. Nevertheless, as the presence of small amounts of long lived emitters is unavoidable, the safety of near surface disposal requires assessment over the long term. Due to the proximity of near surface disposal facilities to the biosphere, there is a significant risk, in the long term, of human intrusion into the repository and this has to be taken into account in safety assessments. The life of a radioactive waste disposal facility consists of three phases: the operational phase, the institutional control phase and the long term safety phase. The paper reviews how the safety of near surface repositories is assessed in all three phases.

1. GENERAL CONSIDERATIONS

The safety of near surface disposal has been the subject of many publications of the IAEA [1–5]. IAEA safety requirements define the regulatory framework for radioactive waste disposal; and the national legislation in Belgium is generally consistent with that framework. Compliance with the safety principles and criteria defined in this regulatory framework should provide for the protection of humans and the environment during all the phases of a radioactive waste disposal facility. Demonstrating the safety of a near surface disposal facility concerns both the implementer and the regulator. The implementing organization should develop arguments in its safety case to prove that its concept meets the requirements and the safety objectives as described in the regulatory framework. Since the Association Vincotte Nuclear (AVN) acts as the technical support organization for the Belgian Safety Authority (AFCN/FANC), the reflections contained in this paper will focus on those elements that are important for safety demonstration in Belgium.

According to the IAEA Safety Glossary [6], safety is the achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in the protection of workers, the public and the environment from undue radiation hazards.

2. NEAR SURFACE DISPOSAL FACILITIES

Near surface disposal is an option used for disposing of radioactive waste containing short lived radionuclides, which will decay to radiologically insignificant levels within a time period ranging from a few decades to a few centuries, and acceptably low concentrations of long lived radionuclides [1]. Near surface repositories fall into two main categories: facilities consisting of disposal units located either above or below the original ground surface, and rock cavity facilities. In the first case, the cover on top of the waste is usually several metres thick while, in the second case, the layer of rock above the waste can be up to some tens of metres thick.

Generally, three phases can be distinguished in the life of a radioactive disposal facility: the operational phase, the institutional phase and the long term safety phase. Each phase corresponds to some specific regulatory requirements and guidance. Depending on the national licensing authorization process, the decision to move from one phase to the next one is generally supported by a safety case. However, irrespective of the phase under consideration in the authorization process, the safety of all subsequent phases should be addressed in the safety case under consideration. The level of information provided and the balance between quantitative and qualitative arguments will vary as a function of the time between the current phase and the phase under consideration.

For near surface disposal facilities, the implementation of the safety assessment, which is a part of a safety case, is guided by the work done within the IAEA's Improvement of Safety Assessment Methodology (ISAM) and Application of Safety Assessment Methodology (ASAM) projects [5].

3. CONCENTRATION AND CONFINEMENT STRATEGY

The 'concentrate and confine' strategy is basic to all radioactive waste disposal facilities. For near surface facilities, concentration is achieved through waste volume reduction and by assembling waste packages in a limited number of emplacements within the disposal facility. Confinement is realized through two complementary strategies:

— The waste is immobilized, by treatment and packaging, in order to obtain zero, or as low as possible, release of radionuclides to the biosphere;
— The waste is isolated from the human environment and the biosphere, to prevent direct access to the waste.

Radiation protection principles [7] constitute the 'backbone' of the regulatory control mechanism for radioactive waste disposal facilities and it is necessary to show that, under all circumstances, the specified radiological criteria will not be exceeded. However, demonstrating that disposal facilities comply with the radiation protection criteria becomes increasingly difficult in the long term, as uncertainties in the predictions of the performance of the repository increase. For this reason, far into the future, radiation dose can be seen as being more of an 'indicator' of safety rather than a 'measure'. Thus, radiological protection criteria are a necessary, but not sufficient, basis for use in demonstrating the long term safety of a disposal facility.

4. DEFENCE IN DEPTH AND MULTIPLE SAFETY FUNCTIONS

As for other nuclear facilities, the safety of a near surface disposal facility requires the application of the 'defence in depth' concept [8]. Applied to radioactive waste disposal, the concept of defence in depth requires the implementation of 'multiple safety functions'. In this case, it is not the number and redundancy of the barriers that is of greatest importance for safety but, rather, it is being able to depend on different mechanisms and/or components to provide safety functions. The safety functions identified are isolation, containment, and limitation and retardation.

— *Isolation.* One of the functions of the disposal system is the long term isolation of waste from humans and the biosphere, in other words, the prevention of direct access to the waste. Engineered barriers and covers on top of the waste for near surface disposal or the thickness of the rock above the wastes for rock cavern disposal contribute to this function.
— *Containment.* Containment implies the prevention, as far as possible, of any release of radionuclides from the repository or any part of the disposal system. Containment cannot, however, be guaranteed over the whole period for which the contents of the repository are considered to present a radiological risk. 'Avoiding ingress of water into the waste disposal facility' can be considered as a subsafety function of containment.

— *Limitation and retardation.* In the event of the partial or total failure of the containment, it is desirable that the flux of radionuclides through the disposal system to its boundaries is retarded and limited. This can be achieved either by taking advantage of radioactive decay during the migration of the radionuclides in the system, or by spreading the radionuclide flux over time. The extent of the retardation of radionuclides depends on the radionuclide and on the performance characteristics of the components through which the radionuclides migrate.

5. SAFETY ASSESSMENT OF A NEAR SURFACE DISPOSAL FACILITY

By way of illustration, it is assumed that the IAEA's Improvement of Safety Assessment Methodology (ISAM) has been adopted and that, for each phase, clear regulatory requirements exist concerning the radiation protection criteria. The last supposition implies that, for each phase, values of radiation dose limits and dose constraints are defined. In addition, it assumes that a sound near surface disposal concept is available.

5.1. Operational phase

From a safety point of view, the focus is mainly on the different operations performed at the disposal facility. Operations include the receipt of the waste package at the site, the packaging of the waste (post-conditioning), the transport and handling of the waste in the disposal module (trench, vaults, etc.). For the safety assessment of this phase, information on the environment of the site, on the waste characteristics and on operational practices and conditions are needed.

As for other types of nuclear facility, the disposal area should be partitioned into different zones for managing the radiation protection. The categorization of the zones depends on the potential radiological hazards in each zone. During this phase, the arrangements for safety at radioactive waste disposal facilities are similar to those at any other nuclear facility. Thus, the demonstration of safety follows the same approach. From a safety point of view, a distinction is made between workers and the public. Dose assessments are made both for normal operational conditions and for anticipated incidental or accidental cases.

5.2. Institutional control phase

This phase starts when no more radioactive waste packages are accepted for disposal on the site and the repository is closed. The reason for an institutional control period is mainly to prevent human intrusion [2]; it may also serve to reassure the local public. The prevention of human intrusion is important for near surface disposal because the radioactive waste is separated by only a few metres from the biosphere.

The institutional control period is usually set such that, at its end, the radiological hazard associated with the facility will have declined to a low level and human intrusion into the facility would result in only a small radiation exposure.

During this phase, no release of radioactive materials is expected from the facility. Even in the case that the facility becomes degraded, the information provided by the monitoring programme should prompt intervention, possibly involving repairs to the barrier system, to prevent releases occurring.

The safety assessment of a near surface disposal facility during this period is mainly focused on the potential for radiological impact associated with unintentional human intrusion and on the active and passive measures to prevent human intrusion [9]. In this context it is noted that:

— The radiological protection criteria associated with human intrusion could vary from country to country;
— The scenarios for modelling human intrusion also vary.

The assessment relies on assumed or stylized human intrusion scenarios. Specific waste aceptance criteria (WAC) can be derived from these stylized scenarios. These WAC define an upper limit to the specific activity concentrations of radionuclides such that the radiation doses at the end of the defined institutional control period in the event of human intrusion would be acceptable.

In summary, safety in this phase relies, firstly, on the assessment of the impact of stylized human intrusion scenarios and, on the basis of this assessment, the setting of waste acceptance criteria and, secondly, on the identification of the active and passive measures to prevent human intrusion. Safety then, relies on a coupling of dose assessment (quantitative arguments) reinforced by administrative and guarding measures (qualitative arguments).

5.3. Long term safety phase

In this phase the evolution of the repository is controlled by physical and chemical processes. Institutional actions such as repairs and maintenance may no longer be considered. In this phase, because of the length of the institutional control period, the direct radiological consequences of human intrusion should not entail unacceptable doses to any intruders. During this phase, the radiological impact of the disposal will result either from natural degradation processes of the disposal confinement or from the delayed consequences of human intrusion.

The radiological safety assessment is needed in this phase because the waste packages contain small amounts of long lived radionuclides. Dose assessment during this phase involves many assumptions about the biosphere and radionuclide transport modelling and questions about the validity and relevance of the data for such periods in the far future. Because of the associated uncertainty of the radiological assessment, dose should not be the only criterion used to assess safety. Other complementary arguments should be provided in order to provide evidence of the long term safety of a near surface disposal facility.

The sensitivity of the radiological impact to the assumptions used in its evaluation can be an important element in the assessment. However, as no actual proof of the validity of the chosen set of assumptions can be given, the set of assumptions should be supported by strong qualitative arguments provided by the implementer in its safety case. Some of the arguments could result from discussions between implementers and regulators. In any case, it is preferable that the set of assumptions be reviewed and approved by the safety authority early in the process.

Complementary to the aforementioned arguments, another important element of the long term safety demonstration of a near surface disposal is the justification of the provisions for defence in depth. Defence in depth is achieved through a multifunctional approach. For each element contributing to safety, the associated safety functions should be identified and described. As a result of this investigation, a complete description for a given scenario should be available, allowing the identification, as a function of time, of which component contributes to safety and of its associated safety function. Such an investigation allows the defence in depth of the repository to be characterized.

By means of ‘what if’ scenarios, it is possible to evaluate how the disposal system will react in the event of a component failure or if the safety function associated to a component does not function properly. In the latter case, the assessment should investigate the sensitivity of the disposal system to such a perturbation. This process helps to quantify the components and safety functions that have a strong influence on the radiological impact. It also provides useful information on the components for which a high level of confidence in their properties is required. Confidence in the components is enhanced by the use of best available technology and quality assurance.

The demonstration of the long term safety of a near surface disposal facility is based on a well developed safety assessment supported by sound argumentation regarding the assumptions made, on the defence in depth concept and on the evaluation of the disposal system's robustness through 'what if' scenarios. In this phase, at increasing times after the end of the institutional control period, the demonstration of safety requires more and more of qualitative arguments.

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DEMONSTRATING THE SAFETY OF DISPOSAL FACILITIES FOR MINING AND MINERALS PROCESSING WASTE

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Abstract

Mining and minerals processing waste is characterized by large volumes and long half-lives. In this respect, it differs from the operational and institutional radioactive waste which is normally disposed of in near surface repositories. Technical and economical constraints usually limit management options to near or above surface disposal. Consequently, reliance has to be placed, to a large extent, on engineered barriers. Since these cannot be expected to last for long periods of time, it is not possible to achieve a 'walk away' solution. Long term, essentially perpetual, maintenance and care will therefore be required and safety assessments cannot be based on the assumption that active and passive institutional control will cease after a period of, for example, 300 years as is usually assumed for near surface disposal facilities. The implications of these particular boundary conditions are discussed with emphasis on regulatory aspects, radiological criteria and approaches to safety assessment.

1. INTRODUCTION

The mining and processing of minerals give rise to large amounts of waste containing elevated concentrations of naturally occurring radionuclides. This includes waste from uranium and thorium mining and milling, residues from other mining activities, from the burning of coal and the extraction of metals from raw materials. In the following, the acronym NORM is used to cover all waste containing naturally occurring radionuclides, including uranium and thorium mining waste as well as industrial residues in which naturally occurring radionuclides are present in technologically enhanced concentrations, often referred to as TENORM.

The characteristics of NORM waste differ from those arising from nuclear power station operations and from the institutional use of radionuclides in several important respects: the volumes are usually much larger, restricting management options both technologically and economically; the half-lives of naturally occurring radionuclides in NORM waste are much longer than the mainly fission product radionuclides — such that radioactive decay does not result in a reduction of the associated radiological risks within foreseeable periods of time. This means that NORM waste is not suitable for disposal in the ‘classic’ type of near surface repository. In many cases, the health risks to be addressed in the management of this waste also come from the chemically toxic or carcinogenic substances present. In many countries, huge amounts of this waste have been produced in the past and have been disposed of without consideration of its associated long term hazard. In many cases, intervention actions have been needed to improve the situation and to achieve long term protection.

These factors have a substantial influence on the technical and regulatory management of NORM waste.

2. WASTE CHARACTERISTICS

In general, NORM waste is characterized by low activity concentrations but large volumes. In most cases, radionuclides of the ^{238}U decay chain present the main radiological risks. However, in some cases (e.g. monazite sands) the radionuclides of the ^{232}Th decay chain are mainly responsible for the radiation exposures.

An overview of approximate amounts and activity concentrations of NORM waste in Germany is provided in Table 1. More details of the German situation are given in Refs [1–3]. Volumes vary between thousands of tons and many millions of tons. Activity concentrations of the waste from the mining and milling of uranium ores typically fall in the range 10–100 Bq/g per radionuclide of the ^{238}U decay chain. For some very rich ore bodies (e.g. Canadian uranium mines in Saskatchewan), the waste contains radionuclide concentrations above 1000 Bq/g, but the waste volumes are limited. The activity concentrations of TENORM, arising in large amounts from other mining and minerals processing activities, are mostly lower — in the range from less than 1 Bq/g up to a few Bq/g. Some waste types such as scales from the extraction and transport of crude oil and natural gas have substantially higher radioactivity contents, but only arise in comparatively small volumes.

3. DISPOSAL OPTIONS

The principle management options for NORM waste are recycling and disposal. Recycling is only possible for waste with a low radioactivity content and suitable physical or chemical properties, which limits this option to the last

TABLE 1. AMOUNTS AND RADIONUCLIDE CONTENT OF NORM WASTE IN GERMANY

Type of waste	Approximate quantity	Typical activity concentration per radionuclide of ^{238}U decay chain
Uranium mill tailings	200 million t	10 Bq/g
Uranium mining waste	600 million t	0.3–3 Bq/g
Sludges, tars, scales, etc. (extraction of ores and fossil fuel, oil and gas industry); slags, dust, zircon sand, sludges (iron and steel industry); residues from the processing of non-iron ores, such as copper, lead, zinc, tin, rare earths, titanium, niobium; waste from certain chemical processes in the sulphur and phosphate industry	10 000–100 000 t/a	Less than 1 Bq/g up to a few Bq/g, up to 100 Bq/g
Ashes, granulates, gypsum from flue gas desulphurization (burning of coals), slags (iron and steel industry)	35 million t/a	Mostly less than or of the order of 0.2 Bq/g

category of waste indicated in Table 1. Most of the other waste types require disposal. For economical and technical reasons, near or above surface facilities have to be used in most cases. Only for the special cases of waste with high radioactivity levels and comparatively low volumes is underground disposal a relevant management option.

The spectrum of options for the disposal of large amounts of NORM waste ranges from doing almost nothing, if this is acceptable from a radiological standpoint, to very expensive solutions. However, the low cost options are often associated with a significant environmental impact and the increased costs of the other solutions may have to be accepted as a way of reducing these impacts. Consequently, the choice of a suitable disposal option requires that a balance is struck between long term risk from the waste and the financial costs of implementing a disposal solution. This aspect is of particular importance in the case of existing waste and is further discussed in Section 4.2.

The near or above surface disposal of NORM waste generally requires engineered barriers. Of particular importance are the covers over the waste to prevent the dispersion of contaminated material and to reduce radon emanation as well as water infiltration. Depending on the nature of the waste and the environmental conditions (e.g. climatic conditions, hydrogeology, land use), covers can range from simple soil layers to sophisticated multilayer cover systems. Depending on the type of waste and the site conditions, additional measures may be applied, such as, the separation of materials with different radionuclide contents, provisions to control the generation of acid (and thereby to minimize the increase of contaminant releases into the water pathway), and measures to improve the geotechnical stability in the case of sludges such as mill tailings.

By implementing a suitable disposal system involving engineered barriers, the associated risks can be reduced to acceptable levels. However, the waste remains at the surface and still represents a potential source of risk. For example, the degradation of the engineered barriers by natural processes and human intrusion into the waste could result in an increase of risk to the local public. Therefore, controls on land use, as well as a monitoring and surveillance programme are required in most cases (see Section 4.3).

4. REGULATORY APPROACH

The radiological boundary conditions for the disposal of large amounts of NORM waste differ substantially from those for waste arising within the nuclear fuel cycle or from institutional radionuclide applications. This has consequences for the regulatory approach adopted.

4.1. Dose criteria

A fundamental radiation protection principle is that radiation doses to the individual should be limited. In principle, the approaches used in other parts of the fuel cycle can be applied, but in the case of NORM waste some important aspects have to be considered:

— In many situations, such as at most German sites, the local population density is quite high. The radiation doses to individual members of the public are significant and there is not much room for conservatism in the dose assessments. It is necessary, therefore, to conduct assessments in a reasonably conservative but, to the extent possible, realistic manner.
— It is not meaningful to limit the periods over which risks associated with the NORM waste are assessed. This represents an important difference as compared with the approach usually adopted for near surface and intermediate depth disposal facilities for radioactive waste. However, despite

the very long half-lives of the radionuclides present, because of the uncertainty of predictions at long times into the future, it would not be meaningful to extend quantitative assessments for near or above surface disposal beyond a few hundred or, at a maximum, beyond the order of a thousand years.

— The dose criteria to be used for limiting exposure to individuals may be different to the criteria applied for the near surface disposal of other types of radioactive waste. The International Commission on Radiological Protection (ICRP) recommends for the practice of disposal of radioactive waste that doses arising from normally operating practices should be compared to a dose constraint of no more than about 0.3 mSv/a [4]. In many cases of NORM waste disposal, assessed doses would not comply with this dose constraint even under the assumption that the disposal system and all its barriers remain intact. If failures of barriers caused by natural processes are taken into account, this criterion would be exceeded in most cases at least with a certain (but not necessarily small) probability.

These differences require an appropriate regulatory approach. In Germany, the overall goal of regulations is to keep the additional dose to individuals in the population from existing mining sites as well as from the disposal (and recycling) of NORM to below 1 mSv/a. This criterion applies to the sum of exposures taking account of all pathways. It is not formulated as a strict limit, and assessments are to be conducted in a reasonably conservative manner over meaningful time periods. Doses and risks from natural events and processes affecting the barriers (e.g. degradation of a cover) are not subject to this dose criterion but have to be addressed within the optimization of protection. This dose criterion is also used as an action level for defining whether intervention measures have to be considered for existing NORM waste.

For newly arising NORM waste, Germany has established criteria in terms of the specific activity of the waste. These discriminate between the different options of recycling and disposal of the wastes. Compliance with these criteria is sufficient to ensure that the dose criterion of 1 mSv/a will not be exceeded under normal circumstances. In this case, a further optimization is not required by the regulations, i.e. the criteria are considered to be already optimized at a generic regulatory level. Details are given in Ref. [3].

4.2. Optimization

The criterion for maximum individual dose is usually not sufficient for determining an adequate waste management strategy. Therefore, in addition to limiting individual doses, it is required to apply the optimization principle. If several management options are available and enable compliance with the individual dose criterion, it is further required to determine the optimal option using the ALARA principle, i.e. to reduce radiation exposures to a level as low as reasonably achievable, social and economic considerations being taken into account.

The optimization principle is particularly relevant for intervention situations, for which, according to ICRP, dose limits do not apply [5]. Although this approach is not strictly followed in many countries, including Germany, optimization can be very useful for determining the remediation option to be chosen.

Optimization is intended to identify the most cost effective balance between the two primary objectives, to limit risks and financial expenditures. Other factors such as non-radiological risks or qualitative factors such as public acceptance also represent important elements of the optimization. Decision making in these situations can be aided by the use of appropriate methodologies and tools for identifying and implementing the optimal solution [6].

4.3. Institutional control and timescales

As already discussed, in most cases the safety of NORM waste disposal facilities has to rely on effective institutional controls. These have to ensure that, after closure of the disposal facility, land use controls are complied with in order to avoid disturbances of the engineered barriers by activities such as the construction of roads or buildings. Moreover, it will be necessary for the disposal facility to be regularly surveyed so that any damage can be identified and, to the extent necessary, repairs initiated. As long as such mechanisms are in place, most natural events and processes, which could damage the engineered barriers, will not have substantial effects.

Since the hazard potential does not change over time, these long term requirements in principle apply to infinite timescales. However, the existence of institutional controls cannot be guaranteed over periods beyond a few hundred or possibly a thousand years. As a consequence, the disposal of NORM waste above or near the surface cannot be seen as a solution in itself. The long term safety of the NORM waste will depend on actions taken by future generations and, beyond monitoring and surveillance, it may be necessary for future generations to carry out substantial repairs or even to replace barriers.

This represents a distinct difference from the concepts of deep geological or intermediate depth disposal, which rely mainly on natural barriers and have no long term requirement for institutional control for safety purposes. The situation is also different from the near surface disposal concept, for which limits on the content of long lived radionuclides are applied based on the assumption that institutional controls are only present for a certain period of time, e.g. 300 years.

These long term requirements for NORM waste disposal might be seen as conflicting with the principle of not imposing undue burdens on future generations [7]. However, since no technically and economically viable alternatives exist today, this burden is inevitable and therefore cannot be regarded as 'undue'.

5. SAFETY ASSESSMENTS

Disposal facilities for NORM waste are usually large and, in many cases, located close to populated areas. Safety assessments for such facilities have to take into consideration a variety of different contaminants and risks to humans and the environment arising from various exposure pathways. They also have to consider a variety of processes and events that could affect the engineered barriers and lead to an increase in risk to the local population. Based on the aspects discussed in the previous sections, some key elements of safety assessments for the disposal of NORM waste are addressed in the following.

5.1. Uncertainties and timescales

Many of the parameters used in the safety assessment of near or above surface facilities are very variable, resulting in uncertainties in the results of the assessment. Examples are the amount of rainfall, retardation coefficients for contaminant migration in soils, residence times, and water and foodstuff consumption rates. A different kind of uncertainty is due to a lack of knowledge resulting from inadequate site characterization and, more importantly, from the unknown future evolution of parameters that could affect the exposure of the population. For complex systems, the use of probabilistic models can substantially facilitate the assessment process and provide additional insights into the system and increase confidence in the assessment results.

An important aspect in assessments of the long term performance of reclaimed sites is the potential for natural events and processes to increase risks. Examples are extreme environmental conditions such as floods or earthquakes and the degradation of barriers due to erosion. The probability and consequences of these events depend on site conditions and may vary significantly between different disposal designs. In many cases only a series of consecutive events will lead to increased risks (e.g. change in climate → deterioration of vegetation on cover → erosion of cover → increased risk of radiation exposure to humans due to enhanced radon emanation and contaminated groundwater). Such sequences can be adequately reflected in probabilistic models (see, for example, Ref. [8]).

An important aspect of a safety assessment is the timescale to be considered. Usually, uncertainties in the results of assessments increase with the length of the time frame being considered. On the other hand, certain natural events and processes may only occur or become relevant in the distant future. Limiting assessment time frames could then result in these events and processes not being adequately addressed.

A reasonable compromise between these conflicting aspects is the requirement of the US Environmental Protection Agency (EPA) for the reclamation of uranium tailings impoundments that a 1000 year term be considered 'in principle' and a 200 year period 'in a strict manner' [9]. The time frame of about 200 years is the maximum period over which the performance of engineered barriers in near surface situations can be guaranteed. It also ensures that all relevant processes are addressed in the assessment, since even slow processes, such as the groundwater migration of contaminants, and geochemical processes, such as acid generation will usually occur within this time span.

This timescale is short in comparison to time frames usually considered for deep geological disposal facilities — of up to millions of years. However, there is no major contradiction here because the long term uncertainties for geological disposal facilities are much smaller than those for near surface facilities. This is mainly due to the fact that the long term safety of deep geological facilities does not depend on only engineered barriers and institutional controls and such facilities are affected by natural and human disturbances to a lesser degree.

5.2. Passive safety features

From the above discussion it is clear that most NORM disposal facilities require maintenance and care for essentially infinite periods of time. However, the extent of such measures and the potential consequences of their not being implemented varies considerably between different disposal options. Therefore, an important element in the optimization of protection is the assessment of the passive safety of different disposal options, i.e. distinguishing between high and low maintenance options and addressing the potential consequences of negligence in maintenance activities.

This can be done by assessing the impacts of natural events and processes under the assumption that no maintenance is performed. Disposal options with a higher degree of passive safety will be affected to a lesser extent and lead to lower risks than options with a low level of passive safety. However, the costs of improving passive safety may be large and, therefore, it cannot be required that the option with the highest level of passive safety is chosen. Instead, it is necessary to use an optimization approach to balance the level of passive safety against the required financial expenditures.

A comparison of the long term stability of two management options for a uranium tailings impoundment, a 'wet' reclamation by the use of a water cover versus 'dry' reclamation using a mineral cover system, is discussed in Ref. [8]. Using probabilistic approaches, it is concluded that, despite the cost advantage of the wet solution, its vulnerability to and potential risks from many natural events, such as extreme rainfall and earthquakes, are so much higher that the additional passive safety obtained by investing in the considerably more expensive dry solution is warranted.

5.3. Integrated risk assessments

The hazards associated with facilities for the disposal of mining and milling waste and for industrial residues with elevated contents of naturally occurring radionuclides are, in most cases, not limited to radiation exposure. Several other risk components can be relevant, such as risks to human health from carcinogenic or toxic substances; damages to ecosystems and natural resources, such as groundwater aquifers; direct physical risks (e.g. due to dam failures). In the case of intervention situations, the risks entailed by the cleanup activities themselves are relevant, for example, the additional release of contaminants to the environment or possible traffic accidents when transporting large amounts of material on public roads.

The assessment of these different hazards and risks is usually made under various jurisdictions with different philosophies, methods and standards. This separate assessment approach does not allow for the consideration to the overall risk originating from a disposal facility and can, therefore, lead to inappropriate decisions. Under unfavourable circumstances, it can result in waste management measures which, for example, improve the radiological situation but produce undesirable consequences for other environmental aspects.

In intervention situations, the positive effect achieved by remedial activities usually appears in several environmental contexts. For example, covering the wastes can at the same time lead to a reduction in the radon released into the air and a reduction of radioactive and non-radioactive contaminants discharged into rivers. The determination of cost effective cleanup measures requires consideration of the costs and benefits, and should take into account all improvements achievable in the different sectors on a common basis and relate them to the financial expenditure required.

Quantitative risk assessments can only be performed if a common assessment basis for the different risk components is available. This can then serve as a basis for identifying appropriate protection and cleanup measures for the respective objects and sites. For this, an integrated assessment approach within which all relevant risk and damage components can be consistently quantified, needs to be developed. Cost effective decision making can then be based on a quantitative analysis. Examples for such integrated risk assessment approaches are given in Ref. [6].

6. CONCLUSION

Several important differences between the disposal of NORM waste as compared to the disposal of other types of radioactive waste have been discussed. These arise from the distinctive features of this waste (low radioactivity concentrations, but large volumes and long half-lives). Management options, in most cases, are limited to near or above surface disposal. Such disposal solutions require perpetual maintenance and care. This should not be seen as contradictory to the fundamental principles of radioactive waste management, because the nature of this waste does not allow for any other long term management option, at least based on today’s technology and economic resources.

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REVIEW OF CONTRIBUTED PAPERS

Session IIIb: NEAR SURFACE DISPOSAL FACILITIES[1]

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Abstract

The paper presents an overview of the papers submitted to Session IIIb 'Near Surface Disposal Facilities'. In this session, 26 papers were contributed from 22 different countries. The papers covered a wide range of topical areas including: (a) generic design and safety assessment of low level radioactive waste (LLW) disposal facilities; (b) status of LLW programmes and specific performance assessment approaches and results; (c) safety and risk analysis for the disposal of naturally occurring radioactive materials (NORM); (d) migration and leaching of radionuclides; (e) use of computer codes and their verification; (f) uncertainty analysis; and (g) LLW repository engineered barrier design, performance and degradation. The paper summarizes the major technical issues for further discussion.

1. INTRODUCTION

A total of 26 papers, including three plenary papers, from 22 countries were contributed to Session IIIb. These countries, with the number of papers contributed by each country (given in parenthesis), were Belarus (1), Belgium (4), Brazil (1), China (1), Egypt (1), Finland (1), France (1*), Germany (1), Hungary (1), India (1), Israel (2), Japan (3), Lithuania (1), Nigeria (1), Philippines (1), Republic of Korea (2), Serbia and Montenegro (1), Slovakia (1), Spain (1), Sweden (1*), United Kingdom (1*), and United States of

[1] The opinions and statements documented in this paper are those of the authors and do not necessarily constitute NRC approval or agreement with the information contained herein. Any such interpretation must be obtained in writing from the NRC.

America (2*). An asterisk indicates that the contributed paper is shared with other countries.

This paper gives an overview and summary of the important topical areas and addresses the specific technical issues arising from the review that need further analysis, discussion and follow-up.

2. MAJOR TOPICAL AREAS

The major topics may be grouped as follows:

(a) *Generic design and safety assessment methodology:* several papers addressed the generic design of low level radioactive waste (LLW) disposal facilities considering two main disposal types, the shallow or surface land disposal type and the subsurface disposal type, which is typically at tens of metres below the surface. Some papers described the design of LLW facilities with concrete vault structures or concrete trenches. The papers addressed the performance of these designs using safety assessment methodology supported by environmental monitoring data. In most cases, the monitoring data, collected for a performance period ranging from a few years to decades, indicated that the facilities are performing as designed. One paper presented a safety assessment of a well-type repository using the IAEA Improvement of Safety Assessment Methodology (ISAM) for near surface disposal facilities. Assessment complexity and rigour is an issue that needs further discussion.

(b) *LLW cover/engineered barrier (EB) design and performance:* the design and performance of engineered barriers, particularly the LLW cover, was a particular area of interest for several papers. In this context, some papers addressed approaches for evaluating the complex nature of the performance of engineered barriers. Others addressed assumptions and scenarios for EB degradation. One paper presented innovative ideas regarding use of the biological soil crust as a top cover to reduce surface erosion. Biological covers were found to be compatible in performance with commonly used geotextile covers. A detailed study was presented on the performance of reinforced concrete trenches using mathematical modelling and environmental monitoring data. Engineered barrier performance is an issue that needs further evaluation and discussion.

(c) *Status of LLW programmes and performance assessment scenarios and findings:* certain authors focused on the specific LLW disposal programmes and facilities in their countries. For example, a paper described the Chinese Beilong disposal site which is a planned regional low and intermediate level waste (LILW) disposal facility. The paper described the generic features and the conceptual model of the facility. Another paper dealt with the safety assessment of the Rokkasho LLW facility in Japan. A paper contributed from Slovakia discussed an operational low and intermediate level radioactive waste (LILW) near surface disposal facility at Mochovce and its predicted performance during an institutional control period of 300 years. A paper from the Philippines described siting initiatives and the current status of three candidate LLW disposal sites. For these disposal facilities, the authors used specific exposure scenarios to calculate radiological impacts. An interesting paper presented an overview of the exchanges of information among four countries (Belgium, France, Sweden and the United Kingdom) regarding the treatment of human intrusion for near surface disposal facilities. This issue needs to be addressed further considering the existing differences in the regulatory frameworks of participating countries.

(d) *Safety and risk analysis of naturally occurring radioactive materials (NORM):* four papers dealt exclusively with NORM waste issues. The first paper described the NORM waste generated from mill tailings, uranium mining, mineral mining and chemical processes. The paper emphasized the technical and institutional constraints of NORM when disposed of near or above the surface and recommended perpetual maintenance and care. The second paper discussed the environmental consequences of the mining and milling of tin and niobium ores. The third paper focused on NORM produced as a result of oil and gas extractions and processing operations. The paper addressed the isolation of NORM and potential disposal in trench and cavern-type disposal facilities. The paper described impact analyses for each of the disposal facilities. The fourth paper dealt with the safety issues associated with processing, handling and transportation of NORM. The paper also discussed the potential environmental risks associated with very low level radioactive waste resulting from the processing of uranium ore. The disposal of NORM waste is an important issue for further discussion.

(e) *Migration and leaching of radionuclides:* three papers discussed radionuclide migration and leaching. The first paper described the leaching rate of ^{137}Cs from spent mixed bead (anion and cation) exchange resin in a cement matrix. A second paper described the modelling of radionuclide migration/leaching based on alteration analysis of engineered barriers. A third paper was dedicated to the study of uranium migration in porous media. The paper evaluated the infiltration of uranium solution through sand columns at controlled pH values and for specific grain size fractions of sand.

(f) *Computer codes/models used in LLW performance assessment:* several papers used computer codes/models in the safety evaluation and performance assessment analysis of LLW disposal facilities. The first paper described a new safety assessment code Safety Assessment Groundwater Evaluation (SAGE) that was developed to describe post-closure radionuclide releases and potential radiological doses associated with a LILW facility. This code was subjected to a variety of tests and verifications. It was also benchmarked against the published data of IAEA ISAM. In a second paper, an alteration analysis of barrier materials was described; use was made of the geochemical code PhreeqC-Trans coupled with geochemical reaction and mass transport analysis. In a third paper, the use of the RESRAD code was described for the evaluation of impacts associated with trench and cavern-type disposal facilities.

(g) *Uncertainty analysis and knowledge representation:* uncertainty analysis plays an important role in the evaluation of LLW performance and the demonstration of compliance with safety standards. Several papers addressed uncertainties as part of their quantitative approach and analysis. However, one paper dealt specifically with analysing uncertainties. This study was been conducted through a technical cooperation project between Brazil, Finland and the USA. The paper summarizes the various sources of uncertainties and a methodology for analysing uncertainty including its propagation. The paper also deals with the need for a good understanding by the public and the decision makers of the importance of uncertainty for safety assessments.

(h) *Waste packages heterogeneity, concentration averaging and gas releases:* several papers dealt with waste sampling, concentration averaging and gas releases from waste packages. One paper reviewed the conventional procedures for safety verification and explained the requirements for continuous use of the scaling factor method or average radioactivity concentration method for the solidified waste in a container. Another paper described attempts to obtain reliable estimates of the amounts and rates of gas production in LILW drum waste packages. Heterogeneity and averaging of waste is an important issue for further discussion.

3. MAJOR TECHNICAL ISSUES

The following major technical issues are outlined for further discussion and evaluation:

(a) *Performance assessment and safety analysis — generic methodology, complexity and rigour:* in several papers, performance assessment analyses of LLW disposal facilities were described. The approaches and methodologies used generally lacked the rigour and detail needed to integrate essential processes with site characterization data, facility design and exposure scenarios. In addition, uncertainty and sensitivity analyses were often either lacking or ambiguous. For example, one paper described the performance of a facility without establishing a proper conceptual model compatible with the source term; others described generic dose impact analyses for specific facilities without justification of the input data used, and in another assessment, a resident farmer scenario was assumed for a source located deep in a trench or in a cavern. In certain cases, the performance period was not defined or assumed to be within the period that the engineered barriers would be intact. It is clear from the foregoing that work needs to be done in this technical area to improve the standard of analysis.

(b) *Realistic scenarios, human intrusion and institutional controls:* the definition of appropriate exposure scenarios is important in connection with the demonstration of compliance with safety criteria. Areas of potential controversy include: defining the location of the individual receptor or member of the potentially exposed critical group, and the assumptions with regard to potential intruders into disposal facilities. Often, the regulatory framework and criteria for use in assessing risks due to human intrusion during the operational and post-closure periods are poorly defined.

(c) *Suitability and verification of computer codes:* several papers used readily available computer codes for radionuclide transport analysis and risk and safety assessment. For example, the SAGE code was used for the safety assessment of a near disposal facility in the Republic of Korea; the RESRAD code was used to derive the radiological impact of trench and cavern-type disposal facilities in Egypt directly after closure and after a post-closure period of 1000 years; the AMBER code was used for implementation of the conceptual model for a LILW disposal site in China. The IAEA ISAM programme was used in several cases for benchmarking and verification of models and stylized calculations. The experience gained in the use of these codes for the specific application is an interesting subject for discussion.

(d) *LLW disposal facility cover/engineered barrier design and performance:* the performance of covers and engineered barriers are important elements affecting the long term performance of near surface repositories. The covers vary in design and in the materials used for their construction. For example, an engineered barrier of a disposal facility located in a tropical climatic zone consists of multiple layers of concrete, a clay backfill, sand, clay and a grassed layer. Another cover design includes multiple layers of geotextile material, a sealing film, a monolithic steel-concrete slab, compacted clay, loam soil and gravel, and a grassed layer. The long term stability of these covers and their performance over an institutional control period of 300 years is an issue of interest for discussion and exchange of information.

(e) *Realistic approaches for NORM disposal:* because NORM contains long lived radionuclides and usually exists in large volumes, certain of the authors caution that there are technical and institutional constraints for its disposal in near surface disposal facilities. Others believe that the use of additional safety arguments, a realistic analysis, and the defence in depth concept can be used to justify disposal in near surface disposal facilities. It is clear that international coherence in this area does not yet exist.

(f) *Repository design versus actual performance using environmental monitoring data:* several papers discussed the design and performance of LLW repositories that have been in operation for different time periods. For some facilities, environmental monitoring data specific for the facility have been accumulated. A discussion of the performance of these facilities in relation to the monitoring data would be of value.

(g) *Heterogeneity and concentration averaging:* waste homogeneity and averaging are topics which must be addressed in a safety assessment and for which varying approaches are currently being adopted.

4. CONCLUSIONS

The papers in the session cover a wide range of aspects and technical issues pertaining to near surface LLW disposal. Several technical issues arising from a review of the papers have been identified as significant, they include: (a) rigour and detail in performance assessment; (b) realistic scenarios, human intrusion and institutional controls; (c) computer code suitability and verification; (d) cover and engineered barrier design and performance; (e) approaches for NORM disposal; (f) repository design versus actual performance using environmental monitoring data; and (g) waste heterogeneity and concentration averaging.

PANEL

Session IIIb
NEAR SURFACE DISPOSAL FACILITIES

Chairperson:	**K. Raj** (India)
Members:	**V. Nys** (Belgium) **W. Goldammer** (Germany) **L.W. Camper** (United States of America) **K.J. Lee** (Republic of Korea) **N.K. Bansal** (India) **Z. Shang** (China) **A. Morales** (Spain)

N.K. BANSAL (India): I think that in near surface disposal the time has come to consolidate the gains and experience of the past 30–50 years. This could be one way of developing public confidence with regard to deep geological disposal.

K.J. LEE (Republic of Korea): I should like to describe the situation in my country regarding near surface disposal.

We have 20 nuclear power plants in operation, meeting about 40% of our electricity demand, but we do not yet have a low level waste disposal site. For some 20 years we have tried to reach a decision on a site, but we have had a succession of failures. The Government has therefore introduced a more transparent process whereby local governments have to obtain endorsements by residents through popular referenda before offering to host a site.

We now have four candidate sites, and it is possible that a decision will be reached before the end of November. Referenda on the four sites will be held on the same day, the requirement being that over half of those entitled to participate should vote in favour of the proposal.

The final determination will be based on a combination of geological suitability criteria and citizen approval.

Z. SHANG (China): At present we have two near surface disposal facilities in my country, where the institutional control period has been set at 100 years.

One issue which we have still to resolve is how much the facilities should charge radioactive waste producers for accepting their waste.

As regards public acceptance, we have found that some provincial governments are keen to host nuclear power plants but do not wish to host near surface disposal facilities.

K. RAJ (India): Perhaps we could hear something about human intrusion and institutional control.

V. NYS (Belgium): In my country, we have given a lot of thought to these issues, particularly in view of Belgium's high population density. We are consulting with the regulatory authorities in countries such as France, Sweden and the United Kingdom, and we hope to benefit from their experience.

W. GOLDAMMER (Germany): In my presentation I drew attention to the differences that exist as regards institutional control periods. Z. Shang just said that in China the institutional control period has been set at 100 years, while I maintain that for NORM one needs institutional control forever. I should be interested in hearing views about such large differences.

M.W. KOZAK (United States of America): Regarding the institutional control concept described by V. Nys in his presentation, it does not correspond to the usual way in which we think about institutional controls. In the case of near surface facilities, there is usually an intention to maintain institutional controls forever, which would be consistent with the approach for NORM. The number of years set for institutional controls in different countries (100 years in the case of China and the United States of America) reflects a societal judgement about how long one can rely on institutional controls for safety.

The concept described by V. Nys seems to be based on the idea that the waste will ultimately be released from institutional controls. In my view, the release of the waste would in effect be a facility de-licensing action, and I do not think that such an action would be taken at 1 mSv/a, but rather at some type of free release criterion for the site.

I think we need to clarify this issue, because there are different understandings of the meaning of institutional control and the institutional control period. In the USA there is no intention to ever release sites from institutional control; it is simply an assumption about how long we can rely on institutional protection. It does not imply an active intention to release.

R. LOJK (Canada): I agree with W. Goldammer. Essentially, we ask for financial guarantees, and we will not release a company — even a mining company — from the requirement to keep in place financial guarantees for the perpetual maintenance of a facility until it can prove that the facility does not require active monitoring.

J.-M. POTIER (IAEA): I do not think that one can decide arbitrarily that institutional controls will last, say, 100 years or 300 years. There will be reassessments of the situation at the disposal site on a periodic basis, maybe every five or ten years, and then a decision will be taken about the extent of the monitoring and other controls during the next five or ten years. So, the duration of the institutional control period will depend very much on the observations which will be made. After, say, 100 years or 200 years a decision may be taken to end the controls or to continue with them, but in a different manner. At all events, it is difficult to make predictions about the duration of institutional controls.

A.-C. LACOSTE (France): I agree with J.-M. Potier. For me, institutional control is typically a step by step procedure. Every five or ten years, say, you consider, in the light of developments, whether to continue with the institutional control. Of course, at the beginning you may have some kind of forecast to the effect that there will be institutional control for 100 years, 200 years or whatever, but that is no more than a forecast subject to revision from time to time.

A. MORALES (Spain): An important consideration when setting the period of institutional control is the amount and concentration of radioactive material in the facility at the time of closure. The 300 years mentioned by J.-M. Potier is a maximum, and this maximum is used for designing the engineered barriers.

W. GOLDAMMER (Germany): Monitoring should be carried out during the institutional control period and, at the end, a decision should be taken, based on the monitoring, on whether the controls are needed or not. This will be something that happens in 100 or 200 years' time. I see it in the same way as M.W. Kozak — these periods of 100 years, 200 years, 300 years are just assumptions we are making at the moment for the purpose of deciding on the design of our facility and on what we can put into it. And the assumption that we can rely on institutional control for only 100–300 years allows us to determine, at least for new facilities, what we can put near the surface and what has to go deeper — to an intermediate depth or into a deep geological repository. This is the real difference between normal fuel cycle operational waste and NORM, because for NORM the hazard potential will be the same in 200 years' time and in 2000 years' time. So, there we do not have a choice.

As far as near surface facilities are concerned, we have a choice as to what we put into them. There may be differences for existing facilities — many of which contain significant amounts of long lived alpha-emitting material, and where it may be necessary to recover some of that material.

J. REPUSSARD (France): Listening to the presentations, especially that of W. Goldammer, I could not help thinking that institutional control over very long periods is not a concept that we can assume will be workable. Companies may never be released from obligations, but they may disappear for financial or other reasons.

We have to compare the kind of risk which populations living around sites would be facing. This is not new. The only element that is new is that we are talking about risks from radionuclides, but many communities in the world live with other types of long term risk. For example, the people of the Netherlands run risks from being below sea level, and people living in the mountains may be at a continuous risk from avalanches.

Perhaps we should try to approach the problem of long term radiation-induced risk by taking into account how humanity has managed to live in situations of risk under other circumstances.

J.T. GREEVES (United States of America): On the question of how to manage the safety of waste containing radionuclides with very long half-lives, we have heard that many people are facing this problem and that they do not know how to deal with it. W. Goldammer gave us a very good description of what the approach is in Germany. The details are different in the USA, but the substance is the same. There are details to be worked out but the approach described by W. Goldammer could form the basis of international guidance, for development by the IAEA, as a way of helping those developing countries which have this problem but which do not have the necessary experience.

P.E. METCALF (IAEA): Regarding J.T. Greeves's comment, we intend to develop a safety requirements document that will cover all types of disposal, including the disposal of NORM waste or mining residues. We will then develop for each disposal option (geological, near surface and so on) a safety guide addressing the question of how to meet the safety requirements.

When we have produced a draft document, it will be circulated to the IAEA's Member States for comment, and there will no doubt be comments regarding institutional control, after which there could be a debate possibly resulting in a consensus. I hope that this process will take place within the next year or so.

A document preparation profile will be submitted next week to IAEA Waste Safety Standards Committee (WASSC) with a request that it authorize us to go ahead with the development of the safety requirements document.

A. DODY (Israel): I understand the institutional control period rather differently — 100 years means that after 99 years one has to do a new safety assessment of the area before the area is released to the public. It does not mean that the area is released to the public automatically after 100 years.

J.-M. POTIER (IAEA): Also regarding J.T. Greeves's comment, I would mention that an IAEA technical document on the long term stewardship of contaminated sites has just been approved for publication. It reflects the experience of IAEA Member States in monitoring contaminated sites.

V. NYS (Belgium): There are different levels of institutional control. Initially, for a fairly short time, there may be active control measures involving, for example, perimeter guards — replaced in due course by passive measures. We advocate a transition from active to passive control measures with time because a period of, say, 200 years is very long compared with the lifetime of most institutions. After all, my country — Belgium — is only about 200 years old.

M. JENSEN (Sweden): In my view, we should not be too concerned about the future. We should instead address the situation existing now. Do stakeholders have confidence in us now? Does the strategy make sense now? Do not go into great detail about what will have to be done in 100 years' or 500 years' time — doing so will not inspire confidence.

K. RAJ (India): The present is admittedly very important, but the future is equally important. We must be able to answer questions from the public about the future.

M.V. FEDERLINE (United States of America): I think it is important that we talk about this from the scientific perspective, but we must talk about it from the societal perspective as well. Let us look at what has worked — uranium mill tailings have been disposed of and the sites are being maintained, and, in Canada, the local community at Port Hope will be taking the decision about the institutional control period. As regards our decommissioning rule in the USA, it came as a surprise to us that the public wanted a restricted release option for decommissioned sites because it generated confidence.

So, I think we should be careful as to how much of a consensus we try to achieve.

There may be circumstances under which different sites are subject to different institutional controls, depending on the sensitivities of the local populations.

K. RAJ (India): Perhaps we could now talk about assessment complexity and rigour.

V. NYS (Belgium): The assessment complexity will depend on the stage reached in the project. If you are at the pre-project stage, a generic assessment is very useful for deciding on the concept, determining the feasibility and estimating the order of magnitude of the hydrological impact.

An assessment is not a scientific evaluation. Safety is based on scientific research, but we should take from the scientific research what is useful for the safety assessment. We should avoid excessive complexity. I do not mean that we should be very conservative and err on the side of simplicity, but we should adopt an integrative approach to all the disciplines that are involved in waste disposal — hydrology, geology, chemistry and so on.

Z. SHANG (China): We have begun to do safety assessments for our two near surface disposal facilities but I think rigour is impossible at this stage. For nuclear power plants we always refer to the Nuclear Regulatory Commission's standard safety assessment, but for the near surface facilities we have no reference. So, it is a real challenge.

We have had some help from the IAEA in this regard, but we need more to enable us to do a good safety assessment for near surface disposal.

K. RAJ (India): In that connection, I would mention that the IAEA's ISAM (Improving Safety Assessment Methodology) and ASAM (Application of Safety Assessment Methodology) programmes are generating a lot of interest. A large number of countries are participating in them.

W. GOLDAMMER (Germany): I would like to add something regarding NORM. When you do safety assessments for sites like some of those in Germany, you have to be very site specific, because you cannot afford any conservatisms. You really need to perform site specific and rigorous assessments which look into the future.

However, we have thousands of small heaps of mine waste and ores in Germany and, in addition, some small scale NORM waste streams. For these smaller problems, we find it effective to use the approach of generic assessment and generic criteria, because we cannot do detailed assessments for all of them. In our regulatory framework we introduced some reference levels for application to these simpler situations; they provide guidance and remove the need to do detailed safety assessments. These reference levels have been calculated in such a way that they give reasonable assurance that the 1mSv/a criterion is being complied with. This approach has proved to be very helpful, and maybe it is something the IAEA should think about. Is it worth establishing international generic safety reference levels for application to small scale mining waste?

D. LOUVAT (IAEA): Something very useful in the context of NORM waste management are the review meetings of the parties to the Joint Convention. At the meeting held in Ouagadougou, Burkina Faso, for the purpose of familiarizing African Member States with the Joint Convention, the most positive responses which we received were from Zambia, Namibia and Niger; these countries have concerns about the management of mining residues. In my opinion, a mechanism within the Joint Convention framework for discussing how NORM waste should be managed could be very useful at the start of the long process of seeking agreement on reference levels, the length of institutional control and so on.

V. NYS (Belgium): I think that a generic assessment is very useful in the pre-project phase. Beyond that it is necessary to take account of the specificities regarding the site, the geosphere and the environment.

Vaults and packages in near surface disposal are generally made of concrete, but there does not seem to be a uniform approach to modelling the behaviour of concrete. Why is this? Is it due to a lack of understanding of the chemical and physical properties of concrete? Could we, as regulators, accept a safety assessment based on some generic data found in the literature? Should we ask for specific data on the concrete used in disposal packages and vaults?

This seems to be a generic problem. Concrete is used worldwide for the construction of repositories and packaging and yet we do not have reliable generic data for it.

N.K. BANSAL (India): Regarding generic assessments in India, we have located near surface disposal facilities in the vicinity of nuclear facilities such as nuclear power stations and reprocessing plants. Consequently, the waste manager does not have much choice as regards site selection. So, basically it reduces to the three safety components: the waste acceptance criteria, the multiple barriers and the site characteristics. For a waste manager in India, the site characteristics are decided by the nuclear facility siting policy, and he cannot play much with the waste acceptance criteria as the waste generated at a particular site has to be managed. So, it is the engineered barrier component which is fine-tuned to the specific requirements of the site.

K. RAJ (India): Would you care to comment on what V. Nys said about concrete?

N.K. BANSAL (India): We feel that this is a very important area. Our regulatory body requires proof that, whatever multiple barriers are created, the system will be safe in the future. We have been asked by the regulators to demonstrate how the engineered barriers are performing. We called in professional bodies to help predict the life of typical reinforced concrete trenches at three sites, and then we made comparisons. There are various components involved in making such predictions, and by varying certain engineering features we were able to assure ourselves that with the present construction methods for reinforced concrete trenches there should be no cause for concern during the next 150–200 years.

I.G. CROSSLAND (United Kingdom): I have views regarding multi-barrier containment and the multifunctional approach which may be considered heretical. But first I will give you some background.

Before working in the radioactive waste management field I worked in the reactor safety field. There you have the concept of ‘redundancy’ and the concept of ‘diversity’. These concepts are defined so precisely that you can express them mathematically, which is how you get to safety fault trees. For instance, for shutting down a reactor you might have control rods and, if they do not work, boron beads. This is redundancy, as each system is capable of shutting down the reactor on its own, and the two systems are diverse. Anyone trying to apply these concepts in radioactive waste management and repository performance assessment soon sees that they do not work. Instead, we have to resort to multibarrier containment and the multi-functional approach, which cannot be defined precisely. Relying heavily on them is very likely to lead to problems. In fact, I think it may be even worse than that — the public sees multibarrier containment and the multifunctional approach as a kind of 'Russian doll'; if one barrier fails, the next one will take over, if that fails, again the next one will take over, and so on. But we all know that it is not like that, and I think, therefore, that it may not be wise to talk so freely about multi-barrier containment and the multifunctional approach.

K. RAJ (India): In the case of nuclear reactors, the systems are well defined. In radioactive waste management you have a wide variety of waste, and that gives rise to complexity.

J.-M. POTIER (IAEA): Regarding the complexity issue, it seems obvious to me that the development of a disposal facility is an iterative process. Consequently, the quality of the data will increase with time. You may start with a generic design and a generic assessment that are not site specific, but as the project advances you will obtain some site specific data and will, of course, reassess the performance in the light of those data. So, the complexity will increase with time. The iteration could take place over a number of years.

V. NYS (Belgium): Regarding I.G. Crossland's comments, I also used to work in the nuclear safety field, where we used to study failures of components. So, I am not surprised that people try to do the same thing in the case of radioactive waste disposal. If we understand the mechanisms on which the safety of disposal facilities depends, we know what will happen if those mechanisms fail. That is a normal way of assessing safety. However, we should not necessarily compare this type of assessment with the dose criteria. It is a sensitivity study. I think it is a very useful tool for identifying which are the weakest or the most sensitive parameters in our concept. It is here that we should focus our efforts on developing specific criteria.

K. RAJ (India): Perhaps we could now hear views about the licensing of small disposal facilities as opposed to large ones.

P.E. METCALF (IAEA): I think the issue here is whether we should have the same licensing procedures for facilities with very small inventories or with only low activity waste as compared with larger facilities such as the Centre de l'Aube.

A. MORALES (Spain): I do not think that it is a matter of modifying the licensing procedures — something needs to be done about the practices and things like that. I will give you an example.

Last week we were preparing a document on the categorization of low and medium level waste. The question of mixing waste of different categories, in terms of activity, arose. It is normally considered that one would not mix different categories of waste, but somebody at our meeting asked what should happen in the case of a country with 20 L of medium level waste and 20 L of low level waste. Should we tell this country not to mix the 40 L but build two facilities, one for each waste category? I think that in such countries the licensing procedures should be the same but there should be more flexibility in some respects.

S. SAINT-PIERRE (World Nuclear Association): I have a question regarding the global consistency of radiation safety standards and the implications for communicating about risk. In that connection, W. Goldammer's presentation was an eye-opener for me.

How do we explain the apparent inconsistency in the limits to public exposure for people living near nuclear power plants as compared with mine tailing sites and some repositories? How can we explain the different limits apparently being used? There are also differences as regards the transport of radioactive materials.

W. GOLDAMMER (Germany): In my presentation I tried to make the point that dose criteria have to be adequate to the situation and said that the 0.3 mSv/a dose constraint cannot be met in the case of mining and milling waste, so you have to be flexible in choosing the criteria. On the other hand, you have to communicate the rationale for choosing the criteria, and I also mentioned the problem which I would have if I tried to communicate the 10 mSv/a and the 100 mSv/a of ICRP 82. I am sure that I could not do it. That is why, in Germany, we try — at least numerically — to have the same value that we use as a public dose limit, 0.1 mSv/a.

However, what is more important is how to demonstrate compliance. The prescribed procedures in the regulations have many built-in conservatisms — which is fine for controlling public exposure to new reactors, where the doses are very low. However, this is something we cannot afford in the area of naturally occurring radionuclides. The doses are larger and therefore we have to be more realistic in our dose assessments.

A.-C. LACOSTE (France): Regarding the questions raised by S. Saint-Pierre, I would say that we must be consistent. However, when we talk about regulations, doses, dose constraints and so on we should bear in mind the difference between what we can do about new facilities or new issues and what we can do about existing facilities or existing issues. Of course we must be consistent, but we must take account of the difference between new things and things from the past. If we do not make the distinction, we shall be in a conceptual mess.

K. RAJ (India): Many countries, including India, are facing the situation which A.-C. Lacoste has in mind. Many old facilities were designed and built to lower standards than those that apply currently. Some of these facilities were actually over-designed, so the regulators are reassessing more realistically what inventories they can hold. This may allow continued, although modified, operation. Otherwise, many of the facilities will have to be shut down.

W. GOLDAMMER (Germany): I agree with A.-C. Lacoste. An existing situation is different from a new situation. In new situations you can do things that you cannot do in existing situations.

I also believe that intervention levels in the case of accidents and past events have to be higher than normal dose limits. But I do not think that in cases of chronic exposure, for example, people being exposed as a result of living all their lives next to a mining waste dump — you can use this as an explanation of why they must accept significantly higher radiation doses than the dose limit. The people might accept it for a short time, but in the long run they will demand the right to be as well protected as everyone else. In their position I would demand that right.

A.-C. LACOSTE (France): New procedures or regulations apply only to new facilities and new situations. In the long term, however, you must, of course, arrive at some kind of consistency, but it takes time. I think that was what you were saying.

L. JOVA SED (IAEA): I do not altogether agree with W. Goldammer. We must be consistent. This is a problem for the nuclear community when it is trying to communicate with the public. One issue is the scientific basis for setting the limits and constraints. The other issue is societal — in a wealthy country, people can probably ensure that they do not live near a facility that they distrust, whereas they may well have no choice in a poor country. However, there is a scientifically based, internationally accepted level which is the same for the two types of country.

A.-C. LACOSTE (France): For me, what happened in eastern Germany as regards uranium mining was in some ways similar to the Chernobyl accident. It was a kind of accident, but one cannot evacuate hundreds of thousands of people. You must accept the fact that they are living in the affected region. You can try to improve their situation, doing the best you can, but you must recognize that you have a legacy from the past and that it will take a long time to arrive at a reasonably good management solution.

W. GOLDAMMER (Germany): I do not think there are any disagreements here. In the case of Germany, it is an intervention situation. It was a kind of accident, and it will take time to rectify matters. The remediation operation, which started 15 years ago, is still under way. Doses will be higher during the remediation period, but the same would be true in a developing country. I think we all agree that the protection targets should be the same in all countries, even if it will take longer to achieve those targets in some countries than in others.

J. KOTRA (United States of America): In his presentation, W. Goldammer showed some stunning pictures of large communities living very close to facilities. What, if anything, has been done to elicit the views of the people in those communities? Is the level of concern about legacy waste the same in these communities as elsewhere in Germany?

W. GOLDAMMER (Germany): The level of concern is not the same, because these communities know that their problem is with natural radioactivity. This is nonsense from a physics point of view, but we all know how public perception works. There are some local pressure groups, but in general the population says: “We have been living with uranium mining for 500 years, so it cannot be that bad.” On the other hand, people see that something must be done — and they want it to be done. But they more or less accept the fact that it will take some time, and I think they are fairly happy with the progress that has been made.

There have been discussions with the communities about the remediation concepts, and some of them have been controversial, but in general there has been a good atmosphere and good cooperation between the authorities and the public, and I think the concepts enjoy a broad consensus. I am sure there would have been far greater difficulties if the subject of the discussions had been a nuclear reactor.

THE SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES

(Session III)

OPTIONS FOR INTERMEDIATE DEPTH DISPOSAL

(Session IIIc)

Chairperson

J. LOY
Australia

Rapporteur

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Spain

DISPOSAL OF RADIOACTIVE WASTE AT INTERMEDIATE DEPTH

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Abstract

Repositories located at intermediate depth, some tens of metres, below the surface are suitable for certain categories of waste. The advantages of intermediate depth as compared with the surface or near surface are the protection afforded by the natural rock barrier and the relative remoteness of surface associated processes, biological and human-made. In the process of public consultation, the potential for avoiding intrusion is perhaps the most valuable feature for intermediate depth repositories, especially if water well drilling can be excluded.

1. INTRODUCTION

A considerable amount of guidance exists on the safe disposal of radioactive waste in geological repositories, usually understood to be located at depths of several hundred metres and also for near surface repositories, including rock caverns at depths of a few tens of metres. For several categories of non-heat producing radioactive waste, such as ^{14}C in graphite, radium and certain reactor components with long lived activation products, geological disposal is sometime envisaged, but in an intermediate depth repository.

Disposal in rock caverns, several tens of metres below ground, is usually considered to be a form of near surface disposal. It is therefore of interest to consider, in a systematic way, what extra protection is offered from the extra tens of metres of depth of an intermediate depth repository. Although some general observations can be made for such disposal concepts, the detailed features are specific to their sites, radioactive contents and designs, and only become evident as a result of specific safety cases.

In addition to other safety aspects, the value of placing a repository at some distance below the surface, away from surface activities, such as erosion and the possibility of direct human action, may be a decisive factor in the choice of intermediate depth for a repository.

2. ELEMENTS OF A SAFETY STRATEGY FOR AN INTERMEDIATE DEPTH REPOSITORY

According to a new Safety Standard of the IAEA [1], the aims of geological disposal are:

- "To contain the waste until most of the radioactivity, and especially that associated with shorter lived radionuclides, has decayed;
- To isolate the waste from the biosphere and to substantially reduce the likelihood of inadvertent human intrusion into the waste;
- To delay any significant migration of radionuclides to the biosphere until times in the far future when much of the activity has decayed; and
- To ensure that any levels of radionuclides eventually reaching the biosphere are such that possible radiological impacts in the future are acceptably low."

With some reservations, the safety goals are very similar for all repositories. The concepts of isolation from the biosphere, absorption of released radionuclides in the engineered and natural barriers, and delay and dilution may be used in the safety case for different types of repository. The role of the natural barriers is an important distinguishing feature for an intermediate depth repository, as compared to a surface repository. This aspect is discussed further below. Finally, some issues in connection with unintentional human intrusion into a repository are discussed.

2.1. Biological activity and erosion

Biological activity, such as root penetration, is one of a category of scenarios that is avoided if disposal is at intermediate depth. Another advantage of an intermediate depth repository compared to a surface repository is the protection provided against natural erosion. It might be a particular issue when the period of concern for the safety assessment is around or above 1000 years.

2.2. Barriers

A safety case must take into account the interdependence between the engineered barrier system and the surrounding environment. Although conditions may be less aggressive than at the surface, the precise value of the benefit of placing a repository at some tens of metres below the surface, with regard to chemical and hydrological conditions, can only be determined by means of a site specific assessment. The barrier environment will have less stability than a deep geological repository, although the lower stress on the surrounding rock will allow for greater mechanical barrier stability. In a granitic type of host rock, such as exists in Sweden, the chemistry changes with depth so that, for example, the existence of an oxygen-free environment at depths above several hundred metres cannot necessarily be relied upon.

2.3. Mitigation

The consequences of a radionuclide release from an intermediate depth repository might be expected to be mitigated in terms of delay and absorption. This is potentially the most important distinguishing feature of an undisturbed intermediate depth repository as compared to a near surface repository. Also dilution of released radionuclides in the geosphere or in the biosphere is more pronounced at depth. In the Swedish repository SFR, the Swedish Nuclear Fuel and Waste Management Company's (SKB) repository for low and intermediate level waste (ILW), any releases occurring during the first thousand years will be diluted in the coastal water of the Baltic Sea.

Dilution may contribute to ensuring that "radionuclides eventually reaching the biosphere are such that possible radiological impacts in the future are acceptably low" [1]. However, dilution may not always be seen as an attribute and a balance may have to be struck between (a) isolation and dilution and (b) collective and individual radiological impacts:

(a) Philosophically, the dilution of a delayed release from an intermediate depth repository can be seen in much the same way as the dilution of prompt releases, that is, operational releases from industrial or medical operations. In both cases, options might exist with a range of environmental impacts and it should be shown that the measures taken balance the need for safety.

(b) Since individual doses will usually be low in a safety case relying on dilution, the safety case should also demonstrate that the best available technique, or good engineering practice, has been used to reduce releases. For most inventories of interest here, the 'dilute and disperse' strategy based on direct release of the whole inventory would not be acceptable.

2.4. Intrusion or human action

Intrusion is one of the main issues for any repository at a depth where drilling for drinking water may penetrate the repository's barriers. The likelihood of human intrusion may be obvious for some repository locations, either because of the potential presence of minerals, or simply because of the shallow depth of the facilities. At a depth of 500 m in a host rock with no mineral deposits, intrusion is almost entirely a philosophical issue, although various scenarios can always be imagined, such as deep drilling in hydrothermal energy projects or excavating for deep underground transport.

ICRP Publication 81 [2] does not promote the idea of dealing with intrusion by using probabilities. Also the US Academy of Sciences report 'Technical Bases for Yucca Mountain Standard' advises against the idea of assessing probabilities by denying that such a process could be carried out in a scientific manner at all for that repository [3]. Both the above documents refer to long lived waste assumed to be located at a depth below that of normal drilling activities, i.e. for drinking water wells. In the case of a repository at depths above that, the likelihood of intrusion is real.

An obvious difference between intrusion scenarios for near surface and intermediate depth repositories is the fact that an intrusion scenario in a near surface repository may include direct exposure to the waste that can be visualized in a large number of ways, whereas intrusion in an intermediate depth repository may be restricted in terms of the number of exposure scenarios that can be envisaged, e.g. the drilled water well scenario.

3. DESIGN OF AN INTERMEDIATE DEPTH REPOSITORY

The barrier systems in intermediate depth repositories will be determined from consideration of the categories of waste intended to be emplaced in them. Figure 1 shows the layout of SFR. It indicates that an intermediate depth repository can host a number of different waste categories in different compartments: Silo for ILW, ion exchange resins in drums and concrete and steel moulds (see no. 3 in Fig. 1), a vault for ILW, ion exchange resins in concrete tanks and incineration ashes (see no. 4 in Fig. 1), LLW vault, scrap metal and refuse in ISO containers (see no. 5 in Fig. 1) a vault for ILW, ion exchange resins, scrap metals and refuse in drums and concrete and steel moulds (see no. 6 in Fig. 1). (In Fig. 1, (1) is the operations control facility and (2) is a reloading area.) In developing waste acceptance criteria for the different waste packages, the safety analysis must ensure that the impact of their different physical and chemical properties does not compromise the overall safety of the repository.

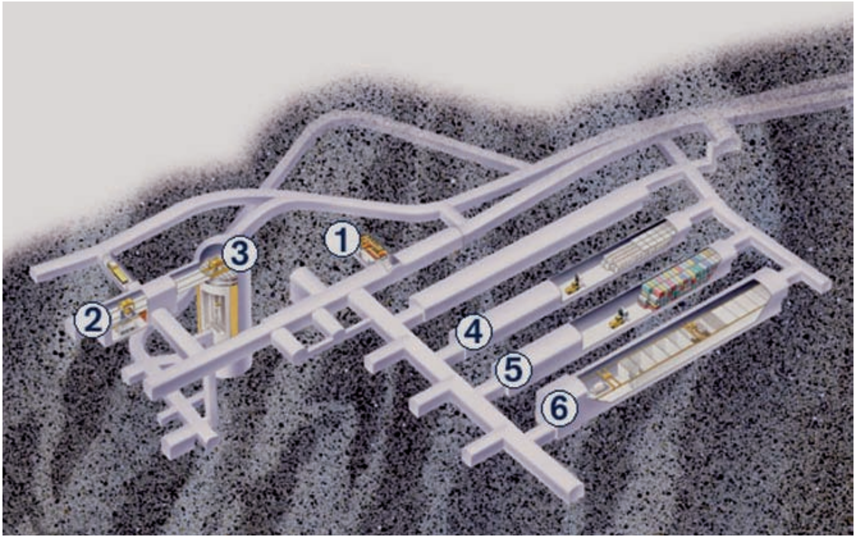

FIG. 1. Layout of SFR, courtesy of SKB.

4. COMPONENTS IN A SAFETY DEMONSTRATION

4.1. Predictability for the undisturbed performance

Some repository concepts that rely on isolation for tens or hundreds of thousands of years will, by necessity, have a large margin of uncertainty associated with their safety analyses, mainly caused by the timescale to be covered. If, because of the characteristics of the waste, isolation is needed for a shorter time span, the behaviour of the barrier systems may be easier to predict, at least regarding their undisturbed performance. Although uncertainties will always remain, the calculations are not likely to be influenced by catastrophic events, such as earthquakes or volcanism, which have to be taken into account for assessments over tens of thousand of years. Therefore, in an assessment of the performance of an intermediate depth repository, many of the elements of speculation that must be included for spent fuel repositories may be avoided.

However, for identical repositories located at different depths, there would intuitively be a better predictability at greater depth because of the variability and unpredictability of surface conditions in general. Scientifically, the value of such predictability at greater depths must be seen in relation to the need for it in a safety analysis, also taking into account that the predictability may be hampered by increasing difficulties in characterizing the environment at greater depths. In some cases, a bounding calculation may be sufficient, showing that safety will be achieved for almost any external conditions. For example, a repository with an exclusive inventory of ^{60}Co would not need to be buried at any depth if control for some 50 years could be guaranteed.

4.2. Optimization

The discussion above implies that the results can be optimized with regard to radiation protection, although the word optimization is used in a somewhat different way to that recommended by the ICRP [4].

If releases were expected to occur from the repository in a hundred years' time, both the expected individual doses from the release and the costs and efforts in constructing the barrier system could be discussed quantitatively. This is true for repositories where the uncertainty in predicted dose is less than the uncertainty in cost. For most deep geological repositories, the uncertainty in the predicted dose makes such a balance prohibitively difficult, although it may still be discussed in a qualitative way or restricted to reference scenarios.

4.3. Handling of intrusion

The safety case in connection with human intrusion should be built on a combined consideration of depth, radioactive decay and active and passive institutional control.

Intuitively, a deep repository can be seen to have less potential for intrusion than a shallow one, but the formal calculation of intrusion probabilities is as difficult as it is for a deep geological repository, as mentioned earlier. This does not mean that a safety case could not include examples of intrusion, or even conditional probabilities for intrusion to demonstrate in a quantitative way what would happen to the repository in the future, e.g. by assuming a certain drilling rate.

The safety assessment treatment of shallow depth disposal is just as complicated as for a geological repository in one aspect, that is, the potential for intrusion. The definition of intrusion therefore requires an international discussion.

The safety benefit obtained from placing a repository below drilling depth is probably seen by many experts and laypeople alike as an important means of avoiding intrusion. However, the exact depth at which a repository would have to be placed to achieve this must be determined site specifically.

Laypeople can easily understand the likelihood, if not the consequences, of intrusion for rock caverns above water well drilling depth. The same is true for active and passive institutional control. It is therefore in the interests of the implementer to explain all the societal components connected to the concept. The final acceptance of a repository concept can therefore be expected to include something of a social contract with the stakeholders regarding the cost of alternatives both for the repository and for institutional measures. Considerable value lies in choosing a depth at which the effects of water well drilling can be disregarded or minimized. This dialogue is foreseen in the new interpretation of optimization by ICRP — allowing for stakeholder consultation in making decisions on what is 'reasonable' in the effort to keep doses 'as low as reasonably achievable' (ALARA).

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THE CURRENT STATUS OF THE JNFL SUBSURFACE DISPOSAL PLAN FOR RELATIVELY HIGH LOW LEVEL RADIOACTIVE WASTE

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Abstract

Since 2001, the investigation of the geology and groundwater at Japan Nuclear Fuel Limited's (JNFL) Rokkasho Mura site has been under way in order to acquire the basic data for the design and the safety assessment of the low level radioactive waste (LLW) subsurface disposal facility. The paper discusses subsurface disposal in Japan and provides a brief overview of the current status of the project.

1. INTRODUCTION

Low level radioactive waste (LLW) is defined in Japan as the whole waste except for the high level waste (HLW). The LLW is categorized as follows:

(a) LLW for near surface disposal without engineered barriers, i.e. extremely low level contaminated waste;
(b) LLW for near surface disposal with engineered barriers, i.e. the waste generated from the operation and maintenance of nuclear power reactors;
(c) LLW for subsurface disposal with engineered barriers, i.e. higher level waste than category (b);
(d) LLW for geological disposal, i.e. highly contaminated transuranic (TRU) waste (but currently under discussion).

In Japan, the facilities for the categories (a) and (b) are already in operation at an experimental or commercial level. Japan Nuclear Fuel Limited (JNFL) has a plan for disposing of category (c) waste in a subsurface facility with engineered barriers (the subsurface disposal facility). This facility will be able to accept the low level waste from nuclear power plant operation and core materials from nuclear power plant decommissioning, estimated to be about 20 000 m^3 in total [1].

In 2001, a preliminary survey was conducted to investigate the possibility of constructing the subsurface disposal facility at the Rokkasho site of JNFL. Since 2002, the investigation of geology and groundwater has been undertaken in detail to provide data for the basic design.

The JNFL site is located in the legislated development area of Rokkasho Mura, Aomori Prefecture in the northern area of the mainland of Japan, about 700 km from Tokyo. The average population density of Rokkasho Mura is 47 persons/km^2 but in the legislated area there is currently no population.

The surface area of the site is about 7.5 km^2, and it currently accommodates the Low Level Radioactive Waste Disposal Centre, the Uranium Enrichment Plant and the High Level Vitrified Waste Storage Centre and the Reprocessing Plant.

2. OPERATION OF ROKKASHO LLW DISPOSAL CENTRE

At the Rokkasho LLW Disposal Centre, low level waste such as that generated from the operation of domestic nuclear power plants has been accepted and buried since 1992. There are two facilities called No. 1 and No. 2, whose capacity is 40 000 m^3, respectively.

The disposal facilities are sited on a terrace some 50 m above sea level, and within each facility, concrete pits, located in a low permeability bedrock at depths of 15–20 m below the surface, are used to hold the waste.

The No. 1 disposal facility can accept homogeneous waste including cemented or bituminized condensed liquid waste, spent resin, etc. The waste buried in No. 2 disposal facility, operating since 2000, is solidified activated metals and plastics waste, etc.

By the end of FY 2004, 135 899 waste packages had been disposed of in No. 1 facility and 38 512 in No. 2 in the form of 200 L drums.

3. THE CONCEPT OF SUBSURFACE DISPOSAL IN JAPAN

3.1. The targeted waste

The subsurface disposal facility will be able to accept waste, such as highly irradiated materials with long lived radionuclides, e.g.^{14}C, whose concentration levels are a few orders of magnitude higher than that currently being disposed of in the existing facilities at the Rokkasho site. The waste prescribed in the reports of the Japanese Government for disposal in the facility include:

— Reactor core surrounding parts, i.e. the channel boxes, control rods and burnable poisons [2];
— Ion exchange resin with highly condensed reactor sludge [2];
— Reactor core internals which have been replaced or decommissioned [2];
— Waste from reprocessing plant operation and decommissioning, containing low level TRU elements [3];
— Uranium contaminated waste from the enrichment plants and fuel fabrication [4].

Waste packages in the form of 200 L drums and rectangular metallic containers will be accepted at the new facility.

3.2. Waste and disposal criteria by international organizations

The IAEA is proposing that waste be classified (see Ref. [5]) as: HLW (deep geological disposal), intermediate level waste (ILW) (intermediate depth disposal), and LLW (near surface disposal). ILW is defined as: (a) having little or no heat dissipation; (b) including long lived radionuclides that will not decay to an activity level acceptable for near surface disposal during the time which institutional controls can be relied upon; (c) requiring a higher level of containment and isolation than in the case of near surface disposal; (d) therefore requiring disposal at greater depths of the order of tens or a few hundred metres. This general description can encompass a wide range of waste types.

The IAEA safety requirements for near surface disposal and geological disposal are being harmonized towards the development of a common framework for radioactive waste disposal [6]. Three categories of long lived low level and intermediate level waste (LL LILW) are identified, such as fission products and TRU waste, graphite waste from gas cooled reactors, containing mainly ^{14}C, and uranium contaminated waste. Geological disposal is thought to be appropriate to ensure a high level of passive safety. However, because of their lower hazard potential (as compared with HLW) and their large volumes, disposal at intermediate depth may be envisaged. ICRP in its Publication 81 [7] also mentions that a number of disposal options are available for LILW, such as, on the surface, subsurface, and deeper underground. According to the IAEA, intermediate depth disposal may be a realistic solution for these waste types.

3.3. Waste and disposal criteria in Japan

As mentioned above, LLW consists of four categories in Japan but on the basis of the IAEA criteria, the targeted waste falls between LLW and ILW [5] or is middle or lower LILW [6].

In the report of the Atomic Energy Commission (AEC) of Japan, the subsurface disposal facility requires: (a) enough depth not to restrict the general use of underground spaces, i.e. 50–100 m depth and to be in an area without significant underground natural resources; (b) proper consideration of the groundwater pathway and good hydraulic characterization in choosing a site; (c) adequate barriers; (d) control of the site for a few hundred years.

The concept being considered would not limit the general use of underground spaces and its depth would be such that the strength of the layer supporting the bases of high-rise buildings would not be compromised. HLW is legislated to be disposed of below 300 m in Japan. However, for the targeted waste, disposal at depths in the range 50–100 m seems to be a reasonable and realistic solution considering the much lower inventory of long lived radionuclides in the waste and the much greater volume in comparison with HLW.

4. THE PLAN AND THE CURRENT STATUS OF THE JNFL SUBSURFACE DISPOSAL FACILITY

4.1. General plan

The preliminary site survey was carried out from 2001 to 2002 and the detailed site investigation took place from 2002 to 2005. Based on the results obtained, the design of the facility will be defined and the documents on safety assessment will be prepared. At the same time, it will be essential to obtain acceptance in the local communities.

4.2. The preliminary survey

From 2001 to 2002, the preliminary survey was conducted to acquire data for assessing the possibility of constructing the facility at the site (see Fig. 1). The survey comprised a geological survey, i.e. nine boreholes and seismic prospecting, and a groundwater survey, i.e. permeability tests and water examination.

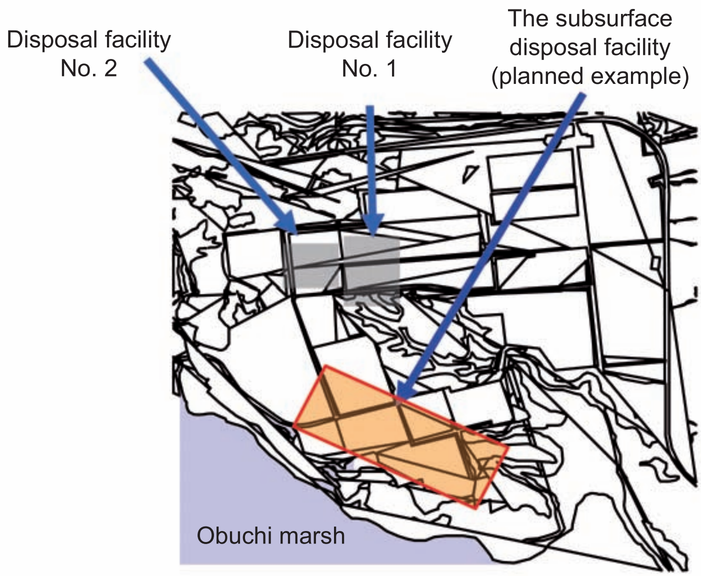

FIG. 1. Example layout of the subsurface facility.

The Takahoko formation, the Miocene deposit, spreads widely at a depth of 50–100 m below ground level at the site. It consists of a middle member (tuff and sandstone), and a lower member (mudstone). It has few cracks and, by triaxial compression tests, it has been found to be strong enough to allow the excavation of tunnels. It has been found, by means of permeability tests, that the groundwater flow is slow and that the movement of radionuclides would be limited. Most water from precipitation runs off the surface or passes through the Quaternary deposit of the surface to the surrounding of the terrace. A portion of it penetrates into the Takahoko formation and flows out to the marsh and the surroundings of the terrace. Considering the past uplift and erosion of the site, i.e. approximately 0.3 m per thousand years [8], these natural processes would not affect directly a facility located 50–100 m below the surface and it would not therefore be a restriction on siting.

As a result of the preliminary survey, it was determined that the facility could be located there.

4.3. The detailed investigation

From 2002 to 2005, the detailed investigation of geology and groundwater was performed in order to collect data for the safety review. To confirm hydraulic conditions and the geochemistry, 13 boring survey holes were drilled, including six boreholes in the swamp and marsh.

The excavation of the 1 km long access tunnel (the entrance level at an elevation above sea level of 8 m and with an incline of 1/10) to the underground investigation area (a depth below sea level of 86 m) was finished in 2004. During the tunnel excavation, geological observations, physics and permeability tests, and pore water pressure measurements, were made in situ. A large test cavern has been constructed at the end of the tunnel to demonstrate the stability of the disposal facility (see Figs 2 and 3). Prior to the excavation, three measuring tunnels were excavated within 20 m of the test cavern to examine the excavation effects.

As a result of the detailed investigations, the small degree of cracking in the Takahoko formation has been reconfirmed, a more precise evaluation of the groundwater flux is being developed and a reducing environment around the facility has been confirmed. Moreover, in the measurements of host rock displacement during excavation, it was confirmed that the formation is strong enough to withstand the excavation of large tunnels, approximately 18 m in diameter.

FIG. 2. The test cavern for investigation.

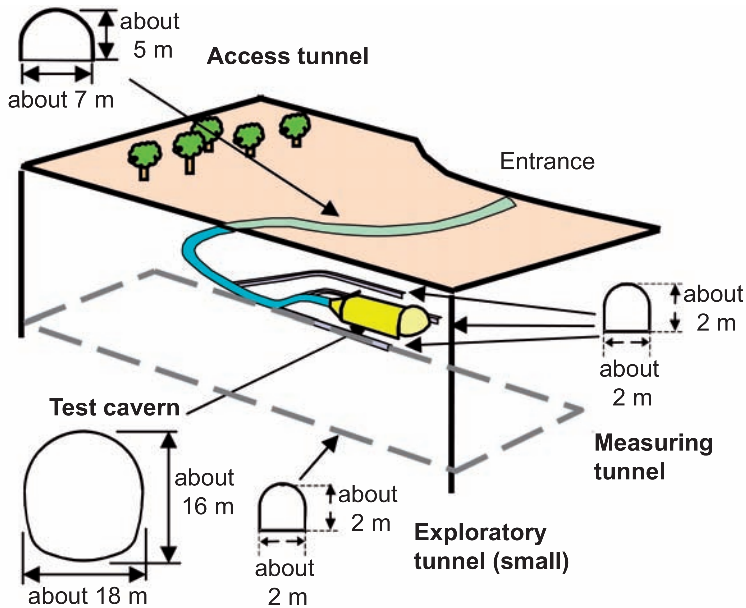

FIG. 3. Image of the tunnel for investigation.

4.4. The concept of the facility

Two types of subsurface disposal facility exist in the world: the tunnel type such as the SFR repository in Sweden and the silo type such as VLJ repository in Finland. Considering the rock type 90 m underground at the Rokkasho site, a tunnel type is considered to be the most appropriate. The diameter of the tunnel will be determined by the results of detailed investigation. In the tunnel, a concrete pit will be installed, which will work both as a basement and as a foundation for the crane to be used to emplace the waste packages.

The multiple engineered barrier system will consist of metallic containers, the filler (low diffusion), e.g. cement, the bentonite (low permeability) and the backfill (see Fig. 4). The host rock works as the support of the engineered barriers and also as the natural barrier. The hydraulic condition and geological properties of the natural barrier have been under detailed investigation.

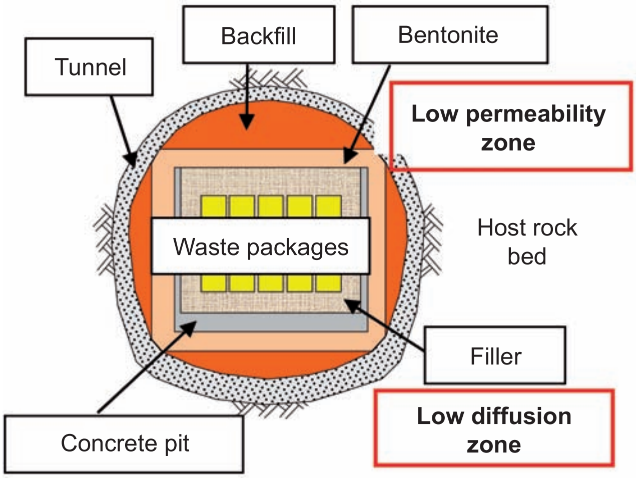

FIG. 4. Cross-section of the subsurface disposal facility.

5. ISSUES IN REALIZING SUBSURFACE DISPOSAL

5.1. Safety assessment

The waste for subsurface disposal includes highly irradiated materials such as in-core stainless steel and graphite containing long lived radionuclides, e.g.^{14}C. It is necessary for the safety assessment of subsurface disposal to make estimates over longer periods than for near surface disposal and it is well known that longer term assessments are subject to uncertainty.

ICRP Publication 81 suggests that one approach for evaluating the performance of waste disposal systems over long time scales is to perform quantitative estimates of dose or risk of the order of 1000–10 000 years. The report of the Nuclear Safety Commission (NSC) of Japan [9] states: “A study may be conducted to examine the validity of the Swedish approach towards taking the best available techniques — that is, attaching relative importance to a time period, such as several thousands of years, during which relatively highly reliable assessments can be made, enhancing the substantial protective capabilities of the disposal system during that period, and thereby securing subsequent longer-term robust protective performance.”

According to ICRP Publication 81, uncertainty analysis should be an integral part of the dose or risk calculation process and, whenever possible, reported results should include ranges on possible values rather than a single point value. Following this, the report of the NSC (see Ref. [5]) also states: “In order to conduct safety assessment with due consideration to this uncertainty, an effective strategy is to apply the risk-based approach that combines the likelihood of a given scenario with its impacts."

For handling uncertainty in long term assessments, it may be appropriate to present results in ranges, and to apply the risk based approach to categorizing scenarios on the basis of their probability and influence.

5.2. Institutional controls

Institutional controls are effective in preventing or reducing the likelihood of human actions after closure. There are two types, one is active controls, e.g. local land use controls and monitoring, and the other is passive controls, e.g. records and markers.

According to the safety concept for near surface disposal in Japan [10], it is necessary to isolate the radioactive waste safely from human activities by means of a graded approach related to radioactivity decay until the exemption level is reached in the activity concentration of the waste. The active control period was estimated as being 300–400 years.

ICRP Publication 81 and the IAEA [11, 12] advise caution in placing excessive reliance on institutional controls, but admit that these controls make a significant contribution to the overall radiological safety by reducing the likelihood of intrusion through ensuring that knowledge of the repository is maintained by means of restrictions on land use and the retention of necessary records. Moreover, it is suggested that consideration be given to local land use controls; site restrictions or surveillance and monitoring; local, national and international records; and the use of durable surface and/or subsurface markers.

The subsurface disposal facility should be under the control of the implementer for several hundred years, during which time the implementer should perform monitoring of the site and enforce the restriction of land use. After several hundred years, some longer term measures should be taken, e.g. the records of the facility should be established and preserved.

6. PROSPECT

Work is ongoing on the conceptual design of the facility and the detailed site investigation. For ensuring the safety of the subsurface disposal facility, it is necessary to predict quantitatively and precisely the function of engineered barriers and of the natural barrier. To prepare the safety review documents it will be essential to construct a safety case of the repository based on the results of the detailed investigation and also referring to the results of studies on geological disposal.

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SMALL DIAMETER BOREHOLE DISPOSAL OF DISUSED SEALED SOURCES

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Abstract

Almost all countries possess disused sealed sources but few have the means to secure their long term safety. The IAEA has been investigating the implications of using specially constructed boreholes as a means of disposing of this type of waste. Under the aegis of the AFRA Technical Cooperation programme the IAEA has commissioned the development of a specific borehole design. This combines stainless steel and concrete to produce a high integrity near field that may, of itself, be capable of containing the radionuclides long enough to allow them to decay to insignificant levels. This allows the possibility of a 'one size fits all' design that can be deployed at a wide range of sites and for a wide range of radionuclides without needing to perform a detailed assessment of the hydrogeology of the site. Consideration of the post-closure safety of such a system suggests a need to place strict, and as yet undefined, limits on the geochemistry of suitable sites.

1. INTRODUCTION

Radioactive sources are used throughout the world for a wide variety of peaceful purposes in industry, medicine, research and education. They have brought great benefits to humankind, such as in the treatment for cancer, the safety testing of welds, the sterilization of medical equipment, and the exploration for oil and minerals. Many radioactive sources exist as so-called 'sealed sources' in which the radioactive material is firmly contained or bound within a suitable capsule or housing. When these sources come to the end of their useful lives, they may still be radioactive enough to be hazardous to people. Unless the source is leaking, the principal hazard is through exposure to external radiation. But, leaking or not, they still need careful management. Often, they can be returned to their manufacturer. But this is not always the case. Even as recently as ten years ago, arrangements for the return of sealed sources to suppliers were not thought necessary. For older sources, it may be impossible to trace the maker. As a result, many countries have disused sealed sources in storage. If they remain there, some of them will require care for hundreds or even thousands of years to avoid hazards to people. Clearly, a permanent solution is required.

Some disused sealed sources are too powerful and/or too long lived for disposal in a near surface facility. Furthermore, their small volume makes disposal in a conventional deep repository devoted only to their disposal uneconomic. To address this issue, the IAEA contracted Necsa (formerly the Atomic Energy Corporation of South Africa Ltd) to develop a practical engineered solution. The outcome of this work is the borehole disposal of sealed sources (BOSS) system, the ultimate aim of which is the safe, secure, permanent and economic disposal of disused sealed radioactive sources. The BOSS system has four main steps:

(1) Recovery and conditioning of sources, which entails the placing of sealed sources within a fully welded 3 mm thick 304 stainless steel container known as a 'capsule';
(2) Safe, secure interim storage;
(3) Containerization of the conditioned sources to form a waste package – this is done by placing the capsule into a hole in a pre-cast concrete insert within a 6 mm thick waste container made from 316 stainless steel. More concrete is placed on top and a lid is welded into place;
(4) Disposal in a specially constructed borehole [1].

These activities may have to be carried out at locations that lack specialized facilities for the handling of radioactive materials. Also, information on the nature, strength and integrity of the radioactive sources may be unavailable or inaccurate. Consequently, all these steps present challenges requiring the development of new techniques and portable equipment [2]. The focus of this paper is on disposal, the last of the four steps and, specifically, the issue of post-closure safety.

2. DESIGN OF THE 'BOSS' BOREHOLE

In the BOSS system, the near field has four main components of which the waste package provides three. Starting from the inside, each disused sealed radioactive source is located inside a 304 stainless steel cylindrical 'capsule' with a fully welded lid. The capsule fits snugly into a hole in a pre-cast concrete insert within an outer cylindrical container made from 316 stainless steel. The container, which also has a fully welded lid, is about 114 mm in diameter and 250 mm long. Leak testing of both the capsule and container guarantees that the radionuclides are safely contained. The fourth component of the near field is the borehole backfill: the concrete that surrounds the waste containers.

A BOSS borehole is about 0.25 m in diameter and about 100 m deep. It will be drilled and constructed using standard techniques developed for water abstraction, oil exploration, etc. The borehole will usually be lined with mild steel or high density polyethylene tubing with concrete pumped into the gap between the lining and the host rock. The purpose of the lining is to aid the package emplacement process, especially by supporting the borehole wall. At the bottom of the borehole is a concrete plug. Once the concrete has set, a fresh batch of backfill concrete is placed in the bottom of the hole and the first disposal package is lowered into this so that it sinks through the fresh concrete and stands on the concrete plug. When this batch of concrete is set, the top of the concrete forms the platform for the next disposal package. The process is repeated until the required number of packages has been emplaced. The topmost disposal package will always be at least 30 m below ground level.

With all the packages in place, the section of borehole lining above the topmost package is removed. A steel deflection plate is placed above the topmost package to prevent inadvertent drilling into the disposal zone and the (now unlined) top of the borehole is filled with backfill concrete to within 2 m of the surface. The final 2 m is filled with native soil. The intention is that, while the general location of the borehole may be well known, its precise location (to within a few metres) will not be. The aim is to improve security by making the borehole difficult to locate without specialized knowledge and equipment.

3. TYPICAL INVENTORY OF DISUSED SEALED SOURCES

The total number of radionuclides in regular use in the form of sealed sources is probably no more than 40 [3]. A few disused sealed sources have very high levels of specific activity — so high, that in some countries they could be classified as high level waste. A mitigating factor is that, when such activity levels are encountered, the radionuclides in question are usually ^{60}Co, ^{90}Sr or ^{137}Cs, all of which have half-lives of 30 years or less.

Of the longer lived radionuclides in disused sealed sources, ^{226}Ra is the most common. This is due to its former popularity for use in cancer treatment. A typical national inventory in a developing country might be less than 4.10^{10} Bq (1 Ci) but inventories of up to 240.10^{10} Bq (2.4 TBq) are known. Other longer lived radionuclides include ^{241}Am and ^{239}Pu (normally as neutron sources in association with beryllium); the former can occur at levels of activity that are similar to (and occasionally higher than) ^{226}Ra. Both these radionuclides have long half-lives (432 and 24 131 years respectively) and both have progeny that are even longer lived.

The only other radionuclides that are likely to occur in greater than TBq quantities are tritium and ^{192}Ir. The latter is sufficiently short lived (half-life 74 days) to make it suitable for decay storage but tritium will usually require disposal.

From this brief discussion it should be clear that, in comparison to the inventories that occur for larger scale disposal practices, the amounts of radioactive material associated with disused sealed sources are relatively small.

4. GENERIC SAFETY ASSESSMENT

Generic safety assessments (GSAs) have been performed for borehole disposal of disused sealed sources as part of the AFRA project [4] and, more recently, for wider application [5]. These assessments are concerned with post-closure safety and their initial purpose was to confirm that the BOSS design was suitable for application in a wide range of African environments. Subsequently, it was suggested that a GSA could be used to simplify the construction of site specific safety assessments. In effect, a site specific assessment would aim to show that the characteristics of a particular site 'fell within the envelope' of acceptable parameters defined by the GSA. Most of these parameters are concerned with groundwater flow and radionuclide transport. The need to determine them would also help to define the site characterization programme. The following sections outline the outcomes of these assessments and the subsequent development of the concept of small diameter borehole disposal as it has emerged from peer reviews and specialist meetings (see Refs [6–8]).

4.1. Natural releases of radioactivity

Conventional deep disposal schemes rely on a combination of near and far field containment. Typically, the schemes aim for the waste package to provide sufficient containment for most of the radioactivity to decay in situ. The role of the far field is then to sufficiently retard and dilute any radionuclides that do escape so that the radiation dose to the exposed critical group falls below the regulatory constraint. The effectiveness of the system usually depends on how well the overall system is able to contain, retard and dilute radionuclides, such as ^{129}I, that are both long lived and mobile. The borehole GSAs have followed this general approach but some recent discussions have suggested that they may be underestimating the value of the corrosion resistance of the stainless steel container and capsule as a containing element.

Most of the radioactivity associated with sealed sources comes from radionuclides with half-lives in the range 5–30 years. These radionuclides are too long lived to be suitable for decay storage but are easily assimilated into disposal schemes. Ten to 20 half-lives will usually be sufficient to allow them to decay to insignificant levels and the corresponding containment time — say 600 years — is well within the lifetime of a well designed waste package. Most notably, very mobile, very long lived radionuclides, such as ^{129}I, are absent from the inventories of disused sealed radioactive sources. Of the radionuclides that are likely to be present, only ^{226}Ra comes close to being in this category. If the waste package could be shown to have a lifetime of tens of thousands of years, this would allow the radium to decay to negligible levels and, more generally, allow the waste package itself to achieve close to 100% containment. A consequence of this is that, to achieve the required level of safety, very much less reliance would have to be placed on retardation and dilution in the geosphere. This would remove the need for a detailed understanding of the groundwater system, which is knowledge that can be difficult to obtain.

The BOSS system uses a 304 stainless steel capsule in concrete and housed inside a 316 stainless capsule that, in turn, is surrounded by more concrete; 304 and 316 stainless steels are both austenitic. Their rates of uniform corrosion are likely to be similar given that the rates appear to be controlled by dissolution of the oxide in the surrounding medium. Electrochemical measurement of the uniform corrosion of 316 austenitic stainless steel at ambient temperature under aerobic, neutral to alkaline conditions indicates a rate of about 0.02 μm/a [9]; the anaerobic rate appears to be similar [10]. With a total thickness of stainless steel of 9 mm (capsule + container) corroding from one side only, this suggests that a time period of 400 000 years would elapse before penetration. The assumption of constant environmental conditions would have to be examined over such long time periods but, if only uniform corrosion occurred, waste package integrity is likely to be maintained for sufficiently long to allow the activity of ^{226}Ra (for example) to decay to negligible levels. Even a time as long as 400 000 years would be insufficient to contain the very long lived progeny of ^{241}Am and ^{239}Pu, but the mobility of these radionuclides in cement is very low and the quantities involved are small so that any impact that they may have on human health will usually be negligible.

Of greater significance is the possibility that localized corrosion of stainless steel could occur. This happens when the prevailing environmental conditions allow an acidic solution to form locally, e.g. within a pit or a crevice where the rate of attack can be rapid. Under some conditions the rate of penetration could be millimetres per year [11]. Conditions that promote localized corrosion include the presence of aggressive anions, especially chloride, elevated temperatures and crevices or surface roughness. Localized corrosion does not occur under anaerobic conditions. Because localized corrosion occurs when conditions become locally acidic, the presence of large quantities of concrete, which is a very alkaline material, tends to inhibit localized corrosion. For instance, in 316 stainless steel at room temperature, a chloride concentration of about 1000 ppm may be enough to initiate localized corrosion at pH 6-7 [7], whereas at pH 13 the chloride level has to be more than ten times higher [12]. A thorough review of the literature is needed to determine the key ions and their acceptable/unacceptable concentrations.

4.2. Human and other forms of intrusion

An OECD/NEA document on near surface disposal [13] states that 20 m is the maximum depth of the 'residential intrusion zone', i.e. the maximum depth of excavation associated with house construction. This may be compared with the BOSS design, which places all the waste packages at more than 30 m depth. Deeper excavations may occur where high buildings are being constructed but this is unlikely to happen away from major cities. With this exception, deeper excavations will only result from mining, cuttings or tunnels for road and railway construction, and for exploratory drilling. If a site has been chosen to avoid mineral resources, mining can be eliminated. If the site has flat topography or if the borehole depth is increased to take the waste below the local topographic base level, cuttings and tunnels for railways and roads can be excluded, which leaves only exploratory drilling.

In general, an advantage of borehole disposal is its small footprint; this makes it very unlikely that another borehole would be drilled in precisely the same place. The BOSS design takes the further precaution of incorporating a steel deflection plate at the top of the disposal zone. The purpose of this is to specifically prevent drilling directly into the waste packages. ICRP Publication 81 [15] calls for:

> "the consequences of one or more typical plausible stylised intrusion scenarios ... [to] be considered by the decision-maker to evaluate the resilience of the repository to potential intrusion."

ICRP Publication 81 is not helpful in determining what might constitute a "plausible intrusion scenario" for a borehole disposal. The AFRA GSA postulated an intrusion borehole at 1 m distance from the disposal while the more recent GSA [4] models assumed an inclined intrusion borehole in which the drill bit penetrates a single disposal container but not the capsule. The effect of natural discharges is calculated by assuming a water abstraction borehole drilled 100 m away. A recent review of ICRP Publication [14] suggests that a borehole at 100 m could itself be almost construed to be a plausible intrusion scenario.

A disposal depth of 30 m is sufficient to avoid human intrusion by excavation. However, given that this is considerably less than the depths used for other forms of geological disposal, non-human intrusions such as that caused by erosion will also need to be considered. Biotic intrusion may be assumed to be prevented by the backfill concrete and the steel container and capsule.

5. SITE CHARACTERIZATION

Important requirements for borehole disposal are that it should be safe, economic and simple to execute. By following the traditional approach whereby reliance is placed roughly equally on near and far field, the GSAs imply that a site characterization programme will be needed to establish the hydrogeology of the site, at least to the extent that parameters, such as infiltration (for unsaturated sites), groundwater flux (for saturated sites), porosity and sorption coefficient can be determined. This may constitute an obstacle to the need for simplicity because the spatial and temporal variability of hydrogeological properties usually makes them difficult to establish with any certainty.

If, on the other hand, long term safety is determined mainly by container integrity, this will increase the need to find a site with suitable geochemistry because of the effect this can have on localized corrosion of stainless steel and degradation of concrete. Consequently, if absolute containment is to be achieved, determining the geochemistry of the site becomes more important than hydrogeology in the site characterization programme. As explained above, an alkaline environment — such as that provided by the use of concrete backfill — provides protection against localized corrosion of stainless steel so that the tolerable concentration of chloride in groundwater could be more than 10 000 ppm. In a system where the groundwater is flowing, however, the level of alkalinity will gradually fall as first sodium and potassium, then calcium and, finally, calcium silicate hydrate phases are leached from the concrete. Such a process will allow the possibility of localized corrosion in the longer term. Of course, with knowledge of the hydrogeology of the site, it should be possible to calculate the time at which the alkalinity falls to a value when localized corrosion could occur and this, in turn, could provide an estimate of waste package endurance. But such a course reintroduces hydrogeology as a key part of the safety assessment and, therefore, of the site characterization programme.

To avoid this unwanted complication, it may be preferable to seek a location with a more benign geochemistry.

The near field design of a BOSS borehole is fixed apart from the number of containers and, possibly, the use of double length capsules and containers where the inventory includes long, pencil-like sources. Optimization of radiological protection is then primarily concerned with arranging the borehole geometry so as to make optimum use of the site. Accepting that the topmost waste package will always be placed at more than 30 m depth, an important function of site characterization is to identify (a) suitable and unsuitable geological formations and (b) the position of the water table and its spatial and temporal variation. Information about the water table is needed because it is judged that, although the BOSS design is suitable for either saturated or unsaturated conditions, alternation between the two is incompatible with corrosion prevention. Because of these constraints it may be appropriate in some circumstances to drill more than one borehole so that the length of the disposal zone can be reduced.

6. CONCLUSIONS

The first imperative of any disposal scheme is to meet national and international standards of safety. Because inventories of disused sealed sources are limited in terms of the volume of waste and the nature and amount of the radionuclides concerned, the use of specially constructed borehole facilities may allow disposal to be effected safely, simply and economically. A depth of at least 30 m is considered to provide sufficient isolation.

The IAEA has commissioned the development and testing of BOSS — a system for the complete management of disused sealed radioactive sources including their disposal in specially engineered, small diameter boreholes. Post-closure safety assessments suggest that the design is capable of meeting national and international standards for long term safety.

If the BOSS borehole design is to be widely deployed, it will need to be tolerant of a wide range of disposal environments. Because of the difficulty of establishing the hydrogeological properties on which radionuclide transport in the geosphere depends, it is envisaged that, in practice, the near field alone will need to be largely capable of providing the required level of containment and, therefore, post-closure safety.

In the BOSS system, this is achieved through the use of a stainless steel and concrete near field. Provided that the stainless steel only corrodes uniformly, this will provide the required level containment. If localized corrosion occurs, however, it may not. A primary aim of site characterization, therefore, is to demonstrate that geochemical conditions at a site will not lead to localized corrosion of the stainless steel.

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THE IAEA PROGRAMME ON ASSISTING MEMBER STATES WITH 'BOSS' BOREHOLE-TYPE DISPOSAL FACILITIES

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Abstract

Radiation sources are being used in almost all countries worldwide. After these sources have been used and when they become waste, the only waste management options available for disused sealed radioactive sources (DSRS) in developing countries are to return them to the supplier, when possible, or to store them safely. The paper presents the IAEA contribution to the development of borehole-type technology dedicated to the disposal of disused sealed radioactive sources and other radioactive waste types from nuclear applications. It also describes the assistance proposed by the IAEA to its Member States through the possible implementation of borehole disposal facilities to solve the long term management issue of disused sources in a safe and sustainable manner.

1. INTRODUCTION

Sealed radioactive sources have been used globally in a wide range of applications in medicine, industry and research for more than a century. At the end of their useful lives, the radioactive sources are defined as spent or disused. However, the residual level of the radioactive material in the sources may still be quite high. Such disused radioactive sources could pose a potential health hazard to the public for periods that, depending on the half-life of the radionuclides, may extend to hundreds and thousands of years. The disused radioactive sources are simply another type of radioactive waste that needs to be disposed of safely.

The high activity content and the high level of specific activity together with the long half-lives of some radionuclides pose problems in managing disused radioactive sources in the context of conventional waste management schemes in most countries. Some radioactive sources, which are long lived and of relatively high activity, do not fall in the category of short lived or low activity waste, normally acceptable for disposal in near surface repositories. This is because the institutional control period of the repository may not be sufficiently long to allow the sources to decay to innocuous levels. The alternative option of geological disposal is not yet available and, in many Member States, may never become available. As a result, disused radioactive sources are currently kept in storage in most countries; a practice that is considered not sustainable in the long run and, in many cases, may represent a high risk situation [1]. Large inventories of disused radioactive sources exist in many countries, which have no other nuclear activities and, therefore, represent the only type of radioactive waste that needs to be managed safely.

During the past decade, the IAEA and its Member States, in particular those within the European Union, have taken steps to lower the risks associated with disused radioactive sources and the likelihood of potential incidents and accidents. Various activities are being implemented to improve the management of disused radioactive sources in order to ensure that they are manufactured, handled, used, reused, transported, stored and disposed of in a technically sound, cost effective and safe manner [2–4].

Although significant progress has been made in the management of low and intermediate level waste (LILW) and of high level waste, the long term safety as well as the security of disused radioactive sources continues to be a subject of concern, in particular the disposal of such sources is still a major topical issue at the international level [5–7]. Quite recently, international concern about the safety and security of radioactive sources was highlighted at an IAEA International Conference hosted by the French Government in Bordeaux, France [8]. Although the conference focused on the safe and secure storage of the sources, issues dealing with the long term management, and specifically disposal, were also discussed in the context of developing a system of national and/or regional repositories for the safe disposal of these sources.

This paper presents the IAEA contribution to the development of borehole-type technology dedicated to the disposal of disused sealed radioactive sources and other radioactive waste types from nuclear applications. It also describes the assistance proposed by the IAEA to its Member States through the possible implementation of borehole disposal facilities to solve the long term management issue of disused sources in a safe and sustainable manner.

2. IAEA ASSISTANCE TO MEMBER STATES IN MANAGING THEIR DISUSED SEALED RADIOACTIVE SOURCES

IAEA activity in disused sealed radioactive source (DSRS) management is concentrated on the provision of comprehensive technical knowledge through information and know-how transfer [2], strengthening national capabilities, developing and implementing innovative technologies that can deal with disused sources in developing countries effectively, and providing direct assistance when required. The assistance provided to operating organizations involved in DSRS management addresses a number of emerging issues:

— Improved characterization procedures;
— Methods to retrieve and verify old waste inventory data with special attention to disused sealed sources;
— Tracking and monitoring of disused sealed sources using a computerized tool developed by the IAEA, the Radioactive Waste Management Registry (RWMR).

Direct assistance is also provided to Member States in the conditioning of disused sealed radioactive sources. The spent radium sources recovery and conditioning project was started in 1995. Its main objective is to provide direct assistance to Member States. This assistance consists of either providing an expert team and the required infrastructure (mobile kit) to condition and render sources safe and secure or providing the technical know-how and the equipment for a national team to conduct such operations. So far, the recovery and conditioning of radium sources has been successfully carried out in more than 50 Member States. Direct assistance to Member States also involves security related missions to check the physical presence of radiation sources, verify source inventories and assess their security.

The return of high activity and/or long lived neutron sources to suppliers is a management option strongly encouraged by the international Code of Conduct on the Safety and Security of Radioactive Sources and which has proven to be very effective in reducing sealed source inventories in developing countries.

3. THE IAEA AFRA[1] PROJECT

In 1995, African delegates at the IAEA Regional Training Course on Management of Low Level Radioactive Waste from Hospitals and Other Nuclear Applications hosted by the Nuclear Energy Corporation of South Africa (Necsa) reviewed their national radioactive waste management programmes. Among the issues raised, common to most African countries, were the lack of adequate storage facilities and disposal options for the long term management of DSRS. With a view to the fact that, in many African countries, DSRS are the main, if not exclusive, components of radioactive waste, the IAEA contracted Necsa to elaborate a disposal concept that could suit African conditions. It was considered that any proposed disposal concept should:

— Recognize that many of the countries concerned do not have a nuclear infrastructure that would allow the construction and regulation of a sophisticated disposal facility;
— Take into account the limited financial resources in some of these countries;
— Be suitable to most, if not all, types of radioactive sources used in African countries;
— Comply with all current safety principles for radioactive waste management in terms of protection of human health and the environment, now and in the future, without imposing undue burdens on future generations.

This led to the design of the borehole disposal of sealed sources (BOSS) concept for disused sealed radioactive sources as a possible disposal option in African countries [9, 10].

In 1996, the development of BOSS by Necsa became part of a new regional project under the IAEA Technical Cooperation Programme and has been funded ever since by the IAEA. The project was then known as the AFRA Regional Project RAF/4/015 (currently RAF/3/005).

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[1] The African Regional Cooperative Agreement for Research Development and Training related to Nuclear Science and Technology (AFRA) is an intergovernmental agreement to promote the development and application of nuclear science and technology in Africa.

Phase I of the project focused on a basic description of the concept and reviewed the inventories and characteristics of spent sealed radioactive sources in some typical African countries. Phase I was completed in 1997.

Phase II consisted of a first iteration to improve individual elements of the concept and to perform a preliminary long term (post-closure) safety assessment. The conclusion of Phase II work was that BOSS easily met internationally agreed safety criteria and that further studies should be conducted to confirm the viability and feasibility of the concept for implementation. Phase II was completed in 2000. Following Phase II, the AFRA Member States repeatedly confirmed their growing need for a practical solution for the disposal of their disused sources at several meetings and training events, and requested the IAEA support for the continuation of the BOSS project.

The objectives of Phase III, initiated in 2001, were to confirm that BOSS constitutes a practical option for African countries to solve their long term management problem with disused sealed sources, to further optimize the reference design, to assess its overall safety and its licensability, and to demonstrate that all technical components of the concept are feasible and can be cost effectively implemented. In addition to the development of a safe and viable concept, the outcome of Phase III work completed in 2005, was the production of a package of supporting documentation by Necsa, covering all technical, safety and regulatory aspects.

An international peer review of the AFRA BOSS system by a panel of senior international experts was organized by the IAEA on behalf of the AFRA Member States in April 2005 with the objective of providing them with the required confidence in the proposed disposal concept and approach, as well as the implementation of such a disposal system, including all aspects of its development and operation under the conditions prevailing in Africa. The overall objective assigned to the review team was to carry out an independent assessment of both the technological and safety aspects of the BOSS system, focusing on the technical feasibility, economic viability and the safety case, including the supporting generic safety assessment.

One of the main outcomes of the international peer review was the positive statement by the expert team that the BOSS concept developed by Necsa had been demonstrated to be a safe, economic, practical and permanent means of disposing of disused radioactive sealed sources. Furthermore, according to the expert team, BOSS is likely to be applicable to a wide range of DSRS and to a wide range of hydrogeological and climatic environments. The experts concluded that the BOSS system should be considered to be a viable waste management option for present-day management of these sources [11].

The series of reports prepared by Necsa during the development phase will be made available to any of the 32 AFRA member countries willing to license and implement a BOSS borehole-type disposal facility.

4. IAEA PUBLICATIONS ON BOREHOLE DISPOSAL

The IAEA has recently published or is developing the following documents on the borehole disposal of radioactive waste. These include both Safety Guides in Safety Standards Series and documents in the Technical Documents Series (TECDOCs):

— Safety Considerations in the Disposal of Disused Sealed Radioactive Sources in Borehole Facilities, IAEA-TECDOC-1368 (2003) [12]. This report discusses the general considerations related to the safe disposal of disused sealed sources, and other limited quantities of radioactive waste, in boreholes facilities. It is particularly aimed at Member States who do not plan to develop other types of disposal facility for nuclear fuel cycle waste.

— Disposal Options for Disused Radioactive Sources, IAEA Technical Reports Series [13]. This report will present a review of relevant information on technical factors and issues, as well as approaches and technologies, leading to the identification of potential disposal options for disused radioactive sources. The report attempts to provide a logical 'road map' for the disposal of disused radioactive sources, taking into consideration the high degree of variability in the radiological properties of such types of radioactive waste. The use of borehole or shaft-type repositories is highlighted as a potential disposal option, particularly for those countries that have limited resources and are looking for a simple, safe and cost effective solution for the disposal of their radioactive source inventories.

— Borehole Facilities for the Disposal of Radioactive Waste, IAEA Safety Guide [14]. Based on the contents of IAEA-TECDOC-1368 above, this document will provide guidance on how the design, construction, operation and closure of borehole facilities for the disposal of radioactive waste should be implemented to meet the relevant IAEA Safety Standards. The safety guide is focused on boreholes with a diameter of no more than a few hundred millimetres and a depth beyond a few tens of metres and up to a few hundred metres for the disposal of disused sealed sources and small volumes of low and intermediate level wastes.

— Generic Post-Closure Safety Assessment for Borehole Disposal of Disused Sealed Sources, IAEA Safety Report [15]. The objective of this report is to document a generic post-closure safety assessment for the borehole disposal concept with the purpose of identifying the key safety features of the borehole under the varying disposal system conditions that might be found in order to support concept design and the licensing processes, and to help guide and facilitate a site specific implementation of the concept.

5. FUTURE IAEA PROGRAMME ON BOREHOLE DISPOSAL OF DISUSED SEALED RADIOACTIVE SOURCES

The generic disposal concept designed by Necsa has been demonstrated to be suitable for a reference inventory representative of sealed sources found in African countries and for a wide range of geospheres and biospheres typical of African conditions [16]. Further site specific adaptation and optimization of the generic concept is expected in order to take account of the safety sensitive features of the site and thus conform to the internationally accepted ALARA principle. Once AFRA candidate countries volunteer for the implementation of a borehole disposal facility and provide accurate country specific information on their source inventory and site characteristics, it will be required to verify that these data fall within the design requirements of the generic concept, and to reassess the safety and feasibility of BOSS on the basis of those country specific conditions.

The international peer review of BOSS successfully concluded the development phase of the project initiated in 1996. Following the positive assessment of the technical feasibility, economic viability and overall safety of BOSS by the expert team, the AFRA member States have decided to reconduct the AFRA regional project for a new five year cycle 2005–2009, identifying the implementation of the borehole disposal technology as one of its main priorities. This decision implies that additional efforts will be needed by AFRA members States supported by the IAEA to make available all necessary requirements and conditions for the implementation of the BOSS disposal system in African countries. The ambitious objective assigned to the new regional project, RAF/3/005, which took over from RAF/4/015, is to have at least one borehole disposal facility licensed and operational by 2009 in one of the AFRA member countries.

Several IAEA developing Member States from other regions have also expressed their intent to assess the suitability of BOSS as a disposal option to solve the long term management issue of their DSRSs and other radioactive waste from nuclear applications. For example, under a new regional project, several Latin and Central American countries have come together under the auspices of the IAEA Technical Cooperation (TC) Programme to explore the possible options for the safe and sustainable management of all types of DSRS and investigate the applicability of the BOSS approach for their small inventories of DSRSs. More recently, at a regional workshop held in Manila, Philippines, nine countries from the Southeast Asian region also expressed their interest in the BOSS concept.

For all these countries with small inventories of radioactive waste, mostly DSRSs, BOSS borehole disposal facilities can be readily deployed with simple, cost effective technologies that are appropriate both to the relatively small amounts and activities of the waste and to the limited resources that can be found in most developing countries. In spite of their apparent simplicity, borehole facilities comply with the same high standards of long term radiological safety as any other type of radioactive waste disposal facility [16].

Since many developing Member States have not yet acquired the necessary expertise to deal with the safe conditioning, storage and disposal of their disused radioactive sources, the IAEA has been assisting these Member States over the last decades in performing this task. As far as BOSS is concerned, the IAEA, through its TC Programme, may assist, upon request, Member States wishing to know about the requirements to be fulfilled for a possible implementation of a BOSS borehole disposal facility. Subject to the availability of resources, the IAEA TC support normally consists of advisory assistance, expert services, access to relevant documentation and training of personnel to establish the necessary infrastructure and capabilities in the country. In the future, the IAEA may consider providing assistance in funding the implementation of BOSS at the request of a Member State or a group of Member States, such as through the regional agreements. The principles, rules and procedures that are applicable to IAEA technical assistance apply, as appropriate, to any such IAEA support in relation to BOSS. More information on BOSS and the IAEA technical cooperation programmes is available on the IAEA web site (www.iaea.org).

6. CONCLUSIONS

One of the steadily increasing needs of IAEA Member States over the last years is concerned with the management of DSRSs. These DSRSs can be encountered in almost all countries. In a number of developing countries, DSRSs often constitute the main if not the only radioactive waste. Furthermore, most developing countries worldwide have no access to existing or planned disposal facilities for radioactive waste. The only options for managing high activity or long lived DSRSs are to store them safely and securely, or to return them to the supplier. As DSRSs pose an unacceptable radiological and security risk if not properly managed, the majority of IAEA Member States from the African region have been investigating suitable solutions to this problem. One of the top priorities assigned to the AFRA project RAF/4/015 was to explore possible disposal options for their small inventories of DSRSs.

The BOSS system developed in the framework of the AFRA project appears to be a safe, economic, practical and permanent means of disposing of DSRSs according to the findings of an international peer review team appointed by the IAEA to evaluate the technical feasibility, economic viability and the overall safety of the system. Following this positive assessment, a number of IAEA Member States have expressed their willingness to look into the possible implementation of BOSS to solve the long term management issue of their DSRSs and other waste from nuclear applications and have requested IAEA support.

The AFRA member States have decided to reconduct the AFRA regional project for a new five year cycle 2005–2009, identifying the implementation of the borehole disposal technology as one of their main priorities. The ambitious objective assigned to the new regional AFRA project in radioactive waste management is to have at least one borehole disposal facility licensed and operational by 2009 in one of the AFRA member countries. The IAEA has planned and budgeted a number of activities to support the implementation of BOSS in AFRA candidate countries.

Through its Programme and subject to the availability of resources, the IAEA may consider providing assistance in funding the implementation of BOSS at the request of a Member State or a group of Member States. If approved, IAEA support will consist of advisory assistance, expert services, access to relevant documentation and training of personnel to establish the infrastructure and capabilities needed in the country for the successful licensing, implementation and operation of a BOSS borehole disposal facility.

ACKNOWLEDGEMENTS

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REVIEW OF CONTRIBUTED PAPERS

Session IIIc: OPTIONS FOR INTERMEDIATE DEPTH DISPOSAL

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Abstract

On the basis of the invited and contributed papers to this session, the paper assesses the need for radioactive waste disposal at intermediate depths. It examines the nature of the waste types that would benefit from disposal at intermediate depth and examines the advantages and disadvantages of the concept. Finally, it explores the need for specific safety requirements and guidance for this category of disposal facility.

1. THE NEED FOR INTERMEDIATE DISPOSAL

Radioactive waste can be classified into six categories: (1) exempt waste, (2) very short lived waste, (3) vry low level waste, (4) low level waste, (5) intermediate level waste and (6) high level waste. The first two classes, exempt waste and very short lived waste, contain small concentrations of radioactive material. In the first case no radiation protection provisions are required, irrespective of whether the waste is disposed of or recycled. The second class contains only radionuclides with very short half-lives; such waste can be stored until the activity has fallen below the levels for exempt waste.

Substantial amounts of waste arising from the nuclear fuel cycle and other practices, including those with naturally occurring radionuclides having activity concentration levels close to those for exemption and clearance of material from regulatory control. This waste type can be referred to as very low level Waste (VLLW) and it requires some radiation protection provisions for its management. An adequate level of safety for such waste may be achieved by disposal in near surface facilities without engineering barriers (trench disposal).

Low level radioactive waste covers a very wide range — from just above levels for VLLW to waste that requires shielding, containment and isolation for periods up to several hundred years. This waste is normally disposed of in near surface facilities with engineering barriers.

High level waste (HLW) contains large concentrations of both short and long lived radionuclides, so that a high degree of containment and isolation from the biosphere is needed, usually provided by deep geological disposal with engineered barriers. HLW generates significant quantities of heat from radioactive decay, and normally continues to generate heat for several centuries.

In addition to the waste types mentioned above, a class of radioactive waste exists, intermediate level waste, which contains long lived radionuclides in quantities that need a higher degree of containment and isolation from the biosphere than provided by near surface disposal facilities, but not so high as that provided by a geological disposal system. For example, in Japan, the following types of intermediate level waste are considered for planning the national radioactive waste disposal strategy: (a) the reactor core surrounding parts, i.e. the channel boxes, control rods and burnable poisons; (b) some of the ion exchange resin with highly condensed reactor sludge; (c) the reactor core-internals to be replaced or decommissioned; (d) and waste coming from reprocessing activities. This category includes also waste, such as ^{14}C in graphite, radium and certain reactor components with long lived activation products.

Additionally, the same extra containment and isolation from the biosphere is needed for a large range of disused spent sources. The lack of regulatory control of these radioactive sources presents a safety problem in developing countries, where disposal is seen as the final solution of the problem.

It might be concluded that both types of radioactive waste, ILW and disused radioactive sources, require an additional level of safety to that provided by near surface disposal systems (trench and vault). Some extra metres of depth, between a few tens and a few hundreds of metres, will provide the additional level of safety needed. The extra metres of depth provide a longer period of isolation from the accessible environment and the likelihood of inadvertent human intrusion is greatly reduced.

Based on these facts it can be concluded that there is a real need for mid-depth disposal. Table 1 shows that in Japan there is an estimated 25 000 m^3 of waste requiring mid-depth disposal. The IAEA safety standard on waste classification does not refer to the mid-depth disposal concept, and consideration should therefore be given to its updating.

TABLE 1. VOLUMES OF RADIOACTIVE WASTE GENERATED IN JAPAN

Volume, m^3	Disposal concept
88 431	Shallow land disposal, depth several m
26 641	Geological disposal, depth greater than 300 m
25 205	Mid-depth disposal, depth 50–100 m

Source: SHIOTSUKI, M., et al., IAEA-CN-135, Contributed Papers, CD-ROM, these Proceedings.

2. THE CONCEPT OF INTERMEDIATE WASTE DISPOSAL

Near surface and deep disposal concepts are the most well accepted ways for disposing of low and high level radioactive waste, respectively. Examples of those systems are the LLW disposal facility at El Cabril, Cordoba, Spain and the planned Yucca Mountain HLW disposal repository in Nevada, United States of America (Fig. 1). Other concepts for co-location of TRU with HLW are shown in Fig. 2.

However not all the radioactive waste can be disposed of in these kinds of facilities for reasons of safety and economy and intermediate depth disposal may be a realistic solution for the other waste types.

An intermediate waste disposal facility can be defined as a disposal concept between near surface and deep disposal, far enough from them to be conceptually different and with a mix of features, characteristics, properties, advantages and disadvantages from both concepts.

The following questions could be raised at this point:

— Is the intermediate depth disposal concept a category of waste disposal system by itself?
— Is it independent from near surface and geological disposal?
— What are the properties that define and characterize this category of waste disposal?

3. TYPES OF INTERMEDIATE DEPTH DISPOSAL FACILITIES

Once we accept that the intermediate depth disposal is a category of a waste disposal system, the next step is to identify the types of facilities which belong to it. Two different existing designs of intermediate disposal facilities

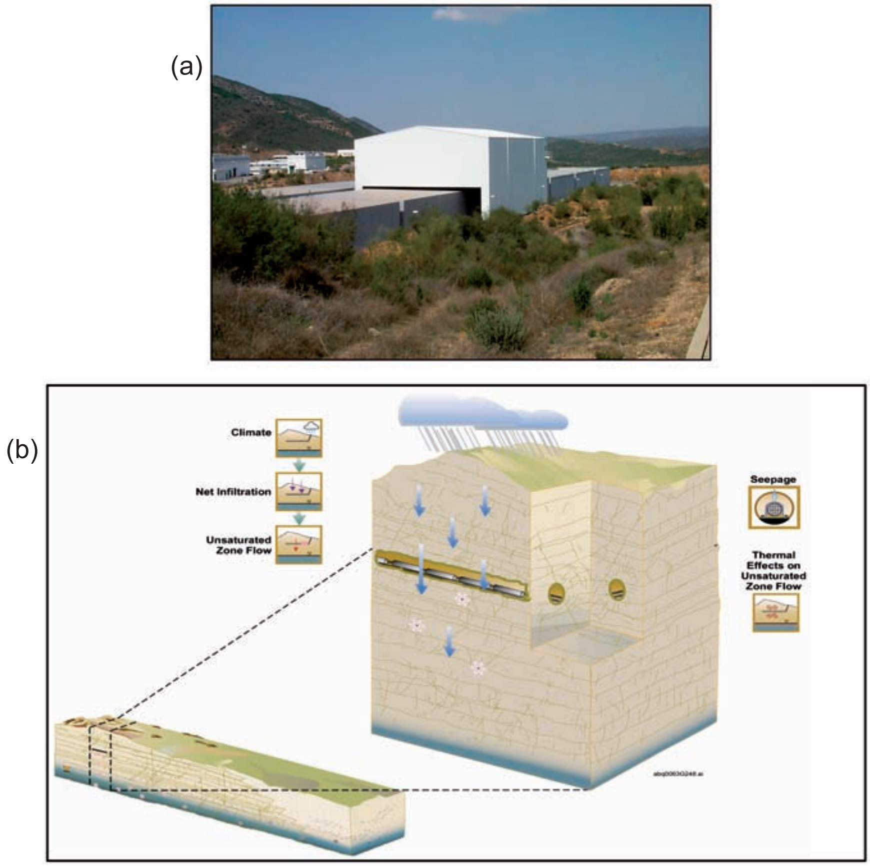

FIG. 1. (a) Near surface disposal facility (El Cabril, Cordoba, Spain) and (b) the planned Yucca Mountain disposal concept (Nevada, USA).

could be part of this category: subsurface disposal facilities and borehole disposal facilities.

3.1. Subsurface disposal facilities

Disposal in rock caverns, several tens of metres below ground, has usually been considered to be a variety of near surface disposal. It is obvious that the additional metres of depth make the properties of the facility substantially different from those of near surface disposal facilities. The fact that the rock caverns are deeper than near surface facilities might indicate that they have similarities with the geological disposal concept.

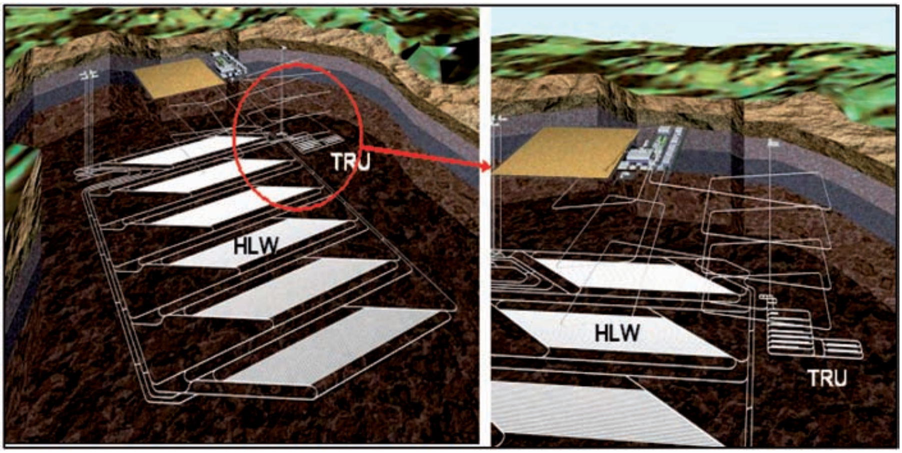

FIG. 2. 'Birds-eye view' of an example concept for TRU co-located with HLW. (Source: SHIOTSUKI, M., et al., IAEA-CN-135, Contributed Papers, CD-ROM, these Proceedings.)

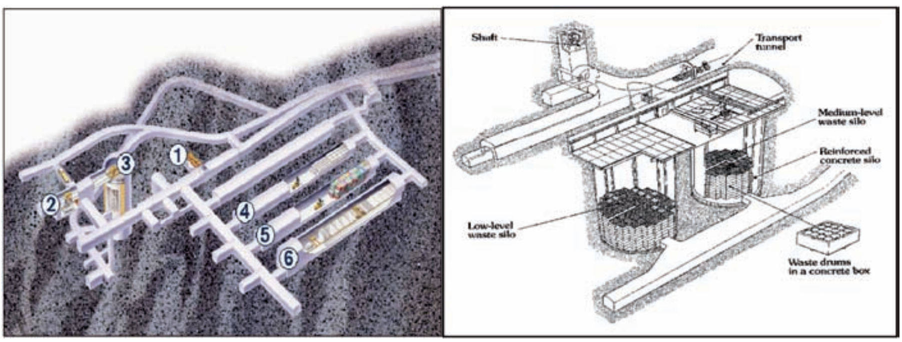

FIG. 3. Swedish and Finnish intermediate disposal concepts, tunnels and silos respectively.

The papers of this session offer two examples of this category of disposal system:

— Forsmark in Sweden is a tunnel type facility (see Fig. 3). It is in operation for the disposal of low level and intermediate level waste. It is located 50 m below the bottom of the Baltic Sea and has a total disposal capacity of 60 000 m^3.
— Olkiluoto and Loviisa disposal facilities in Finland are at depths of about 100 m in crystalline bedrock. The Finnish repositories have two separate silos, one for low level and the other for intermediate level waste (see Fig. 3). The total capacity of the silos is about 40 000 drums (200 L each)

corresponding to the accumulation of waste over 40 years from the operation of each of the nuclear power plants at the sites.

3.2. Well type repository, the borehole concept

The well type repository was used in the past in several countries for the disposal of low and intermediate level waste, including disused radioactive sources from medical, industrial and research and development activities. Because of their shallow depth these repositories are closer to the near surface disposal concept, rather than to the intermediate concept. A typical example comes from the RADON facilities from the former Soviet Union republics. RADON facilities integrate in one site: near surface trenches, vaults and well type repositories at a depth of several metres (Fig. 4).

Countries are undertaking projects aimed at upgrading the safety of these facilities. In some cases, an intermediate disposal system (as defined in this paper) could be the solution for the waste not appropriate for near surface disposal.

The deep borehole option for HLW and spent fuel was also explored in the past in the USA, Sweden, Denmark and Switzerland, as a deep geological disposal facility. For the deep borehole option, solid packaged waste would be placed in deep boreholes drilled from the surface to depths of several

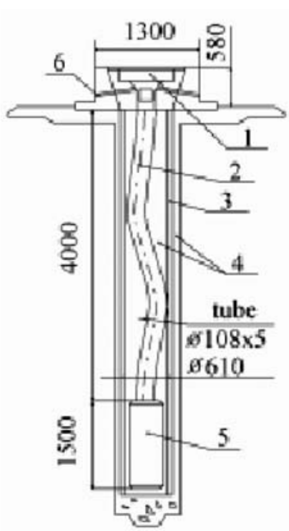

FIG. 4. Typical RADON well type disposal.

kilometres with diameters of typically less than 1 m. The top 2 km would be sealed with materials such as bentonite, asphalt or concrete.

A variant of these systems is the BOSS borehole concept (Fig. 5) for disused spent sources, proposed by the IAEA as a convenient solution for the disposal of spent sources in developing countries. A BOSS borehole is about 0.25 m in diameter and about 100 m deep. It will be drilled and constructed using standard techniques developed for water abstraction, oil exploration, etc. The topmost disposal package will always be at least 30 m below ground level.

Therefore, it is concluded that both disposal designs, the subsurface facility and the BOSS borehole system, belong to the category of intermediate depth disposal.

The following questions can be raised at this point:

— Despite the fact that both designs (subsurface and borehole) are completely different, they share the same properties and features that make them different from a near surface and a geological disposal system. Do they have the same safety features? Do they need the same safety requirements?
— Are the safety requirements for these facilities (subsurface and borehole) different from those for near surface and geological disposal?

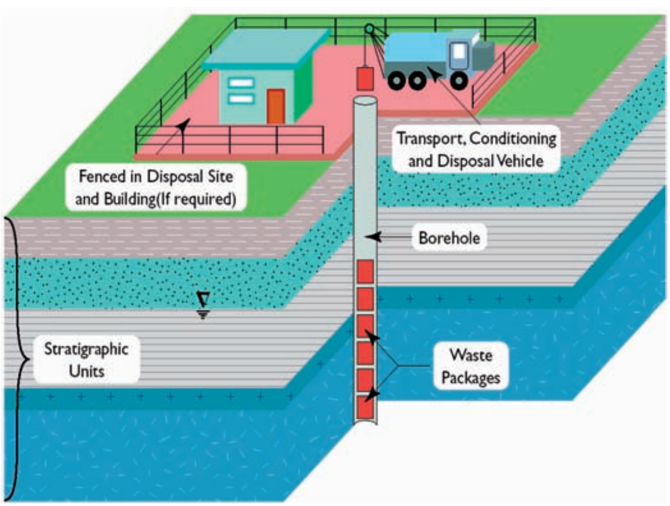

FIG. 5. The IAEA borehole disposal concept.

4. NATIONAL AND INTERNATIONAL DEVELOPMENTS ON INTERMEDIATE DISPOSAL SYSTEMS

Japan is planning the construction of a subsurface disposal facility. The proposed design is a tunnel type facility, such as the one in Forsmark, Sweden. The Japanese authorities are working on the conceptual design and carrying out detailed site investigations. The safety case will be based on the results of the research and development activities related to the site and its environment.

At the same time, the Nuclear Safety Commission of Japan, and the Government are working on the definition of the safety requirements for the facility and on safety standards and criteria for reviewing the disposal facility safety case.

The following questions can be raised at this point:

— Are the safety requirements well established and defined?
— Does a set of international or national safety standards and guides exist for intermediate disposal practices?
— Is the IAEA effort dedicated to the subject well balanced, or is there too much focus on the borehole concept?
— Is borehole disposal the best approach for the disposal of disused radioactive sources or should the subsurface approach be used?

5. SOME CONSIDERATIONS ABOUT THE SAFETY OF THE CONCEPT

— *Regulatory framework.* In order to license an intermediate disposal facility (subsurface or borehole) it is necessary to demonstrate the safety of the system, therefore the appropriate regulatory safety requirements have to be taken into account. However, there are no published IAEA safety requirements for intermediate waste disposal nor a safety guide for the safety assessment of such a facility.
  - To what extent are the documents on near surface and geological disposal relevant?
  - Is a specific safety requirements document needed?
  - Or would it be enough to have a generic set of safety requirements for disposal?

— *Time frames.* The timescale of interest is a function of the nature and depth of the disposal system, the surrounding environment, and the longevity of the radionuclide. The near surface disposal timescale of interest for safety demonstration is around 300 years. In the case of geological disposal, it is greater than 10 000 years. The range for an intermediate disposal facility is between several hundreds and several thousands of years, depending on the depth and on the host geological environment. The longer the timescale the greater the uncertainties in predicting the evolution of the engineering and natural systems and therefore the more difficulties in demonstrating safety.

- Do we need to use the same concepts, techniques and methods as for the safety assessment of a deep disposal facility in stable geological formations?
- How close is the intermediate disposal concept to a geological disposal concept?

— *Groundwater water pathway.* Exposure to the human receptor occurs through drinking water pumped from a well intercepting the radionuclide plume or as a result of the discharge of radionuclides into surface water bodies. For of a near surface facility this is one of the principal exposure pathways to consider. Although for the intermediate disposal system this transfer route can be avoided, the precise value of the benefit of placing a repository at some tens of meters below the surface, with regard to chemical and hydrological conditions, must be evaluated by means of a site specific assessment.

- How difficult is it to find a site with hydrological conditions such that there is no contact with ground water in the short, medium and long term?

— *Natural phenomena*. Biological and physical processes such as plant uptake, burrowing animals, resuspension, and runoff erosion are some of the pathways that can be avoided at intermediate depth.

— *Intrusion.* Intrusion is one of the main issues for any repository at a depth where drilling for drinking water may penetrate the repository's barriers. The likelihood of human intrusion may be obvious for some repository locations, either because of the potential presence of minerals, or simply because of the shallow depth of near surface facilities. At a depth of 500 m in a host rock with no mineral deposits, intrusion is very unlikely, although various scenarios can always be imagined such as deep drilling in hydrothermal energy projects or excavating for deep underground transport.

- Is intrusion an issue in an intermediate disposal system? Or can it be ruled out without any further consideration ?

6. CONCLUSIONS

Some general conclusions that could be made from the keynote and contributed papers are listed below:

- There is a need for intermediate depth disposal for safety and economic reasons.
- The existing disposal facilities at mid-depth (subsurface and borehole) can be grouped in a common category, 'intermediate disposal'.
- The major advantages of this concept are the longer containment period and the limited impact of intrusion as compared with near surface disposal.

PANEL

Session IIIc
OPTIONS FOR INTERMEDIATE DEPTH DISPOSAL

Chairperson: **J. Loy** (Australia)

Members: **M. Jensen** (Sweden)
A. Yamato (Japan)
I.G. Crossland (United Kingdom)
C. Torres Vidal (Spain)
R.H. Gil Castillo (Cuba)
P. Raimbault (France)
J.-M. Potier (IAEA)

P. RAIMBAULT (France): I would like to complete the picture regarding intermediate depth disposal and present a concept developed in France for disposing of a certain category of waste. This was already touched upon in Session IIb by R. Cailleton, when he described the French national plan for radioactive waste management.

In the national plan, a category of waste without a long term management solution has been identified; it is long lived low activity waste. This type of waste includes graphite waste and radium-bearing waste.

The graphite waste comes from the decommissioning of six graphite-moderated gas-cooled reactors which operated in France at three sites and it contains ^{14}C and ^{36}Cl in such amounts that it is not suitable for surface disposal. The specific activity of ^{36}Cl is 1500 Bq/g.

The radium-bearing waste comes mainly from the processing of monazite, which contains the rare earths zirconium and uranium. Also, there is some historical waste. For this waste, the average specific activity of the radium is 220 Bq/g. With this concentration of radium, surface disposal is not appropriate. This waste is now in interim storage at Cadarache, the licence for it is valid only until 2010. So, we have to find a solution fairly soon.

The concept proposed by ANDRA for this kind of waste is a subsurface repository 15 m deep in a clay layer about 50 m thick. The depth would ensure that the radon does not reach the surface. Also, this kind of site would retain the ^{36}Cl in the low diffusivity material. The total surface area would be about 150 ha. It is an economical way of disposing of this kind of waste.

The proposal has been sent by ANDRA to the nuclear safety authority and is currently under review.

R.H. GIL CASTILLO (Cuba): I would like to report briefly on our experience regarding subsurface disposal. In the early 1980s we embarked on a programme for the establishment of a final disposal site for radioactive waste from our planned nuclear power programme. We carried out a site selection process in order to identify favourable sites. In accordance with our regulatory requirements, we developed a conceptual design for a subsurface disposal facility excavated in rock at a depth of about 50 m. This kind of design has several advantages compared to near surface disposal; there is a lower risk of human intrusion and the natural barriers would contain any release. However, when our nuclear power programme was stopped, we faced a dramatic reduction in the anticipated waste inventory and the programme for the development of a disposal facility was therefore also terminated.

We have recently started to consider another subsurface concept — the borehole concept. We are thinking about the concept as a possible method for disposing of disused sealed sources from our nuclear applications.

Our conclusion from a preliminary safety assessment of the concept is that it is possible to dispose of disused sealed sources in this way. This type of concept uses the geological environment to provide containment and to reduce the risk of human intrusion. Also, the concept has some economic advantages for the type and amount of waste to be disposed of.

J. LOY (Australia): Perhaps we could address the question “Is intermediate depth disposal a waste disposal system by itself, independent of near surface and geological disposal — a new field for safety evaluation?”

J.-M. POTIER (IAEA): If we compare near surface disposal facilities to geological repositories, there are at least two major differences. For the near surface disposal facilities, the containment provided by the engineered system is a more prominent feature than for the geological repositories, where normally the geological environment plays a major role in providing isolation and containment. Regarding intrusion, the likelihood of intrusion into a surface or near surface disposal facility is very high. The likelihood of intrusion in the case of geological repositories is rather low.

For the borehole solution, the reason for going underground is that most disused sources are not acceptable in existing surface disposal facilities because of the risk associated with intrusion. By going deeper underground the intrusion risk is minimized. At a depth of a few tens of metres, the likelihood of intrusion is lower. This is one reason.

Another reason for going deeper is to rely not only on the engineered systems but also on the geological environment to provide containment. In that sense, the principles which have guided the design of the borehole concept are most similar to those for geological repositories — lower intrusion probability and a balance between the geological environment and the engineered system.

I.G. CROSSLAND (United Kingdom): As regards the question whether intermediate depth disposal requires a separate classification, my answer is an unqualified "No" — for many reasons. For example, the IAEA is already trying to work towards a common framework — attempting to provide common standards for near surface disposal, deep disposal and even for NORM disposal. So, I see no need for making intermediate depth disposal a separate category.

There is another issue — if we categorize a third type of disposal as intermediate depth disposal, a consequence is likely to be that it will be said: "Long lived waste goes very deep, intermediate waste goes to intermediate depths and low level waste goes to the surface." However, it is not as simple as that: 'deeper' does not always equate with 'safer'. There are some cases where it would be safer to dispose in a plastic clay layer near to the surface than it would be to go deeper into the underlying aquifer.

The other point is that the requirements for intermediate depth disposal and for deep disposal are identical — isolation, containment, passive safety, multiple barriers and so on. There is no difference at all. There is no necessity for separate safety requirements.

So, I come back to the point which I made earlier: when trying to allocate a depth — to find a suitable depth for a specific waste — in the end it comes down to two things: what is the waste and what is the site? Essentially, the waste will go as deep as it needs to go. There is no real need to try to make any further subdivisions.

C. TORRES VIDAL (Spain): There is something that is different between the concepts — the kind of safety demonstration you need to make in order to demonstrate long term safety. The timescale is very important. For near surface disposal it is only of the order of 100 years, whereas for geological disposal it is more than 10 000 years. That is the driving force for the kind of safety assessment one has to carry out in order to prove the safety of the concept.

With 'intermediate' we do not know whether we are closer to 'geological' or closer to 'near surface', and therefore what kind of safety assessment we have to make.

M. JENSEN (Sweden): I agree with I.G. Crossland that the requirements seem to be very much the same — so I do not think there is a need for a separate safety requirements document. However, as pointed out by C. Torres Vidal, there are some other features that might be worth looking at, but I do not think that it should be in a safety requirements document — it should be a different kind of document.

In Sweden, the regulations regarding dose are the same for all kinds of repositories except for some very low level waste repositories where we think that a safety assessment does not need to be made because it is not worth the effort.

P. RAIMBAULT (France): For short lived waste, surface repositories can solve the problem in most cases. For long lived waste, the solution depends on the activity level. For intermediate level waste, there may be a range of possibilities and, for specific types of radionuclides, near surface disposal is not appropriate. For high level waste, it is necessary to go deep and to have good geological material there. In the case of long lived waste it is necessary to provide isolation for waste of very high activity.

M.W. KOZAK (United States of America): Regarding the timescale issue which C. Torres Vidal raised and, indirectly, the issue of short lived low level waste, there is always some long lived component present in such waste and we can never cut off safety assessments at times as short as 300 years.

I agree with other speakers that the criteria are the same for both. In my view, intermediate depth disposal is probably a bit more like near surface than geological disposal, but perhaps that is due to my historical US perspective, because the US low level waste law contains a provision that allows you to place higher activity waste a little deeper in order to avoid intrusion. That is where the class B/C in the US system comes from. Perhaps one can usefully think in terms of a deep near surface facility, which has all the elements of a near surface facility except that one cannot dig into it any more.

J. LOY (Australia): So, you see it as a deep near surface facility and I think that J.-M. Potier sees it as a shallow geological repository. Perhaps there is some meeting of the minds at about 100 m!

W. BREWITZ (Germany): In the central part of Europe, our groundwater resources are at depths in the range being discussed here. Therefore, we have to apply the same type of safety analysis as for deep geological disposal if we are to have a robust and safe system.

I.G. CROSSLAND (United Kingdom): All I am trying to do is avoid having rigid categories of ‘deep’, ‘intermediate’ and ‘shallow’. In reality, nothing is so clear-cut — you need to make a case for each specific site. And if, even for fairly short lived waste, there was a problem with groundwater at a particular location, you would not locate a repository there.

P.E. METCALF (IAEA): In his presentation, I.G. Crossland described an engineered system comprising a very high integrity container made of stainless steel which is expected to last for a very long time in a particular geochemical environment. Would such a system not also be suitable in an environment where there was water present?

I.G. CROSSLAND (United Kingdom): Essentially, the BOSS concept can be implemented in either saturated or unsaturated conditions. What one must try to avoid is a mixture of the two. Cases where the water table is moving up and down through the borehole should be avoided.

C. McCOMBIE (Switzerland): I agree that the safety goals have to be the same for both near surface and deep disposal. Also, the safety approach does not differ drastically between the two.

We have to consider human intrusion and also natural evolution, which has not been mentioned here. Regarding human intrusion, there is a huge difference in the safety assessment if people cannot have easy access to the waste.

With regard to natural evolution — some of the most troublesome long lived nuclides can be retarded significantly if they are within a geological setting. However the geology must be stable over the timescales of concern.

M.W. KOZAK (United States of America): There are not really that many differences. To some extent, it is a myth that geological disposal relies primarily on the geology. We should bear in mind that in Sweden and Finland they have million year canisters — and the canisters for Yucca Mountains are intended to last for hundreds of thousands of years. A lot of benefit is being derived from the engineered systems. It is not primarily the geology that is providing isolation, although it does provide a benefit — and it provides a greater benefit at depth. So, there is really a lot of similarity. I also see far more similarities than differences, with the exception of intrusion.

J. WANG (China): The advantage of near surface disposal is that it is above the water table and therefore the siting requirements are considerably reduced. For intermediate depth disposal, siting requirements are needed. If there were no siting requirements for borehole disposal or intermediate depth disposal, it might be very difficult to make a convincing safety case.

Intermediate depth disposal is just at the depth of very active water movement, and the siting requirements should therefore specify avoidance of aquifers. So, when choosing a site for an intermediate depth repository, clay or layers without water movement would be best.

J. LOY (Australia): Perhaps we could consider the two examples of intermediate depth disposal being talked about — on one hand, subsurface tunnel or cavern disposal and, on the other hand, borehole disposal. Have they any similarity at all, or are they so different that they should not be talked about together? And is the emphasis that the IAEA places on the borehole approach appropriate?

M. JENSEN (Sweden): The issue lies in the probability of intrusion into a borehole. Whether that is acceptable would depend very much on the feelings of the society that might be affected by the disposal. If the likelihood of intrusion into a borehole facility in the future is very small, I think that most people would accept it.

C. TORRES VIDAL (Spain): How much work at the international level has to be done in order to address the subsurface disposal concept? As far as I know, there are no international safety standards relating to it, and yet there are already some subsurface facilities being operated, and we hear that France and Cuba are contemplating the establishment of such facilities.

I.G. CROSSLAND (United Kingdom): I do not think that work at the international level is needed — the existing standards for geological disposal are perfectly adequate. They can be applied equally well to intermediate depth as to deep disposal. In the end it is a question of the suitability of the site, the inventory, the dose calculations, and the human intrusion probabilities — and all these things are already catered for and very easily transferable to disposal at a lesser depth.

C. TORRES VIDAL (Spain): I would like to hear from Japanese or French colleagues who are facing the problem. I imagine that, if we faced this problem in Spain, it would not be so easy to advise using the deep geological regulations to license a near surface facility.

I.G. CROSSLAND (United Kingdom): Recently, when drafting a safety guide on borehole disposal, I consulted the existing documents on deep disposal and near surface disposal safety. I did not find anything in one document that contradicted the other and I did not find much in one document that was not in the other. If there is a significant difference between near surface and deep disposal, it concerns institutional control and the admissibility of extended institutional control being part of a safety case for a near surface disposal facility. That was the only difference between the two documents. So, if the two documents are so similar, and they were written ten years apart, it seems to me that, if you start to produce safety requirements for an intermediate depth facility, you will just end up with the same things.

P. RAIMBAULT (France): Regarding what C. Torres Vidal just said regarding disposal at intermediate depths, in order to ensure safety you have to study all kinds of scenarios, including scenarios that do not correspond to geological disposal. In fact, there are specific scenarios to consider if you are not very far from the surface, and in order to ensure and demonstrate safety they must be addressed.

R.H. GIL CASTILLO (Cuba): From the point of view of safety assessment methodology, ISAM and ASAM are both applicable to intermediate depth facilities, and they can also be used in the case of deep geological facilities.

However, regarding the safety aspects of this type of facility, I think we have to establish specific acceptance criteria, because, as we have heard from P. Raimbault, there may be some different scenarios.

J.-M. POTIER (IAEA): There was a question about what intermediate depth facilities have in common, for example, the Japanese concept compared to the borehole concept. I do not think they have much in common except depth — a few tens of metres from the surface. All solutions proposed — existing and planned facilities — comply with the same safety requirements, or should — there is no reason to have different safety requirements. But the engineering solutions proposed are quite different. That is to be expected, because the proposed solutions are commensurate with the specificities of the waste, and the waste being considered in the Japanese concept and the disused sources do not have much in common.

J. LOY (Australia): Let me take that a little further. Several people in this session have said that disused sealed sources — at least high activity ones — are not suitable for disposal in near surface facilities, because of the intrusion risk. Every country has disused sealed sources of high activity, but does every country need an intermediate depth waste solution at least for those sealed sources ?

I.G. CROSSLAND (United Kingdom): No, because countries that have or are planning a deep facility will, as a rule, fairly easily find some small niche within the facility that will accommodate the sealed sources. So, for them it will not be necessary to drill separate boreholes. For countries where there is no deep facility in existence or planned, however, something else is needed.

C. TORRES VIDAL (Spain): I would not say “No”, because in Spain we have a near surface disposal facility and we cannot dispose of disused sealed sources there. Consequently, we need something other than a near surface facility. We do not know what we are going to do. Maybe we shall wait for a geological disposal facility.

C. McCOMBIE (Switzerland): I should like to make a comment regarding J. Loy’s question about whether the IAEA is placing too much emphasis on the borehole approach. In my view, the IAEA is definitely not placing too much emphasis on this approach and the ‘hands on’ programme in question is extremely valuable. The IAEA has to cater to many countries, and not just to the developed ones.

We are all skirting round one important word: ‘cost’. We put things deep in order to make them safe, so why do we not put them deeper in order to make them safer? It is because of the cost. In the case of France, why is the waste for which it has no disposal solution not being held ready for emplacement in its deep repository? Because that will probably be too expensive. Why is Japan building a 100 m deep facility? Because it is aiming to obtain a sufficient level of safety at an appropriate cost.

Cost is the only reason for making something 'in between'; you may get an adequate level of safety at a lower cost. The cost issue should not, therefore, be ignored.

J. LOY (Australia): That is a good point.

E. WARNECKE (IAEA): The borehole disposal concept was launched with the intention of providing a solution for countries with only very small amounts of waste to dispose of. If somebody wants to deviate from this original idea and use borehole disposal for other purposes, that is not forbidden and it can be done. If you do not want to wait until a deep geological repository is available to accommodate your waste, maybe the borehole concept is the right solution.

J. REPUSSARD (France): Regarding the earlier discussion about the need or otherwise for new safety requirements, I think it would be impossible to explain to the public why there should be different safety requirements, and so I think the IAEA should not develop any new safety requirements to cover intermediate depth disposal.

J. LOY (Australia): I think we agree that there should not be a distinct set of safety requirements for intermediate depth disposal but that there is a need for safety guidance dealing with specific issues.

Regarding high activity disused sealed sources, if a country is waiting for its geological repository to go into operation before dealing with their disposal, is that appropriate in the new security environment? A country may have spent nuclear fuel, but that is controllable if the necessary security resources exist. However, leaving high activity disused sealed sources lying around for, say, 40 years does not seem to me to be a good idea. Perhaps there should be greater urgency regarding the disposal of such sources, which may mean that existing already available disposal options need to be considered even in countries that are looking ahead to developing geological repositories.

J.-M. POTIER (IAEA): My presentation today was about the disposal of disused sealed radioactive sources, but the main focus at the IAEA is on short term actions leading to the safe and secure storage of such sources, as it may take years before disposal facilities are licensed and put into operation. The short term actions are the building of storage facilities and the collection and conditioning of sources.

We have people from many countries in this room, and I would like to ask which of them has a solution for the disposal of high activity sources and what it is.

F. KING (Canada): As far as my country is concerned, the Canadian company Nordion supplies the world with a large percentage of the ^{60}Co used for medical irradiation. The ^{60}Co supplied by Nordion comes from the reactors in Ontario, and we have an arrangement with Nordion to take back the spent ^{60}Co sources. So, we are responsible for that waste stream.

When the radioactive material comes back, we put it into wet bays used for the storage of spent nuclear fuel. It is still thermally hot, in fact, it is thermally hotter than the spent fuel — and it therefore has to cool for a long time. The long term plan is to dispose of it along with spent fuel in a deep geological repository.

J. ROWAT (IAEA): What is the scale of the problem that we are talking about? Are we talking about 200 sources worldwide or 20 000?

J.-M. POTIER (IAEA): We are talking about thousands of sources in several dozen countries.

Further to F. King's comment, the IAEA is encouraging radioactive source suppliers to take back sources from developing countries after use, and it has been quite a successful operation in the case of some countries. Nordion is a major supporter of the take-back programme in question.

I.G. CROSSLAND (United Kingdom): There are millions of spent sealed sources distributed throughout the world, the vast majority of them in North America and Europe.

One of the interesting things that came out of the IAEA's International Conference on the Safety and Security of Radioactive Sources held in Bordeaux was that the countries with the greatest numbers of sources — basically the USA and some of the countries of Western Europe — are responsible for the greatest number of missing sources.

M. JENSEN (Sweden): In response to the question asked by J.-M. Potier, I would mention that in Sweden we plan to put radium sources into an intermediate depth repository, 100–200 m deep.

T. PATHER (South Africa): I think we need to put into perspective why the AFRA countries are considering disposal rather than some other option.

J.-M. Potier's presentation gave an indication of the poor conditions under which sources are often being kept. There have been cases, for example, where radium needles were being kept on the doctor's table, with the doctor not recognizing that they represented a risk to himself and to the patients visiting him; there are hospital waiting rooms where a thin wall is all that separates the waiting patients from the storage area where sources are being kept. It became clear that something had to be done about such situations and the sources brought under better control and good storage arrangements were introduced in many cases. However, there is evidence of storage facilities being forgotten about, so in the end, the AFRA countries decided that a good disposal option was what should be looked for.

L. JOVA SED (IAEA): The international community can be sure that the IAEA will not promote any project that does not comply with safety and security requirements. The borehole disposal concept is not a second best disposal concept. It is safe enough and secure enough to be implemented anywhere.

W. BREWITZ (Germany): I have heard references to 'boreholes', 'deep boreholes' and 'very deep boreholes'. How deep is a very deep borehole? I believe that in Germany we have gone down to 9000 m. A 100 m borehole is not deep, and a 30 m borehole can be opened up very easily, so such boreholes are near surface facilities. Why is thought not being given to drilling down to 200–300 m? Technically that would not be very different, and the safety would be much greater.

I.G. CROSSLAND (United Kingdom): It is a question of applying a graded approach. You say that 200–300 m is safer than 100 m, but then why not 400 m or 500 m? We must keep some sense of proportion about the kinds of waste and the volumes of waste we are dealing with. We are not dealing with spent fuel.

We are not saying 'disposal at 30 m' — we are saying 'disposal at more than 30 m'; the disposal depth will always be at least 30 m, and deeper is not always safer.

A.-C. LACOSTE (France): Regarding what J.-M. Potier said about radioactive source suppliers, I believe that, at least for some kinds of sources, the suppliers should be made responsible for taking care of the sources supplied by them after use. In many cases, use of radioactive sources is not justified. For example, the use of radioactive materials in smoke detectors is no longer justified, so in France we are going to ban the use of smoke detectors containing such materials. This is one way of dealing with an issue before it becomes too complicated.

C. TORRES VIDAL (Spain): I am convinced about the borehole disposal concept from the engineering point of view and L. Jova Sed has said that it was not a second class concept, but it is not yet clear who is going to license borehole repositories.

D. LOUVAT (IAEA): Regarding one of I.G. Crossland's comments, I would mention that, while it is in advanced countries that most radioactive sources have been lost (but also recovered), it is in developing countries that most accidents involving radioactive sources have occurred — so far. That is why the IAEA is helping Member States to control the radioactive sources that they have within their territories and to recover and store them, and is promoting the Code of Conduct on the Safety and Security of Radioactive Sources, an essential principle underlying which is that the suppliers of radioactive sources should take back the sources supplied by them after use.

At the same time the IAEA is helping to develop the borehole concept with a view to eliminating the spent radioactive source legacy in many of our developing Member States.

Who is going to license borehole repositories? We are helping Member States to create regulatory authorities capable of licensing them.

C. TORRES VIDAL (Spain): You do not convince me. I believe that for safety reasons, the borehole concept would not be approved by the regulator in Spain unless it had been first subjected to a first class review process.

M.W. KOZAK (United States of America): Maybe the borehole concept should be reviewed in Spain, Australia, Sweden, Japan and so on, in order to iron out the bugs in the licensing process, and then offered to AFRA countries. The technology is cheap and can be used by everyone.

J. LOY (Australia): Yes, although — as E. Warnecke indicated — the borehole disposal concept is not intended for countries which have more than a small amount of waste, if it is a good concept, why can it not be applied in countries with large amounts of waste?

E. VOMVORIS (Switzerland): Institutional controls are very important. In the case of intermediate level facilities, where would you draw your examples from — surface disposal or deep geological disposal?

If the regulatory body knows that there are going to be institutional controls at a surface facility, it might, without changing the safety goals, decide to require lower technical standards for safety. I can offer a car maintenance analogy — if your engine is going to be checked every 10 000 km, you may treat it differently from the way in which you would treat it if it were going to be checked only once every five years.

M. JENSEN (Sweden): The question of institutional controls is a social and political question. You have to reach an agreement with the communities and politicians regarding what they can live with based on the confidence they have in the country's institutions.

P. RAIMBAULT (France): There are facilities where one needs institutional control in order to ensure safety. This is the case with surface disposal. For very long lived waste, the emphasis is on passive safety — institutional control is not needed in order to ensure safety, although monitoring may be useful for some time after facility closure.

T. TANIGUCHI (IAEA): I should like to make it clear that, contrary to the impression that may have been given here, the IAEA has not proposed the borehole concept. The concept was proposed by countries within the AFRA group. The IAEA's Department of Nuclear Safety and Security is still considering what would be adequate safety standards, including the practicability of such standards.

REGULATORY CONTROL AND COMMUNICATION OF SAFETY ISSUES

(Session IV)

NEW FACILITIES, REASSESSMENT OF EXISTING FACILITIES AND DECISION MAKING ON UPGRADING SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES

(Session IVa)

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SAFETY REASSESSMENT AND DECISION MAKING FOR EXISTING WASTE DISPOSAL FACILITIES

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Abstract

Decision making for existing waste disposal facilities is a complex subject with potentially significant technical, environmental, financial and stakeholder aspects. A properly structured safety case, including a safety assessment and supporting arguments is a key element in the appraisal of these complex problems, and for formulating and communicating the issues so that transparent and equitable decisions can be taken. The paper discusses some of the difficulties and how they might be resolved. The work is illustrated by ongoing work in the United Kingdom.

1. INTRODUCTION

Industrial waste has been generated and disposed of for hundreds of years. The United Kingdom has a long and rich industrial history, one consequence of which is that there are thousands of landfill sites, most of which are closed, but very few of which meet modern standards. Removal and redisposal of the vast majority of this waste to meet modern standards cannot be justified on any rational basis. The situation for radioactive waste is similar, although on a much smaller scale. For much of the twentieth century we have disposed of a variety of radioactive waste types, whether from the civil nuclear or defence industries, or technologically enhanced naturally occurring radioactive materials (TENORM) from 'conventional' industries. The standards to which such disposals have been carried out have varied enormously and the available data on what has been disposed contain many uncertainties. Backfitting of new standards to existing facilities will often be impracticable.

Radioactive waste disposal assessment has evolved rapidly in recent years and most countries now have policies and regulations in place, supported by guidance from bodies, such as the IAEA, which provide a good framework for disposing of radioactive wastes in a safe way. Although it may be relatively easy to identify standards for new disposal activities and demonstrate that they comply with standards, this can be more difficult for historical disposals.

2. RETROSPECTIVE ASSESSMENTS

2.1. Reasons for retrospective assessments

The IAEA has recently published [1] guidance on the upgrading of facilities, which sets out the reasons why this may be necessary, and the means by which it may be achieved.

There are a variety of settings for existing radioactive waste disposal facilities. They may be separate facilities, or contained within managed nuclear sites. The facilities may be closed, subject to institutional controls or continuing to receive waste (if the latter, historical disposals may have been subject to different or less constrained standards). Nuclear sites with old disposal facilities may be decommissioned, cleaned up, or otherwise developed.

For such disposal sites, there are a number of circumstances where retrospective risk assessments may usefully be applied:

— Historical disposals may be causing contamination in the accessible environment. There may also be concerns about rapidly worsening impacts. Information on the nature and magnitude of such impacts, and on their timing may be needed. The results of assessments will inform decisions on intervention.
— Previous assessments need to be reviewed if new information comes to light, e.g. accelerated sea level rise or coastal erosion.
— Changes in national policies, regulations and guidance.

— On-site disposals may have been carried out on sites that are now subject to cleanup and redevelopment. Retrospective risk assessments will inform decisions on whether the waste can be left in situ and, if so, what further engineering may be needed to permit this.
— If the site is still operational, risk assessments will inform decisions on the overall impact of the site and how future disposals should be managed.
— To inform or review decisions on further engineering measures, such as site capping, and the nature and duration of post-institutional control.
— To inform continuous optimization work.

A full risk assessment for a disposal facility is likely to be complex and time consuming. A tiered approach to risk assessment in which less significant risks are screened out an early stage, allowing the main risk drivers to be prioritized, has a number of potential benefits:

— It clearly identifies why some risks will not be investigated further.
— It identifies some risks where action, as opposed to any further investigation, may be preferable.
— It prioritizes resources for the subsequent stages of risk assessment.

2.2. Standards: Interventions and practices

(a) *Practice criteria*. It is reasonable to assess the impact of ongoing disposals against the practice criteria in use for new facilities. In the United Kingdom, these have been set out in regulatory guidance [2] and comprise:
   (i) A dose constraint of 0.3 mSv/a which applies during the period of institutional control;
   (ii) A risk target of 10^{-6} per year for the period after institutional control is withdrawn. Where this target cannot be met, the operator must show that further improvements in safety could only be achieved at disproportionate cost.

   Practice criteria may also usefully be applied during the development or improvement of sites, where new pathways or receptors will be introduced as a result of development, and there is an opportunity to influence development activities to allow constraints and targets to be met.

(b) *Intervention criteria.* Where assessment is for a facility for which remedial action is being considered, the assessment would be made against intervention criteria, i.e. the intervention should be justified, and its nature and duration optimized. Intervention may comprise:

(i) Removal of all or some of the waste originally disposed of;
(ii) Improved isolation or immobilization of disposed waste (e.g. improved capping, grouting etc.);
(iii) Implementation or extension of institutional controls for an acceptable period.

(c) *Mixed criteria*. For sites with both historical and ongoing disposals, it is reasonable to judge ongoing and future disposals against practice criteria, while separately considering intervention for historical disposals against intervention criteria. This is the approach being taken by the Environment Agency in its ongoing assessment of the safety case for a near surface disposal facility in the United Kingdom (see Section 4).

3. DECISION MAKING

3.1. Structured approach

The Government of the United Kingdom and regulators have produced guidance on a structured approach to managing environmental risks [3], elements of which are described below. Good decision making will rely on the effective (inclusive, transparent and well documented) analysis of alternative options. Therefore, a systematic appraisal is important to ensure that decision making is based on clear information about the objectives, the available options, and their relative costs and benefits. This is generally best achieved through a step by step process to help guide the decision in a structured way.

Each appraisal will require different degrees of emphasis at different stages depending on the individual circumstances, but a common framework can be envisaged consisting of the following steps:

— Identify the objective, and ensure a clear and common understanding of the desired outcome.
— Identify the options. In most cases there will be options that are obvious. Some will be less applicable than others and it will be necessary to identify those that have the potential, either in whole or part, to meet the objective.
— Implementation of the options may require the availability of technologies, tools and resources (monetary and non-monetary). Options need to be feasible.

— Identify the impacts of the options.
— Clarify the decision criteria, such as the economic costs, the implications of change, and the human health and environmental impacts.
— Compare the advantages and drawbacks for each option, including the trade-off between quantified and qualitative data, in order to draw conclusions.

Social issues and the perceptions and aspirations of the public and other stakeholders should also be considered as part of the process. Combining all of these elements permits a systematic comparison of options for risk management. The process may be iterative, with options appraisal feeding back to the various tiers of risk assessment.

A range of more or less formalized techniques may be used for carrying out structured appraisals (multi-attribute decision analysis, cost–benefit analysis, etc.). It is important to note that these techniques have limitations, for example, they may not be able to handle combined options. They should be seen as aids to decision making, rather than as providing a definitive answer on the preferred option.

3.2. Role of the environmental impact assessment

The environmental impact assessment (EIA) is a widely used procedure for systematically assessing the environmental impacts of proposed projects. In the European Union, an EIA is a legal requirement for projects likely to have significant effects on the environment. In EIAs, information on the environmental effects of a project, and the main alternatives, is documented in a form that provides a focus for scrutiny of the project. It enables the significance of the predicted effects, and the scope for mitigating them, to be evaluated before a decision is made as to whether the project can proceed. Frequently, under EIA, there is no requirement to produce monetary evaluations of environmental impacts and no requirement to consider formally the costs of risk management options.

Where the assessment of existing disposal facilities is likely to lead to a ‘project’, much of the data gathered during options appraisal will be relevant to the EIA. However many aspects that need to be addressed as part of the EIA will not be major risk drivers and so can be screened out at an early stage of the structured options appraisal.

3.3. Dealing with uncertainty

Uncertainty affects all stages of risk assessment and management processes. Analysing the sources and magnitudes of uncertainties can help to focus discussion, identify knowledge gaps and feed into decisions about the most appropriate risk management options, including whether or not precautionary action is necessary. Uncertainties generally fall into the following categories:

— *Model:* where models provide only an approximation of the real environment;
— *Sample:* where uncertainties arise from the accuracy of measurements or validity of the sample;
— *Data:* where data are interpolated or extrapolated from other sources;
— *Knowledge/scenario:* where the scientific base does not provide sufficient understanding, for example, future scenarios will always be uncertain to some extent.

To evaluate and use risk assessments effectively as a credible basis for decision making, it is important to understand how different sources of uncertainty contribute to the overall range of risk estimates, and whether the risk estimates capture all of the important uncertainties. Sensitivity analysis is an important part of analysing assessment results and is a method used to examine the behaviour of a model by examining the variation in outputs resulting from changes to its inputs.

3.4. Timescales for action

Due to the complexity of the natural environment, conducting a full risk assessment can be very time consuming. Sometimes, it will therefore be necessary to consider short term action to deal with imminent problems, or imminent worsening of longer term impacts, on the basis of hazard or initial risk assessments.

3.5. Stakeholder involvement

Stakeholders are those parties affected by, or concerned with risk and may include government, regulatory authorities and other agencies, professional and industrial bodies, environmental and local interest groups and individual members of the public. Their objectives, interests and responsibilities may be varied and contradictory.

Stakeholders have an important role to play in problem formulation and their early involvement will tend to make risk management decisions more legitimate, effective and durable. The final decision on how best to manage environmental risks should, therefore, always be informed both by science and by stakeholder concerns.

There is always the potential for matters linked with the disposal of radioactive waste to be contentious, particularly where there are perceived elevated risks and uncertainties. Where remediation is being considered, it is likely that local communities will want to be informed of what is being considered, and may wish to influence remediation options. Time and resources should be given to ensure there is time for stakeholders to be properly involved.

4. RECENT EXPERIENCE IN THE UNITED KINGDOM

In November 2004, the Environment Agency started a review of the authorizations for disposal of low level waste (LLW) to the near surface repository near to Drigg, United Kingdom.

The repository comprises two distinct phases:

— From the late 1950s to the late 1980s, waste was disposed of by tipping and burial in shallow, clay-lined trenches. Approximately 800 000 m^3 of waste was disposed of in seven trenches. These trenches are now covered by an interim earth cap, which incorporates a plastic membrane to minimize water ingress.
— Since the mid-1980s, waste has been compacted and encapsulated in cement grout in mild steel containers before being placed in an engineered concrete vault. The existing vault is projected to be full by the end of 2006. The operator plans to develop additional vaults to accept further waste.

The authorization review was based on safety cases submitted by the operator, British Nuclear Group Sellafield Ltd (BNGSL) in 2002 [4] and assessed by the Environment Agency [5]. The safety cases have assessed the impact of LLW disposals into the far future.

All of the scenarios identified in the safety cases end with site destruction (by coastal erosion or glaciation), and all lead to conditional peak risks from historical and ongoing disposals that would exceed the risk target for a new disposal facility (see Section 2.2). The greatest contribution to these higher risks is from the disposals to the original clay-lined trenches of waste containing thorium and uranium.

If the repository is destroyed by coastal erosion (which may occur 500–5000 years from now, assuming coastal defences are not constructed and maintained), the assessed risks to beach users from exposed waste, are about 10^{-4} per year. This may have resource impacts on future generations, should they decide to prevent or remedy this. If the repository is not first destroyed by coastal erosion, calculated peak conditional risks from the groundwater pathway lie in the range 10^{-5} per year to 8×10^{-5} per year.

The assessed peak conditional risk from human intrusion (the assumption is that groups would reoccupy areas contaminated by excavated trench wastes) is 2×10^{-3} per year or possibly greater, the peak occurring after 60 000 years. These risks compare with the 10^{-6} per year risk target for new facilities, described in Section 2.2. The risk assessments show that planned future disposals are unlikely to significantly increase the peak conditional risks at the site, although the risks associated with the planned future disposals may exceed the risk target.

In the 2002 safety cases, BNGSL presented the estimated impacts of the current and future disposals on the site, but it has not demonstrated that the performance of the site has been optimized or that the impacts from disposals are ‘as low as reasonably achievable’. BNGSL will need to show that it has done everything reasonable to minimize the risks.

The Environment Agency is therefore proposing [6] that BNGSL should consider a wide range of risk management options for both historical and future disposals. These should include combinations of:

— Constructing a thicker cap over the disposals;
— Future disposal of only certain categories of waste (e.g. short lived wastes);
— Selective removal of those long lived waste types in the trenches that are assessed as contributing most significantly to risk;
— Extending the active management period.

BNGSL is likely to be allowed three years to complete this work; this time period has been chosen to allow a good level of stakeholder engagement. Future disposals are unlikely to increase the peak risks from the site, therefore the Environment Agency proposes to allow disposals to continue in the short term. This proposal is subject to public consultation.

A similar safety assessment and decision making exercise will be undertaken for the Dounreay facility, United Kingdom, operated by the United Kingdom Atomic Energy Authority (UKAEA) and regulated by the

Scottish Environment Protection Agency (SEPA). The site contains an existing disposal facility in which approximately 33 000 m^3 of LLW has been disposed of. This historical facility comprises several pits, which lie close to the shoreline. It has been recognized that, in the long term, cliff erosion might cause waste to fall on to the foreshore. UKAEA has proposed developing a new LLW disposal facility on the site to accept waste from local decommissioning activities. A long term safety assessment is being undertaken by UKAEA, the results of which will inform decision making although, ultimately, decisions on the acceptability or otherwise of LLW falling on to the shore in an uncontrolled manner may well hinge on other factors.

5. DIFFICULTIES WITH RETROSPECTIVE ASSESSMENTS

Conducting and using retrospective safety assessments in decision making for existing facilities can be complex. The information on which an assessment is to be based may be of poor quality and constraints may exist that a site developer would choose to avoid in designing a new facility (for example, site location and facility engineering). A structured approach to decision making, supported by ‘fit for purpose’ assessments, which recognize uncertainties, and include stakeholder involvement from an early stage, is of crucial importance.

However, a number of issues merit further debate:

- The difficulties in communication and general acceptance of apparently different standards for practices and intervention, particularly where these are applied to different parts of the same site.
- The existence of waste disposal facilities, which were acceptable, but fall short of modern standards may lead to doubts as to the degree of trust that can be placed on modern controls.
- How should acceptance criteria be derived for continuing disposals to a site, when there are historical disposals that may have been to a lower standard?
- Is there sufficient guidance on the assessment of, and decision making on, existing disposals?
- Is there a case for international assistance for countries with limited resources that have issues with existing waste disposal facilities? What form should this take?

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REGULATORY REVIEW OF SAFETY CASES AND SAFETY ASSESSMENTS — ASSOCIATED CHALLENGES

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Abstract

Regulatory reviews of safety cases and safety assessments are essential for credible decision making on the licensing or authorization of radioactive waste disposal facilities. Regulatory review also plays an important role in developing the safety case and in establishing stakeholders' confidence in the safety of the facility. Reviews of safety cases for radioactive waste disposal facilities need to be conducted by suitably qualified and experienced staff, following systematic and well planned review processes. Regulatory reviews should be sufficiently comprehensive in their coverage of issues potentially affecting the safety of the disposal system, and should assess the safety case against clearly established criteria. The conclusions drawn from a regulatory review, and the rationale for them should be reproducible and documented in a transparent and traceable way. Many challenges are faced when conducting regulatory reviews of safety cases. Some of these relate to issues of project and programme management, and resources, while others derive from the inherent difficulties of assessing the potential long term future behaviour of engineered and environmental systems. The paper describes approaches to the conduct of regulatory reviews and discusses some of the challenges faced.

1. INTRODUCTION

Regulatory reviews of safety cases and safety assessments are primarily conducted to assist regulatory decision making on the licensing or authorization of radioactive waste disposal facilities, or to prepare for such decisions. Regulatory review also plays an important role in the development of the safety case and in building stakeholders' confidence in the safety of the facility. The quality of the regulatory review process contributes to the credibility of the regulator, the review findings and the associated regulatory decisions. It is therefore important that the process by which regulatory authorities conduct such reviews is systematic, logical and defensible (open and transparent), based on clear safety requirements, and leads to clear and logical decisions.

Regulatory authorities have to address a number of challenges in achieving the necessary levels of efficiency and effectiveness, and in ensuring that the review process is conducted in an open and transparent manner. Some of these challenges are procedural and technical in nature and are mostly related to the conduct and management of the review. Others are broader and relate to the approaches used by the regulatory authority to address issues, such as conducting regulatory reviews with limited resources, applying the risk based or risk informed approaches to the review process, and involving stakeholders during the review process.

This paper discusses some of the attributes and challenges associated with the regulatory reviews of safety cases and safety assessments. The discussion is based on the work that is being conducted by the Regulatory Review Working Group (RRWG) within the IAEA Application of Safety Assessment Methodology (ASAM) coordinated research project [1]. The two main objectives of the RRWG, which comprises approximately 21 participants from 15 countries, are the development of systematic guidance on the conduct of regulatory reviews of safety assessments, and the development of guidance on how to document safety cases for near surface radioactive waste disposal facilities in order to gain confidence in the safety of the facilities [2, 3].

2. THE SAFETY CASE AND ITS COMPONENTS

The safety case is generally viewed as a collection and integration of arguments and evidence that describe, quantify and substantiate the safety of the facility for the various stages of its development and operation [4]. In other words, the safety case should explain why the intended audience should have confidence in the safety of the disposal facility and its acceptability [1–7].

The IAEA ASAM project has identified the following key items as important components of a safety case [3]:

— "A well documented and quality assured safety assessment, including discussions on how confidence was established at each stage of the assessment and in the overall safety assessment methodology, approach and findings. The safety assessment should, in particular, include a thorough treatment of uncertainty;
— A demonstration of confidence in the disposal system. This implies the need for an in-depth and scientific understanding of the disposal system, including the reliability of the disposal facility engineering, and its possible evolution;
— A demonstration of confidence in the management framework and competence of the proponent/implementer, including demonstration that appropriate management structures and strategies are in place. Similar levels of confidence are required in the competence of the regulatory body;
— An identification of any unresolved issues and a demonstration of confidence in the ability of the programme to resolve them;
— An adequate consideration of alternative options and a clear rationale for the adoption of the proposed or selected waste management option;
— An adequate demonstration that the safety case has been developed via a transparent process with appropriate stakeholder involvement."

The safety case should be viewed conceptually as an open, flexible and living document, which is used as a tool for demonstrating, promoting and communicating confidence in the safety of a radioactive waste facility. Its content and structure are greatly influenced by country specific legislative and regulatory requirements and local concerns. Although some countries do not use the term safety case, many follow processes that are consistent and, in essence, similar to the safety case concept. The process of assembling a safety case is an interactive process that may spread over a long period of time. Therefore, its components will carry different weight and importance over time, depending on the development stage of the facility and the regulatory decision that is under consideration (e.g. site characterization, construction, operation, closure/decommissioning, surveillance/monitoring, and withdrawal of control/de-licensing [8]).

3. OBJECTIVES OF THE REGULATORY REVIEW

The objectives of a regulatory review of a safety assessment or a safety case must be established, taking into account the status of the disposal facility and the associated assessment context, and will typically include:

- Ensuring that the disposal facility will not cause unacceptable adverse impacts on human health, and on the environment now and in the future.
- Determining whether the safety assessment has been conducted in an adequate manner (quality, level and depth) and whether it is 'fit for purpose'.
- Verifying that the results of the safety assessment and the assumptions on which the assessment and the wider safety case are based, comply, or are in accordance with, accepted radioactive waste management principles, and regulatory requirements and expectations.
- Ensuring that relevant measures and contingencies to mitigate possible impacts have been identified and considered, and that adequate follow-up plans for their implementation have been developed.
- Ensuring that uncertainties, as well as mechanisms to address them, have been adequately identified.

Another important objective of the regulatory review is to help regulators understand the issues that are most important to safety.

4. ATTRIBUTES OF THE REGULATORY REVIEW

There are a number of key attributes that influence the quality and success of the regulatory review. These include:

- The regulatory requirements and expectations, including the criteria against which safety will be judged, should be clearly defined and explained to the proponents/implementers and other stakeholders.
- The review team conducting the regulatory review should be independent of the group responsible for the development of the safety case.
- The scope of the review should be clearly defined and the review team should not be unduly influenced by considerations that are outside the scope of the review. Any such considerations should be taken into account in a broader context by decision makers, together with the regulatory review findings.

— The regulatory review process should be structured and traceable with clearly defined roles and responsibilities and decision making steps.
— The regulatory review should be conducted using a level of resource that is adequate and commensurate with the level of complexity of the safety assessment and the potential hazards associated with the waste and the facility under consideration.
— The regulatory review process should include a stakeholder consultation framework with well defined consultation steps, rules of procedure and of decision making.
— The regulatory review should document the rationale for judgements as to whether or not the arguments presented in the safety assessments or safety case are adequately supported by the underlying science and technology, and whether those arguments are in accordance with regulatory requirements and expectations.

Fulfilling the expectations raised by these attributes can represent a significant challenge in itself. For example, the regulatory authorities should possess a sufficient level of internal expertise and hands-on experience in assessing the safety of radioactive waste facilities to allow fulfilment of their roles. Furthermore, reviewers will need to consider both ‘hard’ issues (e.g. objective, technical or scientific issues) and ‘soft’ issues (e.g. subjective, value related issues). Differences of opinion are typically more common and more difficult to resolve on the soft issues than on the hard issues, owing to differences in individual reviewer’s values, experiences, judgements and expectations.

5. MANAGING THE REVIEW PROCESS

The management of a safety assessment/safety case review has to be treated as a project, to which the standard principles of good project management apply. Depending on the scale of the review to be conducted, it may be necessary to establish a team of reviewers. Regulatory reviews may be conducted by the regulatory authority with or without support from external organizations, but the results of the review must be fully adopted and ‘owned’ by the regulatory authority. The guidance being developed within the ASAM project [2] considers the main following aspects:

— Defining the objectives and scope of the review;
— Developing a review plan that identifies the review tasks and addresses other relevant topics;

— Assembling a review team of competent personnel possessing the necessary expertise and experience to undertake the review;
— Defining the project schedule and allocating resources for the conduct of project tasks, including consideration of how reviews should be conducted when resources are limited;
— Identifying the responsibilities of review team members and ensuring that they receive adequate training and guidance in the review method;
— Coordinating the conduct of the review tasks, and ensuring sufficient communication between review team members;
— Early identification of areas of 'regulatory uncertainty';
— Coordinating interaction and dialogue with the operator of the disposal facility, and with other stakeholders during the review process;
— Reviewing and integrating documents generated during the review process;
— Synthesizing and communicating the review findings.

For each regulatory review, a review plan will be required to provide guidance on procedural and technical aspects of the review. The review procedures applied should allow the regulatory authority to demonstrate that competent people have performed the review, and that it has been recorded in a traceable and auditable manner. Project specific procedures might cover structured approaches for documenting review comments, for determining and demonstrating the competence of reviewers, for recording the status of issue resolution, for conflict resolution, and for retaining a long term 'corporate memory'. Further procedures may be necessary if the review includes tasks, such as audits or independent regulatory assessment calculations. Technical guidance might include the criteria against which to judge specific aspects of the safety assessment.

The RRWG document on regulatory reviews [2] is designed to assist in developing international guidance from which a project specific review plan can be developed. Examples of project specific review plans include those developed for the Drigg low level radioactive repository in the United Kingdom [9] and for the Yucca Mountain project in the USA [10].

6. CONDUCTING THE REVIEW AND REPORTING REVIEW FINDINGS

The main components of a safety assessment that have to be considered during a regulatory review can be illustrated for each of the steps within the Improvement of Safety Assessment Methodology (ISAM) (assessment context; system description; development and justification of scenarios; formulation and implementation of models; analysis of results) [11]. For each step in the safety assessment, the RRWG guidance on regulatory review [2] highlights the types of statement related to confidence that the safety assessment should support and lists appropriate questions that a reviewer should ask when conducting a regulatory review. Such questions are designed to help reviewers identify potential weaknesses or deficiencies in the safety assessment, but also to help safety assessors to better document their safety case/assessment and thereby meet regulatory expectations.

In order to assist with the assessment of the safety case against the primary review objectives, it is common for a number of secondary objectives to be specified. These may include evaluating whether the safety case/assessment:

- Has been developed under a suitable quality assurance system;
- Is sufficiently complete, given the status of the disposal programme and disposal facility;
- Is sufficiently transparent in its presentation of data and information;
- Is based on an appropriate assessment context;
- Is based on appropriate assumptions, for example, regarding assessment scenarios, models and parameter values, and contains adequate arguments supporting the adoption of those assumptions;
- Demonstrates an adequate understanding of the disposal system;
- Clearly identifies the uncertainties associated with the understanding of the disposal system and the performance of the disposal facility;
- Includes an adequate consideration of optimization and risk management;
- Defines an appropriate forward programme for improving the safety assessment, the understanding of the disposal system, and the safety of the facility.

7. CONDUCTING REGULATORY REVIEWS WITH LIMITED RESOURCES

The conduct of effective regulatory reviews requires an adequate level of resources, and it is usually a resource intensive exercise covering a wide range of disciplines and expertise. However, the resources available to regulatory authorities in different countries vary widely according to the scale of national nuclear programmes. In many countries with small nuclear programmes or limited uses of radioactive material, the number of regulatory staff that can be dedicated to the review of a safety assessment for a particular waste disposal facility is low and, in some cases, is limited to just one or a few individuals. While some countries with larger programmes have access to more resources, they are often faced with similar difficulties because of the disproportionately large size of their nuclear regulatory programmes and, increasingly, by the demands imposed by the public and other stakeholders.

Failing to provide adequate resources in the context of regulatory reviews may have serious consequences. These include eroding public confidence in the regulator's decision and in its ability to ensure safety, decreasing the level of regulatory scrutiny and delaying consideration of applications and proposals — delays which may penalize proponents. Another consequence is the potential for an increasing level of workload related difficulties within regulatory organizations, which may lead to lower levels of productivity and vigilance. It is not uncommon for organizations to place very significant reliance on individuals dealing with a particular facility over several years or more.

Addressing the issue of limited resources is challenging and the proposed solutions are not always unanimously accepted by the various stakeholders involved, mainly because of diverging perceptions of risks and conflicting priorities. Possible approaches to address the issue of limited resources are discussed in the following paragraphs.

7.1. Risk informed regulatory review

An increasing number of countries (e.g. Canada, Japan, Sweden, United Kingdom, USA) have developed, or are developing, risk based or risk informed regulatory frameworks [12]. Such approaches are designed to improve regulatory efficiency by focusing regulatory scrutiny on areas where there is the greatest potential to achieve safety or environmental protection benefits. Risk informed, performance based regulation is described by the USNRC [13] as:

> "an approach in which risk insights, engineering analysis and judgement (e.g., defense in depth), and performance history are used to: (1) Focus attention on the most important activities, (2) establish objective criteria for evaluating performance, (3) develop measurable or calculable parameters for monitoring system and licensee performance, (4) provide flexibility to determine how to meet the established performance criteria in a way that will encourage and reward improved outcomes, and (5) focus on the results as the primary basis for regulatory decision making."

While it is relatively easy to apply such approaches when undertaking and prioritizing activities relating to regulatory compliance of operating nuclear power plants, it is more challenging to develop and apply such methods to regulatory reviews of safety cases and safety assessments for radioactive waste disposal facilities. This difficulty arises because of the prospective nature of such safety assessments and also because of the need to consider both the details of the assumptions on which the assessment is based as well as the assessment results. In regulatory review of safety cases, the ‘devil is in the detail’. It is important, therefore, that regulatory reviews are conducted to a level of detail appropriate to the technical and scientific basis of the issues being considered. A key question is, thus, how to balance the scope and complexity of a regulatory review against cost and time, while at the same time ensuring safety?

Another difficulty related to applying risk informed approaches to regulatory reviews of safety cases for disposal facilities is that such approaches may prevent the regulator from developing a thorough, holistic understanding of all different aspects related to the assessment of the facility under review. The public and other stakeholders may see this as a lack of competence, even when this lack of understanding is associated with low risk issues. This could be particularly the case during public hearings and meetings when the regulator is challenged and unable to demonstrate a thorough understanding.

One approach to combating this difficulty may be to consider assessment results for a range of subsystem performance criteria other than dose or risk, such as radionuclide release from the near field, or flux through a particular engineered barrier. Regardless of the details of the approach chosen, the regulatory review plan should ensure that the general requirement on the proponent/implementer to demonstrate a sufficiently broad understanding of the disposal system is adequately assessed and reflected by the regulatory review team across the full breadth of the safety case.

7.2. Use of internationally agreed generic disposal concepts and assessment tools

Increasing attention has been focused internationally on the safety of radioactive waste disposal facilities in recent years due to the increasingly global nature of the nuclear industry and the coming into force of the international treaty on waste safety, the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management. This has resulted in increased attention being given to the development and use of international safety standards and to approaches for demonstrating compliance with them.

The Joint Convention has focused attention on the importance of establishing national policies and strategies on the management and disposal of radioactive waste. One of the key elements of such policies is to determine suitable disposal options for all the types of waste generated within a country. Work is currently in hand at the international level to establish a common framework for waste management and disposal that will assist with the establishment of such policies by providing a logical, coherent and safe linkage of waste types with disposal options.

A related development, arising from the concern over the safety and security of disused sealed radiation sources, is the development of a borehole disposal concept making use of narrow diameter boreholes drilled from the surface to depths of several tens of metres. Generic designs have been developed for such facilities [15] and work is in hand on the development of safety guidance, specific to this type of disposal concept [16]. The feasibility of realizing such a disposal facility is, however, heavily dependent on the demonstration of its safety. While the basic concept and its implementation is relatively straightforward from an engineering perspective, safety demonstration remains as complex as for any other waste disposal facility [17]. Nevertheless, because of the generic nature of the design and the similarity of inventories to be disposed, work has been undertaken on generic safety assessment. The approach being adopted is to define envelopes of parameter values relating to, for example, climate, geology, hydrology and inventory, and carrying out generic assessment on the bounding parameter values identified. Site specific safety assessment is then envisaged by demonstrating that the site falls within the defined envelopes of parameter values.

Projects such as ISAM [11] have led to the development of internationally harmonized safety assessment methodologies, and the ASAM [1] project is currently exploring the application of methodologies to various situations and under various circumstances, and regulatory approaches for reviewing and evaluating their adequacy, as reported in this paper.

All these generic approaches can assist in the development and review of actual disposal projects. Again it must be emphasized that such generic work is no substitute for project specific safety assessment and licensing. Nevertheless, the use of internationally endorsed methodologies and of generic approaches can assist and facilitate the development of projects and the evaluation of their safety, and contribute to developing confidence in their safety.

7.3. Use of international assistance

Where resources are limited, to the extent that it is difficult or not possible to establish a sufficiently broad team for a particular review, it may be possible to turn for assistance to international organizations. Such assistance can be in the form of advisory missions on the conduct of the review, technical advice on the review of particular detailed aspects of the assessment, or in the form of provision of the training of local staff on how to carry out the work. Such assistance cannot, however, substitute for the regulatory review and decision making process, which always remains the responsibility of the national regulatory authority.

8. STAKEHOLDER INVOLVEMENT

There is now widespread recognition that radioactive waste management requires not only sound technical assessment of risk, but also public participation, consultation and stakeholder dialogue in order to determine whether proposed solutions and their associated risks will be tolerated by key stakeholders, including the public.

Experience suggests that citizens are capable of engaging with complex technical issues such as radioactive waste management, and should not be excluded on this basis. Indeed, the earlier in the decision process that public and stakeholder engagement occurs — for example, on the consideration of options and alternatives — the greater the chance of gaining stakeholder and general public support for the eventual outcome [18]. A key question is, thus, when and how should stakeholders be brought into the regulatory review process?

A range of different models for stakeholder involvement has been applied in different countries and extensive research has been conducted on the methods of stakeholder engagement both in national and international research programmes.

A key consideration is that stakeholder involvement during the regulatory review process should take place under an open and transparent stakeholder consultation framework with clearly defined rules of procedure. The consultation framework should cover all the steps involved in the regulatory process. This may best be achieved through the implementation of legislative and regulatory tools that set out the format and frequency of the consultations, the procedures to be used for dialogue, rules for comment resolution and decision making, as well as the available appeal mechanisms in case of disagreement with the regulatory decision.

An important consideration for successful consultation during the review process is that the scope of the consultation should be clearly defined and understood by all stakeholders. For example, at the Environmental Impact Assessment stage, the breadth of the consultations should be consistent with the scope and objectives of the assessment under review, and should avoid those issues and details that will be considered during licensing stages.

In some situations, however, stakeholder issues and inputs may need to be considered as they arise and some programmes, therefore, include regular less formal meetings with stakeholders to address these issues.

9. CONCLUSIONS

Regulatory reviews of safety cases and safety assessments are essential for credible decision making on the licensing or authorization of radioactive waste disposal facilities. Regulatory review also plays an important role in developing confidence in the safety case and in stakeholders' confidence in the safety of the facility.

Reviews of safety cases for radioactive waste disposal facilities need to be conducted by suitably qualified and experienced staff, following systematic well planned review processes. Regulatory reviews should be sufficiently comprehensive in their coverage of issues potentially affecting the safety of the disposal system, and should assess the safety case against clearly established criteria. The conclusions drawn from a regulatory review, and the rationale for them, should be reproducible and documented in a transparent and traceable way.

Many challenges are faced when conducting regulatory reviews of safety cases. Some of these relate to issues of project and programme management, and resources, while others derive from the inherent difficulties of assessing the potential long term future behaviour of engineered and environmental systems. Particular challenges are associated with developing and assessing the softer, more qualitative aspects of the safety case over which different safety assessors, reviewers and other stakeholders may have different views.

The IAEA ASAM project is providing a valuable forum for discussing and developing new approaches aimed at meeting the challenges of conducting credible regulatory reviews.

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PLANNING SAFETY UPGRADING MEASURES AT THE PÜSPÖKSZILÁGY NEAR SURFACE REPOSITORY

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Abstract

Although the near surface repository at Püspökszilágy has operated safely for more than 25 years, it is considered to be unsuitable for some of the radioactive waste types previously emplaced in the facility. The results of safety assessments clearly indicate that the spent sealed radiation sources previously emplaced in the repository could result in high doses to individuals who intrude into the facility, and that they could also lead to high doses following any future disruption of the facility by natural processes. Consideration is being given to possible developments at the site, which could include the retrieval of certain waste types from the site and their temporary storage, pending disposal in a geological repository, remedial measures to improve safety of the existing waste and disposal of further waste by creating free capacity within the existing facility. The paper will provide a review of the current situation and will highlight the planned measures to improve the post-closure safety of the site.

1. INTRODUCTION

A number of near surface disposal facilities exist in different countries for which long term safety has not yet been formally demonstrated. At some of these facilities, disposal practices were conducted in the past that would not meet modern concepts of safety, and consideration must therefore now be given to the need for corrective measures [1]. The Hungarian near surface repository at Püspökszilágy belongs to the latter category.

Many of these situations do not fall easily within the current ICRP framework for radiation protection, in that they are neither a justified practice nor a clear intervention. They might be termed mixed practice-intervention situations [2]. This term reflects the fact that such sites may be appropriate for continued use as a justifiable practice, or they may require intervention, after which they may then be appropriate for continued use as a justified practice.

The radioactive waste disposal facility at Püspökszilágy is currently the only site at which radioactive waste is being disposed of in Hungary. The repository was sited in 1971 and commissioned in 1976 in line with the international guidelines of the time.

The disposal facility consists of 60 vaults each of 70 m^3 volume and 6 vaults each of 140 m^3 volume. Initially, both unconditioned and conditioned wastes packaged in plastic bags or metal drums were placed in the disposal cells and partly or fully grouted in situ. Later the practice of grouting was terminated [3]. The site has currently no more unused capacity.

2. SAFETY CONCERNS

In 1998, the new operator of the facility, the Public Agency for Radioactive Waste Management (PURAM) recognized that inconsistencies existed in the recording of the waste that had been disposed of or stored historically at the site. Proposals were made to establish a comprehensive quality assurance/quality control system as part of the review of the safety of the repository.

Because the original licence did not contain waste acceptance criteria (WAC), high activity sources and spent sealed radioactive sources (SSRS) with long half-lives, and including alpha-emitting radionuclides, were disposed of in the repository. The lack of defined WAC meant that there was no safety benchmark, other than external radiation dose rate, against which the type of waste received could be judged.

The facility had not previously been the subject of any comprehensive safety assessment. However, in recent years, several safety assessments have been carried out with the aim of determining the long term radiological impact of the disposed waste and of developing an estimate of the overall disposal capacity of the site as a basis for decision making on the future of the repository [4, 5].

The results of the safety assessments clearly indicate that the SSRS could result in high radiation doses to individuals who intrude into the facility and that they could also lead to high doses following any future disruption of the facility by natural processes. In particular, the presence of certain large sources (e.g. ^{137}Cs) in the vaults gives cause for concern.

International recommendations covering such situations, i.e. the case of exposure resulting from past practices, call for obligatory intervention at predicted individual doses above 100 mSv/a and a more optimized approach to intervention when doses are between 10 and 100 mSv/a [6].

Furthermore, Article 12 of the Joint Convention states: “Each Contracting Party shall in due course take the appropriate steps to review: … the results of past practices in order to determine whether any intervention is needed for reasons of radiation protection bearing in mind that the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including the social costs, of the intervention” [7].

3. IDENTIFICATION AND EVALUATION OF CORRECTIVE ACTION OPTIONS

Because of the large number of parameters involved, an optimized intervention programme should be based on a systematic study. Such a study was carried out in the frame of a European Communities’ PHARE project with the aim of deciding on the most appropriate and acceptable method of safety upgrading [8]. The project developed a consistent scheme for analysing the situation at the repository and for ensuring that all factors essential for successful implementation were addressed.

3.1. Inventory and dose information

Data on the radionuclide inventory of the repository, the chemical and physical characteristics of the waste forms, and the doses associated with individual waste packages were key inputs to this study. The available inventory data were reviewed, and dose information collated. Dose information was drawn from two sources: radiation dose data on individual waste packages, and dose measurements made when two vaults were opened for inspection in 2000 to check on the conditions of the engineer barriers and the disposed waste. The review of inventory data resulted in a significant decrease in the estimated inventories for a number of key radionuclides, among them ^{14}C, ^{60}Co, ^{99}Tc, ^{210}Pb, ^{238}U and ^{238}Pu. Information on the chemical and physical properties of the waste forms has been collated. Waste form and inventory data are available on a vault by vault basis.

Analysis of the available data has shown that the β-γ dose rates from the majority of the items in the repository are relatively modest; 86% of the items have dose rates of less than 1 mGy/h, and less than 2% have dose rates in excess of 100 mGy/h. These observations suggest that external dose is unlikely to be a major issue during any recovery operations.

3.2. Framework for decision making

The ICRP framework for intervention is based on the consideration of an imminent risk. The trade-off between public risk and worker risk during the intervention is therefore relatively straightforward. For waste disposal the risks are mainly potential future risks. When determining the advisability of an intervention, the decision maker must therefore balance these potential future risks against certain risks (both radiological and non-radiological) to workers during the intervention. In addition, risks to the environment or to the public associated with some types of remediation technology may need to be factored into the decision.

The interpretation, analysis and presentation of the results is followed by the decision making process. This is multifaceted in that several varied and sometimes competing factors have to be brought together and reconciled to reach a decision. If several options exist, as it is usually the case in intervention situations addressing the upgrading of safety of existing facilities, the optimal option in terms of benefits (e.g. reduced hazard to the public in future) and detriments (e.g. hazard to workers and the costs of the intervention work) should be chosen [9].

The options for the future management of Püspökszilágy repository were assessed using a formal methodology based on multi-attribute analysis. The systematic approach provided by this methodology ensured consistent and thorough assessment of possible options, and ensured transparency in the decision making process and auditability of the outcome.

Options for the remediation were considered in three groups:

— Administrative approaches: extended institutional control, extensive recording of information about the site in local and national archives, and erection of a permanent site marker;
— Improved isolation of the site from the environment by construction of an engineered clay cap, perhaps coupled with the construction of curtain walls to divert groundwater flow;
— Recovery of waste types of safety significance. Four options for the amount of waste recovered were considered, based on ease of access to individual vaults and ease of identification of specific inventory items.

The options considered are not mutually exclusive, and allow the development of a final strategy by combining options from different groups if desired.

These options were assessed against ten criteria covering:

— Radiological and non-radiological risks to the public and workforce during the implementation of the option;
(a) Post-closure performance of the repository;
(b) Non-radiological environmental impact;
(c) Project risk and timescales;
(d) Sociopolitical acceptability;
(e) The potential for the disposal of future arisings of institutional waste.

3.3. Post-closure performance assessment

Satisfactory post-closure performance is an essential requirement for any future strategy for the management of Püspökszilàgy. Scoping calculations were undertaken to assess the performance of the repository in terms of dose to humans under current arrangements, and under each of the remediation options. Three sets of scenarios for dose assessment were considered:

— Human intrusion (both direct dose to workers and dose to the public due to the subsequent use of land for agriculture);
— Natural disruption of the repository, with and without subsequent dispersion of the waste;
— Transport of radionuclides in groundwater followed by their uptake in the food chain.

The effect of the administrative options is to delay the earliest time at which the human intrusion scenarios become credible. Current plans are for institutional control to be maintained for 100 years after repository closure. Doses to excavation workers fall only slowly after this time, and the effectiveness of the administrative options after this time is considered likely to be small. Doses from agricultural use of the land fall significantly between one and 300 years post-closure to values of the order of 1 mSv/a — close to the doses to excavation workers.

Improving the isolation of the facility from the environment mainly affects the transport of radionuclides in groundwater. Construction of an engineered cap is predicted to reduce rainwater ingress, and hence the amount of radionuclides leached from the facility. In the presence of an engineered cap, doses from groundwater pathways are estimated as being of the order of 1 μSv/a. These doses are judged to be well below the level of concern.

Recovering the waste of identified safety significance would not markedly affect the inventory of those radionuclides of importance in groundwater pathways. The waste recovery options do, however, influence the estimated doses through human intrusion and natural disruption. As the inventory is reduced by recovery of waste, there is a steady reduction in the doses estimated as a result of these scenarios.

The effects of projected future disposals at Püspökszilágy on post-closure performance were assessed. The radiological impact of these disposals is small compared with that of the existing inventory, or of the inventory after recovery of safety significant waste. The limitation on future disposals at Püspökszilágy is therefore likely to be due to volumetric rather than radiological capacity considerations.

3.4. Selection of final strategy

The options were considered at a moderated decision workshop which brought together experts from the United Kingdom and Hungary. The assessment showed that each of the three option groups identified above would add value to a final strategy:

— Waste recovery options improve post-closure performance from the perspective of human intrusion and would allow further disposals at the site by freeing volumetric capacity. Waste recovery should be limited to vaults with little or no concrete backfill, as the risks to workers associated with recovering waste from backfilled vaults was considered to outweigh the benefits to be gained.
— Improved isolation would provide marked reductions in doses to the public through groundwater pathways from radionuclide transport. The doses predicted after installation of a properly engineered cap were regarded as being so low that there was little merit in further reducing them by constructing a curtain wall.
— The administrative options provide two particular advantages: the increase in the period of active surveillance of the site helps to ensure that the other measures have been properly implemented and would allow for remedial action if this were necessary, and active control of the site would eliminate the possibility of exposure of a high activity source being uncovered immediately after repository closure. This event has very low probability, but would be of high consequence.

The strategy selected for the vaults at the Püspökszilágy facility can be summarized as follows:

> Waste from vaults containing less than 10 m^3 of concrete backfill will be recovered. Materials of safety significance will be removed and stored on site, pending disposal elsewhere. Other materials will be conditioned, as necessary, including the application of low force compaction where appropriate, and the compacted materials returned to the vaults. Other institutional waste appropriate for disposal in a near surface facility will be buffer stored on the site pending appropriate conditioning and disposal using the space created by conditioning the recovered waste. After filling, vaults will be backfilled with concrete, ensuring that all space between and above the waste packages is filled. The vaults which are already backfilled will be subjected to any remedial action needed to ensure that the backfilling for these vaults meets the same standard as the newly backfilled vaults. When the facility is closed, an engineered clay cap will be constructed above the vaults.
>
> Active institutional control of the facility will be maintained for 150 years after closure. Full information on the location, construction and inventory of the facility will be lodged in local and national archives. A permanent site marker will be erected.

Creating free capacity within some existing vaults appears not to be very difficult. Originally, 50 L plastic bags and boxes made of paper or wood were used as waste packages. The packages were positioned fairly loosely within the vaults. Consequently, by use of volume reduction technology (e.g. compaction), a considerable amount of space can be created for further disposal. This observation was confirmed during the vault opening operation in 2000. In order to make a judgement on which disposal unit was to be opened for waste retrieval, a detailed analysis of the individual waste disposal units was performed.

It is important to note that two actions — freeing space for disposal of additional institutional radioactive waste in the vaults, and retrieval of specific radioactive waste packages that are causing radiological concern — are interconnected. Both operations would require the opening of vaults that are already temporarily sealed and covered with protective layers of bitumen, clay and grass. For obvious safety reasons, it would not be appropriate to open the vaults more than once either to reduce the volumes of waste packages or to retrieve some specific items.

3.5. Implementation

The part of the strategy involving recovery of the waste, sorting, removal of sources and other safety critical waste, will be undertaken in the short to medium term, and has been elaborated into a concept plant design. It is intended to undertake a demonstration project in which four vaults, including one containing some backfill, are dealt with. This will be essential to ensure that details of the programme are correctly worked out in advance of a commitment to a complete recovery strategy. The licensing procedure for the demonstration phase is in progress.

After removing any soil covering, the vaults will be covered with a temporary containment, maintained at reduced pressure. Recovered waste will be overpacked for transport to the waste treatment building, which will include a contained area for managing the waste. The essential process steps include: unpacking the waste; sorting to identify those waste types to be permanently removed from the vaults; characterizing the waste to be returned to the vaults; compressing compactable waste with low force compaction; repacking the waste and returning it to the vaults for disposal.

The estimated timescale for this demonstration project is nine working months, and the estimated cost around one million euros. A preliminary estimate of the cost and timescale for the entire strategy can be obtained by scaling appropriate elements of the project plan and cost breakdown. More reliable estimates will be possible when the costs and timescales have been reviewed in the light of experience from the demonstration.

4. COORDINATING RESEARCH PROGRAMME

In 2001, the IAEA launched a new Coordinating Research Programme on ‘Application of Safety Assessment Methodologies for Near Surface Radioactive Waste Disposal Facilities’ (ASAM), which is now being implemented. It builds on the experience of the Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities (ISAM) project, with special emphasis on the application of the ISAM methodology to address practical problems of interest. The Püspökszilágy repository has been offered as a test case for the ASAM project.

In the framework of ASAM, the Reassessment Working Group (RWG) was tasked with reviewing the Püspökszilágy facility safety assessment as a basis for discussing issues associated with facility reassessment. The scope and objectives of the RWG are to provide practical demonstrations of the iterative application of ISAM safety assessment methodology to address real problems;

to support the review and judgement of the acceptability of different safety upgrading options by providing a quantitative comparison of them; and practical demonstration of the reassessment process in order to support decision making in the selection of alternatives for upgrading/demonstrating safety [10].

5. SUMMARY

The Püspökszilágy repository is considered unsuitable for certain types of waste formerly emplaced in the facility. Based on recent safety assessments, a judgement has been made that the long term safety of the repository may be ensured, but only with some technical and administrative modifications to the facility.

The use of volume reduction technology, following the retrieval of waste and the removal of specific packages that are giving rise to radiological concern, can provide free capacity within some existing vaults for further disposal of institutional radioactive waste. A demonstration programme, which is due to start in early 2006, will implement, on a small scale, the steps needed to create additional disposal capacity and to remove the most hazardous packages for temporary storage on site.

According to PURAM's plan, the repository will continue to be operational for several decades — receiving radioactive waste from non-nuclear power plant waste producers. By the end of this period, a geological repository is expected to be available to receive the long lived waste temporarily stored in the Püspökszilágy facility for which disposal in the near surface repository is not appropriate.

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REVIEW OF CONTRIBUTED PAPERS

Session IVa: NEW FACILITIES, REASSESSMENT OF EXISTING FACILITIES AND DECISION MAKING ON UPGRADING SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES

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Abstract

The paper contains a review of the contributed papers related to this session. The topics include reassessment of a near surface radioactive waste disposal facility, the upgrading of a national repository for low and intermediate radioactive waste, and the regulatory aspects of radioactive waste management.

The purpose of the first paper [1] is to present a very simple and conservative safety reassessment of the La Piedrera (Mexico) radioactive waste disposal facility. The La Piedrera near surface radioactive waste disposal facility was built in 1984. The disposal system consists of eight vaults with concrete barriers plus one without a concrete barrier. A layer of clean native soil covers the waste. This facility was created to dispose of the radioactive waste created as a consequence of the remediation actions after the 1984 accident in Ciudad Juarez, Chihuahua, which involved the meltdown of a ^{60}Co teletherapy source at a foundry facility. Considerable amounts of contaminated soil, metal pieces, and steel bars for construction resulted from that accident.

Due to the short half-life of the only nuclide involved, ^{60}Co ($T_{1/2}$ = 5.27 years), the assessment was limited to those waste forms that are susceptible to being affected in the short term by the possibility of rainwater entering fractures in the system and to those processes which can cause an immediate radiological impact. The end point of this assessment is to demonstrate compliance with the dose limits for the public. It makes use of the methodology developed by the IAEA under the Improvement of Safety

Assessment Methodology (ISAM) project to confirm that the repository has a low radiological impact on the environment and the public.

The second paper is dedicated to the upgrading of the national repository for low and intermediate radioactive waste in Romania [2]. In 1985 the National Repository for Low and Intermediate Radioactive Waste (DNDR) — Baita, Romania, was built and put into operation. It is sited in the Apuseni Mountains, in an old exhausted uranium mine. The facilities were designed and built according to the philosophy of the 1960s and 1970s for mainly institutional waste. The paper describes the current operational experience and the improvement of existing processes equipment and systems in order to enhance the safety of the facility. The aim is to bring the repository closer to modern standards so that it is able to accommodate waste from the decommissioning of a research reactor. Over the last two years, several systems were significantly improved: the electric and ventilation systems, the transport and manipulation system, the communication system, the physical protection system and the radiation protection system. By the end of 2005, a modern radiation protection and monitoring system and a suitable road transport system will be available. As of January 2004, a very important project for the Baita repository was undertaken: the preparation of the Preliminary Safety Assessment Report, which is expected to be completed by October 2006.

The third paper contains a description of the regulations on radioactive waste management as well as a description of the new regulations which will be issued by the Romanian regulatory authority to reflect international safety standards [3].

The current status of the regulatory system on radioactive waste management in the Russian Federation is presented in the fourth paper [4]. The hierarchical scheme of the legal and regulatory documents in the field of radioactive waste management includes:

— Constitution of the Russian Federation;
— Federal Laws and International Agreements;
— Legislative Acts of the President and Government of the Russian Federation;
— Federal regulations in the field of nuclear energy use;
— Guiding documents of the state safety regulatory authorities;
— Standards and industry regulations.

The system of regulatory documents on radioactive waste management as well as the legislative system of the Russian Federation in general are at the development stage. The paper describes new and recently developed regulatory documents in the field of radioactive waste management intended to bring harmony with international documents. The open items and future plans for improvement are outlined.

In the fifth paper, the regulatory safety concerns on radioactive waste management in Chile are discussed [5]. Radioactive waste in Chile mainly arises from medical and industrial applications and some research facilities, including a research reactor, and a small materials testing reactor (MTR) fuel fabrication plant. Up to now, the spent fuel from the research reactor has been sent to the United States of America, according to an international agreement, but in future, the spent fuel discharged from the reactor will have to be treated in Chile. It is also foreseen that in the near future (2010), nuclear power plants will be constructed in Chile, with consequent waste generation.

Chile has a waste conditioning plant capable of handling almost all medical and industrial radioactive waste generated in the country, and a temporary storage facility for conditioned waste, but this situation will change dramatically, when it becomes necessary to treat the new MTR fuel elements fabricated in Chile. Chile has no specific radioactive waste management regulations, and the work and efforts by the regulatory authority, to complete and update the legal framework, taking into account the possible scenarios of future radioactive waste generation, are described in the paper.

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PANEL

Session IVa
NEW FACILITIES, REASSESSMENT OF EXISTING FACILITIES AND DECISION MAKING ON UPGRADING SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES

Chairperson: **D. Clein** (Argentina)

Members: **D. Bennett** (United Kingdom)
P. Ormai (Hungary)
A.A. Smetnik (Russian Federation)
W. Goldammer (Germany)
P. Lietava (Czech Republic)
V. Nys (Belgium)
P.E. Metcalf (IAEA)

D. CLEIN (Argentina): It has been suggested that we take up the issue of the regulatory review of licence applications. I propose that we focus on licence applications relating to the reassessment of existing facilities.

In general, when regulators have to review licence applications, one of the first things they consider is the safety criteria to be used. In the particular case of the reassessment of existing facilities, regulators may encounter facilities which were originally licensed in an era of different safety standards but which the operator would like to keep operating. In such cases, the regulator may have to consider different approaches to licensing and possibly different criteria. I would like to bring this problem to our panel.

D. BENNETT (United Kingdom): At the Drigg repository in the United Kingdom, together with the existing well regulated practices there are some places where historical waste was disposed of. These disposals are the main contributors to risk at the site. As regulators, we have been very keen to see the operator develop what we call a 'risk management' approach — to demonstrate that he has an understanding of the overall risk at the site from past disposals, present disposals and future ones. We want the operator to carry out a very thorough exploration of the options for managing that overall risk with the aim of identifying the optimum approach. The optimum approach may include a range of intervention measures — for example, measures that are specific to historical disposals and measures that may benefit the whole site, such as work on coastal defences or overall site capping.

That is the kind of approach we are driving for — one that covers both practice and intervention situations within an overall risk management framework.

P. ORMAI (Hungary): The first question we should ask ourselves is whether our situation is a practice or an intervention situation. From my presentation it would appear that it is an intervention situation, but as we are going to continue operating the facility in question, at least as long as there is disposal capacity available, there are elements of a practice. So, it is a kind of mixed intervention-practice situation.

The next question is how to deal with this issue. We have no regulations regarding intervention situations, so the operator has to follow the regulations for practices. We could use the ICRP recommendations, but the ICRP framework is not directly applicable because, in the case of waste disposal, we are dealing a potential future risk rather than an existing risk to workers, the public and the environment.

One needs a different sort of approach in a mixed intervention-practice situation. At first, the main focus should be on evaluating the post-closure situation, because that is the most difficult part of the analysis. Then, when it is clear that corrective actions are needed, the decision making has to take into account the other risks — the social risks, the economic risks and so on.

D. CLEIN (Argentina): What about the communication of this mixed situation? How do you explain that you will regulate the practices at a site in one way but the historical waste on the same site in a different way?

W. GOLDAMMER (Germany): Let us assume that there is only a clear-cut intervention situation to manage — with no intention of disposing of any further waste. What safety criteria should be applied in the case of this facility? Would they be different from the safety criteria being applied in the case of new facilities? What about the long term risks? Should there be a relaxation as regards the allowable long term risks from this facility as compared to those from a new facility?

I doubt whether people living nearby could be convinced that, as this is a facility built 40–50 years ago, the long term safety criteria should be different from those which would be applied in the case of a new facility. I think that is the core question we must answer when dealing with existing facilities.

P.E. METCALF (IAEA): As regards communicating with stakeholders, there has to be a rational basis for the safety standards. The concepts of 'intervention' and 'practice' were explained in ICRP Publication 60; a practice situation was defined as a situation where a new activity is being introduced which will give rise to some exposure, and to benefits, but which can be controlled. An intervention situation was defined as a situation where there is an existing exposure which has to be reduced in the best way possible, taking costs and benefits into account.

The problem is that we have a grey area in between. In this grey area, unless there is a rational basis for the radiation protection regime, it will be difficult to explain things to stakeholders. I would tend to agree with W. Goldammer.

A.-C. LACOSTE (France): I have two examples of this kind of issue.

The first one relates to the decision we took in France to close the surface repository at the Centre de la Manche. That repository had started operating in the 1960s, just after the decision of a number of countries not to use the oceans any longer as a repository. The decision to close the repository was taken at the beginning of the 1990s. However, a view expressed by some was that the repository should not be closed without its contents being known. Our response was that we were not absolutely sure of the inventory, but that by making conservative assumptions it was possible to be certain that no safety issue existed. After a lot of discussions, the French Minister for the Environment called for a National Commission to deal with the matter. The Commission was required to advise on whether it was worth opening the surface repository in order to learn more about what was inside it. The Commission's conclusion was that it would not be appropriate to open the repository, because the cost in terms of occupational exposure would be out of proportion to the benefit in terms of greater knowledge regarding its contents. Since then, the repository has been closed down and the controversy has subsided.

The second example relates to Cadarache, where trenches had been used for waste disposal — a typical legacy from the past. We had so little knowledge of what had been put into the trenches that I decided that the trenches should be cleaned up and all the waste should be treated and transferred to proper repositories.

So, there you have two contrasting decisions regarding the same issue — what to do with waste disposed of according to an old way of doing things. There was no discussion about interventions or practices.

D. CLEIN (Argentina): Would you say that the decisions were based on common sense?

A.-C. LACOSTE (France): We considered all the data, and if I were faced with those two situations now I would take the same decisions that were taken then. However, I am not sure that they were entirely rational decisions, because there were so many things to take into account.

P.E. METCALF (IAEA): I am sure that A.-C. Lacoste took the decisions in question on an informed basis. There must have been predictions of what the doses might be. In the case of the Centre de la Manche, for example, if it had looked as if, in 50 years' time, people were going to receive, say, 50 mSv/a, he would undoubtedly have thought seriously about — if not removing material — doing something in terms of institutional control. One needs some point of reference for one's decisions, and people are going to ask which the best point of reference is.

D. CLEIN (Argentina): Regulators are often subject to so many pressures that sometimes they do not know what the most rational approach is.

P. ORMAI (Hungary): When one is planning corrective actions there are usually plenty of options, but two factors can very much limit the options — namely, the volume of waste to be treated and the disposal route (if there is no disposal route, it is very difficult to design a retrieval strategy). When the options are very limited, maintaining the status quo may be a solution.

A.-C. LACOSTE (France): Regarding what I said about not being sure whether the decisions were entirely rational, one purpose of the decision taken in the case of Cadarache was a way to point out that there were new ways of doing things and that some disposal solutions were no longer acceptable, to point out that we were embarking on a new waste management policy in France. In that sense the decision was not entirely rational. I wanted to set a warning.

W. GOLDAMMER (Germany): I think that is a very interesting example, but I am not quite clear about what your rationale was in the case of the Centre de la Manche. On one hand, you said that the repository started operating in the 1960s, so it was not based on today's technology. On the other hand, you said that there was no discussion about interventions or practices. Were the criteria used by you to judge the significance of possible future impacts the same as you would use for a new practice today?

D. LOUVAT (IAEA): The philosophy behind ICRP Publication 82 was formulated not for the purpose of addressing this type of issue and, in any case, decisions should not be based only on dose criteria, it is rather a problem of optimization. The two examples A.-C. Lacoste gave related to cases dealt with by means of optimization. It was possible to estimate the doses that the workers would receive if they opened up the repository at Centre de La Manche compared to the potential doses which could occur in the future if no action were taken.

I do not think that we should base decisions purely on the different dose criteria for practices and interventions. It is generally a question of optimization.

P.F. HEILBRON (Brazil): I agree with D. Louvat, because, when you carry out an intervention, you are reducing the risk for the public but increasing the risk for the people involved in the cleanup. You have to be very careful to balance these two things, and the only way to do that is to make an optimization analysis.

V. NYS (Belgium): I do not think it is just a question of optimization calculations. As P. Ormai indicated, there must be a disposal route. It is not a question of solving the problem for 10–20 years — the problem has to be solved for a much longer period.

F. KING (Canada): I have a question for D. Bennett.

My understanding from what you said about the Drigg repository is that you have the results of a safety assessment which show that both the old practice and the current practice do not meet the safety criteria, so that from an operational point of view it is just ‘business as usual’ while you are deliberating about what the final solution should be.

If that is the case, I was wondering whether you had considered temporarily changing the waste acceptance criteria (WAC) in such a way that only certain waste streams would be allowed to enter the facility. Then, those waste streams which did not meet the current safety criteria, could be put into interim storage while you continue your deliberations.

D. BENNETT (United Kingdom): It is really the historical disposals that are the problem, rather than the current disposals. The importance of current and future disposals on the overall impact is less. We have considered the kind of approach that you are thinking of, but we have opted to carry on with ‘business as usual’ for the time being.

C. McCOMBIE (Switzerland): I agree with what was just said about optimization, but the definition of ‘optimization’ in the IAEA Safety Glossary talks about ‘social and economic factors being taken into account’. Do regulators take them into account? Did they take them into account at Cadarache? Was it not cheaper at Cadarache to remove the waste than it would have been at the Centre de la Manche?

A.-C. LACOSTE (France): In the cases of Cadarache and the Centre de la Manche, I tried to do a kind of optimization, but I would not use the expression ‘optimization calculations’. There were too many qualitative aspects to my decisions for one to speak of ‘calculations’.

In the case of my decision regarding Cadarache, I wished to make it clear to the French Atomic Energy Commission (CEA) that certain practices were no longer acceptable, by imposing on the CEA a huge financial penalty. My decision was also influenced by the fact that there was a disposal solution for the waste that was going to be removed from the trenches. In such a situation one has to take account of many things, most of them qualitative.

J.-M. POTIER (IAEA): I was involved in the closure of the Centre de la Manche as an implementer and I would like to add something to what A.-C. Lacoste said about his decision regarding the repository there.

The repository at the Centre de la Manche was operated from 1969 until 1992, and the main problem we had during that period (a problem which is probably common to many disposal facilities) was that the waste acceptance criteria became more stringent regarding the acceptance of long lived radionuclides. In the 1980s, the activity limit for long lived radionuclides was reduced by a factor of ten, and at the time of the closure, the waste packages which had been disposed of in the repository at an earlier stage did not comply with the new waste acceptance criteria. So, critics of the repository requested that these old waste packages be retrieved. A feasibility study was carried out in order to assess both the feasibility and the radiological impact on the workers of retrieving the waste packages. The conclusion of the study was that the waste packages should be left, as A.-C. Lacoste mentioned, but because of the long lived radionuclides in the packages, it will not be possible to release the site after the envisaged 300 years of institutional control. So, the regulators have decided that monitoring should continue as long as is necessary — probably beyond the 300 year period.

So, when waste acceptance criteria become more stringent, what should be done with the waste already disposed of?

A. ZURKINDEN (Switzerland): After listening to this morning's presentations, I feel the need for reassurance. I should therefore like to ask whether there are any near surface disposal sites which are not already a problem and which are not expected to become a problem in the near future.

P.E. METCALF (IAEA): The Centre de l'Aube and El Cabril are well engineered facilities.

J. KOTRA (United States of America): I want to add something to what P.E. Metcalf said in his presentation about the United States approach being risk informed and how that can be problematic if you do not have all the information that you need. We like to think of the approach as risk informed and performance based. A risk informed performance based approach allows the greatest reduction in risk for the resources available — taking into account the social and economic factors. It provides a structure within which to take the decision and makes the basis for the decision more visible. I do not know whether that necessarily makes things any easier, but it certainly makes all the variables that you are wrestling with more visible to yourself.

A.-C. LACOSTE (France): Regarding A. Zurkinden's question, I think the answer is "Yes", but we must be cautious about compliance with the waste acceptance criteria. In countries with a low level short lived waste repository there is often great pressure on the operator to accept waste which is not exactly covered by the waste acceptance criteria for example, disused sealed sources. It may not make a great impact on the total radioactive inventory of the repository, but this type of waste cannot be accepted if the sealed sources are long lived ones. This is a kind of social and political pressure which the operator and the nuclear safety authority must withstand.

Regarding J. Kotra's comments about risk informed decision making, the difficulty is that in quite a lot of cases you do not know the risks. If you are not sure about the contents of an old repository what does 'risk informed' mean? In my view, the situation is just like the one you have with an old nuclear power plant which is subjected to non-destructive tests; you carry out the tests, but you do not have the results of such tests carried out at the beginning of the life of the plant because those tests did not exist at that time, so you cannot compare the initial state of the plant with the present state. In each situation, you are not risk informed — and you nevertheless have to take a decision.

P.E. METCALF (IAEA): In my view, the discussion has shown that safety criteria are important and decision aiding tools are also important, but even with these aids the regulator still has to make a judgement taking into account a whole range of factors. It is not a mechanical process — it is a process that involves a lot of value judgements as well.

D. CLEIN (Argentina): I would like to pose the following question: does the regulator require a safety case for such situations?

P.F. HEILBRON (Brazil): In Brazil, a safety case is something like a preliminary safety analysis. The operator sends it to us and we comment on it and then the operators produce the final safety report. It does not matter whether it is for a nuclear power plant, a repository or a contaminated site.

P. LIETAVA (Czech Republic): I think the real issue is 'What is the safety case in the context of national legislation?' The term 'safety case' is very well defined in the IAEA Safety Glossary, but in different countries there are different interpretations. In general, I think that the regulator requires a safety case containing a safety assessment.

P.F. Heilbron described the situation in Brazil. In my country, there are different safety cases, starting from the initial safety case and ending with the decommissioning safety case (or closure safety case for a repository).

C. McCOMBIE (Switzerland): In his presentation, P.E. Metcalf talked about regulatory review of the safety case, but there is a kind of safety case which you submit, not to the regulator, but to the general public. We are using the same words — safety case — for slightly different documents aimed at different audiences.

As an implementer, when submitting that kind of safety case to the public, I would like to know that the safety case already submitted to the regulator had been approved.

P.E. METCALF (IAEA): We should not get tied up in semantics. In different countries there are different approaches and different terminologies, but everywhere you must present all the arguments and all the evidence, you must submit a safety assessment, you must describe the logic of your design, and you must demonstrate that you have a good organization — and, when you talk to the public, you must show that there is a good regulatory process as well.

D. CLEIN (Argentina): I should like to ask P. Ormai for his views regarding the relationship between the regulator and the implementer.

P. ORMAI (Hungary): In our case, we involved the regulator as one of the stakeholders in the decision making process, making it clear what we were planning to do and how we were planning to do it. When we decided on the options to be recommended, in what was clearly a brand new situation, the regulator demanded another safety case, with a full justification for those options selected and an assessment of the doses to workers and the public. We had to do a lot more calculations and provide a lot more evidence.

D. CLEIN (Argentina): Would you like a more permanent exchange of views with your regulator?

P. ORMAI (Hungary): Yes. As I tried to explain, our approach is a kind of staged approach, because the problems are really complex. When we decided to start the demonstration project, it was our intention to try a kind of iterative discussion with the regulator. That is our approach, but it depends very much on the regulatory body of course.

D. CLEIN (Argentina): Is it possible to maintain a permanent dialogue between the implementer and the regulator in this area of radioactive waste management?

D. BENNETT (United Kingdom): This is a country specific matter to some degree. From the United Kingdom perspective I would say that it is certainly possible. It is also very important. I think it is the kind of dialogue that should start at an early stage. What the two parties should do at an early stage (I say ‘two parties’, but there may be a number of regulators) is get together and try to map out and agree on the process lying ahead, so that everybody’s understanding of the process and the regulator’s needs is clear.

W. GOLDAMMER (Germany): I think it is important to try to structure the discussions on decision making by using decision aiding approaches. These are no substitute for the decision making process, but they are of great help, as I have seen in many cases.

V. NYS (Belgium): I agree with W. Goldammer. I would simply add that, producing a safety case and a safety assessment is a very long process. The regulator should therefore be informed early in the process about the problems involved and try to solve them with the implementer. So, for me it is very important to have a dialogue during the whole process.

D. CLEIN (Argentina): What if there are several regulators?

D. BENNETT (United Kingdom): In my country, in the area of radioactive waste management, we have two main regulators — the regulatory body which deals with worker safety at the site and my organization, which deals with off-site impacts. For a number of years, until about three years ago, there was a fair amount of criticism from various nuclear facility operators regarding matters such as the divergent views of the two regulators and confusion as to their requirements, and accusations that the two regulators were pulling them in different directions.

In order to resolve this issue, about three years ago we organized a one day workshop for operators that was independently facilitated. The facilitator asked all the operators for examples of problems due to the regulators and then selected about half a dozen of the examples which were examined by the two regulators and the operators with a view to establishing the reasons for the problems and what could be done about them. It was a very informative workshop from which it emerged that there was a kind of ‘common-mode failure’ in most instances on the part of the operators, who were not explaining to the regulators at an early stage what they had in mind, so as to raise the awareness of the regulators, and were failing to gain an understanding of the regulators’ concerns. As a result of the workshop, there is now a commitment to early dialogue for new projects, and particularly for one-off projects.

Also as a result of the workshop, the two regulators acquired a better understanding of how the regulatory process should have worked and what the priorities should be.

Since then we have been making sure that we get together both at the national level and at the local level at least every year in order to compare priorities and working practices and, where we can, to tackle issues of common concern. Also we are doing things such as attending each other’s training courses so that we get a full understanding of each other’s points of view.

The issue has not gone away completely, but I think the situation has improved.

A.A. SMETNIK (Russian Federation): The situation in my country regarding communication between regulatory bodies is very simple. The nuclear regulatory authority, which is the body responsible for issuing licences, bases its conclusions largely on the expert reviews by the environmental department.

Today, in the Russian Federation, we do not have disposal facilities. We have only storage facilities. We have this situation because, up to this year, we did not have safety standards and rules for regulating disposal activities, so the regulatory authority could not issue licences for such activities. This year necessary standards and rules were approved, and I think that the disposal facility licensing process will start soon.

P. ORMAI (Hungary): An old repository can be a national asset. We all know how difficult it can be to site a new repository, so we should be very pleased to have a repository at all. However, we must realize that the old repository will not be safe in the long term and we must do what is necessary in order to keep our facility and bring it to a safe condition.

W. GOLDAMMER (Germany): I would like to make two suggestions regarding what the IAEA could do in the future.

I have been involved in several IAEA projects — and my impression is that the people there responsible for old repositories require additional guidance on doing safety assessments for the long term, with particular emphasis on the human intrusion issue, for example, on how to develop credible scenarios and on how to define the parameters. Therefore, it might make sense to seek agreement on some stylized intrusion scenarios, because the nature of human intrusion will be the same all over the world.

My second recommendation concerns decision making. There are usually many factors involved, and the question arises of how to bring them all together in arriving at a decision and then how to explain the decision and communicate it to the public. I think there is merit in using some kind of decision aiding techniques. Whether you do that or not, there have to be some structured ways of arriving at a decision, and I think it would be very beneficial to have more guidance on that.

V. NYS (Belgium): I agree completely with W. Goldammer. In my view, more work needs to be done on the human intrusion issue.

P.E. METCALF (IAEA): We have seen that the regulatory process is not straightforward. You need resources and a methodology. My experience in the IAEA over the past few years has been that quite a lot of smaller regulatory authorities need to develop more capacity and gain more experience. Therefore, programmes like the ASAM programme, where people can come together and exchange experience and work on common projects, are very useful. I would encourage people to become involved in such projects.

D. BENNETT (United Kingdom): In my view, optimization is the right way forward in dealing with existing facilities and it should be based on a structured approach that involves regulators and other interested stakeholders from an early stage.

As has been said, there are grey areas, but I think one could perhaps make them a lighter shade of grey through the production of guidance — with a few case studies — on how to tackle situations where new disposals are planned at sites where disposals took place in the past.

D. CLEIN (Argentina): I would simply add that, faced by the challenge posed by the regulatory review of licence applications relating to existing radioactive waste management facilities, the regulatory authorities in many countries must change their ways of operating.

REGULATORY CONTROL AND COMMUNICATION OF SAFETY ISSUES

(Session IV)

COMMUNICATING THE SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES

(Session IVb)

Chairperson

C. McCOMBIE
Switzerland

Rapporteur

P.F. HEILBRON
Brazil

EXPERIENCE OF THE REPUBLIC OF KOREA IN COMMUNICATING THE SAFETY OF RADIOACTIVE WASTE DISPOSAL

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Abstract

After experiencing a series of unsuccessful site selection attempts for radioactive waste disposal over the last 20 years in the Republic of Korea, it has been concluded that there was insufficient public participation in the decision making process. In the paper, the status of radioactive waste management in the Republic of Korea and its site selection activities are briefly reviewed and two specific cases of experience in communicating the safety of radioactive waste disposal are presented with the intention of contributing to the improvement of communication with the public.

1. INTRODUCTION

In the view of the author, the failure to secure a disposal site for radioactive waste in the last 20 years in the Republic of Korea was mainly due to the lack of skill in communicating the safety of radioactive waste disposal to the public. In this presentation, two case studies aimed at improving communication with the public on the safety of radioactive waste disposal are described. In addition, the status of radioactive waste management in the Republic of Korea and its site selection activities are briefly reviewed.

2. STATUS OF RADIOACTIVE WASTE MANAGEMENT IN THE REPUBLIC OF KOREA

Two types of radioactive waste exist in the Republic of Korea: low level waste (LLW), and spent fuel. Both of them are stored on site at nuclear power stations. The on-site or at-reactor storage capacities for LLW and spent fuel will reach their limits between 2006 and 2014 depending on the particular nuclear power station site. Hence, there is concern in the Republic of Korea about finding sites in time for locating both the disposal facility for LLW and the ‘away-from-reactor’ interim storage facility for spent fuel. The disposal of HLW is not included in this presentation since the Republic of Korea does not possess any high level waste (HLW) at the moment [1].

In 1986, the Korea Atomic Energy Research Institute (KAERI) was designated to be responsible for managing radioactive waste in the Republic of Korea, and the Ministry of Science and Technology (MOST) was the responsible authority on the government side. Several unsuccessful site selection campaigns were carried out under the responsibility of KAERI and MOST. In 1997, the responsibility for radioactive waste management was transferred from KAERI to the Korea Electric Power Corporation (subsequently Korea Hydro and Nuclear Power Company — KHNP), and the responsible authority became the Ministry of Commerce, Industry, and Energy (MOCIE) instead of MOST. In this paper, four site selection attempts in the KAERI/MOST era and four more in the KHNP/MOCIE era are reviewed with the purpose of learning lessons from the failed attempts.

2.1. Site selection activities (1986–1996)

In the first attempt, three candidate sites were proposed. During the geological survey work, strong protests from local residents were encountered, and all activities were stopped in 1989. Local governments declared their positions against the siting programme, and the central government followed with the nullification of the siting programme for fear that unfavourable results would influence the upcoming presidential interim evaluation. The failure was due to a lack of transparency in conducting the geological survey. There also existed a lack of communication and coordination between KAERI, local residents, local government and central government.

The second attempt, at Ahnmyundo, started with the close cooperation of the local provincial government. A large scale investment for local community development was officially promised in compensation. During the negotiation process, however, the scheme was prematurely disclosed by media, and a riot of local residents occurred. Antinuclear and intervener groups joined the local residents in their protests. The Government had to eventually give up the attempt. The strong residents’ opposition was caused by the exclusion of public participation from the major steps of the decision making process: it was a case of decision making first and persuasion afterwards. The widespread dissemination of unfounded information on the negative aspects of radioactive waste was also prevalent.

The third attempt was different from the previous attempts. Recognizing the importance of the social aspects, a site selection study was conducted by a group of institutes of social studies led by Seoul National University.

Antinuclear protests were organized against the study and the study results have never been presented. The process was another failure. In this attempt, the movement of antinuclear groups was strongly organized for systematic intervention and public arousal. After this, radioactive waste management became a major political issue in the 1992 National Assembly Election.

In the fourth attempt, the ‘Law of Compensation’ was established to officially provide the local government with financial support in providing compensation. With the backing of the law, KAERI/MOST solicited applications from local governments. Even though 56% of local residents of Uljin supported the application, the violent riot led by antinuclear protesters, including the seizure and blockage of major roads, forced KAERI/MOST to withdraw from the site. Serious conflicts among residents occurred. They were concerned with the allocation of supporting funds, and a strong hostility between local proponents and opponents developed.

2.2. Site selection activities (1997–present)

The first site selection attempt under the responsibility of KHNP/MOCIE was based on a new law called ‘Law of Solicitation’ together with the existing Law of Compensation. In 2000, KHNP/MOCIE announced a bid from a community in a coastal area. The prerequisite was that the bid should be approved by the local council prior to formal application. Subsequently, no formal application was received related to the initial bid.

In 2002, another bid was solicited, jointly announced under the names of seven government department ministers, and targeted at four designated candidate sites (two on the east and two on the west coasts). There was no bid application on this occasion either, except by Booan County on Weedo Island, which was not included in the original list of four designated candidate sites. In spite of the strong desire of the Weedo residents, there was a series of violent activities by antinuclear protesters at other places in Booan County; the activities included:

- Imposing fines on persons who did not participate in the opposition demonstration.
- Pressure to sign against the project via house-to-house visits.
- Inducement of local government employees to resign.
- Forcing local leaders to be in the front line in opposing the project.
- Instigating students not to attend school.
- Assaulting teachers in front of their students.
- Putting stickers on proponent houses.
- Vandalism with red paint.

— Intimidation using phone calls and letters.
— House intrusion, destruction of households and harassment.

In February 2004, one more bid was solicited by KHNP/MOCIE. It was open to all local governments and was supported by another new law called ‘Law of Consent’ which requires the majority consent of county level local residents using an official balloting process prior to a final decision. The new bid was closed in November of 2004, and there were no bids.

On 16 June 2005, the Government of the Republic of Korea announced another new bidding procedure and a ‘Special Law’ which supports its activities. In this procedure, LLW disposal was separated from interim spent fuel storage. The local government, as approved by its local councils, can only solicit the bid by 31 August 2005 and local referendums must be finished by 15 September 2005. A majority consent out of one third of the eligible voters participating is required. The Special Law also specifies that the bid winner receives as follows: (1) a lump sum cash support of 300 billion won; (2) a site charge per waste drum disposed; (3) the movement of the KHNP headquarters to the disposal site; and the provision of other lucrative governmental projects.

3. COMMUNICATION WITH THE PUBLIC

From the previous activities, the importance of public acceptance is evident. No decision was able to be made based upon efficiency alone, but was heavily dependent on public acceptance of its outcome. Decisions have usually been made by a group of experts using the technique of cost–benefit analysis (CBA), and the public are persuaded or convinced afterwards through explaining, educating and publicizing. This type of one way communication has drawn a strong negative response from the public even with the series of patchwork laws, such as the laws of compensation, solicitation consent, and the special law, that the Government continues to create and impose. The public’s distrust of decision makers has increased. Therefore, it is recognized that to regain public trust, public opinion must be assimilated during the decision making process, rather than afterwards, using proper communication [1].

Two specific cases of experience in communicating the safety of radioactive waste disposal are presented, which might contribute to improving communication with the public. They are inclusion of public risk perception as a decision making element in selecting the options for spent fuel management; and use of electronic public participation (EPP) in analysing public opinion on the idea of disposing of LLW within the Seoul National University campus.

3.1. Case 1: Inclusion of public risk perception in the decision making process [2]

Radiation risks are perceived very differently by each person since each individual has his or her own psychological effects and lives in different societal and socioeconomic environments. The 'perceived risk' by a member of the public is very subjective, and should be well distinguished from the 'numerical risk' that is objectively computed by a group of experts using rather sophisticated means with sufficient data and information. Hence, public opinion could be consolidated and represented by adopting the 'public risk perception' as one of the elements in the nuclear related decision making process. A psychometric model could reveal the individual's psychological basis of risk perception and quantify the public risk perception. The model presumes that risk perception may be determined by a combination of degrees of dimensions of psychological risk.

The purpose of the Case 1 study was to find the best option for interim spent fuel management in the Republic of Korea. Based upon a simple cost comparison analysis, six options were selected: intersite transhipment of pressurized water reactor (PWR) fuels, at reactor (AR) dry storage, away from reactor (AFR) interim storage, overseas storage, overseas reprocessing, and direct use of PWR fuels in CANDU (DUPIC). The expert group, composed of 16 nuclear experts and professionals, participated in the expert assessment, and identified five decision making elements for this case: economy, safety, technology, international affairs and public risk perception. The results of cost analysis are used for utility analysis of the first decision making element (economy). Utilities of the second decision making element (safety) are calculated using the existing data on collective dose. Utilities of the third decision making element (technology) and the fourth decision making element (international affairs) are quantified using the results of the expert poll on the degree of contribution and diplomacy, respectively. Utilities of the fifth decision making element (public risk perception) representing the public opinion are quantified using the psychometric model with the data collected from the public poll through a prepared questionnaire. For the public poll, 375 people were selected to evaluate the risk perception, including the nearby residents of nuclear power plants.

Seven psychological risk dimensions (i.e. inequity, not easily reducible, risk to next generation, catastrophic potential, unknown to science, immediacy of consequences and dread) are reduced to four factors using a statistical factor analysis for the optimization of computation. Using the expert poll, the weighting vector (normalized eigenvector) of decision making elements is computed. The weights are calculated by normalizing the initial eigenvalues.

The resultant factors and corresponding weights are: 0.531, 0.191, 0.154 and 0.123. The assigned value for the fifth decision making element (public risk perception) is given by the linear combination of these four factors, and their corresponding weights, which are computed by the results of the public poll for the given option.

Each linguistic variable is converted into a corresponding triangular fuzzy number for the analysis of vague expressions of the public. Total utilities computed using the Multi Attribute Utility Analysis (MAUA) are summarized for ranking, and the rank is compared with that obtained using fuzzy integrals. Both results show no rank changes. The results of the case study are summarized in Table 1.

Based upon the results of the Case 1 study, it can be concluded that the inclusion of public risk perception as one of decision making elements suggest that one of the most important elements in communicating is the safety of a nuclear related decision making subject. For public acceptance, it is essential for a comprehensive tool and system to be developed for narrowing the opinion gap between the public and experts on radiation risk.

3.2. Case 2: Use of electronic public participation in decision making processes [3]

In recent times, electronic public participation (EPP) through the Internet has gained more and more power due to its effectiveness and popularity. Through EPP, the public are able to not only have an easy access to a vast amount of information but also participate directly in the decision making process and to express their opinions without difficulty. EPP can be

TABLE 1. RESULTS OF STUDY ON SPENT FUEL MANAGEMENT OPTIONS [2]

Option Ψ_i	Description*	Total utility	Fuzzy integral	Ranking
Ψ_1	AR dry storage (2)	0.676	0.657	1
Ψ_2	Inter-site transshipment of PWR fuels (1)	0.573	0.566	2
Ψ_3	AFR interim storage facility (3)	0.492	0.487	4
Ψ_4	Overseas storage (4)	0.557	0.512	3
Ψ_5	Overseas reprocessing (5)	0.420	0.461	5
Ψ_6	DUPIC (6)	0.224	0.258	6

* The numbers in parentheses are the ranks of a cost comparison analysis.

achieved at each phase of the decision making process by sending email notes, participating in electronic debates, and responding to cyber poll surveys.

The cyber poll survey can be successfully used for EPP if the views of the public participating in the decision making process can be assessed. First, an appropriate questionnaire is prepared so that the poll participant can fully express his or her characteristics. Next, the method of quantifying the characteristics is developed for further manipulation of the acquired data. The specific steps taken for assessing the public opinion using the cyber poll survey are as follows: (1) selection of the decision making factors representing the personal characteristics of the respondent and affecting public opinion; (2) analysis of response elements for each decision making factor using a fuzzy approach; (3) aggregation of the decision making factors using fuzzy weighted averaging; and (4) derivation of the value representing the characteristics the public through a defuzzification process.

The procedure has been applied to the cyber public poll survey which was conducted for the siting of the radioactive waste disposal facility on the Seoul National University campus. The cyber poll survey was carried out using Internet. A total of 259 persons over the age of 20 took part in the poll survey. Anyone who visited the web site could participate in the survey by answering the prepared questionnaire.

The web visitor was first asked whether he or she agreed or disagreed with the idea. Next, six decision making factors which characterized the personal identity of the poll respondent were presented for responses in order to evaluate the characteristics of the respondent. Age, income, education and residence of the respondent were chosen as four independent decision making factors. Knowledge of radioactive waste and degree of concern about environment and nuclear energy were treated as two dependent decision making factors.

To determine the fuzzy variables assigned to the dependent decision making factors, a set of specific questions were prepared in the poll survey questionnaire. For example, in order to assess the decision making factor of knowledge on radioactive waste, a set of appropriate multiple choice style questions were prepared so that the respondent could simply choose from a set of given answers.

In order to evaluate the characteristics of poll respondents, the defuzzified values are computed. As can be seen in Table 2, the defuzzified values in the column 'Disagree' are greater than those in the column 'Agree', except in the case of weighting with Income Dominant.

The higher value of 'agree' than 'disagree' in the case of weighting with Income dominant may indicate that more people with higher income agreed with the idea than ones with lower income. Residence and knowledge are found to be dominant decision making factors in the Case 2 study. As can be seen in the far right hand column of Table 2, the differences are 0.12 and 0.11 for residence and knowledge, respectively, and are substantially bigger than for the other four dominant cases.

Based upon the results of the Case 2 study, it can be concluded that EPP could be successfully and comprehensively utilized in the nuclear related decision making process, especially in assessing a cyber public poll survey incorporating the characteristics of the public.

4. CONCLUSION

After experiencing a series of unsuccessful site selection attempts for radioactive waste disposal over the last 20 years in the Republic of Korea, it has been concluded that there was insufficient public participation in the decision making process. Public participation programmes are complex and require continuing efforts to enhance them. A successful programme cannot be accomplished overnight. Patience and persistence is needed to develop a comprehensive programme, with emphasis on the improvement of communication in relation to safety in particular. The Case 1 study suggests that public risk perception could be an important decision making element in communicating the nuclear safety. The reduction of the gap between perceived and numerical risks appears to be one of the important issues in promoting public acceptance. The Case 2 study suggests that utilization of electronic public participation could greatly contribute to enhancing the effectiveness of communication.

TABLE 2. DEFUZZIFIED VALUES FOR DIFFERENT CASES [3]

Weighting method	Agree	Disagree	Difference (disagree–agree)
Age dominant	0.29	0.29	0.0
Income dominant	0.48	0.42	–0.06
Education dominant	0.53	0.56	0.03
Residence dominant	0.40	0.52	0.12
Concern dominant	0.47	0.50	0.03
Knowledge dominant	0.36	0.47	0.11
No weighting	0.43	0.47	0.04
Weighting on expert opinions	0.43	0.52	0.09

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SKI'S EXPERIENCE IN COMMUNICATING SAFETY IN THE SITING OF A FINAL REPOSITORY FOR SPENT NUCLEAR FUEL

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Abstract

The paper summarizes experiences obtained by the Swedish Nuclear Power Inspectorate (SKI) in the ongoing siting process for a final repository for spent fuel in Sweden. It emphasizes the importance of public involvement at all stages of the decision making process and describes the roles and involvement of the various stakeholders.

1. INTRODUCTION

This paper summarizes some experiences gained by the Swedish Nuclear Power Inspectorate (SKI) during the ongoing process for siting a final repository for spent nuclear fuel. The focus is on activities in the municipalities involved in the siting process. In order to give the proper context, some basic elements in the legislation, which are important for public participation and confidence in the siting process, are outlined. The importance of clearly defined responsibilities and early participation of the regulators in the siting process are emphasized.

2. DIVISION OF RESPONSIBILITIES

The Swedish legislation stipulates that the holder of a licence to conduct nuclear activities shall adopt the measures necessary to "in a safe manner, handle and dispose of waste generated by the activity or ... nuclear substances which are not re-used". Thus, the nuclear power plants have the technical and financial responsibility for siting, developing and constructing a final repository. The task for SKI is to ensure that the nuclear power plants live up to their responsibility. The authorities must also clarify in their regulations the safety and radiation protection requirements for final disposal and the required facilities.

The nuclear power plants have assigned their legal obligation to develop and implement final disposal measures to the jointly owned company, the Swedish Nuclear Fuel and Waste Management Co. (SKB).

3. THE SITING PROCESS

An important step in the nuclear waste programme was taken by SKB in 1992 when the company initiated an active siting programme by informing all Swedish municipalities (about 280) about the programme and invited them to participate in the siting process, on a voluntary basis. It can be said that municipalities at this point become stakeholders in the Swedish nuclear waste programme.

There are currently six municipalities involved in so-called feasibility studies for a final repository for spent nuclear fuel. These studies are entirely based on existing information, i.e. no drillings have been made. In a second phase, at least two sites will be chosen for careful site characterization, including extensive drilling programmes. In the third phase, one site will be chosen for detailed characterization which in practice means construction of the first part of the final repository. Detailed characterization requires a licence from the Government, based on an extensive regulatory review. A licence application might be submitted in the period 2005–2010 and initial operations of the final repository could then start after 2010.

The feasibility studies were concluded during the year 2000. Preliminary final reports for all six municipalities have been published by SKB. The municipalities have reviewed SKB's preliminary reports and the final reports took into account this review. Typically the municipalities submitted the reports for comment to 50–150 different organizations (e.g. local and regional administrations, political parties, neighbouring municipalities and interest groups of all kinds), mostly locally/regionally based but often also some academic institutions.

SKB suggested two sites for site characterization in 2001: Östhammars municipality and Oskarshamn municipality. At the same time, SKB presented amendments to its research programme to take account of certain conditions defined by SKI and the Government.

3.1. Stepwise implementation

In SKI's opinion, which is shared by most concerned parties in Sweden, the stepwise approach to implementation is essential since it allows, at each step, for evaluation of the steps taken so far and for deciding on the appropriateness of the next step. Thus, at each step, it is possible to reverse or redirect the waste management programme. A key element in the Swedish stepwise approach is the requirement in the Act on Nuclear Activities that SKB must present its research and development programme to the Government every third year, which may result in new conditions being set for SKB's future work. The review of the programme is carried out by the SKI which, in turn, invites comments from a large number of organizations, e.g. other authorities, municipalities involved in SKB's siting process, environmental groups, universities. Thus, the review serves the two-fold purpose of giving a broad audience insight into SKB's work and providing the same audience with the possibility to comment, and hence influence, SKB's future work.

3.2. Stakeholders

A discussion on stakeholders in the Swedish nuclear waste management programme must first of all recognize that there is not a formal definition of a stakeholder and that the concept is rarely used at all. The general attitude is, rather, that those who have an interest or feel concerned should be taken seriously and listened to. This is, for example, reflected in the Environmental Code which states that the implementer, in this case SKB, must consult "government authorities, municipalities and organizations together with the public widely. Consultation will relate to the localization, extent, design and environmental impact of the measure together with the content and preparation of the environmental impact statement." Thus, the Environmental Code emphasizes public participation and does not specify any criteria for qualifying as a stakeholder.

Without an exact definition, the stakeholders include:

— The implementing organization, SKB;
— Municipalities involved in the siting process;
— Regulatory authorities, primarily SKI and SSI;
— Environmental organizations on a national level;
— Local interest groups;
— Affected individuals.

In addition to these parties, the County Administration Boards have important functions. They are requested to assist the implementer in identifying stakeholders and in facilitating consultations and exchange of information.

The stakeholders are active to varying degrees and in different ways, depending on the actual phase in the siting process. Some brief comments on each stakeholder are given below from SKI's perspective.

3.2.1. SKB

SKB is of course one of the main stakeholders and has many tasks in the siting process. According to the legislation, SKB must both provide information on its activities and consult those affected by the siting. Although there is a clear division of responsibilities between SKB, on the one hand, and the authorities, on other, there is frequent confusion among the public about the difference between SKB and SKI.

Thus, an important lesson learned for SKI as well as for SKB, is that it is of great importance to spend a lot of time in clearly explaining the roles of each organization. In the early phase of the siting, it is at least equally important to discuss roles and responsibilities, as it is to describe basic technical aspects of the disposal concept.

Since the start of the active siting process in the 1990s, SKB's attitude to public participation has evolved from an 'information approach' towards a more transparent and communicative approach.

3.2.2. SKI

Before SKB started the current siting process in 1992, SKI had only limited experience of siting. The siting of the final repository for low and intermediate level waste, SFR, and of the central interim storage, CLAB, in the 1980s gave some insights into the complexities of siting but cannot be compared to the siting of a final repository for spent fuel, which always and everywhere appears to be controversial.

SKI at first considered siting as a task essentially for SKB and the municipalities that volunteered. The main concern was that the regulators' independence and credibility would, or at least could, be lost by an active participation in the siting process. However, due to its own research projects and to increasing demands from the municipalities, SKI has been quite active in the siting process since about 1995. Furthermore, SKI's research relating to risk communication, transparency in decision processes, etc. has continued to increase.

The experience clearly shows that regulators can and should participate in the siting process and that it can be done without compromising integrity, independence and credibility. This is, for example, supported by the fact that good cooperation has been established between SKI and the municipalities, e.g.

through public meetings, seminars and the development of the decision making process.

3.2.3. Municipalities

All municipalities have established organizations for monitoring and providing input into SKB's studies. However, the most important task for the municipal organizations has been to inform the local populations about the feasibility studies and to engage in dialogue with people. There are at least two purposes (more or less explicit) for establishing this dialogue. In the dialogue, issues emerge which provide input into the feasibility studies. Furthermore, the dialogue provides a good basis for the municipal reviews of the feasibility studies and the subsequent decisions.

The municipalities all have different arrangements for their participation in the siting process. However, in all cases, the municipal council has decided the tasks and mandate for the organization which represents them and in all cases dialogue with the local populations has the highest priority. The municipalities receive money from the nuclear waste fund to facilitate their involvement in the siting process.

3.2.4. National environmental organizations

The national environmental organizations rarely engage in the siting process. This is to a large extent based on their fundamental criticism of the siting process. They claim, for example, that it is not acceptable to start siting before a firm decision has been taken on the method to be used. Most of them also oppose the concept of disposal, which they consider unsafe, and claim that alternatives have not been given proper attention. There are also financial limitations which affect their ability to engage extensively in the siting process (but see Section 4).

3.2.5. Local interest groups

Most of the parties involved in the siting process consider participation of local groups to be important and beneficial to the siting process, in general, and to the critical review of the feasibility studies, in particular.

Local interest groups are very active in some municipalities and are virtually absent in others. It is more or less impossible to make a general characterization of these groups; they are individual and must be respected as individuals.

3.2.6. Affected individuals

In the feasibility studies, it is usually not possible to identify individuals who might be directly affected by a final repository (e.g. landowners). When the siting process proceeds to a later stage and possible areas for site characterization, etc. are identified, it will be possible to identify those directly affected.

The approach taken by both SKB and the municipalities is to reach out to the public widely in order to prepare for the forthcoming phases in the siting.

4. VOLUNTEERISM AND FUNDING

As described above, the municipalities participate in the siting process on a voluntary basis. In SKI's opinion, the principle of volunteerism is a necessary condition for the site selection. This means that the municipalities concerned should give their consent to each stage of SKB's siting process. Even if volunteerism means that a municipality can say no to a new stage in the site selection process, it is a fact that the municipalities concerned feel that the commitment towards accepting a final repository in the municipality becomes greater with each new stage that they approve.

In order for volunteerism to work satisfactorily, the municipalities must have the possibility to closely follow and, in particular, to influence the scientific/technical investigations and the decision process. In order to facilitate this, the municipalities receive stakeholder funding from the state up to a certain amount. The funding has been of great importance for the quality and the progress of the siting process.

Over the years, it has been suggested many times that non-governmental organizations (NGOs) should receive stakeholder funding. The Government decided in 2004 that it would be possible for national environmental organizations to receive money from the nuclear waste fund. It should, however, be pointed out that the municipalities could also fund activities of the local NGOs. This is also done in practice. Typically the municipalities have paid for certain activities arranged by the NGOs. In one municipality, an NGO controls about 10% of the municipality's budget for the siting process. This has, for example, allowed the NGO to have a part-time employee.

5. NATIONAL CONCERN WITH A LOCAL SOLUTION

A dilemma in the debate on the siting of a final repository for spent nuclear fuel is the fact that it is a national concern requiring a local solution.

The political leadership in the municipalities has repeatedly asked for better support from the Government and politicians active at the national level. The Government has, on the other hand, maintained that it should not engage too much in the process since it will make the final decision.

The Government cannot grant a licence for a final repository without the consent of the concerned municipal council. However, under certain circumstances, there is a theoretical possibility for the Government to overrule the municipal veto. Although this possibility has never been used and would in practice be essentially impossible to use, the mere existence of the possibility has occasionally caused debates and controversies in the municipalities. Even if there are good formal reasons for the Government to be able to overrule a municipal veto it is clearly an obstacle in a siting process based on volunteerism.

6. TRANSPARENCY IN DECISION MAKING

A prerequisite for a transparent and democratic multistakeholder process is that it should be possible to understand how facts, expert judgement and value judgement interact to form the basis for a decision. This was explored by SKI in a joint research project called RISCOM. The overwhelming conclusion from RISCOM was that that all issues raised in the interaction between SKB and its environment (various stakeholders) can, without exception, be brought back to claims of truth, legitimacy and authenticity. It is suggested that these three aspects are equally important in the decision making process and should be evaluated as separate entities. The RISCOM project introduced the concept of ‘stretching’ to emphasize that transparency requires that SKB’s environment is sufficiently demanding and that SKB should be challenged from different angles.

In a multistakeholder process, an important task for the regulators is to assist the municipalities in this stretching. The regulators should thus act as the ‘people’s experts’ in the process.

However, the factual statements and the values held by the regulators as well as their authenticity, also need to be evaluated by the public. For example, radiation protection criteria are one important area where the principles of transparent decision making should be applied. In fact, the criteria are the starting point for the safety analysis that SKB will have to present for a final repository. The criteria identify the questions that the safety analysis needs to answer. The development of radiation protection criteria may thus be as important as the safety analysis itself regarding the evaluation of value statements.

The following sections describe two channels for stretching, which were viewed as particularly useful by the RISCOM project.

6.1. Environmental impact assessment (EIA)

EIA is identified as the lead process for public participation and stretching. Well structured procedures for EIA have been developed in recent years in the municipality of Oskarshamn in Kalmar County, which is used as an example here. As background, it should be mentioned that there are three nuclear power reactors, as well as the Swedish central interim storage for spent fuel (CLAB) in Oskarshamn. Thus, the municipality has long experience of interaction with both the nuclear industry and the nuclear regulators.

In 1994, an EIA-Forum in Kalmar County was created at the initiative of Oskarshamn. The Forum was originally created because SKB proposed to bring the encapsulation plant for spent fuel to CLAB. However, the scope of the Forum has since been expanded to include the enlargement of CLAB's storage capacity and SKB's feasibility study for a final repository for spent fuel in Oskarshamn.

The EIA is structured in three phases (see Table 1) and all of them have actually been carried out for the enlargement of CLAB. Of particular interest for the regulators were the two 'hearings' that were held after SKB had submitted the application for the enlargement.

The framework that has developed has proven very useful since it has been designed to allow for discussions between the stakeholders, but at the same time, allowing them to maintain independence. A key ingredient for its success has been that the procedures are flexible enough to accommodate new needs as they appear during the process. It has also been very valuable to be able to 'test' the framework on the case of the enlargement of CLAB. Since all phases were carried out for CLAB it has given the stakeholders confidence in the procedures.

6.2. Hearings

In short, RISCOM proposed an increased use of hearings in the Swedish decision process. The motivation was that hearings are useful for testing the arguments of all parties and that they also test the authenticity of stakeholders and experts. It should be noted that the purpose is not to stretch only the implementer. As exemplified above it is equally important to stretch, for example, the regulators. However, RISCOM stressed that great care must be taken to avoid the creation of adversarial procedures, which may hamper genuine and sincere communication.

TABLE 1. THE FRAMEWORK FOR THE EIA IN KALMAR COUNTY

Phases in EIA	Actors	Activities	Product
Phase 1 Prestudy	All stakeholders[1]	Meeting with EIA-Forum[2]. Local meetings, hearings etc.	Advice on the EIS
Phase 2 Implementers work	Implementer	Project work	Licence application
Continued EIA	All stakeholders	Seminars, hearings etc.	Understanding
Phase 3 Final phase of EIA ≈ first phase of licensing	Regulators interacting with municipality	Review and decide Hearings	Improved licence application

[1] Stakeholders include implementer, regulators, County Administration Board, municipality and the public.
[2] EIA-Forum: A group of representatives from each stakeholder.

7. CONCLUSIONS

— The regulators must be independent and have the capacity to review the safety assessment of the implementer.
— The regulators also have the challenging task to be people's experts in stretching the implementer.
— The regulators should be exposed to stretching by other stakeholders.
— Experience shows that regulators should engage early in the prelicensing phase, e.g. in EIA and siting, and that this can be done without compromising the independence and integrity needed in the licensing phase.
— EIA appears to be an efficient 'vehicle' for public participation.
— The EIA should be complemented with hearings, in both the pre-licensing and licensing phases, since these increase the transparency of the decision making process.
— Hearings should be designed to avoid adversarial situations, which would otherwise make the stakeholders act more strategically than communicatively (in order to 'win the case').
— The state funding of the municipalities' activities in the siting process has been extremely important.

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COMMUNICATING THE SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES
International and US experience[*]

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Abstract

The scientific and engineering aspects of waste management safety are no longer of exclusive importance. The ability of waste management organizations to communicate effectively and to adapt to an evolving social context within which waste management decisions are made, have emerged as critical contributors to public confidence. This changing context, along with examples of how waste management professionals and organizations are working to improve the quality of their communication about the safety of radioactive waste disposal facilities, are discussed.

1. INTRODUCTION

Today's environment for communicating about safety is complex. Public fear and concern about exposures to hazards, generally, have increased, along with a corresponding demand for more information and greater participation in safety related decision making. While informing and involving stakeholders is indeed challenging, J. Creighton, reminds us, that "[i] increasingly, public participation in governmental decision making is considered part of the very definition of democracy" [1]. It is in this context that institutions seeking to achieve acceptable solutions to the management of high level radioactive and spent nuclear fuel wastes, also seek to improve the quality of their communication about, and public understanding of, the safety and risks of these solutions.

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[*] The views expressed herein are those of the author and do not reflect any judgement or determination by the Nuclear Regulatory Commission on matters addressed or the acceptability of a licence application for a geological repository at Yucca Mountain, United States of America.

In the United States of America, statutory provisions for stakeholder participation exist under both the National Environmental Policy Act and the Nuclear Waste Policy Act. The latter applies to the disposal of high level radioactive waste and spent nuclear fuel. In addition, environmental standards and licensing criteria for disposal of high level radioactive waste and spent fuel are developed with extensive public participation and input. In many other countries, as well, legislation requires that regulatory processes be open to the public, with consultation of the public by the regulatory bodies and public hearings being held in the case of major decisions. In some cases, these laws are reflected and reinforced by international treaties or conventions, such as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [2] and the Espoo Convention [3], both of which also require provision of information to neighbouring countries. In matters of environmental decision making, generally (including decisions about radioactive waste disposal), 36 European nations have become signatories to the Aarhus Convention [4], committing these nations to take measures that ensure public participation and early access to information. This Convention includes a presumption in favour of access, and imposes on its participants the duty to make information ‘effectively accessible’ to the public by providing information on the types and scope of information that exists and the processes by which it can be obtained.

Given the greater access to safety information and trends toward greater participation in waste safety decision making, it is important that waste management organizations and practitioners understand how they can provide information that is understandable and, therefore, more likely to be applied accurately when informed stakeholders become participants. Waste management organizations and regulators appreciate now, more than in earlier years, that part of their job is helping stakeholders, including the general public, understand issues of safety and risk, no matter how complex they may be. The public may not make technical decisions, but their opinions deserve consideration by those who are making the decisions. Listening to and communicating with the public does not mean that agendas and priorities must be based solely on prevailing public concerns. Implementers, regulators and policy makers in many nations are working to improve safety communication in order to enhance the quality of stakeholder participation in waste management decision making.

Addressing these challenges on an international level is the Forum on Stakeholder Confidence (FSC). The Forum was created under a mandate from the OECD/NEA Radioactive Waste Management Committee (RWMC) to facilitate the sharing of international experience in addressing the societal dimension of radioactive waste management. It comprises nominees from the

OECD/NEA member countries, most of whom represent national organizations (implementers, regulators, policy makers, and research and development organizations) with responsibility for, and experience with, interacting with stakeholders. The focus of its activities, workshops and publications is to foster greater awareness of the lessons and experiences from these national efforts. At its opening workshop, in 2000, the FSC explored the relationship between the changing environment in which radioactive waste decisions must be made, the importance of trust for institutional players, the increasing interest in stakeholder participation, and the changing character of interaction among the players ('dialogue dynamic'). The FSC observed that the complex interplay among these variables compelled radioactive waste management institutions to seek ways to adapt in order to realize new solutions [5].

2. TECHNICAL EXCELLENCE ALONE IS NOT ENOUGH

For at least two decades, it has been observed that factors other than numerical data can exert a powerful influence on public perceptions of safety and risk. Perceptions of fairness, trustworthiness, integrity and motivation, among others, also feature prominently in the public's evaluation of safety information [6, 7]. Such perceptions are further complicated by the fact that radioactive waste management issues are often linked to broader societal controversies over environmental protection, risk, energy policy and sustainability. Because of changes in society's decision making environment, and heightened public sensitivity to all matters connected with environmental protection, nuclear power, radioactivity and radioactive waste, any decision regarding whether, when and how to implement waste management solutions will typically require thorough public examination and the involvement of many relevant stakeholders. The quality of safety information provided to, and the quality of communication with these stakeholders will have much to do with how proposed waste management solutions are perceived by them.

From its inception, in 2000, the FSC has recognized that, because of changing expectations in the broader society, waste management institutions are challenged to engage in new forms of dialogue and decision making processes that address the views of a broad range of interested stakeholders. The FSC described the changing character of dialogue and decision making processes as a shift from the traditional 'decide, announce and defend' model, focused only on technical content, to one of 'engage, interact and cooperate', for which both technical content and quality of the process are of comparable importance to a productive outcome. In this climate, scientific and engineering aspects of waste management safety are no longer exclusively important. The ability of radioactive waste organizations, including regulators, to adapt to this new context is now accepted as critical contributors to public confidence. Technical competence, while still essential, must be viewed as necessary, but no longer sufficient. Stakeholder confidence and trust in regulatory and implementing institutions are seen as key conditions for a successful societal decision making process for radioactive waste management. To be fully effective in carrying out their mission, regulatory authorities, such as the Nuclear Regulatory Commission (NRC) in the USA, need not only be independent, competent and reliable, but also strive to achieve the confidence and earn the trust of stakeholders and the public at large [8].

In short, stakeholder confidence in institutions, and in the processes those institutions use for reaching decisions that affect safety, is seen as a key condition for ultimate societal acceptance of decisions regarding the management of radioactive waste. In order to build confidence in these processes it is important that they be explained, and even more important, that they can be understood as being open, transparent, fair and broadly participatory. It is important, therefore, that radioactive waste management organizations expand their vision and practice of safety communication to include these process elements, along with technical information, if they are to communicate effectively with the broader community of stakeholders.

3. CHANGES BY INDIVIDUALS AND ORGANIZATIONS THAT IMPROVE SAFETY COMMUNICATION

Effective communication about the safety of waste management issues requires considerably greater effort, time and resources, than have traditionally been devoted to the task. It is one thing to commit to openness in the abstract. It is quite another for individuals and institutions to make the difficult changes and commit limited resources to make it a reality. There are many challenges to translating complex technical and policy issues into language that is accessible and understandable, such that a broader community of stakeholders may understand and participate meaningfully in an open decision making process. Many waste management professionals and organizations fail to apprehend the need for public understanding of and participation in decisions that they view as technical in nature. Many of the decisions concerning radioactive waste disposal, while certainly informed by technical information provided by experts are, in fact, laden with choices of values. These include, for example, choices about who or what should be protected, for how long, and at what expense. Openness also implies that individuals and organizations are open to the potential for stakeholders' input to influence the decision making process, and stakeholders want to know if and how their participation influences the ultimate decisions.

As waste management practitioners, we recognize that our communication roles are evolving. In particular, as dialogue and stakeholder involvement has assumed a more visible part of the waste management process, we, as scientists and engineers, are called upon to address new questions raised by the general public. Those who represent implementers are engaging in more frequent dialogue with the public. Regulators are becoming involved in the waste management process far earlier than before. Indeed, those of us who represent regulatory agencies frequently find ourselves in the role of 'safety communicators' and 'peoples' experts' and recognize the need to be involved in that role from the start of consultations with local communities, before final decisions on facilities, sites and concepts are reached [8]. Across the board, we now know that there needs to be greater clarity of roles for the institutional actors as well as greater visibility of those actors and their actions.

With greater visibility and interaction, however, comes greater exposure to potential criticism and public dissatisfaction with the effectiveness of that interaction. Implementers and regulators, in particular, have been frank in analysing the discomfort of public rejection and are working to bring about major systemic changes to their organizations' interactions with stakeholders [5]. Making changes to organizational culture is admittedly slow and painful, but such change is underway. FSC has documented the experiences of many national programmes and institutions that are learning and adapting to demands for better and broader communication about the safety and risk of radioactive waste management [9, 10].

In practice, improvements in safety communication result from changes made by individuals and organizations at both the interpersonal and at the strategic level.

At the interpersonal level, individuals representing waste management organizations are applying a variety of skills and tools to communicate in sensitive situations where people are worried about their health and safety and about the protection of their environment. To be effective, safety communicators are learning to listen with empathy; translate technical information into terms that are both understandable and respectful; manage conflict; and work to build trust and credibility, in their actions as individuals and those of the agencies they represent. Ideally, since all employees have the potential to serve as ambassadors for their organization, waste management organizations should encourage every employee to cultivate these skills. Initially, however, when attempting to bring about agency-wide improvements in safety communication, many organizations find it useful to seek out the assistance of professionals in communication, facilitation or conflict resolution.

At the strategic level, waste management organizations are committing to long term planning and coordinated safety communication efforts; cultivating and nourishing strategic partnerships with stakeholders; formulating honest, consistent messages; and developing and continually refining appropriate organizational tools for both internal and external communication about safety. FSC has also compiled a short guide to the array of tools and techniques that various radioactive waste management organizations are developing and applying to the challenges of enhancing stakeholder interaction [11].

4. CASE STUDY: IMPROVING COMMUNICATION IN THE USA ABOUT THE REGULATION OF HIGH LEVEL WASTE REPOSITORY SAFETY

In the USA, the NRC strives to serve the public interest as a reliable, objective, open and efficient regulator. In that regard, the NRC views nuclear regulation as the public's business, and has identified openness in its regulatory process as an explicit goal of the agency [12]. In articulating this objective, the NRC recognizes that it must inform the public about the regulatory process, and offer a reasonable opportunity for meaningful participation in that process. The NRC long ago established mechanisms and procedures to afford the public access to major regulatory decisions. Over the past six years, the NRC has worked to enhance its public interactions and foster confidence in the NRC's actions as an effective and independent regulator. The NRC continues to make changes to provide the public with process and risk information that is clear and understandable.

In 1999, the NRC proposed new regulations for the potential repository at Yucca Mountain, Nevada, USA. These proposed regulations represented a significant change from prescriptive, generic criteria, developed in the late 1970s, to a more risk informed rulemaking framework that incorporated insights about repository risks and performance that have emerged over the past 20 years. NRC technical staff held public meetings in Nevada, near the site of the potential repository, as well as in Las Vegas, to obtain public comments on the proposed criteria. I, along with my colleagues, other scientists, engineers and attorneys, who had drafted the NRC's proposed regulations, went to Nevada to discuss the timing and technical content of NRC's proposal, to answer questions, and to invite the public to comment.

We were knowledgeable about the technical bases for the proposed requirements, and experienced with presenting complex technical and policy issues to scientific and technical audiences. We were not prepared, however, for the range and intensity of questions and comments from the audience. Many participants had questions about issues that were not directly applicable to the proposed regulations, but which reflected deep interest and concern. Over the course of the meetings, the questions and comments from the audience clearly showed that we had not succeeded in communicating the reasons behind, and safety of, the NRC's proposed regulations. It was obvious that these meetings had not contributed to public confidence in us, the NRC staff, or in the Commission's proposal. Our observations were confirmed by written comments that the NRC received after the meetings. Our observations and the public feedback convinced us of the need to improve the NRC's approach to future interactions and involvement with the public.

Reflecting on this experience, we sought specific ways in which the NRC might improve. We wanted to design future interactions with the public that would better communicate the NRC's primary mission of protecting public health and safety and the environment. We also wanted to convey better the NRC's duty and commitment to be open and receptive to people's input, and to act in ways that would enhance their confidence in the agency. Eventually, the NRC made many significant changes — organizational changes, process changes and, eventually, policy changes, all of which reflect, to greater or lesser degrees, the NRC's commitment to improve stakeholder confidence. They also reflect a conscious change in our expectations of interactions with stakeholders. Our intent is to inform, not persuade, to improve common understanding of technical and policy issues and to foster a more meaningful dialogue.

At first, we made identified simple changes to our meeting preparation. These included identifying lessons learned in earlier meetings; allowing staff more time and resources to prepare for stakeholder interactions; assigning a project manager for each public meeting who is not also a speaker at the meeting; and providing expert coaching for all speakers in risk communication techniques. As scientists and engineers, we are effective when communicating with our colleagues. We are accustomed to interacting with other technically trained specialists who insist on precise and complex explanations of technical and policy issues. As a group, we are not, generally speaking, familiar with risk communication nor are we trained public affairs specialists. As a result, we often use technical jargon and acronyms in our speech and in our presentations, rather than the more direct, plain language explanations that the public seeks and has a right to expect. To address these communication challenges, the NRC obtained expert training in risk communication, and we continue to increase the number of staff members that receive training before interacting with the public. We now review all of our presentations for clarity and plain language.

Next, we adapted our processes for interacting with stakeholders. In response to requests from the public, the NRC extended the allotted time, to allow for broader public involvement, and to allow enough time for the public to understand and evaluate the technical information and policy implications. Besides showing that we heard the public's concern, and were able to grant the extension request, extending the time available for comment also allowed us more time to review transcripts of the earlier meetings. We were then able to catalogue the comments and questions brought up at the meeting, and later provide personalized answers to some specific questions we had not answered adequately, at the meetings.

Working with a trained facilitator, we restructured the format used for public meetings. For instance, formal presentations, if needed at all, are much shorter, and we intersperse them with multiple opportunities for questions and dialogue. We also use other formats, such as public round table discussions, poster sessions, open houses and displays at technical conferences, as the situation warrants. Whichever format we select, we make greater efforts, when scheduling interactions, to recognize that stakeholders interested in Yucca Mountain have multiple demands on their time, and attention. Many attendees at the NRC's public meetings have complained of schedule conflicts with public meetings conducted by other organizations, such as the United States Department of Energy, state and local governments, as well as by multiple other review or oversight bodies.

To coordinate and carry out a more ambitious approach to public interaction, still more organizational changes were needed. We established a high level waste (HLW) public outreach team of technical and support professionals from various disciplines and offices within the NRC, including members from the NRC's Spent Fuel Project Office, the NRC's Office of Public Affairs and the NRC's contractors at the Center for Nuclear Waste Regulatory Analyses. This team developed, and subsequently updated, a Communications Plan for the NRC's HLW regulatory programme. We have improved our coordination with other agency offices and divisions, and we represent the USA and the NRC at international forums, such as the FSC, on issues involving stakeholder interactions. Eventually, senior technical staff was assigned responsibility for HLW regulatory communications, and staff excellence in interacting with stakeholders about the NRC's HLW regulatory programme are consistently recognized and rewarded.

It is important to keep in mind that these improvements, as significant as they are, did not occur in isolation. As the NRC's HLW regulatory programme pursued greater effectiveness in engaging stakeholders, the NRC as a whole was coming to grips with the need to improve the quality of its interactions with stakeholders and to place greater importance on inspiring their confidence and trust.

Communications plans are now required for all major NRC programme initiatives. In 2003, the Chairman of the NRC chartered a task force on external communications, and a report of its findings and recommendations were issued in a public report later that year [13]. Coincident with the release of this report, the Chairman announced his intent to appoint an agency Director of Communications who would report directly to the Chairman and provide policy and guidance for communications activities across the agency. The new Director assumed his position in 2004. Last year, the NRC issued guidelines for agency staff for interacting with stakeholders [14] and, as a separate document, published the technical basis for the NRC's guidelines [15]. In 2005, the NRC issued similar guidelines for improving internal risk communication [16]. All of these documents are available to the public. Also, in 2005, the Commission has directed NRC staff to publicize the results of research projects in understandable terms, particularly those results involving conservative bounding analyses, using plain language, and in a manner that fosters understanding of the context and limitations of the NRC's research findings. In addition, the Commission also directed NRC staff to add a "For the Record" section to its web site to provide NRC responses to inaccurate, misleading or false information in print, on television and radio, to provide the public with accurate and truthful information.

We have now applied this new approach at more than 30 public meetings. In response to specific public requests, the NRC held workshops and meetings to explain NRC licensing, inspection and hearing processes. We have responded to requests from local government officials in Nevada to conduct meetings in local communities where residents can hear and ask questions about the NRC's licensing and oversight role for the potential repository. Management and organizational commitment, intensive staff preparation, training and rehearsal by all speakers, and actively anticipating questions and discussing suitable answers in advance, have all helped to foster more constructive interactions with citizens in Nevada. Follow-up meetings on proposed NRC regulations, as well as information workshops, meetings and displays on the NRC's regulatory process, hearing process and draft licensing guide, have generated many high quality, constructive comments from a wide array of stakeholders. We have received positive feedback from meeting attendees and local government officials, and have been invited to conduct more meetings, from other communities within Nevada. In general, media coverage of the NRC's actions with respect to Yucca Mountain has been more accurate and balanced. These are all positive signs that NRC efforts to improve its communications with the public are on the right track and are making progress.

To support the NRC's communications goals for its HLW programme, we are continuing to develop communication tools that aid the technical staff in conveying key technical and related policy messages. We try to identify key scientific and regulatory concepts that need to be ‘translated’ from technical language to plain language. Among the more important of these are the role of performance assessment modelling and the NRC’s identification of key technical issues for evaluating safety at Yucca Mountain. We continually prepare and update handouts, displays and presentation materials to help the NRC’s stakeholders better understand NRC policies, and the technical bases for its regulatory decisions. As we develop these materials, we examine them carefully to evaluate the following: are stated messages expressed effectively? Are the NRC’s core messages of commitment to safety, independence and fairness, consistently reinforced? And, do the materials provide a means for follow-up and feedback?

To build on these improvements, the NRC may face significant new challenges in the coming year. Next year, the NRC may receive a licence application from the Department of Energy for the proposed repository. US law sets forth a three to four year timeframe for the NRC to make its licensing decision. Balancing the NRC’s commitments to openness and stakeholder confidence with demands on time and staff resources, as well as with the constraints imposed by the NRC’s hearing process, may well compel more changes beyond those discussed above.

5. CONCLUSIONS

In seeking to improve its communication about safety and increase stakeholder confidence in its regulatory programmes, the NRC has made, and continues to make, changes as an organization. At the same time, the NRC is also encouraging and supporting its staff members to improve their individual interactions with stakeholders on behalf of the NRC. Many of these changes could be seen as small, common sense improvements. Taken as a whole, however, these improvements reflect a changing vision and increased commitment to discharge our regulatory responsibilities through a more inclusive regulatory process. By engaging the public earlier, listening to individual issues and concerns, and providing understandable and honest responses, we are earnestly working to make the NRC’s regulation of nuclear waste understandable and worthy of the public’s trust. Many of the examples of the NRC’s experience that I have discussed here are mirrored in other national waste management programmes. They serve as indicators of an evolving international concern for enhancing the quality of safety information available to stakeholders. The USA welcomes the opportunity to learn from the many waste management organizations and regulatory bodies represented at this conference, as we work together in pursuit of this common objective.

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CANADIAN EXPERIENCE IN COMMUNICATING THE SAFETY OF RADIOACTIVE WASTE DISPOSAL

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Abstract

The paper describes the recent experience of Ontario Power Generation (OPG) in obtaining community acceptance to construct a deep geological repository (DGR) for low and intermediate level waste (LILW) in the Municipality of Kincardine, Ontario, in particular, how the subject of the safety of the proposed facility was communicated. The paper also briefly reviews other Canadian disposal initiatives that involved extensive public communication on safety. Current practice in Canada is that sites for nuclear waste long term management facilities are identified based on the principle of volunteerism. This requires that communities draw a positive conclusion about the acceptance of a proposed facility. Believing that the proposed facility will be safe is paramount in drawing this conclusion. The various means employed by OPG to provide assurance to residents of Kincardine and surrounding communities that the proposed facility will be safe are outlined.

1. OVERVIEW OF RADIOACTIVE WASTES IN CANADA

The power reactor industry in Canada consists of 20 reactors in the Province of Ontario owned by Ontario Power Generation (eight are leased to Bruce Power Ltd). In addition, there is one reactor in each of the provinces of Quebec and New Brunswick, operated by their respective provincial utilities. The three provincial utilities are responsible for the waste that they generate. OPG manages Bruce Power's waste. Atomic Energy of Canada Limited also possesses significant volumes of radioactive waste arising from its past and continuing research and development activities.

In accordance with the Canadian Nuclear Safety and Control Act, a licence is required before radioactive substances can be possessed and the licensee must present a long term plan for their waste management. Presently, with the exception of uranium mine tailing facilities, there are no long term management facilities, including disposal, for radioactive waste in Canada. All radioactive waste arising from the power reactor industry and nuclear research and development activities is currently in interim storage. The Nuclear Waste Management Organization (NWMO), established in 2002 in accordance with the Nuclear Fuel Waste Act, is finalizing its study of various approaches for the long term management of all nuclear fuel waste in Canada and is expected to submit its study report and recommended approach to the Government of Canada by November 2005. In its draft report [1], the NWMO recommended an Adaptive Phased Management approach whereby a voluntary host community would be sought to host a deep geological repository for nuclear fuel waste, as well as a possible centralized storage facility.

2. REVIEW OF RELEVANT CANADIAN EXPERIENCE IN COMMUNICATING SAFETY

While the main purpose of this paper is to review experience in communicating safety in the site acquisition phase of OPG's deep geological repository project for low and intermediate level waste (LILW), an overview of other related Canadian experience is presented here with references to where additional information can be found.

The Canadian Nuclear Fuel Waste Management Program was established by the Government of Canada and the government of Ontario in 1979 to develop a method to dispose of nuclear fuel waste in the crystalline rock of the Canadian Shield. It soon ran into significant local controversy when geotechnical investigations were proposed in a community in northern Ontario. In response to the controversy, the Federal Government directed that no siting activities were to occur until the disposal concept was approved. The report of the environmental assessment panel set up to review the concept was published in 1998 [2] and concluded that, inter alia: "As it stands, the AECL concept for deep geological disposal has not been demonstrated to have broad public support. The concept in its current form does not have the required level of acceptability to be adopted as Canada's approach for managing nuclear fuel wastes." Communication of safety had not been successful.

The NWMO took over from the Canadian Nuclear Fuel Waste Management Program and benefited from its experiences. Whereas the earlier programme was primarily technology driven, the NWMO, over the last three years, has primarily been consultation driven. Its interim work products [1] attest to the degree to which communication with a wide range of stakeholders has played a central role in the conduct of its activities.

In the Port Hope area of Ontario, there are about 2 million m^3 of low level radioactive waste, mainly contaminated soil, resulting from the refining and conversion of radium and uranium by a former Federal Crown Corporation, Eldorado Nuclear. Several initiatives over the years have been implemented to find on-site or off-site solutions. In 2001, the Federal Government and the (then) three local municipalities signed agreements to provide for long term storage within the communities. Key to achieving these agreements had been a realization by the communities that off-site solutions were unlikely to be found and an emphasis by the proponent on dialogue with the communities. Further information on the Port Hope initiative and related communication activities can be found in Refs [5, 6].

3. OPG'S LILW DEEP GEOLOGICAL REPOSITORY PROPOSAL

3.1. Description of local area

The Municipality of Kincardine is located on Lake Huron in Bruce County, Ontario. The economic base for Bruce County is diverse and includes agriculture, tourism and recreation, a service sector, manufacturing, light industry, fishing and some aggregate resource extraction. The Bruce nuclear site is the largest single employer in the County with more than 3500 employees. The population of Kincardine is approximately 11 000, with an additional 650 seasonal residences.

3.2. Review of options

In 2002, Kincardine approached OPG, seeking it to sign a Memorandum of Understanding (MOU) related to the management of radioactive waste at OPG's existing Western Waste Management Facility (WWMF) on the Bruce nuclear site. The MOU was signed in April 2002 and provided for:

- A review of the technical feasibility of various long term management options for low and intermediate level waste at the WWMF;
- A socioeconomic impact assessment in Kincardine of the existing operation of the WWMF and of the potential long term options;
- A review of European and American models for long term management of low and intermediate level waste, including site visits to look at issues, such as technical infrastructure and community compensation.

In support of the MOU, Golder Associates were retained to assess the geotechnical feasibility of constructing various types of long term waste management facilities at the WWMF. The study was based only on existing geotechnical data and did not include any new field investigations. Based on the results of the geotechnical feasibility assessment, it was determined that a deep geological repository in either shale or limestone formations (at a depth of 425–800 m) would be feasible.

In addition, Quintessa Limited (United Kingdom) conducted preliminary safety assessments of the waste management concepts. Based on the assumed geological and hydrogeological conditions at the Bruce site, Quintessa's safety analysis indicated that a deep geological repository in either shale or limestone would meet the radiation dose criteria of ICRP Publication 81 by a very large margin [7].

Golder Associates also conducted various economic and social analyses and integrated these with the technical studies to form an Independent Assessment Study [8]. The purpose of the economic and social analyses was to provide information on the potential of the proposed long term LILW facility to:

— Affect resident's attitudes and behaviour towards the community;
— Cause economic effects on local businesses and on the municipality;
— Affect tourism and agriculture.

Public attitude and tourism research indicated that none of the options considered would have significant adverse effects on the public's feelings of safety and on community satisfaction. Over 75% of Kincardine respondents were very or somewhat confident in the existing technologies for processing and treatment of low and intermediate level waste. Residents did not anticipate any changes to their attitudes if a long term low and intermediate level waste management facility were located at the WWMF. Tourism research indicated that none of the options would be expected to have a measurable effect on visits to Kincardine or on tourist activities.

As a part of the Independent Assessment Study, community information and consultation programmes were also undertaken. The objectives of the programmes were to inform the local community about the study of the options and to provide the opportunity for stakeholders to give their input and to discuss any concerns that they had.

Following a review of the Independent Assessment Study Report, municipal support was indicated at the Council Meeting of 21 April 2004, at which the following resolution was carried:

> "that Council endorse the opinion of the Nuclear Waste Steering Committee and select the 'Deep Rock Vault' option as the preferred

course of study in regards to the management of low- and intermediate-level radioactive waste".

The Council's decision to support the deep geological repository (DGR) as its preferred option was based on the following key points:

— It provided the highest level of safety of any option;
— There would be a rigorous environmental assessment and opportunities for public input would be provided through the Canadian Nuclear Safety Commission regulatory process before construction was approved;
— The DGR would permanently isolate the low and intermediate level waste stream, much of which is already stored on site;
— It would provide significant economic benefit to the residents of the municipality;
— No high level waste or used nuclear fuel would be allowed in the facility.

3.3. The Hosting Agreement and community poll

The Hosting Agreement was negotiated by a steering committee with representatives of OPG and Kincardine in the period May–October 2004. The Agreement includes payments to Kincardine and four adjacent municipalities, a property value protection plan, and provisions of new jobs among its features [9].

In October 2004, immediately following the signing of the Hosting Agreement, a storefront Community Consultation Centre was opened in the downtown core of the Municipality. The storefront, staffed by the Municipal Council and OPG representatives, provided an opportunity for the local residents to obtain information about the DGR proposal, and to provide feedback to the Municipality and to OPG and to discuss any issues and questions that they had. Issues raised in the consultation period included:

— Potential for high level waste to be disposed of at the facility;
— Potential for the contamination of ground water, drinking water and Lake Huron;
— Risk of the repository flooding;
— Health and safety risk to future generations.

Following the three month consultation period, a telephone poll of permanent and seasonal residents was conducted by Kincardine to gauge community acceptance of the proposed facility. A total of 72% of eligible residents participated in the survey. Of those, 60% voted yes, 22% voted no, 13% were neutral and 5% voted don't know or refused to participate [9].

4. DESCRIPTION OF THE PROPOSED REPOSITORY

An illustration of the proposed repository concept is shown in Fig. 1. It is composed of a series of vaults located at a depth of 660 m in Ordovician age (approximately 450 million years old) limestone overlain by a 200 m 'cap' of Ordovician shale. It is expected that the upcoming site geotechnical characterization investigations will show that both the limestone and shale formations are homogeneous in nature, have wide lateral extent and are of very low permeability such that contaminant transport would be controlled by diffusion (i.e. extremely slow).

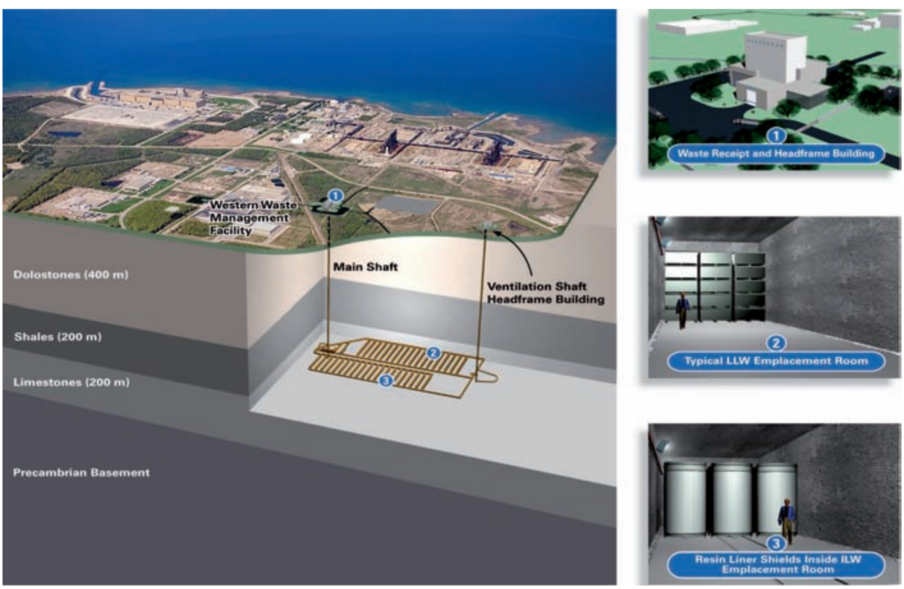

FIG. 1. Proposed deep geological repository for LILW on the Bruce nuclear site.

5. BASIC CHALLENGES IN COMMUNICATING THE SAFETY OF DISPOSAL FACILITIES

There are a number of factors that present significant challenges in communicating the safety of radioactive waste disposal facilities:

(a) Most members of the general public have little time to try to understand issues related to facility safety. While polling indicates that radioactive waste safety is considered to be important, communication mechanisms such as ‘open houses’ often result in very poor turnouts.
(b) The media often seeks to report on conflict and dire consequences to promote story interest. The public is not sure who to believe and becomes more apprehensive.
(c) The public has an inherent reluctance to trust the proponent of any initiative, irrespective of the nature of the initiative.
(d) A general lack of familiarity and comfort with things ‘nuclear’.
(e) Conveying the concept that disposal facilities will be safe for the long time frames for which radioactive wastes can remain hazardous presents a unique challenge.

5.1. Contributors to success in communicating safety

Success in communicating safety of a proposed radioactive waste disposal facility is dependent on many factors involving the message and the means by which it is delivered. The main contributors to success in providing assurance of safety during the site acquisition phase of the proposed LILW DGR in Kincardine are shown in a structured manner in Fig. 2.

Some of the specific practices and activities that contributed to the success of our communication activities are listed below:

— Where possible, communication efforts were a joint effort by Kincardine and OPG.
— Communications staff had long histories of living in the local area.
— The importance of surrounding communities was recognized in communication efforts.
— Special attention was given to providing briefings and information to community leaders.

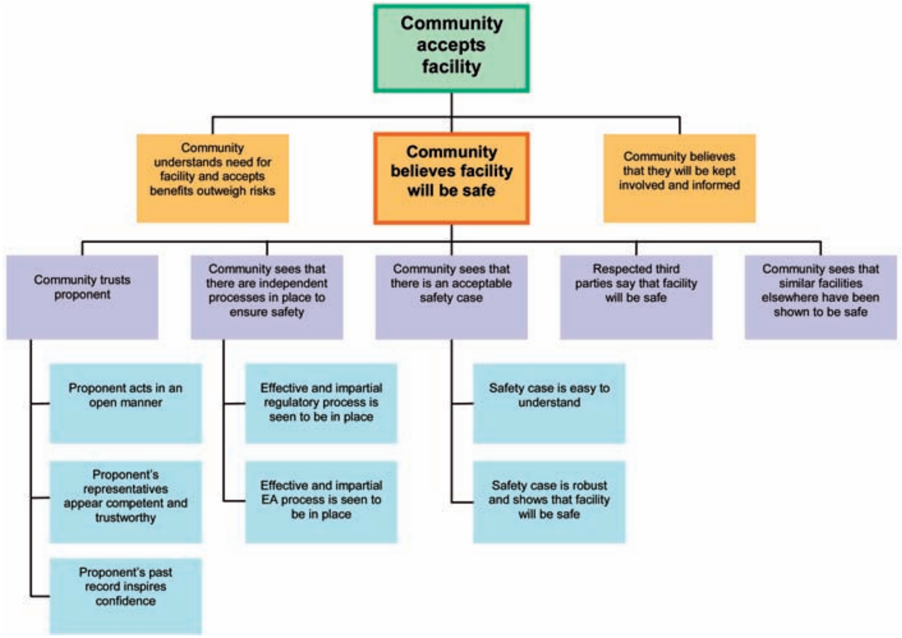

FIG. 2. Success in communicating the safety of radioactive waste repositories.

— Information used for public communication was provided to staff working at the Bruce nuclear site to pass on to their neighbours.
— Specific community questions and concerns were addressed promptly and directly.
— Newspaper advertisements quoting respected specialists were used effectively.
— Visits were made with Council members to repositories in other countries.

Further information on OPG's deep geological repository project can be found at www.opg.com/dgr.

ACKNOWLEDGEMENTS

The assistance of T. Squire, Director Public Affairs, Nuclear Waste Management at Ontario Power Generation, Canada, in preparing this paper is gratefully acknowledged.

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REVIEW OF CONTRIBUTED PAPERS

Session IVb: COMMUNICATING THE SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES

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Abstract

The objective of the paper is to summarize the international trends related to communicating the safety of radioactive waste disposal highlighting the main issues raised in the contributed papers of Session IVb.

1. INTRODUCTION

Communication is part of a process known as 'Confidence Building'. Confidence Building includes all the activities that are carried out as part of evaluating safety and communicating the safety analysis results for a facility following a systematic safety assessment process.

Confidence building focuses on three key questions:

— How does the assessor gain sufficient confidence in his/her own assessment results?
— How does a regulator gain enough confidence to make a decision on proceeding with a disposal facility?
— How do the public and other stakeholders gain confidence that the impacts from a facility will be within acceptable limits?

Between 1997 and 2002, the IAEA sponsored a Co-ordinated Research Project (CRP) on Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities (ISAM) in order to focus on the methodological aspects of the long term safety assessment for such facilities. In particular, one of the objectives of the CRP was to build confidence in the approaches and tools used. The CRP had over 70 active participants and attracted interest from around 700 people involved in safety assessment in 72 Member States. The results were published in 2004 by the IAEA[1].

2. INTERNATIONAL TRENDS IN COMMUNICATING THE SAFETY OF RADIOACTIVE WASTE DISPOSAL

The ISAM project obtained information from participants on the topic of communication by means of a questionnaire. The survey results are presented in Tables 1 and 2. It should be noted that these survey results might reflect a bias as a result of receiving completed questionnaires mainly from those organizations that have well developed communications programmes.

Table 1 summarizes the main audiences identified, the percentage of the respondents who communicate with each type of audience and the perceived importance of each audience from the point of view of the respondents. In addition to the audiences listed in Table 1, some more specific audiences were also identified, such as school students, visitor groups, antinuclear groups or youth groups. However, the relative frequency of communications with these groups can be considered as very low compared to the other audiences.

TABLE 1. AUDIENCES FOR SAFETY ASSESSMENTS AND PERCEIVED IMPORTANCE

Audience	Proportion of respondents who communicate with audiences (%)	Perceived importance by the respondents
Regulatory bodies	88	High
Academic and scientific organizations	100	Medium
The public	94	Medium
The media	94	Medium
Government bodies	100	Low
Non-governmental organizations	88	Low

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment Methodologies for Near Surface Disposal Facilities: Results of a co-ordinated research project, ISAM, Vol. 2, IAEA, Vienna (2004).

In communicating with the different audiences, diverse methods and tools have been used by radioactive waste management organizations. The perceived relative importance of these methods and tools is presented in Table 2. Other methods and tools mentioned include workshops, topical days, seminars, official statements, personal contacts, lectures, conferences and training courses.

In Table 3, the efficiency of the various communication methods and tools is ranked on a scale from 1 to 5 (with 5 being the most effective), although it should be noted this is a very subjective process. Most organizations have received feedback on the communication methods and tools that they have used. From regulatory and government bodies, the feedback was generally technical. Feedback from the media was generally perceived as positive. Schools and student groups tend to show a high level of interest, raising specific questions. There were a number of comments suggesting a high degree of belief that with non-governmental organizations, use of efficient communication methods and tools can contribute to improved relationships.

TABLE 2. COMMUNICATION METHODS AND TOOLS AND THEIR RELATIVE IMPORTANCE BY AUDIENCE

Communication methods and tools	Regulatory bodies	Academic and scientific organizations	Public	Media	Government bodies	Non-governmental organizations
Pamphlets, brochures, leaflets	44	56	88	69	56	81
Video tapes	25	31	63	44	25	38
Visitor centres, facility tours	19	56	69	69	50	50
Presentations at schools	0	25	56	0	0	0
CD-ROMS	6	13	31	13	13	0
Web pages	50	63	63	63	50	63
Technical papers	94	94	19	19	69	44
Progress reports for governments	50	38	6	6	81	19
Paid advertisements	6	6	19	25	6	13
Press conferences	6	0	19	75	6	13
Others	19	31	13	19	25	25

TABLE 3. COMMUNICATION METHODS AND TOOLS AND THEIR RELATIVE EFFICIENCY
(ranked on a scale from 1 to 5, 5 being the most effective)

Communication methods and tools	Regulatory bodies	Academic and scientific organizations	Public	Media	Government bodies	Non-governmental organizations
Pamphlets, brochures, leaflets	2	2	4	3	2	3
Video tapes	2	3	3	3	2	3
Visitor centres, facility tours	2	3	4	4	3	4
Presentations at schools	1	3	3	1	1	1
CD-ROMS	3	3	3	2	2	2
Web pages	2	2	3	3	2	2
Technical papers	4	4	1	2	3	3
Progress reports for governments	4	3	1	3	4	2
Paid advertisements	2	2	3	3	1	3
Press conferences	2	2	3	4	2	2

About 30% of the respondents had conducted surveys or opinion polls. The types of surveys conducted ranged from polls of public perception about radioactive waste to specific questions related to radioactive waste management issues. It was also mentioned that in many countries, groups other than radioactive waste management organizations also make use of public polling to determine attitudes on radioactive waste and other topics involving nuclear power.

Regarding the decision making process related to siting and construction of radioactive waste management facilities, the following audiences and stakeholders have in general been identified and consulted: local inhabitants, political authorities, non-governmental organizations, academic audiences and experts, and regulatory bodies. In some cases, there are national laws or policies, which make this a requirement as part of the process of obtaining permission to develop a disposal facility.

Regarding the use of referenda on issues related to waste management; only one country/organization reported conducting one, and the result of this referendum was negative.

The ISAM survey also revealed that when communicating with different audiences there are several frequently asked questions such as:

— How dangerous is radioactive waste?
— What sites have been studied?
— What is the future of the repository?
— Is the repository safe?
— What are the plans for future management of radioactive waste in the country?
— Where does the waste come from?
— What will happen in the longer term?
— How can you put the public in jeopardy by transporting the waste on public roads or through communities and towns?
— What else are you hiding from us?

General questions may also be raised by stakeholders regarding the strategy and status of radioactive waste management activities, about the environmental impact of radioactive waste (along with impacts on plants and animals), public protection, licensing conditions and plans for deep geological disposal of radioactive waste.

3. RESUME OF ISSUES RAISED IN THE CONTRIBUTED PAPERS

A resume of the contributed papers on the issue of communication can be seen in Table 4.

4. TOPICS FOR DISCUSSION

From the work in the area of communications it is clear that a variety of communication methods are actively being used by various organizations involved in radioactive waste disposal. During discussions, and by way of feedback on the questionnaires of the ISAM IAEA project it was found most organizations expend little effort on determining the most effective ways to provide information and to gather feedback from various audiences. Most organizations use methods that they have observed in use by others.

TABLE 4. RESUME OF PAPERS

Country site selected	Communication methods and SI[1] involved	C.M.[2]	Difficulties
Latvia—yes	National Regulatory Authority educates teachers of physics as well as pupils in radiation safety issues, by lectures and published documents and information on web site.	Yes	Divergence between SA conclusions of the Baldone RW repository and the public perception of risk
Denmark—not yet	Ministry has prepared a leaflet with information on the project to all municipalities and a number of interested parties and NGOs The leaflet is downloadable from the homepage of the Ministry for the Interior and Health. Following this, it is the intention to have one to two mini-seminars for interested parties. All working papers will be accessible at the homepage of the Ministry for the Interior and Health, in order to allow interested parties to follow the process.	No	None at the moment
Malaysia—not yet	Not explained.	No	Public acceptance of the public living near the disposal site must be gained to avoid delay of the project.
Brazil—not yet Two NS[3] repositories constructed for the wastes generated due to the Goiânia accident.	A CD-ROM was made. Public hearing Two reports need to be made (a technical one for the competent authority and a simplified one for the public hearing). An expert system for site selection is being developed by one institute of CNEN in order to be easily understood by the public and decision makers.	Yes	Not in my back yard syndrome Very political issue
Canada—yes	Includes an Independent Assessment Study, community information and consultation programmes. The objectives of the programmes were to inform the local community about the study of the options and for stakeholders to provide their input and discuss any concerns that they had. This results in a final resolution “that Council endorses the opinion of the Nuclear Waste Steering Committee”.	Yes	

TABLE 4. RESUME OF PAPERS (cont.)

Country site selected	Communication methods and SI[1] involved	C.M.[2]	Difficulties
Sweden — not yet	SI involved: The implementing organization, SKB. - Six municipalities involved in the siting process. - Regulatory authorities, primarily SKI and SSI. - Environmental organizations on a national level. - Local interest groups. - Affected individuals. Good cooperation has been established between SKI and the municipalities, e.g. public meetings, seminars and public hearings. The most important task for the municipal organizations has been to inform the local populations about the feasibility studies and to engage in dialogue with people. The municipalities receive money from the nuclear waste fund to facilitate their involvement in the siting process as well as national environmental organizations and some NGOs.	No	A dilemma in the debate on the siting of a final repository for spent nuclear fuel is the fact that it is a national concern requiring a local solution. The political leadership in the municipalities has repeatedly asked for better support from the Government and politicians active on the national level. The Government has on the other hand maintained that it should not engage too much since it will make the final decision. The Government cannot grant a licence for a final repository without the consent of the concerned municipal council. However, under certain circumstances there is a theoretical possibility for the Government to overrule the municipal veto. The mere existence of the possibility has occasionally caused debates and controversies in the municipalities.

TABLE 4. RESUME OF PAPERS (cont.)

Country site selected	Communication methods and SI[1] involved	C.M.[2]	Difficulties
Republic of Korea—No	Two specific cases of experience in communicating the safety of radioactive waste disposal were introduced, which might contribute in improving the communication skills with the public. Case 1 is the inclusion of public risk perception as a decision making (DM) element in selecting the options of spent fuel management; and Case 2 is the use of electronic public participation in analysing the public opinions on the idea of disposing of LLW within the campus of Seoul National University. Uses of questionnaires, email notes, participation in electronic debate (web) and responding to cyber poll survey on the second case study. The Case 1 study suggests that the public risk perception could be an important DM element in communicating the nuclear safety. The reduction of gap between the perceived and numerical risks appears to be one of important issues in promoting the public acceptance. The Case 2 study forecasts the comprehensive utilization of electronic public participation in the future, which could also greatly contribute in enhancing communication.	Yes	Many attempts and failures due to: strong protests of local residents due to lack of transparency in conducting the geological survey. Lack of communication and coordination among KAERI, local residents, local government and central government. Exclusion of public participation in the major steps of decision making (DM) process. Serious conflicts among residents appeared in the allocation of supporting funds, and the strong hostility was built up between local proponents and opponents. A series of violent activities of anti-nuclear groups occurred on many others attempts.

[1] SI: Stakeholder involvement.
[2] C.M.: Compensation to municipality.
[3] NS: Near surface.

— Safety cases appear to be the main method of communicating results to the regulatory authorities, which is often the audience of prime concern. Should safety cases be prepared with only the regulator in mind?
— Experts are quite good at providing information, but not so good at making it easy to understand. So do science journalists play an important role in the communication with the public?
— There was a time when people had more faith in science and technology than they have now. We must now learn to live in controversy; does this mean that we must be prepared to engage in a genuine dialogue?
— A person who lives near the repository usually asks simple questions. They also know that there is no facility free of risk. Can communication play an important role in showing them that the risk may be very low in comparison to the societal benefits?
— In some countries operators should develop two reports. A very technical one for the competent authorities and a second one in plain language for external audience presentations/debates. Is this the answer?
— Scientists see risk as the product of the probability of occurrence of an event multiplied by the consequences of this event. The public sees risk as consequence only. How to solve this problem of communication?

All these questions can be rearranged into four main ones shown below:

(1) What ‘safety’ does the public demand? (What are the lessons learnt from the public perception of risks?)
(2) How to communicate safety (or Safety Case) using plain language and supporting tools?
(3) What should we do to enhance communication with the public and stakeholders?
(4) How should we change ourselves to be more flexible and trustworthy organizations?

PANEL

Session IVb
COMMUNICATING THE SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES

Chairperson: **C. McCombie** (Switzerland)

Members: **C.S. Kang** (Republic of Korea)
D. Bennett (United Kingdom)
J.P. Jonsson (Sweden)
J. Kotra (United States of America)
F. King (Canada)
P.F. Heilbron (Brazil)
M. Takeuchi (Japan)
S. Saint-Pierre (World Nuclear Association)

S. SAINT-PIERRE (World Nuclear Association): On behalf of the World Nuclear Association (WNA), I would like to present one success that the worldwide nuclear industry has achieved as regards communicating about the safe management of nuclear waste and spent nuclear fuel.

Basically, it is a position statement that we have developed with the primary aim of helping the waste professionals working within the industry. This WNA position statement looks at the issue from a global perspective and focuses on the best practices that exist. When you do this, you see good things about waste management around the planet. You see that nuclear power plant operators have, over the last decades, made huge progress in reducing the waste generated. You also see that low level waste disposal sites are up and running, and running well. You see that the storage of high level waste and spent fuel is a reality as well. You see that the transport of this material has been occurring all round the world for decades. And finally, you see that there is a well recognized disposal method — deep geological disposal — that has undergone expert reviews.

So, what is left? Two remaining factors: the technical demonstration of a deep geological repository and, more importantly, gaining broad public support.

T. DYEKJAER-HANSEN (Denmark): My country has no nuclear power plants, so we do not have the option of siting a repository at or near such a plant.

Our policy is to have a transparent process for the management of our radioactive waste — a process based on showing people what we are doing and asking them whether they like it. We started the process only recently, and so far there has been only one hearing, but we learned a lot from it despite the small number of stakeholders who were invited to participate.

How much safety does the public demand? We presented our dose constraint, 10 μSv/a, the same as the value used in Sweden, and the Greenpeace representative, said it was ten times higher than the value used in Norway and asked why we could not adopt the Norwegian value. We explained that it was equivalent to the clearance level and was one hundred times below the dose limit, but this did not satisfy the Greenpeace representative, who asked why people in Denmark should have less safety than people in Norway.

M. TAKEUCHI (Japan): I am sorry that I do not have a success story to tell you about concerning repository siting in Japan. In December 2002, we started the open door solicitation system, which means asking for volunteer municipalities.

We have been conducting publicity activities and holding discussions with different municipalities. We have been receiving enquiries from various municipalities and holding explanatory meetings and workshops to enhance the public's understanding.

Two and a half years have passed, but no applications have been received from municipalities.

C. McCOMBIE (Switzerland): NUMO has been waiting two and a half years and is still in a volunteering process without a volunteer. In the Republic of Korea and in the United States of America they gave up looking for volunteers after only three months. If you have a solicitation or volunteering approach, when do you decide that it has not worked?

M. JENSEN (Sweden): In the Nordic countries, the local power lies with the municipalities. The two Swedish municipalities that are now being investigated as possible sites are of about 20 000 people each. In other countries, like Germany and the USA, the unit is much bigger — it is more like a million people in a US state or a German 'Land'. In my view that is an important difference, in that you can have some kind of rapport or understanding among 20 000 people but less so among a million people.

C. McCOMBIE (Switzerland): That is a good point. Much depends on where the power is concentrated. If there is a small enough number of people in the community that you can talk to all of them then you are in a good position as long as that small number of people can take the decision. But it is often the bigger communities surrounding the small community that have the power, and that give rise to problems.

J.P. JONSSON (Sweden): Further to what M. Jensen said, there are some very well informed municipalities in Sweden, and we have good relations with the people living and working in those municipalities. However, with SKB now applying for a licence, power is moving from the municipality level to the national level as SKI and the environmental court reviews the application, and finally it will be the Government that takes the decision. So we have to start educating a wider public — the inhabitants of Sweden as a whole — about our different responsibilities and roles in the siting process as the issue shifts from being discussed at the municipality level to being discussed at the national level.

J. KOTRA (United States of America): One of the things we have learned is that we have a responsibility to stakeholders at the county level who are designated under law as affected units of local government that they all have different concerns. Also different counties and different states have different concerns, and you have to be very mindful of that.

C. McCOMBIE (Switzerland): Clearly much depends on where the decisions are going to be taken. Perhaps A. Zurkinden could tell us about the situation in Switzerland.

A. ZURKINDEN (Switzerland): In the case of the plan to build a repository near to Wellenberg, a local community in the centre of Switzerland with a population of about 2000 people, the community has voted five times in favour of the plan. Also at the Swiss national level, the population was in favour of the use of nuclear energy and accepted that radioactive waste should be disposed of in a repository. However, at the intermediate level — at the level of the Kanton (and the Kanton has only 23 000 inhabitants) — they voted against the plan. So, what is democracy?

C. McCOMBIE (Switzerland): The Swiss solution was to change the law as regards who is responsible.

F. KING (Canada): Regarding our experience, the municipality of Kincardine has about 12 000 residents. If you add the surrounding communities, there are perhaps another 12 000. The vote was held only in the municipality itself. It was won but it was not won by a big margin. We deliberately did not encourage voting outside that municipality in the surrounding communities. I doubt whether we would have won the vote in the larger region and if it had been conducted at the provincial level I am sure that we would not have won the vote.

So, I think the message is that you should keep the vote to within the people who are going to be directly affected.

C. McCOMBIE (Switzerland): Maybe that is the reason why most successes tend to occur in communities where there is prior understanding of what is happening.

F. KING (Canada): One further point. As I indicated in my presentation, I think the local community has to see that there are advantages for it which are bigger than the perceived disadvantages. Outside a local community, the comparison will look different.

L.W. CAMPER (United States of America): Further to what T. Dyekjaer-Hansen said, most members of the public believe that reducing exposures from 10 μSv/a to 0.1 μSv/a, for example, leads to a commensurate risk reduction. They do not realize that with such very low exposures and associated risks that does not happen. How can we convey to the public that the existing standards are adequate for protecting public health and safety, and that there is not a commensurate risk reduction when you go to ever lower numbers and that the money could be spent in ways that would benefit public health and safety more.

T. DYEKJAER-HANSEN (Denmark): That is a good question, and I would like someone to give me the answer, because I am sure that this problem will come up again and again.

There was an OECD/NEA meeting earlier this year where this problem was discussed. Perhaps someone from OECD/NEA could tell us about it.

F. KING (Canada): In such discussions and in our publicity material we use comparisons with natural background. Of course, we have to explain to people what natural background means but we find that it is accepted as a reference point.

C. McCOMBIE (Switzerland): I think the word which the public likes to hear in such discussions is ‘safe’. However, radiation protection people do not like to say that anything is safe. If someone asked the participants of this conference whether geological disposal was safe, I hope that most of them would say that it is.

M.V. FEDERLINE (United States of America): I would like to raise the question of consistency in the nuclear industry. The radiation protection community says that future doses cannot be estimated beyond a few hundred years, when we consider the licensing of new reactors we talk about materials degradating over periods of 50–60 years and when we consider the radioactive waste issue we talk about waste canisters that are going to last for perhaps 10 000 or 100 000 years. We accept that uranium mill tailings will remain on the surface, but require that other materials presenting similar risks should be put into an underground repository. How should we deal with such inconsistency?

D. LOUVAT (IAEA): Regarding this discussion on numbers, in my view there are two documents of importance: the Basic Safety Standards, which specifies the requirements for the radiation protection system; and the new Safety Requirements on geological disposal. These two documents give, for protection of the public, only one number: 1 mSv/a.

If you want to communicate safety, you have to explain what the radiation protection system is. The system is admittedly imperfect but it is reviewed on a regular basis, and so far, it has protected workers, the public and medical patients adequately.

I do not know why people choose 0.01 μSv/a, 0.1 μSv/a or even 10 mSv/a or 100 mSv/a. That is inconsistent. The disposal community should stay with what is in the radiation protection system.

C. McCOMBIE (Switzerland): We like to talk about the ‘objective risks’ associated with a situation, but unfortunately the public is often worried about the ‘perceived risks’ which are different from the objective risks. That is one of the issues we should bear in mind.

P.F. HEILBRON (Brazil): In Goiânia, when we were trying to convince people that there was a need to construct a repository, the questions were not about 1 μSv/a or 10 μSv/a, they were worried about the price of their lettuce and apples. We are discussing only radiological issues here in relation to communication, but maybe there are more important issues to be discussed than those.

F. KING (Canada): In response to M.V. Federline’s question, I would say that the public is not interested in talking about the consistency of radiation protection standards. When you are out in the field people do not want to hear you talking about dose levels at which there is only a very low probability of their getting killed. They do not raise such issues, and I suggest that proponents should not raise them either.

J. KOTRA (United States of America): In the light of my experience in the field, I agree with F. King. However, when different authorities in a given country are not in agreement with one another, people note the inconsistencies. They also note the inconsistencies when the authorities in different countries disagree, as in the case of Denmark and Norway, referred to by T. Dyekjaer-Hansen. In the USA, there was a disagreement between the Environmental Protection Agency and the Nuclear Regulatory Commission regarding the Yucca Mountain standards, and this was a major issue in many of our public interactions. Generally, however, there is not much interest in consistency; the public tends to raise a lot different issues.

C. McCOMBIE (Switzerland): That worries me, because we seem to spend all of our time talking about long term radiological impacts and similar things.

P.E. METCALF (IAEA): Contrary to what has been said here about there being too much focus on radiation dose levels and the like, safety cases concentrate very much on the quality of the engineering, the logic, the management approaches and so on. We need some dose criteria in order to evaluate impact, and regulators require us to do that.

The problem is that the 10 μSv number is misinterpreted. There was never any intention that 10 μSv should be used as a dose limit or a constraint for a facility, and, if national authorities cannot interpret the international system of radiation protection properly, then they are incompetent.

C. McCOMBIE (Switzerland): That sounds like a shifting of the blame. When you are communicating safety, what counts is not what you say but what is heard. If people are hearing something different from what you are saying, it could well be that you as a communicator are a large part of the problem.

C. PESCATORE (OECD/NEA): We feel safer with things that we are familiar with and know how to control. The best way to work with a community on a project is not simply to present the safety standards that will be applied but to help the members of the community get acquainted with what is being done. Then, as at Port Hope and in Belgium, people come to realize that the numbers are not very important — that there is no risk in fact.

In this context, it is important to distinguish between actual doses and potential doses. In the case of a surface repository that you plan to look after for 300 years, you can talk about actual doses because the facility remains under institutional control and there will be no release, because you will be checking all the time.

In the case of a situation where there is a long term hazard you cannot rely on this type of institutional control, and you have to talk about potential doses. Potential doses are not the same as actual doses because it is likely that thanks to the containment strategy applied they will not be incurred. When radioactive waste disposal people talk about doses they often forget the adjective that radiation people use — ‘potential’ meaning something that is most unlikely to happen.

C. McCOMBIE (Switzerland): People do not want to hear you saying: “We doubt whether you will ever receive any dose.” I cannot imagine any normal person being pacified by such a statement. It is the wrong message. People want to hear you saying: “We are sure that you will never receive a dose that is not safe.”

M. TAKEUCHI (Japan): For the general public it is very difficult to understand what we are talking about. We can understand the difference between 0.1 mSv/a or 10 μSv/a, but the general public will never understand it.

Once I said to my wife: “Do you know about the risks associated with nuclear power and radioactive waste management?” She replied: “No, I do not, but you work at a nuclear power station, so I feel safe.” That is how the general public thinks. Comparing risks is a good tool, but I am not sure that it is enough.

C.S. KANG (Republic of Korea): F. King mentioned using natural radiation background as a point of reference. But the danger of using this is, that if we use the 'radiation risk factor' generated by ICRP then we can find ourselves predicting that there is some kind of danger associated with the natural radiation background.

F. KING (Canada): Further to what C. Pescatore and M. Takeuchi said, I remember when I entered the radioactive waste management field, about ten years ago, I heard a presentation on discrete fracture modelling. After it, I felt so uncomfortable that I called my geotechnical manager and said: "Initiate a research programme where you do not have to use discrete fracture modelling in order to convince the public that the repository is safe!"

Forget about the quantitative arguments when you go out to the public — use the other arguments. In the case of the Kincardine site we explained that over the past million years there have been nine glacial cycles during which 3 km of ice had covered the site, and we can show by means of geochemistry that there was no interaction between the upper aquifers and the pore water at the level of the planned waste repository. Salinity was another argument — the fact that the water is highly saline means that it has been in contact with the rock for a very long time.

There are many arguments, multiple lines of reasoning, that people can understand — at least better than discrete fracture modelling.

R. LOJK (Canada): We must stop saying things like 'generally' and 'subject to…' and including all sorts of disclaimers in every report. None of us simply says "it is safe", even when there is no need for disclaimers. We must train ourselves to respond directly to questions like: "Is it safe?"

Also, we must put risks into perspective — we sometimes allow a reactor to operate, knowing that a crack may develop during the operating period, and that the consequences of that crack opening would be much greater than the consequences of any release from a deep geological repository. We hold ourselves to a much higher standard than anyone else.

The problem is often with numbers. If we mention numbers, we end up having a discussion about numbers rather than a discussion about safety. That it is our fault — no one else's.

W. BREWITZ (Germany): I would like to tell you about some of my personal experiences in communicating safety.

In the case of the Konrad mine, in the 1970s and 1980s we did quite a good communication job. We took people underground, and explained everything to them, and even today, I meet stakeholders who remember me with appreciation. I think that personal contact is very important, but in your contacts you must be honest and provide sufficient information. That is not how some public relations specialists behave. I think the technical experts can play a very important role, and I object when people put the emphasis on more brochures and more TV spots. That is not the most effective communication method.

As regards the safety case, we had a public hearing which lasted 78 days — the longest public hearing we had ever had in Germany. We did calculations which were very conservative on transfer and transfer times to deep groundwater. I had the suspicion that this would be an issue, but it was not. It was accepted. Instead, the stakeholders asked questions like: "What is going to happen to the sugar beet on the surface? What is going to happen to house prices?" These were the questions discussed in depth. Even today there are two court cases pending, and it is exactly for these things.

C. McCOMBIE (Switzerland): My experience suggests that concerns change as one moves to the site specific situation. People are not worried about dust and emissions and traffic until the site is identified. At the feasibility stage, it is much more academic, and we spend our time talking about 100 000 years into the future.

J. ROWAT (IAEA): I think most people are apathetic about most things. For example, I do not care about the mortality risk associated with horse riding as I do not ride, and I think most people are like that about ionizing radiation. Who really cares about it apart from a community like ours?

F. KING (Canada): I agree with you. Mr. Russell of our Nuclear Waste Management Organization has criss-crossed Canada during the past year, trying to solicit opinions about the long term management of used fuel, and the turnout at his meetings has been extremely poor.

J. KOTRA (United States of America): There have been references to the regulator becoming the proponent of a project, and I should like to make it clear that we are very serious about our responsibility to take an independent decision. Once that decision is taken we have to defend the basis for that decision — but not to become a proponent for the project.

It is a question of the clarity of roles, about which the public is incredibly sensitive, and there has been a lot of misinformation with regard to how independent or otherwise the Nuclear Regulatory Commission may be. We have to contend with that.

With regard to the observations of J. Rowat and F. King, considering how sparsely populated the area around Yucca Mountain is, we consistently get very good turnouts at our meetings. There is a lot of interest in hearing what the regulator has to say. We were told by the implementer, the USDOE, that nobody would come to our meetings, but we find that that is not the case.

People have many concerns other than radioactive waste disposal, but when a potential site has been identified in their community many of them become concerned, and they will turn up at your meetings if you schedule them in ways that are sensitive to the other demands on their time. Hold your meetings in the evenings, at an easily accessible location and contact local opinion leaders ahead of time to find out how you can best reach out to their constituents. Apathy has not been my experience in the case of the Yucca Mountain project.

C. McCOMBIE (Switzerland): You implied in your statement that the turnout at meetings organized by the USDOE has been low.

W. BOYLE (United States of America): Perhaps the experience is different as between regulators and implementers. I was involved in the DOE's rule making and I experienced apathy. At one meeting, arranged at a time and location to accommodate people's schedules, no members of the public showed up. At another meeting in Las Vegas, the only people in the room were those who were being paid to be there — including paid professional opponents. My experience is that most people would much rather correct their children's homework or watch television.

Maybe that is the fault of the DOE in the case of the Yucca Mountain project, because we are perceived as having lied all along.

S. SAINT-PIERRE (World Nuclear Association): In my opinion, the reason why people do not show up at meetings about a project is that basically they know that it is safe. Do you think that people would stay away from such meetings if they thought that the project was dangerous?

C. McCOMBIE (Switzerland): If I believe a project is safe and am asked whether I consider it safe, I answer: "Yes", provided that I tell the people who work for me to answer such questions with 'yes' as the first word. You should not answer the other way round, with your provisos before the positive answer.

K. RAJ (India): I should like to say a few words about dealing with journalists and local residents and about the importance of language.

About ten years ago, when we inaugurated our first interim storage facility for vitrified waste, the newspapers next day said things like: "Inauguration of first dumping graveyard". We realized that we must cultivate the press preferably during 'peacetime' — when we are not in the news because of an accident — by bringing journalists to our facilities and letting them move around and see how much care is being taken with the radioactive waste.

Another thing we have realized is that in the villages surrounding our facilities there are schoolteachers who could be very good explainers of our activities. So, we are conducting regular programmes for schoolteachers, and also for schoolchildren, again bringing them to our facilities. In addition, we are arranging seminars for college teachers on our activities.

We have co-located our disposal facilities with nuclear power plants in order not to have to transport waste over long distances. Most of the nuclear power plants are near villages where the level of development is not very high and the villagers ask: “What are we getting from these facilities?” In fact, it is very clear what they are getting. Because of the nuclear power plants and the co-located disposal facilities, the villages are enjoying significant development benefits in the form of good schools, good roads, good communications and — most important — jobs. Our facility managers mix with the local communities, attending their traditional events. The message they convey to the villagers by doing so is: “If I can live close to the nuclear power plant and the disposal facility, why can’t you?” Such first-hand interactions help to develop trust.

Who should be a public relations specialist? Among us there are people who are good at communicating as well as having an extensive background in radioactive waste management. So, we use them for communicating. They do a wonderful job with the help of experts in the preparation of posters and pamphlets in simple language and in the local language.

The language used in communicating is very important. For example, after the Three Mile Island accident our Government decided that for every nuclear power plant in India there should be a plan for evacuating people. We started doing emergency exercises. In those days, however, we spoke of ‘emergency drills’ and we had problems with the word ‘drill’. When we went to villages, the villagers said: “You never came to us before. Why are you coming now?” and “Are you going to drill that reactor?” They believed that we were going to drill a hole in the reactor and thereby release the pressure. So, we corrected our language.

C. McCOMBIE (Switzerland): I was interested to hear what you said about selecting the good communicators. I think that in our organizations we should at least have communication training if we do not use communication specialists.

R. LOJK (Canada): What we do is not dangerous — it is perceived to be dangerous.

For example, a small licensee in Canada was enlarging his plant near to which was an orange juice factory that employed 300 people. Somebody in the local community said that, if the plant was expanded, they would never buy orange juice from the factory because of the contamination risk. That got into the newspapers and the orange juice company owners said in a letter to us: “If you allow that person to expand his plant, we shall shut down our factory and move away.” They could not afford to have people believing that their orange juice might be contaminated with radioactive substances. That shows how important public perception can be.

A. DODY (Israel): Earlier on, P.F. Heilbron showed a slide with the question: “What else are you hiding from us?” More than 50% of the members of the public ask that question. Although we do the best possible safety assessments, use the best computer codes and so on, the public still feels that we still do not tell the full story. The main problem is lack of trust.

J. KOTRA (United States of America): With regard to communication training, the Nuclear Regulatory Commission now insists on very intensive preparation for any kind of interaction with the public. That includes the training of our technical people if they are going on the road with us to talk about particular issues. We insist that power point presentations be prepared weeks in advance. We ‘dry run’ them and videotape them, we critique them and we then have a dress rehearsal. I have had tremendous opposition from some of my technical colleagues because of the amount of work that this entails, only to have them come back to me after a very difficult meeting and say: “Now I understand why all that was necessary.” We have found that such a kind of training and preparation can work wonders.

C. McCOMBIE (Switzerland): I think the best approach is to train scientific and technical professionals in communication skills, but it is not the only approach. I remember going to a visitors’ centre and being met by a charming lady whose first words were: “I don’t know much about this. I don’t work for them, but I shall take you around.” My experience has been that in the programmes which seem to me to be successful, they do it that way round.

W. BOYLE (United States of America): Further to what S. Saint-Pierre just said, I think that if they have a concern, people will show up at meetings. I do not want to give the impression that the million and a half residents of Las Vegas and southern Nevada are generally apathetic about perceived dangers in their community. We have two television stations in Las Vegas that run 24 hours a day, one for the city and one for the county, that endlessly transmit the proceedings of various governmental meetings — planning meetings, city council meetings, county commission meetings — and you can see that people turn up when they have a concern. When the zoning status of the lot next door to them is being changed to permit a high density housing project or a road is being widened and they will be at greater risk from the traffic, they show up at such meetings.

However, people do not show up at meetings about the Yucca Mountain project even though it is endlessly repeated in the newspapers and on television that we are going to build a dump. They do not perceive it as being as bad a thing as the zoning status of the neighbouring lot being changed or a nearby street being widened.

C. McCOMBIE (Switzerland): Maybe they don't show up because they don't think that it would make any difference if they did show up. How do you know that that is not the case?

P.N. ALFORD (United States of America): I agree with the point just made by C. McCombie.

As someone without a scientific or technical background, I should like to say that underlying all communication are systems of values and beliefs, and each person brings their value and belief system to the discussion. So, when you mention a number (350 mrem or 15 mrem or 0.1 μSv), each person judges that number in the light of their value and belief system. Until you are communicating with that person in a way that acknowledges his value and belief system, you are not going to get anywhere. It is rather like two trees standing in the woods — they stand there, but they do not connect.

I think F. King gave an interesting description of a whole siting process in which the members of that community looked at each other and said: "Well, it looks as if the waste is here to stay." They had to come to some sort of consensus, on the basis of their value and belief systems, that they had to take responsibility for the waste. Something similar happened in Sweden — at Östhammars and Oskarshamns. Unfortunately, as the circle broadens, going beyond the community, embracing the region or the State, it becomes very difficult for people to have such a consensus of belief.

I do not know how you appeal to people's value and belief systems, but I do know that it is extremely important to recognize that they exist whatever communication techniques you use.

C. McCOMBIE (Switzerland): My impression is that neither the IAEA nor OECD/NEA does much in the area of communication with the public. Should the two organizations do more in the public communication area? Is there more that they could usefully do?

W. HILDEN (European Commission): I think there is one thing that could be usefully encouraged by international organizations — that is communication between municipalities which already have nuclear sites or are going to have one. There is an initiative in Europe, called the GMF, whereby municipalities in a few European countries exchange experiences and build up knowledge.

C. PESCATORE (OECD/NEA): Further to what W. Hilden said, the GMF runs a research programme on public participation which involves people, like the social scientists.

Also the GMF and OECD/NEA are organizing a national workshop in Spain, to consider strategies for negotiating with governments in the future and how to structure decision making in Spain.

W. BREWITZ (Germany): I think that the international organizations could an act as initiators.

Last year there was a forum on stakeholder confidence organized by OECD/NEA held at the Gorleben site. Recalling how tense the atmosphere has been regarding the Gorleben site for the past 20 years, I was pleased to learn that the workshop went very well. The opponents of Gorleben had the feeling that they were accepted and that their arguments were listened to, and I understand that the international participants played a useful role as mediators.

A.J. HOOPER (United Kingdom): I should like to mention the European Commission's COWAM project which stakeholder groups from the United Kingdom appreciate. We initially doubted whether it was worthwhile for NIREX to participate, but we are now participating through various stakeholder groups, particularly ones which have waste in their local communities and are very interested in the developing policy for its long term management. They find it very useful to talk with people from elsewhere in Europe about how they are dealing with the same issue.

As regards the IAEA, I think that it has a very good process for setting down the requirements that we should all respect, and that if the process were explained a little more clearly, that would be very helpful — certainly in relation to the consultation that we are going through in our country at the moment on radioactive waste management policy. We find it very helpful to point to statements by the IAEA and to say how we are measuring up against the best practices established through inputs from all around the world.

R. LOJK (Canada): The Canadian Standards Association has a system of committees that involves the public, industry, academia and so on. If we were to adopt an IAEA standard directly without its being reviewed by these committees, the same cross-section of national groups could not participate in the creation of that standard.

C. McCOMBIE (Switzerland): I believe very strongly that you should listen to people, but I also believe that there is no point in listening unless the people feel that there is some chance that you will react to what they have said.

CLOSING SESSION

(Session V)

Chairperson

K. ISHIGURE
Japan

SUMMARIES OF SESSIONS

Session IIa

THE GLOBAL WASTE SAFETY REGIME

Chairperson

K. HIGASHI
Japan

In the opening presentation, the role of the IAEA in relation to the safety of radioactive waste disposal was described. This encompasses the administration of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention), the development of international safety standards, and the provision of assistance in the use and application of the standards. It was noted that the principal document of the waste safety standards provided the technical basis for the Joint Convention. The objective of the Joint Convention is to ensure a high level of safety worldwide in the management of radioactive waste. The process for achieving this objective involves the preparation, by Contracting Parties to the Convention, of national reports and the review of the reports at the periodic review meetings. The presentation provided an encouraging view of the progress being made towards global waste safety, e.g. the recent agreement on international safety standards on geological disposal, the appreciable progress in geological disposal projects in several countries (United States of America, Finland, Sweden and France), and the public approval for a disposal facility at Kincardine (Canada).

The second presentation covered the preparation and peer review of the national reports for the Joint Convention and summarized the recommendations of the first review meeting held in 2003. Key factors to enhance the efficiency of the Joint Convention process include having a wider membership and improved national reports. It was concluded that the Joint Convention can play a major role in improving waste safety worldwide. In this connection, a recommendation from the first review meeting that countries should each develop and implement integrated waste management and decommissioning plans was considered to be very important and as reflecting the ‘spirit of the Convention’.

A presentation on the waste safety standards covered the history and hierarchy of the standards, the process for their development and the current status of documents in preparation. Specific mention was made of the Safety Requirements on the Geological Disposal of Radioactive Waste which was approved by the IAEA Board of Governors in September 2005. An IAEA plan to encourage the effective use and application of the standards in IAEA Member States was also emphasized.

A summary and review of ten contributed papers from nine countries was presented. These papers covered a wide range of topics pertaining to the global waste safety regime, e.g. experience in the preparation and peer review of national reports for the Joint Convention, the import and export of spent nuclear fuel and the products of its reprocessing, international and regional cooperative efforts on waste safety, national regulations and licensing procedures for radioactive waste management, especially spent radiation sources, and the safety management system for geological disposal projects taking account of their long term nature.

The presentations were followed by a panel discussion on three major themes: (a) enhancing participation in the Joint Convention; (b) effective use of the waste safety standards globally; and (c) the importance of international cooperation in the field of radioactive waste management. The major points from the panel discussion are summarized here.

The discussion on the Joint Convention initially focused on the likely reasons for the slow growth in the membership of Contracting Parties. Some of the reasons identified are: (1) the low priority accorded to this by the Member States; (2) the very elaborate requirements for the preparation of national reports; (3) the requirement for the presentation of national reports at the review meetings; and (4) the cost of participation. It is noted that several major nuclear countries are expected to join the Joint Convention soon. The measures to encourage more Member States to join were discussed and the following suggestions were made:

— To provide advice to potential Contracting Parties on the preparation of national reports and on dealing with the follow-up requirements (it was noted that a ‘tool kit’ to assist in this matter is available on the USDOE web site and in a guidance document issued by the IAEA);
— To simplify requirements in relation to national reports for review meetings;
— To convince countries that are not already Contracting Parties of the benefits of joining the Joint Convention. (It should be seen as a learning process in the improvement of waste safety at national and global levels. Both the IAEA Secretariat and the existing contracting parties have an

important role to play in this area to generate a better understanding of the various aspects of the Joint Convention.)

In connection with the effective use of the waste safety standards, it was noted that an IAEA survey, with a response from 23 countries, indicated that 70% use the standards either as reference documents or for formulating their own national standards. In order to obtain a more comprehensive feedback, other Member States were also requested to respond to the questionnaire sent by the IAEA. The standards can be used in the context of the Joint Convention as an aid in the preparation and review of national reports.

The panel members and participants emphasized the importance of regional and international cooperation in sharing information and experience in the field of radioactive waste management. In this context, the proposal by Japan for the extension of the Asian Nuclear Safety Network (ANSN) to the field of radioactive waste disposal was welcomed.

Session IIb

NATIONAL STRATEGIES TO ENSURE THE SAFE DISPOSAL OF RADIOACTIVE WASTE

Chairperson

A.J. HOOPER
United Kingdom

The session was started with a presentation of the proposed IAEA Common Framework for Disposal to be applied to all kinds of waste generated from nuclear activities, including disused sealed sources and NORM. This has been developed following a recommendation made at the 2004 Cordoba symposium. In the draft proposal, waste types have been linked to a disposal option commensurate with their associated radiological hazard, using safety based evaluations of 'acceptable', 'not acceptable' and 'not appropriate'.

Presentations from France and the USA described the national strategies in those countries. In France, a National Plan for Radioactive Waste and Recoverable Material Management has been developed in direct response to a recommendation from the first Joint Convention Review Meeting. The presentation highlighted waste types for which there is currently not an identified solution and laid out the strategies and processes through which appropriate solutions would be identified. The USA presentation identified the policy, legislative framework and institutional roles and responsibilities covering the management of all types of waste. Key challenges remaining to be addressed were identified. These concern making decisions in the face of uncertainty; improving public trust and acceptance; and knowledge management.

The final keynote presentation described the progress of the European Commission Framework Programme SAPIERR Project which is investigating the idea of a European regional repository for the spent nuclear fuel and high level waste generated from the power programmes of a number of countries. Analysis of the quantities and types of such waste in the countries of the participating organizations led to the identification of a proposed standardization of waste disposal packages and, in turn, of the likely economies of scale.

The rapporteur for the session summarized 32 contributed papers, from 30 countries, highlighting the interest in regional disposal solutions for both low and intermediate level waste and high level waste and spent fuel, disposal of institutional waste, including spent sealed sources, in boreholes, and the importance of waste classification schemes and of clearance levels to the development of national strategies in many of those countries.

Following these presentations, a panel discussion was held. The points raised by the panel members and the audience are summarized below:

— There are some waste types for which the most appropriate management route is not yet evident. Some countries are exploring 'intermediate depth' disposal options for which the requirements for site selection and disposal depth are currently less clear than for the well defined disposal options.
— The Common Framework, as currently presented, does not sufficiently recognize issues of practicality. A number of countries may have only small amounts of different waste types such that the development of ideal solutions for each type is not a realistic approach because it fails to take account of economic realities. The IAEA could play a valuable role in giving guidance, on an individual basis, to such countries on the optimum approach for managing the range of waste types that exists in the country. It was recognized that the solution finally chosen in a national strategy is strongly influenced by sociopolitical inputs but it is important that scientific and technical information is made accessible to the decision makers to help inform their decisions.
— The management solution for waste containing naturally occurring radionuclides (NORM/TENORM) and contaminated land will also be strongly influenced by considerations of practicality but it is important for public and stakeholder confidence that the approach to achieving safety and environmental protection is seen to be coherent. ICRP Publication 82 is considered to provide a useful basis for dealing with the issue of long term potential exposures from such waste types and contaminated land.
— Given the long timescales for the development and subsequent implementation of solutions, knowledge management is an issue that should be addressed in national strategies related to radioactive waste management. In particular, consideration needs to be given to documenting the basis for decisions and requirements; to the achievement of continual learning; and to the training and development of specialists.
— There is clear interest in regional solutions to radioactive waste disposal and the concept is supported by the IAEA, particularly because of its potential security benefits. It is recognized that this approach should not be pursued in place of developing a national solution, but be part of a dual-track option. Furthermore, great care is required to ensure that any initiatives in this field are not detrimental to the progress of developed

national waste management programmes. It was suggested that the Joint Convention might provide a suitable forum for the discussion of regional solutions, and that a special interest group might be formed on the subject. Ultimately, just as for national strategies, a regional strategy will only proceed if there is the sociopolitical acceptance of the need and if there is an associated political commitment.

— Where the driver for a regional solution is economy of scale, an alternative national strategy may be to use a generic technology that is simpler than the development of classically defined disposal facilities, for example, borehole technology for spent sealed sources.

Session IIc

THE SAFETY CASE AND CONFIDENCE BUILDING

Chairperson

T. PATHER
South Africa

The notions of 'safety case' and 'confidence building' are very often used in discussions on the safety of radioactive waste disposal facilities. In the context of geological disposal, because of the long timescales involved, it is not possible to demonstrate safety directly and recourse must be made to other, less direct, evidence. The safety case is a synthesis of evidence, analyses and arguments that quantify and substantiate a claim that the repository will be safe. It includes, in particular, the presentation of evidence that all relevant regulatory safety requirements and criteria can be met.

The keynote presentations described the safety case concept and its use in radioactive waste disposal safety assessment, and identified areas where it has been utilized and where it would be useful to develop further international consensus. The presentations covered the structure and content of the safety case, its use in the licensing process, and its use as a vehicle for communication with interested stakeholders.

It was stressed that the various technical arguments used and the presentation of analyses must take account of the concerns and level of technical knowledge of the intended audience. A safety case will have a variety of different audiences, including the implementer, the regulator, policy makers and other stakeholder groups. This needs to be considered when developing documentation; it may be appropriate to develop a range of documents that differ in their levels of technical content and detail, but are consistent in the underlying basis and in the key messages they present.

In his summary of the 11 contributed papers, the rapporteur identified the following key points: (1) identification of key components for the safety case; (2) treatment of regulatory requirements and compliance; (3) staged or phased process for repository development; (4) identification and definition of scenarios; (5) treatment of parameter uncertainty; (6) confidence building; and (7) IAEA support for Member States.

Following these presentations a panel discussed a number of issues that were highlighted during the presentations or raised in questions from the audience.

Providing for protection of the public at long timescales, far beyond the lifetimes of current generations, requires the use of predictive models and stylized scenarios to show compliance with radiological criteria. The subject is difficult and the existing international radiological protection guidance is being variously interpreted in different countries. The subject would therefore benefit from further international guidance.

The use of the concepts of safety case and confidence building for facilities other than deep geological repositories was discussed. It was pointed out that near surface disposal is now widely practised and experience therefore exists of the reliability of safety assessment tools in this context. The possibility of this experience being transferable to geological disposal was discussed.

The technical terms used in this area are, in some cases, not agreed upon or understood by all experts; the examples discussed were ‘disposal’ and ‘safety assessment’. It is even more problematic when the terms are translated into different languages. Furthermore, the terms used within the technical community are not easily understood by the various stakeholders, especially those without technical backgrounds. In this context, more work could be done by the international organizations, firstly, to develop standard agreed terms for the use of experts and, secondly, to develop explanatory material for the use of non-experts.

For building confidence in a proposed facility, it is essential that the regulator and the regulatory process are credible. The regulatory body must be seen to be independent and competent. It must also be adequately funded. It must guard against the potential to become biased in favour of a project, especially when it has been associated with it for many years. Other mechanisms, such as expert peer reviews, may be employed to provide an independent view of proposals but the basic confidence must come from the credibility of the regulatory body.

There are concerns about the possible lack of regulatory experience in countries that are developing new programmes in this area and this was identified as a topic for follow-up by the international organizations.

Session IIIa

GEOLOGICAL DISPOSAL FACILITIES

Chairperson

F. BESNUS
France

This session comprised five topical presentations and a report of the contributed papers, followed by a panel discussion.

A volunteering approach to siting has been adopted in the Japanese high level radioactive waste disposal programme; communities are being invited to volunteer as potential hosts for the repository. A flexible approach is being used to define the repository concepts; they will be tailored to the characteristics of volunteer sites. The main research and development challenges for repository design and development will therefore be identified and resolved as the repository concepts become clear over the next decades.

Siting was also the subject of the presentation of the International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM) which is an association of radioactive waste management organizations from many of the countries most involved in large scale radioactive waste disposal. It provides a forum to promote the exchange of knowledge, experience and information among its members. In the presentation, the conditions for success, the constraining factors and the future challenges were discussed. The use of a volunteering approach involving stakeholders is now seen as the way forward. It was noted that, since the siting process can take several decades, the need for stable political decisions over such time periods is important.

Experiences from two national programmes were described:

— The USDOE gained considerable experience in creating and communicating the case for the safety of the potential Yucca Mountain repository culminating in approval in 2002 by the President and Congress. The experience that supported the successful site recommendation process involved a three-tiered approach. First, a highly technical case was made for regulatory compliance. Second, a broader case for safety was made in an Environmental Impact Statement. And third, plain language brochures were made available to the public in hard copy and on the Internet, to explain the DOE’s action and its legal and scientific bases.

— The French 2005 Clay File is a document which contains an assessment of the feasibility of a disposal system in a specific clay formation. The presentation described the preparation and the content of the material that the French national organization responsible for radioactive waste management (ANDRA) submitted to its supervisory ministries in June 2005. The File will be the subject of an international peer review in November 2005. It addresses, in particular, the management of uncertainties, the geological survey and review, and reversibility.

A presentation from Finland set out an approach for demonstrating the safety of a geological repository based on the experience gained from the successful Finnish project. It emphasized that absolute proof of the long term safety of geological disposal is not possible and, instead, a judgement is required which should be based on the concepts of reasonable assurance and multiple lines of evidence.

Similar issues were dealt with in the contributed papers summarized by the rapporteur. They addressed progress in disposal programmes, regulatory issues, and knowledge and ‘know-how’ preservation. For the latter, timescales of centuries have to be taken into account. Two goals are assigned to knowledge preservation: (1) the efficient use of information in ongoing programmes to support decisions; (2) the transfer of information to future generations to enable them to take informed decisions.

The panel discussion focused on the following topics: siting and site requirements, safety assessment approaches, and innovative technologies and demonstration programmes.

Regarding siting, the purely scientific approach is no longer considered to be appropriate. The volunteering approach with stakeholder involvement is becoming the reference. Siting should be a step by step process with clearly identified rules. It should involve communication with the public and the regulator must also be involved. The trend is to select a ‘suitable’ site rather than the ‘best one’, recognizing that there is room for flexibility in combining engineered systems and site characteristics to achieve safety. Thus, there is no reason for defining more precise requirements for siting internationally than those already existing. However, this should not prevent international initiatives on providing guidelines regarding favourable site features that would facilitate safety demonstration.

Probabilistic and deterministic approaches are useful and they are not mutually exclusive. The deterministic approach can treat uncertainty in a bounding conservative way, while the probabilistic approach can treat parameter uncertainty in an explicit way. They provide complementary tools for the interpretation and presentation of the results of calculations. Whatever method is used, there is, in the end, the need to explain and clearly justify the relevance of the assumptions made.

In the context of radioactive waste disposal, the regulation of long term radiation protection has been identified as a complex issue that could benefit from further international guidance. The relevance of protection criteria (doses, risks, fluxes, etc.) and their interpretation in the very long term remains open to discussion. Considerable differences can be observed between national regulations in the setting of time frames for safety consideration and the associated protection criteria. These differences are difficult to explain and to justify and may add to a lack of trust among stakeholders in the capacity of the disposal system to protect people and the environment in the long term.

Demonstration programmes in underground facilities were identified as indispensable tools for assessing design performance. It was noted that this topic has not been the subject of a detailed international exchange of information.

Session IIIb

NEAR SURFACE DISPOSAL FACILITIES

Chairperson

K. RAJ
India

In the first presentation, the design and development of near surface disposal facilities was discussed and, in this context, examples were given of the existing facilities in different countries. The available technical options for different categories of low level radioactive waste, namely, short lived, long lived and very low level, were presented, with a summary of the possible reasons for adopting a particular disposal option and the limitations associated with it.

The second presentation addressed how the safety of near surface repositories should be demonstrated, with a particular focus on the assessment of the radiological impact of inadvertent human intrusion. The differing natures of the safety assessment during the various phases of the repository, identified as the operational phase, the institutional control phase and the long term safety phase, were discussed. It was pointed out that the balance between quantitative and qualitative arguments changes with time; confidence in the radiological impact indicator 'dose' decreases with time and this has to be counterbalanced by additional safety arguments, such as those based on defence in depth and robustness.

In the third presentation, several important differences between the disposal of waste containing naturally occurring radioactive material (NORM) as compared to other types of radioactive waste were noted. It was pointed out that the distinctive features of such waste arising from mining activities, i.e. low activity concentrations, large volumes and long half-lives, limit the available management options, in most cases, to near or above surface disposal. In particular, the long half-lives of the radionuclides in the waste mean that institutional control has to be retained, essentially, in perpetuity. For these reasons, the regulatory criteria cannot be fully consistent with those applied to near surface disposal facilities for other types of radioactive waste and a greater reliance has to be placed on the flexibility afforded by the concept of optimization of protection.

A summary and review of 26 contributed papers from 22 countries was presented by a rapporteur. These papers covered a wide range of topics pertaining to the safety of near surface disposal facilities, e.g. safety assessment (generic methodology, realistic and conservative scenarios, human intrusion and institutional controls; verification of computer codes), design and performance of covers and engineered barriers, realistic approaches for NORM disposal, repository design versus actual performance using environmental monitoring data, and heterogeneity and concentration averaging of radioactive waste.

The presentations were followed by a panel discussion on four major themes: (a) human intrusion and institutional control; (b) safety assessment; (c) mining and minerals processing waste; and (d) small disposal facilities for limited radioactive waste inventories.

The experience obtained during the last 30–40 years in all facets of the disposal of radioactive waste in more than 100 near surface disposal facilities represents a valuable potential resource. It would be useful to collect and analyse this experience with emphasis on documenting the lessons learned.

In the context of human intrusion and institutional control, it was observed that while the institutional control period may be projected during the initial phase of the licensing procedure, it may only be finally determined as a result of a step by step process of periodic review of the safety performance of the repository. Planned institutional control periods for existing near surface repositories vary from 100 to 300 years. It was pointed out that such times should not be seen as the times at which the site could be released from control but rather as the times for which institutional control can be relied upon to exist.

In the discussion on safety assessment it was noted that ‘generic’ safety assessment could have a role in the evaluation of the very small radioactive waste repositories which exist in some countries, for example, as a result of cleanup or other intervention actions. A generic assessment framework could allow reference levels to be defined such that the requirements for site specific assessments could be simplified. In this context, the output of existing IAEA projects, such as ASAM, could provide the basis for international guidance.

In the context of generic assessments, it was pointed out that there is an absence of generic data on the performance of common materials, such as concrete, used in the construction of packaging and engineered barriers.

The conclusions of the discussion on the problems of the management of mining and minerals processing waste were generally supportive of those of the invited presentation on the subject. In this context, it was recognized that the international guidance on the safe management of this waste type is not yet adequate and it was recommended that it should be improved based, in the first instance, on the experience described in this session.

It was pointed out that there are apparent inconsistencies in the radiological criteria used for controlling different types of waste facility, for example, conventional near surface repositories versus mining and minerals processing waste deposits, and old versus new disposal facilities and that these inconsistencies tend to undermine the trust of the public in the regulatory process. It was generally agreed that there must be coherence and consistency in radiological criteria but that it would take time to achieve consistency for some situations, e.g. the legacy waste. In other situations, involving naturally occurring radionuclides, full coherence and consistency is not achievable and this has to be explained to the relevant stakeholders.

Session IIIc

OPTIONS FOR INTERMEDIATE DEPTH DISPOSAL

Chairperson

J. LOY
Australia

The session began with a presentation on the safety issues related to disposal at intermediate depths (tens of metres to about one hundred metres). Disposal at these depths is seen as having the same aims as geological disposal (as stated in the new IAEA Safety Requirements on the Geological Disposal of Radioactive Waste): to contain the waste until most of the radioactive content has decayed, to isolate the waste from the biosphere until such time that much of the radioactive content has decayed, to delay any significant migration of radionuclides to the biosphere, and to ensure that, for any migration that does occur, there is an acceptably low radiological impact. In terms of the safety case, the advantages of intermediate depth over near surface disposal are that there is likely to be a lower risk of inadvertent intrusion, a much lower impact of biological processes and less aggressive conditions for barriers. The performance of the repository may be more predictable because of the absence of surface processes and because of the inaccessibility of a repository at geological depths. The issue of human intrusion is a challenge for all forms of repository. The likelihood of human intrusion can be reduced in the long term, if knowledge of the repository is retained. Information conservation may be achieved through establishing an appropriate archive. It is suggested that national archive bodies should be involved through legislation and that the IAEA would be a possible location for an international waste disposal archive.

The next presentation described the current status of a subsurface tunnel and cavern facility being developed at Rokkasho Mura in Japan. The concept is aimed at disposal of ‘relatively higher low level radioactive waste’, that is, reactor core surrounding parts (channel boxes, control rods, burnable poisons), ion exchange resins, decommissioned or replaced reactor core internals and long lived waste from the fuel cycle plants. The depth of the facility has been selected to limit the possibility of human intrusion, taking into account excavation depths for high rise buildings and other activities. The detailed investigation for the facility has involved borehole drilling and seismic investigation to establish site scale geology and hydrogeology; an exploratory drift to establish the near field geology and hydrogeology; and a test cavern to establish the stability of an underground facility.

The third presentation addressed the disposal of disused sealed radioactive sources in small diameter boreholes. The issue is that certain sealed radioactive sources are too active and/or too long lived for disposal in a near surface facility, particularly because of their potential impact in the event of human intrusion into the repository. The small volume of the sources also means that they do not require large near surface or cavern type disposal at intermediate depth. The presentation focused on the development of the specific borehole design being supported by the IAEA under the aegis of the AFRA regional organization. The safety case for this form of borehole disposal of sealed sources derives from the small volume and nature of the waste, and a high near field integrity due to the surrounding stainless steel and concrete barriers. This emphasis on the near field for safety means that knowledge of the geochemistry of the site is more important than the hydrogeological characterization, because of the need to limit the likelihood of localized corrosion of the stainless steel. The risk of human intrusion is minimized by the depth, of at least 30 m, the small footprint of the facility, the deflector plate, and the use of native soil in the upper layer. The particular value of the concept is that it is ‘one size fits all’ and can be adapted to the inventory of the country and to the nature of the site. An international peer review team has reviewed the borehole concept and reported that it offers a potentially safe, economic, practical and permanent means of disposing of disused radioactive sealed sources. It was stated that the AFRA member States have decided to proceed to the next phase of the project, which includes implementing the borehole technology.

The final keynote presentation described the IAEA programme on assisting Member States in dealing with sealed high activity radioactive sources (SHARS). This has arisen from the international work in the management of sources, the analysis of lessons learned from radiation accidents, and the requirements of the Code of Conduct, as well as the success of the radium conditioning programme. The new programme includes the development of mobile conditioning capacity and of storage and transport shields together with the development of the borehole concept described in the previous presentation.

The session participants, through the statements of the panel members, also heard about a proposed intermediate depth facility in France for dealing with low level but long lived waste, such as radium and irradiated graphite, and the assessment of intermediate depth cavern and borehole proposals in Cuba.

The highlights and conclusions of the panel discussions in the session are summarized below:

— Intermediate depth disposal is an appropriate concept that many countries may need to consider as part of their radioactive waste management strategies. Choice of the option by any country would depend on several factors including: the national inventory, the cost effectiveness of different available disposal routes, the availability of deep geological repositories, and public acceptance.
— The basic safety requirements for intermediate depth disposal are the same as for near surface and geological disposal and therefore no new international Safety Requirements are needed. In addition, the approach to assessing safety is also the same. However, it might be useful to have additional guidance for intermediate depth disposal to reflect the different balance of argument in an intermediate depth safety case as compared with near surface or deep geological disposal.
— There may be elements of safety assessment that can be applied generically, especially in relation to human intrusion, but otherwise safety assessment must be specific to the site and the disposal concept.
— The Rokkasho project is a very good example of a thorough evaluation of a cavern disposal facility.
— The borehole concept being developed through AFRA and the IAEA is a highly promising approach that could enable some countries to dispose of disused sealed sources and it is appropriate, in principle, that it is supported by the IAEA.
— The same standard of safety must be achieved for boreholes as for other types of disposal. However, the IAEA should develop specific safety guidance applicable to the borehole concept. An important step for the general acceptance of the technique would be for a borehole system to be licensed and operated in one or more countries.

Session IVa

NEW FACILITIES, REASSESSMENT OF EXISTING FACILITIES AND DECISION MAKING ON UPGRADING SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES

Chairperson

D. CLEIN
Argentina

The session, involving contributions from 11 countries, comprised three invited presentations, a report on five contributed papers, and a panel discussion. Two of the invited presentations dealt with the reassessment and upgrading of existing facilities from the viewpoint of the regulator and implementer, respectively. The third presentation was devoted to regulatory review and licensing in a more generic way, based on the conclusions reached in the IAEA's ASAM programme.

In the generic presentation, it was stated that the regulatory review of safety cases and safety assessments is essential for credible decision making on the licensing or authorization of radioactive waste disposal facilities. The regulatory review process typically includes ensuring that the disposal facility will not cause any adverse impacts, providing assurance that the safety assessment has been conducted adequately, verifying that the results of the safety assessment comply with regulatory requirements, ensuring that measures to mitigate possible impacts have been identified and ensuring that uncertainties have been identified and taken account of. The whole process must be transparent. Some potential difficulties in conducting regulatory reviews were raised, including issues of project and programme management, limited resources for reviews, conflicts due to multiple regulatory agencies and difficulties in assessing the potential long term behaviour of systems.

One of the invited presentations described some ongoing work in the United Kingdom concerned with the reassessment of the low level near surface radioactive waste repository at Drigg. The regulator has started a reassessment of the facility based on the safety case submitted by the implementer. Scenarios identified in the safety case lead to indications that peak risks from historical and ongoing disposal activities that could exceed the risk target for a new disposal facility under certain conditions. The regulator is therefore requiring that a wide range of risk management options be considered by the implementer.

In the remaining invited presentation a report was given on the planning of safety upgrading measures at a near surface repository for radioactive waste in Hungary (Püspökszilágy repository). Based on recent safety assessments, a judgement has been made by the implementer that the long term safety of the repository can be ensured, but only with some technical and administrative modifications to the facility. A project has been launched to select the most appropriate methods for enhancing safety, and to prepare for corrective actions. The intention is also to provide free capacity within some existing vaults by the use of volume reduction technology. Following the volume reduction and the removal of specific packages that are giving rise to radiological concern, a considerable amount of space can be created for further disposal of institutional waste.

The review of the five contributed papers covered activities in Chile, Mexico, Romania and the Russian Federation. It was notable that the assessment methodology developed in the IAEA's Improvement of Safety Assessment Methods (ISAM) programme had been applied in most of the cases described.

A large part of the panel discussion dealt with the reassessment of old disposal facilities that could lead to the need for intervention action.

Optimization is considered as an essential tool for use in managing the issue of potential non-compliance of old waste repositories with modern waste acceptance criteria or of managing inadequately performing repositories. When considering the remediation of old facilities, there is a need to take account of factors, such as the volume of waste and the availability of alternative disposal options and of the need to analyse the cost–benefit balance, taking into account the risks for both the public and operating staff. It is clear that significant experience has now been obtained in this area in many countries and it could be usefully gathered and synthesized into guidance on how to perform optimizations and make decisions in this context.

It was observed that the human intrusion scenario is a common factor in many of the safety assessments of old near surface facilities. At present there is no uniformity of approach for the assessment of human intrusion in this context. A stylized approach would often be appropriate in these cases. It would be valuable to have international guidance on the elements of a common stylized approach for assessing human intrusion into near surface repositories.

The discussion showed agreement that a well documented safety case is a key element for aiding the decision of the regulator in the regulatory review of a licence application. However, its content remains, in practice, country specific, that is, the scope of the safety case may be different in different countries.

Within the constraints imposed by the requirement for regulatory independence, the relationship between regulator and implementer should be as close as possible. There should be a regular exchange of information at an early stage of the licensing process so that expectations are well understood. The regulator should provide the implementer with detailed guidelines on regulatory requirements, in line with the national legislation.

Session IVb

COMMUNICATING THE SAFETY OF RADIOACTIVE WASTE DISPOSAL FACILITIES

Chairperson

C. McCOMBIE
Switzerland

The session began with four invited papers giving communication experiences from the Republic of Korea, Sweden, the USA and Canada. The first of these described an analysis by university academics of the multiple trials in the Republic of Korea at voluntary siting; the second by the Swedish regulator concerned communication approaches in national siting projects; the third, also by a regulator, summarized both international and specific US work; the last detailed the Canadian implementer's successful efforts to agree with a local community on siting a low and intermediate level radioactive waste repository. The rapporteur of the session then summarized four relevant contributed papers from Latvia, Denmark, Malaysia and Brazil. These presentations were followed by a panel discussion in which the speakers were joined by panellists from Japan, Denmark and the United Kingdom.

The list of questions posed to the panel and the audience included those listed below, but discussions ranged more widely.

— Who should be communicating safety: the implementer, regulator, policy maker or IAEA?
— Which are the key target audiences: general public, local public, media, scientists, younger generations?
— How should we be communicating: by numbers and plots, risk comparisons, indirectly, such as through analogues, personal contacts, etc.?
— Are our organizations structured and staffed appropriately: how many technocrats, public relations specialists or sociologists?

In the remainder of this session summary, the main points made by panellists and by members of the audience are noted.

There is an increased awareness of the importance of communication and this has resulted in increased effort by implementers, regulators and international bodies. The variety of stakeholders involved implies that specific, tailored communication approaches are needed. At the present time, even internal communications within an organization or industry can be a challenge. Regulator-implementer interactions, on the other hand, are improving, or have been improved. An urgent task is to communicate more with the next generations, i.e. to strengthen education and knowledge transfer. The most important and most challenging communication is between experts and the public.

Important general points were made concerning these communication processes; they were that, today, there is movement, from informing to dialogue to participation. It is also necessary to recognize that, in this context, the risk perceived by the public is as important as the actual or scientifically derived risk. Although there are sometimes important culturally dependent differences in choosing the most effective communication approaches, cross comparisons have shown that there are also very many commonalities. Important for experts — although less for the public — is that it has proven to be difficult to have a consistent safety framework and communication platform across all radioactive waste management applications, ranging from high level waste disposal to the remediation of mine sites.

Bitter lessons have been learned from project failures (e.g. in Canada, the United Kingdom, Switzerland and the Republic of Korea) but there have also been positive lessons from successes in Finland, Sweden and recently in Canada. The common message is that success depends on openness, trust in organizations and the personal behaviour of those involved. Several organizations have made changes in their cultures and structures in order to emphasize these characteristics. The most effective communication has been by technical staff — provided that these have had proper training and professional support. The Safety Case (however defined) is a key concept in the dialogue. It is the prime vehicle for regulator/implementer communication. For the public, however, it is important to avoid technical jargon and too many numbers; here the effectiveness of alternative lines of argument may outweigh that of presenting direct safety assessment results. It is crucial that the implementer or regulator does not swamp the public with too much documentation, but rather tries to listen empathetically to their concerns — and to respond to these.

The changing role of the regulator in some countries was discussed. Increasingly, the regulator has a more direct role as the representative of the public, although there is still some sensitivity about avoiding being viewed as a ‘promoter’ of a facility. It was agreed that there needs to be early regulatory involvement in projects and that the direct inclusion of regulators in the siting process is a productive approach. To fulfil their expanded role, regulators need to have adequate resources and capabilities.

In siting, the trend is clearly from DAD (A) (referring to ‘decide-announce-defend-(abandon)’) through technocratic approaches to achieving community assent and even to joint decision making or volunteering. In deciding on siting strategy it is important to know where the ultimate decision power lies. Here mention was made of the ‘doughnut effect’ in which agreement has been reached at the local community and the national levels, but where opposition at an intermediate level blocks progress. Providing benefits to a local hosting community is normal practice; it is necessary but not sufficient. A sharp spatial cut-off in such benefits is best avoided. A prerequisite for successful siting is to establish consensus on the need for the facility. But there are other key local issues, including property protection liabilities, job potential, etc. The environmental impact assessment (EIA) process is an efficient vehicle for public participation and it reveals that non-radiological impacts can be more important to the local public than far future dose predictions. There were varying reports on the observed enthusiasm or apathy of local residents for participation in dialogue. Meetings arranged by regulators appeared to attract more interest in some countries — perhaps because the public feels that it can exert more influence here.

The contributions to the conference illustrated that a large variety of tools for communication are available. There is also some information available on their relative effectiveness. Some examples of communication vehicles that always function well are visitor centres, demonstration experiments, and well designed, topical web sites. Natural and archaeological analogue studies can be very valuable, provided that these are used correctly and not oversold.

Measures are being taken to address the challenge of communicating safety, e.g. the IAEA’s Improving/Application of Safety Assessment Methods (ISAM/ASAM) project. Mostly, efforts are aimed at the nuclear community but exceptions exist, e.g. the European Community’s Community Waste Management (COWAM) project or the Forum on Stakeholder Confidence of the OECD/NEA. The IAEA can help the communicators by ensuring that a coherent system of targets and recommendations is available. Further, the IAEA could invest more effort into providing, in a form suitable for public communication, explanations and justifications for the guidance that it gives. Finally, the international organizations were recognized as having increased their involvement in the crucial task of providing further education of professionals in the waste management area. This is being done, for example, by the IAEA’s Network of Centres of Excellence for Training in Geological Disposal Technologies and the World Nuclear University (WNU). Education of young professionals and of the public at all levels should be a high priority IAEA objective.

SUMMARY BY THE CONFERENCE PRESIDENT

K. Ishigure
Japan

Since 2000, the IAEA has organized a series of conferences and symposia on the safety of radioactive waste management which have addressed the safety of radioactive waste management (Cordoba 2000), issues and trends in radioactive waste management (Vienna 2002) and the disposal of low activity radioactive waste (Cordoba 2004). This Tokyo conference is the latest in the series and the first held in Asia that focuses on the safety of radioactive waste disposal.

In the following, I will try to summarize the highlights of the Tokyo conference with special attention to evidence of progress and to international aspects.

1. THE GLOBAL RADIOACTIVE WASTE SAFETY REGIME

The entry into force of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management in 2001 was an important step forward in raising the importance of the subject at the international level. By becoming Contracting Parties to the Convention, countries have given legally binding commitments to manage their radioactive waste safely and in accordance with internationally established principles.

Participants at this conference discussed the benefits to be obtained from being part of the Convention and ways in which more countries could be encouraged to join — so that the Convention could become truly global and able to properly fulfil its objectives. The existing Contracting Parties and the IAEA were encouraged to be inventive and flexible in looking for ways to attract new countries.

There has been good progress, in the last year, in the development of international safety standards — with the publication of the long awaited standards addressing the subjects of (a) clearance of materials containing low levels of radionuclides from regulatory control and (b) the safety of geological disposal. It was noted that the ways in which the standards are used by countries varies; some countries use the standards directly and incorporate them into their own regulations, while others use them as a basic reference for developing their regulations. The standards are increasingly seen as representing best practice in the field rather than, as often in the past, the lowest common denominator.

Various regional initiatives were seen as evidence of movement towards a global approach to safety, for example, the information networks established in Asia and Latin America and the increasing use, by countries, of the peer review services of the international organizations. In this regard, the proposal of Japan to expand the Asia Nuclear Safety Network to include radioactive waste management was welcomed by the conference.

2. INTERNATIONAL AND REGIONAL STRATEGIES

The most appropriate disposal solutions for the different types of radioactive waste vary depending on the nature of the waste and range from disposal on, or near, the surface to disposal deep underground. This is reflected in the IAEA's 1994 Classification of Radioactive Waste. However, the 1994 classification is far from being comprehensive and omits several important waste types; it is therefore scheduled for updating. As described at the conference, an input to this process, a common framework project has been under way for some time at the IAEA. It is aimed at determining, mainly from the perspective of hazard, the most appropriate disposal solution for each major waste type.

Many countries have comparatively small volumes of intermediate and high level radioactive waste. It would be disproportionately costly for each of them to develop its own geological repository. For this reason, studies have been initiated at a regional level, supported by the European Union, to examine the feasibility of a regional repository in which the waste from several countries could be placed. However, no potential site has yet been identified. The issue is sensitive for some countries because it is considered that it might undermine their own national disposal projects. On the other hand, regional repositories could be attractive from nuclear safeguards and security perspectives (and in line with such initiatives at the IAEA). The discussions at the conference reflected the division of opinion on this subject.

3. GEOLOGICAL DISPOSAL

The main popular focus continues to be on the geological disposal of high level waste. The good progress of recent years towards achieving operational geological repositories is continuing in several countries and reports from three of them were made at the conference.

The technical discussions at the conference focused on some of the remaining philosophical difficulties. In the context of geological disposal, because of the long timescales involved, it is not possible to demonstrate safety directly and recourse must be made to other, less direct, evidence. The approaches being used to make the 'safety case' for these repositories and to improve confidence in it were discussed.

Providing for protection of the public at long timescales, far beyond the lifetimes of current generations, requires the use of predictive models and stylized scenarios to show compliance with radiological criteria. The subject is difficult and the existing international radiological guidance is being variously interpreted in different countries. The subject would therefore benefit from further international guidance.

4. NEAR SURFACE DISPOSAL

More than 100 repositories of the near surface type are in existence in the world and they account for the main part, by mass and volume, of the disposed radioactive waste. They are used mainly for the disposal of low and intermediate level waste of short radioactive half-life. They vary in quality and some are currently being upgraded to bring them into compliance with modern standards.

The approach for designing near surface repository systems to achieve safety is well established. For such systems, compliance with the international radiological protection criteria can be achieved by a combination of engineered barriers and institutional controls to prevent inadvertent intrusion into the waste. This contrasts with the situation at the sites at which large volumes of waste from the mining and milling of radioactive ores or from other industries producing waste containing natural radionuclides have been deposited on the Earth's surface. At these sites, the radiation exposure of local populations is often in excess of radiation protection limits for members of the public. Because of the large volumes, the practical protection measures which can be taken are limited. The international guidance on their safe management is not yet adequate and it was recommended that it should be improved based on, in the first instance, the experience described in one of the presentations at the conference.

5. INTERMEDIATE DEPTH DISPOSAL

Work on some types of disposal at intermediate depths (typically 50–100 m) was presented. It was emphasized that the safety principles and methods for assessing safety are no different from those used for other types of disposal.

Ongoing international projects to help remove the global problem of disused sealed radiation sources by the technique of borehole disposal were described. Although the approach promises to be much less costly than alternatives, such as near surface and geological disposal, it was stressed that safety would not be compromised and that international standards would be respected. An important next step for the general acceptance of the technique is for a borehole system to be licensed and then operated in one or more countries. There was general support for the approach as having the potential to solve a real problem existing in many countries in the world.

6. COMMUNICATING ON THE SAFETY OF RADIOACTIVE WASTE DISPOSAL

A lesson learned from the early years of radioactive waste disposal is that it is difficult to make progress with the development of repositories, and especially high level radioactive waste repositories, without involving those who may be affected in the decision making process. Several experiences of how the communications with affected parties have been managed in national projects were described during the conference. From these it is clear that it is now generally recognized that openness, trust and participation are all essential in such communication. The importance of using all available approaches and techniques for communication was also emphasized.

7. CLOSING REMARKS

At this conference a first attempt was made to involve the public in an event of this type; the public have been allowed to attend in the sub-hall and, in addition, the events in the main conference hall have been made available on the Internet. However, to be honest, I do not think that many ordinary members of the public would be able to understand our discussions. Even the experts in this room feel the need to have a common and clear definition of terms, for instance ‘the safety case’. I would like to point out that it is becoming more important for us to develop and use a special ‘language’ or ‘languages’ for communication with the public, with scientists and engineers of ‘the third body', as well as between ourselves. We also need to establish and train a group I will call 'interpreters' or experts in communication with the public.

I believe that the discussions at this conference have been fruitful and that the exchange of information between you, the participants, will prove to be very useful for your future work. The conference has allowed us to review the current world situation in the field of radioactive waste disposal and to become aware of the progress and changes that have occurred in recent years. As a result of the discussions, some gaps and areas for improvement have emerged which have led to suggestions being made to the international organizations for additional work and guidance.

I think from this report it can be seen that, overall, it is a positive story; progress is being made — and soon, perhaps, radioactive waste will no longer be seen as an 'intractable problem'.

As you will be aware, radioactive waste disposal is a very important subject for Japan and you will have seen from the papers presented this week that a lot of work is going on here. Those of you who are going on the visits later today and tomorrow will be able to see some aspects of the work.

We have been very happy to host the conference in Japan and are pleased that it has been such a success.

Lastly, I would like to thank all participants, in particular the chairpersons, the keynote speakers and the panellists for their active contributions to the conference.

I would like to express my special thanks to F. Besnus, who is the Chairperson of the Programme Committee, and Y. Kawakami of Japan Nuclear Energy Safety Organization, who is the Chairperson of the Local Organizing Committee, for their excellent preparation of the conference.

And also, I would like to express my special thanks to P.E. Metcalf, J.-M. Potier and M. Davies of the International Atomic Energy Agency and to G. Linsley, for their excellent secretariat work; and to H. Schmid and K. Morrison for their careful organization of the details of the conference.

I hope that you enjoyed your visit and that you take back with you some happy memories of your time spent here.

CLOSING ADDRESS

T. Taniguchi
Deputy Director General,
Department of Nuclear Safety and Security,
International Atomic Energy Agency,
Vienna

On Monday when I made my opening address, I spoke about the evolution of the global nuclear safety regime and the reasons why it has come about. Essentially, it is because of the global nature of the nuclear industry and the importance of maintaining high levels of nuclear safety worldwide. I also spoke of a global radioactive waste safety regime, which has emerged as a component part of this global nuclear safety regime — a component involving not only waste from nuclear fuel cycle installations but also from the many and increasing uses of radioactive materials worldwide. I spoke of the role of the IAEA in this global regime — developing safety standards and assisting in their use and application. I emphasized the need for it to fulfil this role competently, particularly in view of the re-emergence of nuclear energy generation as a major component in the worldwide mix of energy generating options, and the ever increasing demand for energy worldwide. I also spoke of the international waste safety action plan, which was established to assist the IAEA in focusing its work in the waste safety area, and which has been updated on an ongoing basis. The plan was initiated and updated based on the outcome of recent international conferences and symposia on the safety of radioactive waste management — Cordoba 2000, Vienna 2002 and Cordoba 2004. We now have the task of reflecting on the outcomes of the long and lively debates of Tokyo 2005 to see where our efforts should be focused and directed over the next few years.

The global safety regime

A clear need exists to involve more countries in the Joint Convention. The conference suggested adopting innovative ways to encourage involvement; one idea was to reconsider observer status as a way of involving more countries. Another was to simplify the reporting and review mechanisms. The meeting also suggested that the Convention should consider the establishment of working groups that could explore issues, such as the use of safety standards, the rules of procedure, even the establishment of international archives of information important to the long term safety of radioactive waste disposal facilities. I would encourage Contracting Parties to the Convention to give consideration to such matters at its forthcoming meetings.

International Safety Standards

The International Safety Standards for radioactive waste disposal have received considerable attention this week. There seems to be general support for the idea that one set of safety requirements could cover the safety of all types of disposal facility but that specific guidance should be developed on best practice for how particular types of disposal facility should comply with the requirements. The recently adopted Safety Requirements for Geological Disposal with its clear and precise set of 23 requirements seems to be a good model for such a Safety Requirements document.

The need was identified to develop or improve guidance relating to the disposal of waste containing naturally occurring radionuclides, the classification of radioactive waste, the management of low activity waste and of long lived non-heat generating waste. Further consideration also needs to be given to providing international guidance on the safe management of existing disposal facilities and on radiation protection criteria for the longer term.

Application of the Standards

Regarding the more general use and application of the safety standards, it would seem that regional networks have an increasing role to play as an important component in the global regime. Good experience has been demonstrated in Latin America and Europe and the proposed Asian regional network deserves support. International peer review is playing an increasing role, as evidenced by some regulatory authorities from countries with significant nuclear programmes requesting review of their activities against international standards. Also international cooperative programmes, such as ISAM and ASAM, have proved their value in harmonizing safety assessment methodology and assisting in its application for near surface disposal. The need for programmes covering other all disposal approaches has to be considered. The need was also recognized for further development of regulatory capacity in some countries to complement that of the organizations developing and operating radioactive waste disposal facilities; this may be an area where regional and international initiatives could be of value. Similarly, the establishment of national waste management strategies could be assisted through further international debate and agreement on the concept of a common framework, with particular reference to waste containing naturally occurring radionuclides and low activity waste.

The use of safety cases in developing confidence in the safety of radioactive waste disposal facilities is becoming accepted international practice. Correspondingly, there is a need for effective regulatory dialogue to ensure that such safety cases and their supporting safety assessments meet regulatory expectations and provide a basis for communicating safety to all stakeholders.

Communication

Considerable discussion took place on the communication of safety with stakeholders. Obviously many lessons have been learned in this regard but they need to be adapted to country specific situations. Suggestions were also made for the international organizations to explore what further positive role they could play in this regard. It is vital that we continue to expand the networks of communication between experts throughout the worldwide community to share the knowledge we are developing in the area of radioactive waste safety, and to ensure that knowledge is preserved and effectively passed on to succeeding generations. We have learned some hard lessons over the past two decades and are developing sound approaches to both ensuring safety and providing the public with assurance of that safety. We must not lose this knowledge and experience.

It is clear from the week's discussions that safety philosophies for radioactive waste disposal are maturing — although there is still room for refinement. The structure and content of the basic safety arguments are also maturing. These developments have been assisted considerably by the ongoing process of international interaction and debate. It is important that we do not lose momentum in this regard as the world community is looking towards us collectively to ensure that radioactive waste can be safely managed and that we are able to answer the question I posed on Monday: "Can radioactive waste be safely managed and disposed of?" The answer does appear to be an unequivocal "Yes", but it is also clear that we need to be ready with strong and varied evidence to support this answer.

In closing I would like to thank all of you for supporting the conference, especially the speakers, chairpersons, rapporteurs and panellists for their hard work in preparation for the meeting and everyone for their lively input during the week. I would like to emphasize again the gratitude of the IAEA and of all participants, to our Japanese host organizations and the staff members from NISA and JENES for all the time and effort they have expended personally. This has been an extremely well organized event, which has enabled the debate to go forward both effectively and efficiently. I thank our hosts for their generous hospitality and the opportunity to enjoy some Japanese culture — particularly that blend of ancient and modern culture that Tokyo represents.

CLOSING ADDRESS

S. Matsuura
Nuclear Safety Commission,
Tokyo,
Japan

On behalf of my Japanese colleagues, I would like to congratulate you, the participants, on a successful conference, full of productive discussions.

Nearly 400 participants from about 60 countries and organizations from a variety of experienced nuclear communities have provided us with a wealth of lessons and strategic ideas. The well coordinated preparation by the IAEA Secretariat and the Japanese counterparts doubtlessly lies behind the success of the conference and deserves the highest appreciation.

First of all, I would like to stress that this conference marks a big step forward for international cooperation in radioactive waste disposal. The IAEA has convened a series of international conferences in response to the growing need for safe management and disposal of radioactive waste in many countries. This international conference on the Safety of Radioactive Waste Disposal has been organized with the hope of taking a further step forward by sharing information and discussing current issues in radioactive waste disposal. At this conference in Tokyo, we have come to understand that the time is approaching for big decisions to be made in each country on disposing of its radioactive waste. We can also conclude that every country concerned shares the same safety principles regarding radioactive waste disposal. In addition, the basic political and social approach to facilitate disposal is also becoming clear despite the very different conditions in each country. This conference has advanced the common principles and bases for the safety of radioactive waste disposal. I do hope that they will be further disseminated through your actions in broadly sharing its outcomes in your own countries.

The second point to note is the need to build an adequate global, regional and national framework to facilitate radioactive waste disposal. Conventional framework building for international cooperation has been made in the steps of national, regional and then global scales. On the radioactive waste disposal issue, however, the approach seems to be the other way round, i.e. from international, to regional, to national scales. This new approach is important for the building of an internationally common technical basis, as well as for establishing safety regulations easily understandable to the public. The conference has revealed that many countries are now taking such an approach. I hope this conference will expedite further international cooperation in radioactive waste disposal.

This conference is the first organized by the IAEA in Asia on the subject of radioactive waste disposal. It is important that we have been able to discuss issues common to Asian countries, where rapid economic growth and the resulting increased energy demand and the associated increase in nuclear power capacity, are foreseen. To achieve the utilization of nuclear power in harmony with the environment, we have to make every effort to pave the way for safe radioactive waste disposal. Actions by all countries to develop common safety approaches and standards will help to achieve the targets of this conference. I look forward to seeing further cooperation in achieving this goal.

Finally, I wish you a safe return flight back to your countries. I now declare this conference closed.

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Demonstrating the safety of radioactive waste disposal remains a challenging issue, from both technical and sociopolitical perspectives, and is receiving increasing scrutiny throughout the world. This conference was the latest in a series organized by the IAEA on the subject of radioactive waste safety. The emerging global nuclear safety regime and its implications for radioactive waste management – in particular the impact of the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management, the international safety standards and national waste management policies were discussed at this conference. These proceedings report on the various sessions and include the presentations, together with concluding summaries from the session chairpersons and the Conference President. The contributed papers and presentations, as well as the complete text of the printed volume, are provided on a CD-ROM that accompanies this publication.

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