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Waste Management Options: Must Geological Disposal be Re-Invented?

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Burning nuclear fuel for electrical power generation is the main source of high level and long-lived radioactive waste. In some countries, all used nuclear fuel is considered as waste and will be specifically prepared for direct disposal (conditioned), while other countries choose to reprocess the fuel, which leaves the highly active residuals as waste. Both types of wastes are characterised by the fact that they continue to generate heat for some decades, and that, even while most of the radioactivity decays, they remain considerably radioactive for periods in excess of several thousand years.

Early in the nuclear age it was recognised that a strategy was required that would keep these wastes remote from humans for these very long times. Most nations where long-lived radioactive waste is an issue have set up radioactive waste management programmes that ultimately aim to place this waste in a geological disposal facility.

This concept involves deep underground repositories that ensure security (i.e. resistance to malicious or accidental disturbance) and containment of the waste over geological time scales. Potential host geological 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 result is a very long lasting, passively safe system, that requires no burden of care to be placed on future generations, and can ensure that no significant radioactivity from the waste ever returns to the surface environment.

Currently 16 OECD member countries have active programmes of geological disposal and participate in relevant Nuclear Energy Agency (NEA) activities. Objectives and goals vary considerably between those programmes, as do the technical concepts pursued and the status thus far reached. This reflects different boundary conditions, such as country size, size of nuclear programme, organisation, and time frame of power programmes. Also, different geological formations are envisaged for disposal sites, ranging from embedded salt and salt domes to tuff, granite and different types of clay formations. Regarding the technical aspects, different concepts of a multi-barrier approach are pursued, with different emphasis given to the role of engineered barriers (e.g. waste containers).

At the NEA, cooperative work in this area is guided by the Radioactive Waste Management Committee (RWMC), which is a forum of senior representatives from implementing agencies, regulatory authorities, policy makers and relevant R&D institutions. This cross-party representation of industry, safety authorities, and governmental policy bodies, and the wide range of expertise it musters from the NEA member countries, make the RWMC a uniquely placed international forum to address issues in radioactive waste management.

Review of Developments in the 1990s

To evaluate the progress made towards implementing geological disposal, RWMC recently published a major review study assessing the developments in the field of deep geological disposal over the past ten years. The review draws on answers to a questionnaire provided by member countries as well as the European Union (EU) and the IAEA, and on an evaluation of literature, workshops and reports from member countries and international organisations. The report covers the areas of scientific and technical basis, safety assessment, legal and regulatory developments, as well as communication with public.

The key messages from this review study are as follows:

- Significant progress has been made in relevant scientific understanding and in the technology required for geological disposal. This includes a deeper scientific understanding of the processes which determine the effectiveness of repositories at isolating waste over long periods, improved characterisation and quantitative evaluation of the ways in which engineered barriers and surrounding rock contribute to safety, specific investigations at candidate sites, and also experience with practical aspects of underground engineering and implementation.
- The technology for constructing and operating repositories is mature enough for deployment. This is backed up by experience gained worldwide in underground research laboratories (URLs) 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 geological repository for long-lived waste started operation in March 1999 in the USA.
- There is a high level of confidence among the scientific and technical community engaged in waste disposal that geological disposal is an appropriate and safe means of long-term waste management. This is a consequence of the many years of work by numerous professionals in institutions around the world, an extremely free exchange of information and knowledge between these professionals, and a strong tradition of open documentation available for peer and public review.

Generic URLs, which are used principally to investigate the characteristics of broad rock types, to test models and to develop experience in techniques, and site-specific URLs, that form an integral part of the investigation of a potential repository site, have both been particularly helpful in establishing technical confidence in this concept of waste management. Examples are the Asse mine in Germany, Stripa and Äspö in Sweden, Grimsel and Mt Terri in Switzerland, the URL in Canada, Tono in Japan, Tournemire in France, the Yucca Mountain Exploratory Studies Facility (ESF) in the USA, and Hades/URF at Mol in Belgium. Other generic and site-specific URLs are currently planned, such as those at Meuse in France, at Pribram in the Czech republic, and Horonobe in Japan.

Moreover, deep underground disposal of radioactive wastes has been and is taking place, and is direct proof of the feasibility of such projects. Low level radioactive waste was disposed of in Germany in deep underground caverns in the Asse salt mine, as a demonstration project, between 1967 and 1978, and in a salt dome at Morsleben since 1981, at depths exceeding 500 metres. Most notably, in the USA, the world's first purpose-built deep geological repository for long-lived wastes has been operating at the Waste Isolation Pilot Plant (WIPP), at a depth of 650 metres below ground in a bedded salt formation in south-eastern New Mexico, since March 1999. The waste being disposed of there contains significant long-lived radioactive components, although high-level, heat-generating wastes are excluded.

In Finland, Norway and Sweden, underground repositories for low and medium level waste are operating at intermediate depths between 50 and 100 metres, at the Olkiluoto nuclear site (since 1992), at the Loviisa site (since 1998), at Himdalen (since 1999), and at the Forsmark site (since 1988).

Although the technology is well developed, there is a need for continued high quality scientific and technical work to adapt the generic knowledge to specific sites, and to increase technical confidence through further reduction of uncertainties. This further refinement, testing, demonstration, implementation and quality control are challenging tasks that will extend over decades.

Waste Disposal, Environmental Issues and Sustainable Development

The deep-rooted public anxiety on waste disposal issues shows that technical confidence is not necessarily enough to gain support from wider audiences. The protection of the environment and the ethical issues that this raises are as important topics in the debate over the long-term management of radioactive waste as is the technical safety of repositories.

While, on the basis of laws and regulation, most countries do not embed radioactive waste disposal into a wider environmental framework, general principles developed in the field of environmental protection directly influence the management of radioactive waste. The UNESCO Declaration on the Responsibilities of the Present Generations Towards Future Generations, the Declaration of the UN Conference on Environment and Development (the Rio Declaration), the discussion of general ethical principles, and the concept of sustainability, govern the debate on radioactive waste management as an environmental issue.

The Rio Declaration, for example, recommends the systematic use of environmental impact assessments (EIAs) for projects whose impacts might be significant; it recommends that the public take part in the decision-making process; it introduces the polluter-pays principle as well as the precautionary principle. These broad principles and approaches apply to radiological and non-radiological hazards.

EIAs, which address radiological impacts on people and on the natural environment, together with environmental impacts from other aspects of the proposed facility, are today considered very important licensing steps in most countries with disposal programmes, and are an obligatory step in the member states of the EU.

However, although most countries would claim coherence between nuclear waste regulations and other environmental legislation, there is little direct connection to issues like sustainability or broad-based approaches at the legislative level to assure a uniform degree of environmental protection from radioactive materials and non-radioactive hazardous waste.

Therefore, there is a need to examine the place of waste management within the broader debate on sustainable development. Waste management is a key element in the debate about the role of nuclear power in this context. The most important principles of sustainable development have been addressed in major waste management policy documents, e.g. the NEA Collective Opinion documents, the last of which was published in 1995. This document established consensus on the environmental and ethical basis of geological disposal and said, *inter alia*, that:

- The current generation, which has benefited from the energy produced, should provide future generations the means to dispose of the waste.
- Geological disposal is an ethical waste management strategy.

While it is recognised that many relevant concepts are already incorporated in policy statements for the management of long-lived waste — e.g. the principles of "polluter-pays", of "reasonable assurance", and of not placing undue burdens on future generations — it will be helpful to better clarify the meaning of waste management principles and terminology within the context of sustainable development. At this time, the OECD is pursuing a horizontal project on economic, societal and environmental aspects of sustainable development with the objective of delivering a report to the OECD Ministerial Meeting in 2001. The NEA is working to introduce the full range of nuclear issues into the framework of this report.

Waste Management Options

As well as meeting stringent technical and environmental safety requirements, geological disposal must also pass the test of social and political confidence. It is in this context that the merits of other radioactive waste management options must be explored and discussed.

A variety of waste management options has been under intense scrutiny. Some, while extensively evaluated and found to be technically feasibly, are seen today as more exotic approaches: sub-seabed disposal, deep-well disposal, and even space disposal. They all have been found wanting in terms of cost or risk, or impracticable because of political or legal restrictions.

On the other hand, the options most often suggested in today's public and scientific debates are extended storage of the waste, and partitioning and transmutation of long-lived radionuclides within the waste. Both options might be components of an overall waste management strategy and the technical feasibility of both options is being intensively explored, e.g. in France. The potential merits of extended storage — the long-term monitored storage of high level and long-lived waste under institutional control — are being discussed in advisory groups and panels (e.g. in the UK and Switzerland). However, it should be clear that neither option avoids the need for some final disposal route.

On the other hand, many of the principal waste management strategies discussed today as "waste management options" are inspired by the hope of future breakthroughs in major technological areas concerning waste management, or even in fundamental science and R&D. However, progress in the areas of waste conditioning and of repository design and engineering has been achieved mainly by gradual improvements in design concepts and in the technology that is available to implement them. There have been relatively few new design concepts and technological breakthroughs; the trend has been towards incremental improvement and more rigorous demonstration of existing concepts. As understanding has increased, no radical changes in philosophy of approach have proven to be necessary, confirming the soundness of the basic geological disposal concept.

Retrievability and Reversibility

The waste management options most extensively investigated today are retrievability and reversibility, and specific concepts of these options are part of the disposal programmes in some countries, e.g. Sweden, the USA (Yucca Mountain). The purpose of including retrievability in disposal programmes is, broadly, two-fold:

- In the immediate future, to demonstrate that there is the potential for flexibility in waste management programmes as they may develop over the next few decades or even few hundred years.
- In the long term, to allow future generations the possibility to re-examine the technical decisions or solutions enacted by this generation.

The first objective is a more immediately practical goal in the design of waste management and disposal programmes, and satisfying this objective will provide good prospects that the objective based on ethical concerns will also be satisfied. A flexible approach means that alternative options are, where possible, kept open. It may, for example, involve designing a repository in such a way that future attempts to change the repository or to retrieve the waste are not impaired. These concepts span technical, regulatory and ethical issues, and it is important that a broad-based understanding is developed of their strategic value and implications.

The ability to retrieve the waste at each stage after emplacement has technical benefits, e.g. an unsatisfactory situation could be remedied. It also has public and political confidence benefits, i.e. a greater level of flexibility in the programme and knowledge that irreversible steps are not being taken. There may, however, be technical, policy-related and cost disadvantages which deserve consideration.

Stepwise Decision-Making

The long duration of the process of geological disposal until the final closure of the repository, as well as the novelty and complexity of the task, make it impossible to perform detailed planning of the entire repository development process at the outset of a project. For such complex long-term projects, a phased, step-wise approach with well-defined milestones is necessary. Distinct steps seen in most programmes include: concept development, site selection, repository construction, waste emplacement, backfilling and sealing around waste containers, and backfilling and sealing of other parts of the repository including shafts or access drifts, leading to final closure.

At each stage, the decision to proceed to the next stage needs to be matched by an appropriate level of confidence in the prospect of achieving a facility with an acceptable long-term safety. The level of confidence must be sufficient to justify the commitment of resources that the next stage is likely to involve and should take account of the options that remain open. In general, these will include the possibility of reversing a given step.

Decision-making in the stepwise process of repository planning and development is based on:

- General agreement regarding the ethical, economic and political aspects of the appropriateness of the underground disposal option.
- Confidence in the organisational structures, and the legal and regulatory framework, for repository development, including agreement on development stages.
- Confidence in the practicality and long-term safety of disposal.

In this process, detailed development must proceed iteratively, as information and experience are acquired. This allows planning to be responsive to new findings and to possible changes in the legal and regulatory framework of a country.

Clear definitions of what this means in practice are lacking, but specific examples suggest there is more chance of successful licensing if applications are made for discrete, easily overviewed steps in the development. One example is in Switzerland, where a prime reason for the loss of a public referendum at Wellenberg was that the public preferred to give an initial permit for the construction of an exploratory tunnel, rather than directly for the final repository. The complexity of the public debate is illustrated by the UK example, in which permission for an exploratory facility at Sellafield was refused, even though it was made quite clear that this facility would only be used for exploration to support a future finding on the suitability of the proposed location.

On the other hand, in order to preserve credibility and confidence in this step-wise approach itself, there must be an understanding of what is to be broadly achieved at each step, and what would be required to make this step. Dialogue is needed between implementers, regulators and other stakeholders, to define the requirements to be fulfilled in order to progress from one stage to the next, and to ensure that the process is perceived as being equitable outside the community of technical specialists and decision-makers.

Stakeholder Involvement

Geological disposal is a technical and social project over many decades. While the socio-political and administrative framework of modern societies seems to be well equipped to support long-lived institutions, there is limited experience with the planning and implementation of long term projects. To make geological disposal happen, a broader socio-political process is needed and the appropriate framework must be set. To a large extent, this will challenge the classical, technically centred infrastructure “triangle” of implementers, regulators and technical experts in waste management.

The step-wise decisions of whether, when and how to implement geological disposal will need a thorough public examination, and the involvement of all relevant stakeholders including waste management agencies, safety authorities, local communities and elected representatives. So far, experts have dominated the national programmes and the decision processes in the nuclear waste area, and often the entire problem of nuclear waste disposal has been appreciated as an issue to be dealt with by technical experts only. However, in the end decisions on such items as siting and permits for construction of repositories will be political decisions, with input from experts and other stakeholders, and it is clear that many of the issues that need to be addressed before such decisions can be taken are value-laden and of a political and ethical nature.

To achieve and maintain public confidence, there should be opportunities for comment and input from affected and interested groups, as well as rigorous technical review from the regulatory authorities. The technical community must be ready to discuss topics of the public's choice, as well as to communicate better the consensus and confidence that exists in the technical feasibility and safety of deep geological disposal.

There is a need to identify audiences, perspectives and expectations, and to share experience in building public confidence and, in particular, in how to obtain the trust of local communities, their representatives and intermediaries with the technical decision-makers. An important aspect is that stakeholders should be afforded opportunities to interact as early as possible in the process of repository development. The process by which proposals are brought forward by an implementer, and critically examined by regulatory authorities, must also be trusted, and decisions made must be transparent, e.g. to address local concerns.

Waste Management Policy is Needed

Independently of the future use of nuclear power in the world, there is internationally a clear need for the development of deep repositories. The current debates within waste management programmes do not, in many cases, question geological disposal as the preferred means of disposal for long-lived wastes. The large quantities of waste existing today in civilian and military programmes must be disposed of in a safe manner.

Today, a consensus exists between experts in various countries that sites can be properly identified and characterised, that geological repositories can be designed so that no short-term detriment to populations will result from the waste disposal, and that an acceptable level of safety is provided for times far into the future. The broad lines of the step-wise approach are fairly well understood.

The identified need to increase flexibility in concepts, to facilitate interaction with civil society, and to broaden the socio-political basis for decision-making, should not keep decision-makers from designing, implementing and pursuing a coherent and transparent policy in waste management issues. In the end, the debate on nuclear waste disposal is inextricably linked to the continuing discussion on future strategies for nuclear energy.