Progress Towards Geologic Disposal of Radioactive Waste: Where Do We Stand ?

An International Assessment

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of all OECD Member countries, except New Zealand and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

– *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*

– *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*

– *developing exchanges of scientific and technical information particularly through participation in common services;*

– *setting up international research and development programmes and joint undertakings.*

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

FOREWORD

Radioactive wastes of all kinds need to be managed responsibly to ensure public safety and protection of the environment, as well as security from malicious intervention, now and in the future. The most challenging task involves management of the long-lived waste that must be isolated from the human environment for many thousands of years. The preferred option for eventual disposal is emplacement in repositories deep underground in well-chosen geologic media.

Since the geologic disposal concept was proposed, research and development efforts world-wide have increased understanding of how underground disposal facilities will function over very long periods of time, and have enhanced confidence in the ultimate safety of the concept. While significant progress has been made towards development of these facilities, there have also been delays and setbacks primarily due to failure of the waste management experts and institutions to win sufficient public or political support. In recent years, as the concept itself is nearing implementation in several countries, support is being voiced in some quarters for postponement of disposal and for more review of alternative waste management options. On the other hand, reflections in international groups of experts have repeatedly confirmed the conviction that geologic disposal is ethical, environmentally sound and safe, and other management options are, at most, complementary to geologic disposal rather than complete, long-term alternatives.

This text draws on information and views collected from radioactive waste management experts from OECD/NEAMember countries and presents an assessment of developments in the field of deep geologic disposal and management of long-lived radioactive wastes over the past ten years. The report reviews both technical and societal aspects, and should be of interest to decision makers with responsibilities encompassing radioactive waste management as well as to interested individuals and groups.

This report is based on, and complements, two publications recently finalised by the members of the OECD/NEA Radioactive Waste Management Committee, which include senior representatives from waste management agencies, regulatory authorities, policy-making bodies, and research and development institutions with responsibilities in waste management. The two publications deal with "Geological Disposal of Radioactive Waste: Review of Developments in the Last Decade" and "Confidence in the Long-term Safety of Deep Geologic Repositories – Its Development and Communication". These and other reports are identified on page 27 as suggestions for further reading.

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INTRODUCTION

Radioactive waste exists now and it will continue to be produced. In nuclear countries, it results mainly from the civil nuclear power programmes and, in some cases, from military programmes. In these countries it will also come, increasingly, from decommissioning facilities that have reached the end of their life or have become redundant. In non-nuclear countries, radioactive waste originates from medical, industrial and research uses of radioactive materials. Radioactively contaminated residues also result from industrial activities, such as oil extraction, where radioactivity is incidental. In all cases radioactive waste needs to be managed responsibly to ensure public safety, protection of the environment, and security from malicious intervention now and in the future. This need would remain, even if it were to be decided tomorrow to discontinue nuclear power programmes or other uses of radioactive materials.

Radioactive waste can be short- or long-lived depending on its intrinsic rate of decay. Many countries have established routes for the safe disposal of lightly contaminated materials or materials whose radioactive contamination is relatively short-lived. These materials present relatively low hazards and comprise the bulk of the volume of radioactive waste. Long-lived radioactive waste arises in much smaller volumes but it remains hazardous over many thousands of years and needs to be isolated from the environment over commensurably long time-scales. This waste includes, for example, the used nuclear fuel of nuclear power plants, in countries where this material is seen as no longer constituting a resource, or the solidified high-level waste resulting from the reprocessing of used fuel. The present report is concerned with the geologic disposal of long-lived radioactive waste.

The concept of removing long-lived radioactive waste from the human environment by placing it in deep underground repositories – geologic disposal – was proposed over 40 years ago. Since then the concept has developed further. Details vary from country to country, and also according to the type of waste. In general, the geologic disposal concept involves treating the waste in order to achieve a suitable physical and chemical form, packaging it inside long-lived engineered barriers emplaced deep underground, and sealing these facilities with appropriate materials. In these underground surroundings, as opposed to in the surface environment, conditions remain stable over the long periods needed to allow the radioactivity to decay to a sufficiently low level.

The deep geologic repository concept has been arrived at after considerable thought, research and development, and debate, including ethical discussions and consideration of other options. Monitored storage was excluded as a final management option because of its requirement of maintaining active controls over extremely long periods of time. Studies were performed on concepts such as disposal in oceanic sub-seabed sediments and in ultra-deep boreholes, as well as on “exotic” proposals, such as disposal into geologic subduction zones, disposal in polar ice caps, and launching into space. All of these were found wanting in terms of cost or risk, or impracticable because of political or legal restrictions.

In recent years, as the concept itself is nearing implementation in several countries, support is being voiced in some quarters for postponement of disposal and for more review of alternative waste management options. The debate on this and other issues is not closed yet, and waste management experts have become acutely aware that technical expertise and technical confidence in the geologic disposal concept are insufficient, on their own, to justify to a wider audience geologic disposal as a waste management solution. Overall confidence must be developed in a much wider audience if a decision to implement disposal is to be acceptable.

This report presents an assessment of the current status of deep geologic disposal and of developments in the past decade. It is based on information and views collected from radioactive waste management experts from OECD/NEA Member countries, and on a review of other inputs. It reviews both technical and societal aspects, and should be of interest to decision makers with responsibilities encompassing radioactive waste management, and to interested individuals and groups. Key points of interest are summarised in the next section and expanded upon in the subsequent sections which consider: progress in related science and technology, progress in implementation of the concept, and other factors necessary to achieve an appropriate level of societal acceptance. Conclusions and remarks related to the requirements for further progress are given in the final section.

1. AWIDE TECHNICAL CONSENSUS EXISTS ON KEY POINTS

On the following principal points there is virtually unanimous agreement amongst those directly involved in waste management, be they developers, regulators, or policy makers.

- **Long-lived radioactive waste exists. Of the various disposal options considered, deep geologic disposal is the most appropriate means of long-term management.**

  Arange of alternatives have been reviewed in the past and found to be wanting in some respect. On the other hand, geologic disposal conforms to ethical concerns, is technically feasible, and has been judged to provide a high degree of public safety, security from malicious intervention, and protection of the environment both in the short and long term.

- **Significant progress has been made in relevant scientific understanding and in the technology required for geologic disposal in the past ten years.**

  This includes a deeper scientific understanding of the processes which determine the effectiveness of repositories in isolating the waste over long periods; improved characterisation and quantitative evaluation of the ways in which the engineered barriers and surrounding rock contribute to safety; specific investigations at candidate sites; and also experience with practical aspects of underground engineering and implementation. As understanding has increased, no radical changes in philosophy of approach have proven to be necessary, confirming the soundness of the basic geologic disposal concept.

- **The technology for constructing and operating repositories is mature enough for deployment.**

  This is backed up by experience gained world-wide in underground research laboratories and, in several countries, in existing underground facilities for disposal of radioactive waste, including waste containing longer-lived radioactive components. In particular, the first purpose-built geologic repository of long-lived waste started operation in March 1999 in the USA.

- **The time-scales envisioned in the past forimplementation of geologic disposal were too optimistic.**

  This was partly due to technical optimism, especially with regard to the difficulty of adequately characterising deep geologic environments, but was mainly due to an underestimation of the political, public and regulatory dimensions of disposal projects. From a technical point of view, there has been no urgent need for final disposal facilities because of the recognised high level of safety of interim storage facilities, the relatively small volumes of long-lived radioactive waste from civilian programmes, and the storage time needed to allow adequate cooling of the more radioactive waste before geologic disposal can take place.

- **There is a high level of confidence amongst the scientific and technical community engaged in waste disposal that geologic disposal is technically safe.**

  This is a consequence of the many years of work by numerous professionals in institutions around the world. There has been an extremely free exchange of information and knowledge between these professionals and there has been a strong tradition of open documentation available for peer and public review. The common perception amongst the public that there is a strong body of technical opinion challenging the feasibility of safe disposal does not reflect the realities of the debate. The number of sceptics is relatively small in the broader technical community, whereas there is a wide consensus on the safety and benefits of geologic disposal within the technical community of waste management experts.

- **The broader public, however, does not necessarily share the high level of confidence of the scientific and technical community.**

  Developments related to radioactive waste disposal are correctly subjected to detailed scrutiny by regulatory and planning authorities. Furthermore, because of ethical and political dimensions, they are a subject of wider-reaching and less-technical discussion. There are reservations in the broader public towards committing irreversibly to an action whose consequences are not fully understood. Lack of confidence by part of the public may also be connected to a lack of confidence in the safety of nuclear power, and sometimes to outright opposition to nuclear power and associated organisations, or even to a general lack of trust in scientific developments.

- **There is a need for continued high-quality scientific and technical work.**

  Although the technology for geologic disposal is well-developed, its further refinement, testing, demonstration, implementation and quality control under reference conditions are challenging tasks extending over decades.

- **There is a need for coherent policy and strict regulatory frameworks, with identified decision points, which also allow for public dialogue.**

  As for controversial projects of any nature, universal or overwhelming support is not a realistic aim. On the other hand, society must be assured that every decision taken is a considerate one. A decision-making process characterised by intermediate milestones and decision points is necessary for such complex, long-term projects. This process of step-wise decision making should allow opportunities for comment and input from all affected and interested groups, and should include rigorous technical reviews and the discussion of topics of the public's choice. In particular, the waste disposal community must be ready to discuss the merits of other waste management strategies, including improving the flexibility in the implementation of geologic disposal. Moving ahead in a step-wise fashion towards implementation of deep disposal would assure that a decision to implement disposal fully is not taken irreversibly in one step and would allow the identification and development of other options. Ultimately, governments are responsible for making decisions that meet with an appropriate level of public support and provide the framework in which the necessary actions can be taken.

2. DEEPGEOLOGIC DISPOSAL – A CONCEPT NOT LIGHTLY CHOSEN

It was recognised early in the nuclear age that a strategy was required that would keep the waste produced remote from humans for the very long times required to allow sufficient radioactive decay of the long-lived components. It was also judged to be ethically correct that the generation, and organisations, that had created the waste should provide for its safe and permanent disposal.

The concept of geologic disposal of long-lived radioactive waste involves deep underground repositories that ensure security, i.e. resistance to malicious or accidental disturbance, and containment of the waste over very long times. The concept was developed after wide-ranging consultation, with considerable thought and discussion, including consideration of other options. Potential host geologic formations are chosen for their long-term stability, their ability to accommodate the waste disposal facility, and also their ability to prevent or severely attenuate any eventual release of radioactivity. This natural safety barrier is complemented and augmented by an engineered system designed to provide primary physical and chemical containment of the waste. The whole system is thus designed to ensure that no significant radioactivity from the waste ever returns to the surface environment and to provide very long-lasting safety and protection of the environment in a manner that requires no burden of care to be placed on future generations.

Most nations where long-lived radioactive waste is an issue have set up radioactive waste management programmes that ultimately aim to emplace this waste in a geologic disposal facility. The possibility of other management options is still, however, sometimes raised in discussion. The options most often suggested in today's public and scientific debates are extended storage of the waste and partitioning and transmutation[1] of long-lived radionuclides within the waste. Although both options might be components of an overall waste management strategy, and extended storage over a few decades is already planned in some countries, neither option avoids the need for some final disposal route, such as a geologic repository. They cannot be regarded as complete alternatives to disposal.

The current view of the international radioactive waste management experts, as expressed in the 1995 NEA Collective Opinion, is that:

1. *Partitioning and transmutation involves processing waste to extract the long-lived radionuclides, and then irradiating them in a nuclear reactor or an accelerator to yield products with shorter half-lives that require isolation over a relatively short period of time in order to reduce their hazard. Special facilities would have to be built to that effect. It is recognised that it would not be feasible to apply the technique to all types of waste, so that some quantities of radioactive materials will still require long-term isolation, i.e. in a geologic repository.*

- our responsibilities to future generations are better discharged by a strategy of final disposal than by reliance on stores which require surveillance, bequeath long-term responsibilities of care and might in future be neglected by society; and
- deep disposal in geologic formations on land is currently the most favoured strategy for long-lived wastes.

This view must, however, be defended in open debate if it is to gain ultimate widespread acceptance. The ethics of geologic disposal, and how it might be adapted to satisfy competing societal aims, are discussed in Chapter 5.

3. SCIENTIFIC AND TECHNICAL PROGRESS HAS BEEN ACHIEVED

An extensive range of technical activities is needed to implement disposal: wastes must be conditioned and stored, long-lasting containers developed, sites chosen and characterised, safety assessed, licenses applied for (and granted), and the facility constructed, operated and finally closed. Over the past decade, progress has been made in many of these activities and, in particular, in the science and technology necessary to underpin the safety assessment and implementation of geologic disposal. Specific areas where considerable progress has been made include:

- **Development orconstruction of facilities forthe treatment and intermediate storage of waste.**

  Particularly notable are the developments in storage technologies and in the construction of centralised storage facilities for high-level, reprocessed waste and used fuel, e.g. the CLAB and ZWILAG facilities in Sweden and Switzerland respectively.

- **Experience in laboratory and field experiments, including the study of natural analogues.**

  Comprehensive scientific research programmes have been established to study safety-relevant processes under the particular conditions that may pertain for geologic repositories. This includes phenomena as diverse as metallic corrosion, evolution of clay properties, solute migration in different media, chemical sorption and long-term climate change. Natural analogue studies involve examining processes occurring in nature similar to those which would determine the long-term behaviour of a repository. They are seen as especially valuable in the building of confidence, since they allow a check of our understanding of processes that are too slow, or too large in scale, to be directly measured in the laboratory or the field.

- **Construction and operation of underground rock laboratories.**

  R&D work has been carried out in more than ten underground facilities world-wide, at locations that are not foreseen as repository sites, but may nevertheless provide relevant information. In addition, a few underground rock laboratories are located at potential deep repository sites. Such laboratories provide the environment for developing and proving underground engineering methods and invaluable data for the testing of scientific and mathematical models used in safety assessment. They can also provide practical demonstrations that can improve confidence of all those who observe their operation, and have acted as centres for promoting international co-operative research projects.

- **Experience in site characterisation.**

  Ten years ago, few data were available from potential geologic disposal sites and environments, and data collection strategies and methods were less developed. Today, extensive programmes involving detailed characterisation with geophysics, numerous boreholes and even exploratory shafts and ramps have been carried out at sites in several countries, including Belgium, Canada, Finland, France, Germany, Sweden, Switzerland, the UK and the USA. Valuable experience has also been gained in using the geological data to understand the expected safety performance of the sites.

- **Development of the engineered barrier design.**

  Partly in response to the perceived difficulty of adequately characterising certain geologic environments, more attention has been paid in the past ten years to developing so-called robust engineered barrier systems. These are systems which, by a combination of physical barriers and chemical controls, can confidently be expected to provide a high level of long-term containment while making relatively few demands on the characteristics of the host rock. On the other hand, in some programmes where actual sites have been investigated, a high level of refinement has been applied to adapt the engineered barrier design to actual site characteristics.

- **Improvement of safety assessment techniques.**

  Together with an improved scientific understanding and data from experimental studies, improved mathematical models and advanced computing techniques have been applied that provide representations of the potential behaviour of geologic disposal systems and their components that are more realistic, and in which more confidence can be placed. Developments have also been made in the techniques for promoting comprehensive consideration of the relevant features, events and processes and for organising and presenting safety assessment calculations. A fuller recognition has been achieved of the importance and inevitability of different types of uncertainty (e.g. due to a lack of detailed knowledge or sparse data) and methods have been developed for handling these uncertainties. Thus, overall, there is more confidence that the results of assessments that employ such methods, models and data are a reliable basis for judging the acceptability of a repository site and design from the point of view of safety.

- **Improved integration of site characterisation, design and safety assessment.**

  The above-noted progress in data collection, scientific understanding and quantitative modelling has allowed advances to be made in the understanding of the performance of geologic disposal system components and their respective roles in different rock types and, also in different site-specific circumstances. This progress, together with better integration and control of characterisation and design programmes focused on the requirements of safety assessment, has allowed better direction of these activities.

- **Development of regulatory frameworks, including requirements for compliance.**

  In most countries with a need for eventual geologic disposal, regulatory guidelines are now in place that set out principles and specific requirements for underground disposal.

In several countries, site-specific requirements have also been set and/or more detailed guidance given on the manner in which the developer of a repository will be expected to demonstrate compliance. A process of regulator-developer exchange has been established in many countries, including review of the developer's research activities and iterative safety assessments. In addition, experience of the compliance process has been gained through the licensing process for facilities for disposal of low- and medium-level wastes, and through the review of safety studies in support of decision making at various stages of development of deep geologic repositories.

Overall, the scientific and technical effort that has been made is of considerable breadth and depth. Considerable resources have been expended and many avenues have been investigated in order to ensure that sound technical solutions are available, and underpinned by good scientific understanding.

4. IMPLEMENTATION OF GEOLOGIC DISPOSAL – PROGRESS BUTALSO SETBACKS

The progress which has been made in the scientific and technical aspects of geologic disposal means that the necessary technology for geologic disposal is available today. Adeep geologic facility for the disposal of used nuclear fuel and high-level radioactive waste has not yet been implemented, but underground facilities for the disposal of wastes with lower radioactive content have been commissioned in several countries.

- **Final disposal of radioactive wastes in underground caverns is already taking place and is direct proof of the feasibility of such projects.**

In Germany, low-level radioactive waste was disposed underground in the Asse salt mine, as a demonstration project, between 1967 and 1978, and a deep repository for low- and medium-level waste has operated in a salt dome at Morsleben between 1981 and 1998. Both facilities are at depths exceeding 500 metres. The licensing procedure to permit the disposal of waste which does not emit heat in a disused iron ore mine at Konrad, at a depth of 1000 metres, is in its final stages.

In Sweden, a repository at intermediate depth for the disposal of low- and medium-level waste has been operating at the Forsmark nuclear site since 1988. In this case, the disposal caverns are excavated in granitic bedrock, offshore, about 60 metres below the bed of the Baltic Sea, and accessed by a tunnel from land.

In Finland, a facility for the disposal of low- and medium-level waste was opened in 1992 at the Olkiluoto nuclear site and in 1998 at the Loviisa site. These consist of caverns excavated in granitic bedrock at depths of around 100 metres below ground.

In Norway, the Himdalen facility for low- and medium-level waste started operation in 1999. It consists of four caverns under 50 metres of bedrock cover.

Most notably, in the USA, the necessary permits were granted in 1999 to start disposal of waste from the US defence programmes at the Waste Isolation Pilot Plant (WIPP), in south-eastern New Mexico. The waste to be disposed of contains significant long-lived radioactive components, although high-level, heat-generating wastes are excluded. The waste is being placed in caverns excavated at a depth of 650 metres below ground in a bedded salt formation. The first shipment of waste was placed in the repository on 26 March 1999, marking the operation of the first purpose-built, deep geologic repository for long-lived wastes in the world.

- **Programmes forthe disposal of long-lived waste appearto be most advanced in the USA and Scandinavia.**

  In the USA, comprehensive surface-based investigations have been completed, and access and experimental tunnels have been constructed at 350 metres below ground at the Yucca Mountain site in southern Nevada. A comprehensive "Viability Assessment" was submitted to Congress in December 1998. It is expected that a site recommendation will be made in 2001 and, if Yucca Mountain is recommended as the national repository site, that a license application could be made in 2002.

  In Finland, one local community has agreed to host a national repository and a final siting decision should be made in the year 2000.

  In Sweden it is planned to start investigations at two sites a few years into the 21st century.

- **In some other countries, delays or setbacks have been experienced, or there is uncertainty about the future of geologic repository projects.**

  In Canada, an independent panel reporting to the government on its review of the concept of geologic disposal of nuclear fuel waste concluded in 1998 that, from a technical perspective, the safety of the concept had, on balance, been adequately demonstrated. The panel also observed, however, that, at this stage, the concept had not been demonstrated to have broad public support and, therefore, did not have, in its present form, the required level of acceptability to be adopted as Canada's approach for managing nuclear fuel waste. In particular, organisational reforms and fuller consultation processes were recommended.

  In the UK, the rejection in 1997 of the planning application for the construction of a rock characterisation facility at Sellafield, as a step towards the possible development of a deep repository, left the UK with no practical plan for the disposal of long-lived radioactive waste. A subsequent inquiry by the UK House of Lords has since endorsed geologic disposal as both feasible and desirable, while noting that public acceptance is required. As in Canada, widespread consultation and organisational reforms are recommended.

  In Switzerland, the proposal to develop a geologic repository for low- and medium-level waste at Wellenberg was rejected in a public cantonal referendum. The option of resubmitting the proposal with a modified design and implementation process is being considered.

  In Germany, the investigation of the suitability of a large salt dome at Gorleben to house a repository for all kinds of wastes, including used nuclear fuel and high-level waste, is well advanced, and vertical shafts have been sunk to a depth of 960 metres. However, the present federal government in Germany has declared its intention to end nuclear power production and to re-evaluate options for long-term waste management. Whereas the eventual need for deep disposal facilities is acknowledged, there is considerable uncertainty in timing and in the political attitude to progressing with disposal projects.

In summary, although significant progress towards implementation has been made in several countries, the rate of progress has been slower than expected ten years ago, and significant setbacks have occurred in some countries.

The slower progress in some countries may be partly attributable to an earlier technical optimism, e.g. related to the difficulties of geologic characterisation and developing adequate understanding of real sites. In addition, the burden of regulatory compliance – demonstrating with a high degree of confidence that very challenging safety standards will be met over long times into the future, and ensuring adequate traceability and transparency in the demonstration – has only become apparent as programmes enter the phase of developing specific proposals, and submitting them for regulatory examination.

The slower progress is not critical in a technical sense because the waste can be safely stored and it was always expected that the development of geologic disposal would be a long-term project. More significant are the setbacks that have arisen mainly from an underestimation of the public and political dimensions of the geologic disposal of radioactive waste. These issues, which can drastically slow or even stop any progress, are explored in the next chapter.

5. CONFIDENCE OF THE TECHNICAL EXPERTS – NECESSARY, BUT NOT SUFFICIENT

In recent years, waste management institutions have become acutely aware that technical expertise and technical confidence in the geologic disposal concept are insufficient, on their own, to justify to a wider audience geologic disposal as a waste management solution, or to see it through to successful implementation. Partly due to a sensitivity of the public on all matters connected to protection of the environment, to nuclear power and especially nuclear waste, and partly because of the unique nature and required longevity of the proposed disposal concept, the decisions whether, when and how to implement geologic disposal need a thorough public examination and greater public involvement in decision making. Overall confidence must be developed in a much wider audience if a decision to implement disposal is to be acceptable.

Requirements for broadly based confidence

Confidence in decision making for geologic repository developments is likely to require not only confidence in the technical safety case for a repository, as judged by decision makers in waste management agencies and regulatory authorities, which is a prerequisite and has been the main concern of the waste management experts and institutions to date, but also:

- confidence, on the part of the wider technical community and of the public, in the ethical, economic and societal aspects of the appropriateness of geologic disposal; and
- public confidence that the organisational structure, legal frameworks and regulatory review process provide a well-defined, logical and credible decision-making path.

Confidence in the ethical, economic and political aspects of the appropriateness of the geologic disposal concept cannot be achieved in isolation, but requires a review of the concept within a wider context, including evaluation of other possible strategies.

Policy and legal frameworks – opportunities for public involvement?

An important basis is the establishment of stable national policy and legal frameworks which set out the intended path of decision making over the long time-scales associated with the development of geologic disposal. Such frameworks exist in several countries, e.g. Finland, France and the USA, but, at this stage, are less clear in some other countries. The 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, developed under the administration of the International Atomic Energy Agency (IAEA), may give added impetus to the establishment of national policies where these are not already in place.

The level of public consultation which should be built into the development of policy or the decision-making path is a matter for national consideration. In Sweden, the main vehicle for public dialogue has been meetings with local groups to define the contents of an acceptable documentation for an environmental assessment study.

All countries should also be aware that the debate on radioactive waste and other environmental issues is becoming increasingly internationalised. Scientific and public debate will occur in international fora, whether or not provision is made within national frameworks, and such debate has the capacity to affect national views.

Step-wise implementation – opportunities for step-wise decision making

The planning, technical development and associated research, siting, construction and eventual licensing and operation of a geologic disposal facility is expected to take place over a period of several decades. It has long been recognised that during this period there will be a step-wise, incremental development of a safety case for the repository as the design is refined, the understanding of safety-relevant phenomena is developed, and data are accumulated. It is now increasingly recognised that the decision to commit resources to each stage of a repository development should be accompanied by an appropriate level of confidence in the safety case and, also, that the step-wise development of the disposal facility and its associated safety case provides an opportunity for a step-wise regulatory and societal review process.

An open, step-wise, regulatory review process, led by a respected regulator, can give confidence that the developer’s proposals are subject to detailed technical scrutiny on behalf of the public. At certain key milestones, more direct public consultation may be required. This may range from widespread consultation with national organisations on matters related to strategy, to intimate discussion with directly affected communities and their representatives when considering developments at a specific site, as well as parliamentary debate in order to judge progress to date and make specific forward-looking decisions.

Ethical and other concerns – the broad picture

Implementing the geologic disposal concept addresses the ethical concern that the generation that has benefited from nuclear power and other uses of radioactivity should provide a means for the safe and permanent disposal of the resulting waste. This is the principle of inter-generational equity. More recently, an equally valid ethical concern has been raised that this generation should not foreclose options to future generations, or hinder their ability to make decisions. It has been suggested by some critics that geologic disposal limits the choices open to future generations. On the other hand, those engaged in waste management point out that there is an overriding concern of assuring that, at least, a passively safe solution – geologic disposal – is provided that does not require burden of care by future generations, and that a phased repository development process keeps options open for very long times into the future.

There also exists an issue of intra-generational equity, in particular the issue for society to identify an ethical approach to the handling, within current generations, of resources and of public involvement in the decision-making process. Thus, when considering resource allocation, risks from radioactive wastes should be kept in perspective with competing projects in the area of human health and environmental protection. Also relevant in this context is the consideration of equity and fairness for communities which are judged to be affected by the construction and operation of a centralised national facility such as a geologic repository for long-lived waste.

The predominant views among the waste management experts remain the same as those expressed in the NEA1995 Collective Opinion. It is accepted, however, that this community alone cannot decide on strategies with ethical, economic and political dimensions. Rather, an informed societal judgement is necessary. The judgement must be taken with a broad view of the options, but must also take into account the practical constraints of the problem. In no society will a complete consensus ever be reached. Ultimately, governments are responsible for making decisions that meet with an appropriate level of public support and provide the framework in which the necessary actions can be taken.

Flexibility of the geologic disposal concept – listening to public concerns

Key concerns raised by the interested public groups are their perceived lack of involvement in the decision-making process, which is discussed above, as well as their belief that accepting the concept of final disposal means relinquishing immediately all control over the emplaced wastes. This is an unwarranted fear.

Although geologic disposal is conceived as a passively safe arrangement, with no requirement for long-term control, the concept does not preclude monitoring and maintenance of a repository by this and future generations. Society may choose to implement long-term institutional controls, including protection of the site and monitoring. These actions can certainly enhance confidence – one key objective of geologic disposal, however, is to ensure that even if such controls were to fail, human health and the natural environment should still be protected.

Geologic disposal aimed at a final repository configuration offering maximum passive safety can also be implemented in a staged or flexible manner which postpones steps that are difficult to reverse. In Sweden, for example, it is proposed to dispose of only 10% of the used nuclear fuel wastes, initially, and then pause for a number of years in order to evaluate the experience gained and monitor the emplaced waste. In other countries, the possibility of emplacing waste, but delaying the final backfilling or closure of the underground tunnels, has been considered (e.g. in Switzerland, the UK and the USA). This creates an underground store from which wastes could be relatively easily retrieved, if necessary, but could also be easily closed if that decision is reached.

An important message that the waste management institutions have difficulty communicating is that waste would never be placed in a underground facility if safety were in question and, furthermore, that the geologic disposal concept is reversible, i.e. wastes could be retrieved by mining if required. The degree of difficulty and the cost involved in retrieving waste safely from a repository depend on the details of the disposal concept, including the materials that are utilised. Retrieval is judged to be an extremely unlikely scenario, however, and the implications of doing so would have to be weighed against the benefits at the time.

The role of the waste management experts and institutions

The waste management experts and institutions should continue with the scientific and technical work necessary to provide safe and economic means for long-term waste management. While society and governments must decide whether and when to implement solutions, it is the responsibility of the waste management experts and institutions to ensure appropriate solutions are available.

The procedures and methods adopted by the waste management experts and institutions to address its future needs will be nation- or programme-specific. The development of these procedures and methods, and progress in repository development, will, however, be influenced by developments elsewhere, and will proceed most effectively through the exchange of ideas internationally. International fora will continue to be important in meeting the future needs of waste management organisations and also communicating to wider audiences. The sharing of insights and resources in co-operative projects has proved valuable to both implementers and regulators. International fora allowing cross-party dialogue and co-operative projects are thus likely to continue to play an important role in the future for all those involved in waste management.

Ultimate responsibility for public and political affairs lies with society and government. However, waste management specialists must also be willing to engage in activities at the interfaces of technical, public and political affairs, and to recognise that the ensuing exchanges must be two-way. That is, technical specialists must give information on practical requirements, constraints and options, but also listen to, and attempt to satisfy, public and political concerns, which may include non-technical issues.

6. SUMMARYAND CONCLUSIONS – LOOKING BACK, LOOKING AHEAD

Substantial scientific and technical progress towards implementation of geologic disposal has been made in the last ten years, thanks to the extensive work carried out in national programmes. This progress is assisted, encouraged and guided by exchanges in international fora.

Several underground facilities for disposal of lower activity waste are in operation, and this includes waste with long-lived components. A purpose-built geologic repository for long-lived waste started operation in 1999 and, in a few countries, geologic repository projects for the disposal of used fuel and other high-level waste are nearing the point where decisions to commence construction may be made, although, as yet, no such repository is in operation. Indeed, in most countries projects are still many years away from implementation. Nevertheless, in spite of the setbacks that have occurred, and although some countries have delayed their repository siting programmes or questioned the wisdom of a selected location, no nation has rescinded its decision to pursue geologic disposal.

The waste management experts remain confident in the concept of geologic disposal. Indeed, their confidence in the feasibility of secure and safe deep geologic disposal has been enhanced by:

– the improved understanding of safety-relevant processes through site characterisation and R&D;
– the development of detailed repository concepts in many countries;
– the demonstration of the safety of repository concepts through the application of rigorous safety-assessment methods;
– the independent review of these assessments by national and international groups of experts;
– the development, and in some cases demonstration, of technologies necessary for implementation of deep geologic repositories.

Opinions expressed by a wide cross-section of waste management experts thus confirm the consensus view that, at present and for the foreseeable future, geologic disposal represents the only truly available option for assuring safety and security over several tens of thousand years and more. Perhaps the greatest challenge facing these experts is to ensure that their confidence in geologic disposal is communicated to, and shared by, the public at large. Indeed, the general public is often not aware that a widespread technical consensus on the feasibility of safe disposal exists. Strongly expressed opposition by a minority of scientists and engineers can give an impression of a large divergence of views in the technical community.

It is widely acknowledged by experts in the field and by other interested parties that the issue of long-term waste management has ethical, social and political dimensions. The acceptability of a long-term management strategy, such as geologic disposal, can only be decided at a societal or government level, after consultation with a range of relevant organisations and taking account of public views. A step-wise process leading to implementation of geologic repositories will allow more time and increased opportunities for broadening the basis of support or identifying alternative options. Universal, or overwhelming support is not, however, a realistic aim. As for controversial projects of any nature, an appropriate societal decision-making process will be necessary in all nations opting for geologic disposal.

The waste management experts, and their institutions, must fulfil their responsibilities to develop technically sound, safe and economic solutions and to engage in open debate on these solutions. Society as a whole has a right and a duty to become involved in the choice of methods, and in the allocation of proportionate resources, for the management of all wastes, radioactive and non-radioactive, that have a long-term hazard potential.

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