Radioactive Waste Management

Reversibility and Retrievability in Geologic Disposal of Radioactive Waste

Reflections at the International Level

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996); Korea (12th December 1996) and the Slovak Republic (14th December 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the 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 27 OECD Member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

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

FOREWORD

The NEA Radioactive Waste Management Committee (RWMC) is a forum of senior representatives of operator, regulator, policy-making, and R&D organisations in the field of radioactive waste management. The Committee assists Member countries by providing guidance on the solution of radioactive waste problems, and promotes safety in the short- and long-term management of radioactive waste.

The RWMC has defined strategic areas where progress would be highly beneficial to the further development of radioactive waste management and geologic disposal programmes, and has also identified key topics within each strategic area (NEA, 1999a). One such topic, within the area of "Overall Waste Management Approaches", is the reversibility of decisions in waste disposal programmes and the potential for retrieval (retrievability) of disposed waste from a geologic repository. A group was set up in order to explore this topic, with members drawn from implementor, regulator, and policy-making organisations from eleven countries, as well as the European Commission. A questionnaire was circulated to obtain preliminary input. The group then met to discuss the issues and drafted a report. That report was further developed with input from other members of the RWMC, the result of which is produced herein.

The concepts of reversibility and retrievability are currently being discussed and defined within the national programmes of several countries and there are, as yet, varying views on the desirability and the methods and degree of their implementation. The intention of this report is to provide an overview of the relevant issues based on the current understanding and views of experts from the waste management community in NEA Member countries. A better understanding and communication of these issues will clarify the value of flexible, step-wise decision making in repository development programmes and may help to generate a climate conducive to the further progress of such programmes.

TABLE OF CONTENTS

1. INTRODUCTION

Radioactive waste needs to be managed responsibly to ensure public safety and the protection of the environment, as well as heightened security from unauthorised intervention, now and in the future. One of the most challenging tasks is the management of long-lived radioactive waste that must be isolated from the human environment for many thousands, or even hundreds of thousands, of years.

There is a consensus among the engaged technical community that engineered geologic disposal provides a safe and ethical method for the long-term management of such waste (NEA, 1995). This method is also cited in the national policies of several countries as either a promising or appropriate method for dealing with long-lived radioactive waste.

Engineered geologic disposal means emplacement of the waste in repositories constructed deep underground in suitable geologic media. Thus the waste is contained, and safety assured by passive barriers with multiple safety functions, so that there is no need for any further actions by future generations. Primary principles of the engineered geologic disposal concept are that waste will only be emplaced in a repository when there is high confidence in the ultimate long-term safety, and that the long-term safety must not rely on actions following the closure of the repository. This does not mean, however, that actions cannot be taken. Most repository development programmes include the possibility of post-closure activities for security and monitoring purposes.

Many radioactive waste disposal organisations have chosen to consider the possibilities for incorporating the concepts of reversibility and retrievability in their programmes. This is to increase the level of flexibility in their programmes and, thus, their ability to respond to changes in technical information and policy factors. It is also considered important to recognise ethical concerns which may contribute to achieving wider societal confidence in the engineered geologic disposal option.

Reversibility and retrievability are not new issues. They have been considered in some national programmes from the earliest times and general comments on flexibility, reversibility, and retrievability have been made in previous NEA documents (see Box page 9). Reversibility and retrievability are brought to prominence now because the ability to reverse decisions and retrieve the waste has a direct bearing on the decision-making process for repository implementation that is being developed, or is already underway, in several countries. The concepts span technical, policy, and ethical issues and it is important that a broad understanding is developed of their value and implications.

This document reviews those concepts as they may apply to the planning and development of engineered geologic repositories for spent nuclear fuel, vitrified high-level radioactive waste from spent fuel reprocessing, and other long-lived radioactive waste.[1] This is based on the views of the wide community of operator, regulator, policy making, and R&D organisations represented in the RWMC. It thus complements the European Commission Concerted Action on Retrievability (EC, 2000) amongst implementing organisations of a group of European countries and, also, the proceedings of a recent international seminar (IAEA, 2000).

The document is structured as follows:

- Chapter 2 introduces the relevant concepts and defines the terminology that is used in this document.
- Chapter 3 discusses the place of reversibility and retrievability in decision making for repository development. This chapter is supported by Annex 1, which presents an overview of ethical principles underlying repository planning and development.
- Chapter 4 identifies and discusses possible reasons for and against making provisions for retrievability in waste disposal programmes.
- Chapter 5 discusses the practical requirements for retrievability, including the technical feasibility of waste retrieval at each stage after emplacement, R&D requirements, institutional arrangements, and monitoring aspects.
- Chapter 6 discusses the implications of incorporating reversibility and retrievability in national policy, including financial, organisational, and regulatory arrangements.
- Overall conclusions and recommendations are presented in Chapter 7.

---

[1] This document applies to engineered geologic repositories, typically planned and developed at depths of 200 to 1 000 metres below ground, that are intended as final disposal (not storage) facilities. Consideration has not been given to alternative waste disposal concepts such as disposal in very deep or long boreholes drilled from the earth's surface, which would not favour retrievability.

Statements related to flexibility, reversibility and retrievability from previous NEA documents

The 1995 Collective Opinion on the Environmental and Ethical Basis of Geological Disposal (NEA, 1995) points out that:

"step-wise implementation of plans for geological disposal leaves open the possibility of adaptation, in the light of scientific progress and social acceptability . . . and does not exclude the possibility that other options could be developed at a later stage"

and observes that:

"Retrievability is an important ethical consideration since deep geological disposal should not necessarily be looked on as a totally irreversible process completely foreclosing possible future changes in policy."

The international assessment Progress Towards Geologic Disposal of Radioactive Waste: Where Do We Stand? (NEA, 1999c) states that:

"An important message that the waste management institutions have difficulty communicating is that waste would never be placed in an 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."

and that:

"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."

2. CONCEPTS AND TERMINOLOGY

The planning and implementation of a geologic repository typically proceeds by an incremental, **step-wise approach** (NEA, 1995; NEA, 1999b). At each step, the decision to proceed or not is made in the light of technical factors and, also, social and political acceptance. The step-wise approach provides opportunities for societal and political review, and allows for a gradual growth in confidence in the feasibility and safety of the facility, as information and experience are acquired.

Disposal means the emplacement of radioactive waste in a repository without the intention of access or retrieval, while **storage** (which is not discussed in this document) means the holding of radioactive waste in a facility that provides for its containment, with the intention of retrieval. Disposal rests on the concept of inherent passive safety, while storage requires active stewardship to assure safety. Although there is no intention, it may be possible to retrieve waste from a repository designed for disposal. Indeed, retrievability may be accommodated by deliberate provisions in repository and/or waste package design and/or by postponing measures that would limit access to the waste, such as backfilling and closing of drifts as well as sealing of shafts (closure of the repository). However, retrievability provisions can in no case be allowed to undermine the long-term passive safety of a repository.

The terms reversibility and retrievability are used differently by different organisations. For this report, the following definitions have been agreed upon.

Reversibility denotes the possibility of reversing one or a series of steps in repository planning or development at any stage of the programme. This implies the review and, if necessary, re-evaluation of earlier decisions, as well as the means (technical, financial, etc.) to reverse a step. Reversibility denotes the fact that fallback positions are incorporated in the disposal policy and in the actual technical programme. Reversibility may be facilitated, for example, by adopting small steps and frequent reviews in the programme, as well as by incorporating engineering measures. In the early stages of a programme, ***reversal*** of a decision regarding site selection or the adoption of a particular design option may be considered. At later stages, during construction and operation, or following emplacement of the waste, reversal may involve the modification of one or more components of the facility, or even the retrieval of waste packages from parts of the facility.

Retrievability denotes the possibility of reversing the action of waste emplacement. It is thus a special case of reversibility. ***Retrieval*** is the action of recovery of the waste or waste packages. Retrievability, the potential for retrieval, may need to be considered at various stages after emplacement, including after final sealing and closure. In discussing retrievability and retrieval, it is important to specify what is to be retrieved, since this affects the implementation and technical feasibility. Retrievability could, for example, refer to: retrieval of individual waste packages which are identified as faulty or damaged, even as emplacement of other packages continues; retrieval of some or all of the waste packages at some time after emplacement; or retrieval of the waste materials if the packages are no longer intact. Retrievability may be facilitated by the repository design and operational strategies, for example, by leaving underground access ways open and emplacement/retrieval systems in place until a late stage, and through the development and use of durable containers and easily excavated backfill.

3. THE PLACE OF REVERSIBILITY AND RETRIEVABILITY IN DISPOSAL PROGRAMMES

3.1 The need for flexibility in decision making for repository development

Engineered geologic disposal will be implemented in a step-wise manner, with well-defined stages interspersed with decision points that allow opportunities for technical, regulatory, policy, and, in some cases, public review. Steps that can be recognised in most programmes include: concept development, site selection, repository construction, performance confirmation (or demonstration phase), waste emplacement, backfilling and sealing of the repository. In addition, many sub-steps may be defined that are specific to individual programmes.

At each succeeding step in a repository planning and development programme, the amount of technical information available will increase, leading to changes in the level of technical confidence. For example, the safety case for a repository will evolve as the site is characterised, the design is refined, and the understanding of features, events, and processes relevant to the performance of the repository is improved. Non-technical factors and external constraints and opportunities may also change. A repository programme will need to respond flexibly to:

- new technical information regarding the site and design;
- new technological developments relevant to nuclear waste management;
- changes in social and political conditions and acceptance; and
- changes in regulatory guidance and its interpretation or even, possibly, in basic safety standards.

Such changing information and conditions can affect not only the decision at hand, but may also lead to the re-evaluation of earlier decisions. For instance, a license or permission for the construction and operation of a repository (i.e., for the emplacement of radioactive waste packages) will be reviewed at specified intervals in order to verify that adequate assurance of the long-term safety of the repository is preserved.

A flexible approach to decision making means that, at each development stage, alternative options are maintained for the later development of the repository and waste management. Examples are the characterisation of more than one host rock option (in countries where this is feasible) or several potential repository sites, and the development of alternative designs or design variants, e.g., the investigation of alternative waste package and/or backfill materials.

Options for the timing of key steps are another possible degree of freedom. The construction of interim storage facilities may allow flexibility in timing of the development of final disposal facilities. Designs that ensure good conditions in the underground for extended periods may allow delay of repository backfilling and sealing and/or a period of underground monitored storage for the waste.

It may be desirable to keep several design, site, and repository management options open for an extended period, including the option to retrieve the waste. There are, however, likely to be technical and financial implications, and, possibly, policy implications of keeping alternatives open. In any event, complete flexibility cannot be retained throughout the development process, since progressively firmer decisions must be taken in proceeding from one development stage to the next if the final goal of providing long-term passive safety is to be met (NEA, 1999b).

Flexibility is not an objective in itself, but is good practice. It can contribute both to technical confidence in the ability to safely manage the waste and, also, to a confidence in wider audiences that an irreversible decision is not being made. The provision of flexibility should not be seen as a lack of confidence in ultimate safety of disposal, but rather as a desire to make optimum use of the available waste management options and design alternatives.

3.2 Reversibility within a flexible approach to decision making

A flexible approach to decision making involves measures to facilitate the *reversibility* of decisions in repository planning and implementation. Accordingly, it is good practice to discuss the degree of reversibility of the decisions made or to be made when planning or implementing a repository.

The implementation of a geologic disposal concept, including allowance for reversibility of decisions, aims to fulfil the ethical requirement that the generation that has benefited from nuclear power provide the means for the safe and permanent disposal of the resulting waste, while leaving open to future generations the possibility to modify the implementation or reverse the process if desired. While reversibility is consistent with the ethical principle that the needs and aspirations of future generations should be respected, including their freedom to make their own decisions, a balance has to be struck between this and the complementary principle that undue burdens should not be placed on future generations. These burdens may include requirements to monitor the repository, to maintain the appropriate technical expertise, and to maintain administrative and decision-making capabilities.

More generally, responsible decision making may seek to achieve a balance between several ethical principles (e.g., see the NAPA Principles in Box 1 of Annex 1) working within the confines of safe waste management practice. The ethical principles underlying repository planning and development are discussed more fully in Annex 1.

In any event, the actual decision to reverse one or a series of planning and development steps would need careful consideration. For instance, a change in direction of an established technical programme to a less well investigated option should consider that there may be equal or greater problems associated with the new option that are as yet unknown. The resources already invested and the confidence in any new path must be assessed. This may include an assessment of political and social impacts and confidence, as well as technical confidence and financial cost.

3.3 Retrievability in the context of reversibility of decisions

Providing for the waste to be emplaced in a retrievable manner enhances the possibility of reversing decisions in repository development and provides an additional degree of flexibility. This additional flexibility may:

- allow the ongoing development of the repository to respond to new technical information or policy directives;
- allow technical controls to take place under more desirable conditions;
- allow an unsatisfactory situation to be remedied; and

- in the long term, afford future generations a better possibility to re-examine the technical decisions or solutions enacted by this generation, which is an ethical concern as discussed above.

The declared and demonstrated possibility to retrieve the waste at each stage after emplacement may also have public and political confidence benefits, in that it removes the concerns that some may have to commit irreversibly to a given decision. There may, however, be technical, policy-related, and security disadvantages which deserve consideration. In particular:

- the application of nuclear safeguards to a repository in which the wastes remain “retrievable” has not been worked out yet and deserves further attention;
- there is an argument that retrievability runs counter to the primary objectives of geologic disposal to provide permanent safety and not to facilitate irresponsible attempts to retrieve the waste or repository materials.

The present consensus amongst the engaged technical community is that retrievability can be considered in geologic disposal programmes, but that it is not essential for safety. If incorporated, it can be considered consistent with the primary objective of providing adequate long-term safety and security only if it is implemented in such a way as not to reduce the long-term passive safety, to preserve adequate security, and not to impose undue burdens on future generations.

4. ARGUMENTS FOR AND AGAINST RETRIEVABILITY PROVISIONS

4.1 Introduction

Whilst, as a matter of principle, emplacing waste in a manner that favours its retrievability at later stages provides an additional degree of flexibility, which is useful for decision making, it is helpful to explore arguments for and against retrievability provisions. A perspective can thus be gained on the benefits and possible drawbacks of enhancing retrievability.

4.2 Factors favouring waste retrievability provisions

Broad factors that might lead or contribute to a decision to retrieve waste and weigh in favour of building provisions for retrievability are as follows:

- technical safety concerns that are only recognised after waste emplacement and/or changes in acceptable safety standards;
- a desire to recover resources from the repository, e.g. components of the waste itself, or the recognition or development of some new resource or amenity value at the site;
- a desire to use alternative waste treatment or disposal techniques that may be developed in the future;
- to respond to changes in social acceptance and perception of risk, or changed policy requirements.

4.2.1 Technical safety concerns or changed safety standards

The ability to retrieve waste in the event of unforeseen technical safety concerns may be the most important reason for measures to enhance retrievability from the point of view of achieving widespread confidence, even if the likelihood of the need for retrieval for this reason is very low.

The safety case for the repository should be sufficiently robust that it should not be compromised by any new technical information regarding the site and design that arises after waste emplacement. Wastes will not be emplaced except following production of a robust safety case based on a comprehensive exploration of the site and testing of key safety arguments, and the inclusion of retrievability will not be a reason to accept a lower degree of confidence in the long-term safety.

It is possible, however, that new observations, e.g., as a result of site or repository monitoring, or advances in scientific understanding will reveal unexpected characteristics or phenomena that are detrimental to the long-term safety of the repository. If the new observations and advances in scientific understanding invalidated, partly or totally, the arguments for confidence in long-term safety that supported previous licensing steps, this would be a regulatory concern. Waste may or may not need to be removed as a result of this finding. In particular, it is considered extremely unlikely that the hazard or risk of loss of containment would be such as to require urgent recovery of waste, or recovery of more than a small fraction of the waste or waste containers. More likely, improvements might be made to the engineered barriers within the existing disposal system or the waste would be removed after an alternative disposal route had been prepared.

Changes in technical safety standards may also occur in the future that place either greater or lesser demands on repository performance. A situation could arise in which an existing disposal facility did not meet new standards. In this case, a decision would have to be made on whether compliance should or could be achieved retroactively or was worthwhile. As discussed above, the retrieval of waste should only be undertaken if an alternative, and more acceptable, waste management solution was available.

4.2.2 Resource implications

The value of spent fuel as a resource, should energy strategies change, is often cited as a reason for keeping this material retrievable, i.e., the material may not always be considered a waste. It is unlikely that vitrified high-level waste or other long-lived wastes could one day constitute viable energy resources. Another possibility is the desire to recover elements that are rare or do not occur in nature and may have uses in future technologies. These might be extracted, in principle, from spent fuel and from vitrified high-level waste, although the economic viability of this would have to be demonstrated.

The recovery of the waste containers for their metal contents is a possibility, but it would be regarded as uneconomic and irresponsible by current standards. In general, the resource potential of the waste and other repository materials needs to be addressed in decision making for repository development.

The existence of natural resources and the amenity value of the land are important considerations when siting nuclear waste repositories. Retrieval may need to be considered due to the discovery of a previously unrecognised resource at a disposal site, or the land might acquire some new amenity value, e.g., due to changes in surface development. In this case, the waste might need to be removed either because of actual safety concerns, or because of a perception that the presence of the waste was inconsistent with the use of the resource or amenity.

4.2.3 Availability of new waste treatment or disposal technologies

Research is continuing on partitioning and transmutation (P&T). It is accepted that these techniques do not offer a realistic alternative to geologic disposal, but they might be incorporated into waste management strategies in the future to reduce the waste volume for disposal and alter its characteristics. Even so, this does not mean it will be acceptable from a safety perspective to recover waste that is already emplaced, unless the design has been specifically made with this option in mind. In such circumstances, waste might be recovered to comply with a policy decision.

Other novel waste management or disposal techniques might be developed, although the motivation for developing such techniques is likely to be diminished if geologic disposal is successfully implemented. The arguments for and against recovery of emplaced waste are liable to be similar to those discussed in relation to P&T.

4.2.4 Social acceptance and perception of risk

At present, the inclusion of retrievability in waste disposal programmes is favoured as a policy in several countries for ethical reasons and for public confidence. People consider a technology safer if they know what will be done in case of an accident, no matter how unlikely such an accident may be. Waste retrieval can be seen as an ultimate measure to be taken in case of an unforeseen event.

The view is taken in some quarters that, once the concept of geologic disposal is demonstrated, public acceptance of it will likely increase. However, public acceptance and risk perception, and views on what is acceptable safety, may change in the future, and knowing that retrieval is always an option could ease public concerns about geologic disposal.

4.3 Possible factors opposing waste retrievability provisions

Reasons for not including retrievability provisions in repository design may be connected to factors such as the additional complexity entailed, the cost-worthiness of a retrieval option, and long-term security concerns. They include:

- uncertainty about negative effects, including conventional safety and radiological exposure of workers engaged in extended operations and/or associated monitoring, or marginal gains;
- the possibility of failure to seal a repository properly due to the adoption of extended or more complex operational plans to favour retrievability;
- the favouring of irresponsible attempts to retrieve or interfere with the waste during times of political and/or social turmoil when safeguards and monitoring features are no longer in place;
- a possible need for enhanced nuclear safeguards.

4.3.1 Uncertainty about negative effects on operational and long-term safety

Potentially negative processes may be introduced by measures introduced to extend the open period of a repository or associated monitoring and maintenance, e.g. degradation of repository materials or near-field rock conditions during an extended period of open underground access ways. Any such effects would have to be assessed and assurance reached that any detrimental influences did not significantly degrade long-term safety. Minor detriments may be offset by the reduction of uncertainties in post-closure performance gained through additional data collection in the prolonged pre-closure period, but this may be marginal.

The introduction of provisions for retrievability must not be detrimental to long-term safety. Thus, for example, locating a repository at a depth that is less than optimum from a long-term safety perspective in order to facilitate retrieval is unlikely to be acceptable (although such a facility might be acceptable as an interim storage facility).

If an extended pre-closure period is implemented after emplacement of the waste in order to permit retrievability, the repository design and operation must still ensure adequate operational safety. The maintenance and monitoring necessary to ensure retrievability may lead to increased doses to workers and more prolonged hazard of conventional and mining accidents, although doses and non-radiological risks should be managed to remain within acceptable targets. Very extended times for open access to the disposal areas may imply substantial underground refurbishment programmes or even, for some types of waste and retrievability concepts, repackaging of wastes. In such cases, it would have to be considered whether any additional doses to workers were justified in terms of reduction of potential long-term doses or increased confidence in long-term safety.

4.3.2 Uncertainty over final closure and sealing

A possible risk of an extended operational period associated with retrievability, say, over 100 years or more, is that the repository may not then be properly closed and sealed. This may occur due to the failure of organisational or financial arrangements or loss of technical capability. As a result, the repository access ways may be left open but not maintained or only poorly sealed. In this case, the open, perhaps collapsed, or poorly filled access ways may provide a path for the movement of groundwater, gas, and contaminants and also more easy access for inadvertent or irresponsible interference with the repository.

4.3.3 Enhanced opportunity for irresponsible entry or interference with repository

Government and regulatory control should not be relied upon in the long-term. This is one of the main reasons why the geologic disposal concept has been proposed and developed: to relieve the burden on future generations to maintain and control the disposal site. Even in the span of a few decades, adherence to law and regulation can decline in a society, especially if economic conditions change or in case of political troubles and war. In such a case, a repository in which waste retrievability provisions were implemented might offer an easier target for irresponsible recovery of waste or engineered barrier materials or malicious damage than a repository without retrievability provisions.

4.3.4 Need for enhanced safeguards

In the case, primarily, of repositories for spent fuel, any measures taken to enhance waste retrievability run counter to the objective of making the diversion of nuclear materials to military purposes as difficult as possible. According to the Treaty on the Non-Proliferation of Nuclear Weapons, safeguards negotiated with the IAEA must be applied to the management of source or special fissionable materials to prevent the use of those materials in weapons. The agreements reached between Treaty signatories and the IAEA pursuant to that Treaty provide that nuclear safeguards can only be withdrawn if the nuclear material is, in the judgement of the IAEA, "practicably irrecoverable" (IAEA, 1972). By making nuclear material more recoverable rather than less, retrievability provisions may necessitate an enhanced level of safeguards and oversight. For example, the level of safeguards required during any extended open period of a repository would likely be much higher than what would be required following final closure. Similarly, a repository designed to facilitate waste retrieval even after closure would likely require more careful monitoring than a repository not so designed, placing an undesirable burden on future generations.

4.4 Conclusions

A decision on whether or not to include provisions for retrievability in a repository design must weigh the potential advantages against the possible disadvantages. This type of decision can only be made in the context of a specific repository programme, and not for all repositories in general.

Building provisions for retrievability provides flexibility in dealing with unanticipated, but possible, future conditions such as: technical safety concerns that are only recognised after waste emplacement and/or changes in acceptable safety standards; a desire to recover resources from the repository or the recognition or development of some new resource or amenity value at the site; a desire to use alternative waste treatment or disposal techniques that may be developed in the future; and changes in social acceptance and perception of risk, or changed policy requirements.

Reasons for not including retrievability provisions include: uncertainty about negative effects, including conventional safety and radiological exposure of workers engaged in extended operations and/or associated monitoring, or marginal gains; the possibility of failure to seal a repository properly due to the adoption of extended or more complex operational plans to favour retrievability; the increased possibility of irresponsible attempts to retrieve or interfere with the waste during times of political and/or social turmoil; and a possible need for enhanced nuclear safeguards.

It must always be borne in mind that the ultimate goal of a repository is to provide passive, safe isolation of wastes over the long term, and that retrievability is only a sub-goal or preference. Any provisions for retrievability must be implemented in a manner that preserves adequate safety and security during both the operation of the repository and in the long term. No circumstances have been identified that would require urgent retrieval of waste. Even if retrieval became the preferred option at some future time, there would always be time to implement it in a judicious manner, i.e., when an alternative storage or disposal facility was prepared to receive the retrieved waste. This allays the need for stand-by, redundant systems for waste storage or alternative disposal routes.

5. PRACTICAL REQUIREMENTS FOR RETRIEVABILITY

5.1 Introduction

If retrievability of waste is claimed, certain practical requirements must be met to assure its feasibility. These include:

- technical understanding and capability at each stage of repository development following waste emplacement;
- R&D to develop equipment and techniques to correct any shortcomings in the present technical capability for retrieval;
- appropriate institutional arrangements and planning to ensure the continued availability of technical and decision-making capabilities;
- site and repository monitoring to ensure that conditions necessary for various retrieval methods are met.

5.2 Technical feasibility of waste retrieval at each stage of repository development

The European Commission's Concerted Action report on retrievability (Grupa et al., 2000) discusses the technical feasibility of waste retrieval over 13 time periods. Here, retrieval is discussed during four broad stages of repository development distinguished, primarily, by the physical ease with which retrieval might be accomplished.

A generic difficulty in repositories for spent fuel and high-level radioactive waste, at all stages, is dealing with the heat and radiation output from the waste. Either ventilation must bring the temperature down to a level acceptable for long-term storage and retrievability, or methods must be designed to retrieve the waste remotely under high-temperature conditions. High radiation output may similarly mandate methods to retrieve waste remotely. In some disposal concepts, there may be a period in which temperatures and radiation fields are too high to undertake waste retrieval safely, forcing the delay of any desired retrieval.

5.2.1 During waste emplacement

In most repository designs, high-integrity waste packages are emplaced in tunnels, drifts, or boreholes.[2] Emplacement would be accomplished using remotely operated equipment. The emplacement zones would be monitored and the environment controlled, e.g., control of groundwater ingress and ventilation. In most systems, the remote emplacement equipment is designed to be capable of use in reverse mode, e.g., to recover faulty or dropped containers, and if required could be used for larger scale recovery of the waste. If backfill is emplaced immediately around each container, then measures to remove the backfill are also usually required as part of the normal design, e.g., to allow for correction of unsatisfactory emplacement. Thus, during the period in which waste is being emplaced in the repository, it is expected that the waste could also be retrieved by reverse use of the systems designed for emplacement.

5.2.2 After waste emplacement and before gallery/vault backfilling

In some repository concepts, either backfill is not foreseen or its emplacement can be delayed for a period. This is not a practical possibility for all sites and designs. Nevertheless, in some borehole emplacement designs, although the boreholes themselves may be backfilled, the emplacement rooms, or galleries from which the boreholes are accessed, could be kept open and the waste retrieved by the reverse use of emplacement equipment. Special consideration may have to be given to removing containers from backfilled boreholes, especially if swelling materials are used and/or in creeping rocks. Additional design measures may be necessary to ensure the stability of underground openings and that good environmental conditions can be maintained over the extended period.

5.2.3 After gallery/vault backfilling and before repository closure

After the emplacement tunnels, drifts, or galleries are backfilled, the central waste-handling areas, service areas, and access ways could still be held

---

[2] In this document, “borehole” is used to refer to the relatively short (a few metres to possibly tens of metres) boreholes that may be drilled from access ways or vaults to accommodate one to a few waste containers. The term “pit” is also used in some countries.

open. The necessary inspection and maintenance could be easily achieved in these areas. Either final seals could be placed at access points to the emplacement tunnels or only temporary seals need be emplaced. In most concepts, the backfill in the emplacement zone creates a stable physical and chemical environment around the waste containers. Thus, the emplacement geometry is preserved and any degradation of the waste containers should be very slow, so that there are good prospects of locating and retrieving the intact containers over a long period of time.

Retrieval will involve breaching of the underground seals if placed, progressive removal of the backfill with attention to re-establishing rock stability if necessary, and careful excavation around the waste containers. Special equipment may be necessary both for the remote removal of backfill from around waste containers and removal/lifting of containers. In principle, the equipment may be quite similar to that used today in mining and nuclear decommissioning.

5.2.4 After repository closure

Closure involves backfilling of most or all underground areas, and backfilling and sealing of the access shafts and/or drifts. The majority of surface facilities would also be removed, although some structures related to site security and information might be retained.

Closure is a significant milestone in the development of a repository from technical, administrative, and social perspectives. It marks the transition from an underground facility from which retrieval is still contemplated to a final disposal facility. Such a step will only be taken if a very high level of technical confidence has been reached in the long-term safety of disposal at the site, no other reasons to retrieve the waste can be foreseen, and the social acceptability is also firmly established. The likelihood that the waste would be retrieved after this step is, thus, very low. Nevertheless, for at least as long as the information about the site and wastes is preserved, retrieval of the waste would be possible by mining techniques.

The waste retrieval procedure is likely to vary depending on the time period that has elapsed since repository closure. For short periods after closure, perhaps some years or decades, it may be possible to re-open repository access ways and galleries. After longer periods, particularly in the case of creeping or less competent rocks, the underground openings would no longer be stable, and new shafts and access ways would have to be excavated.

5.3 R&D requirements for waste retrieval

During the waste emplacement period and before extensive placing of backfill, waste retrieval could usually be achieved by the reverse use of emplacement systems. After placing of backfill, special techniques may be necessary but, in principle, the equipment could be similar to that used today in mining and nuclear decommissioning projects. Special measures will be necessary to undertake mining and retrieval operations at the high temperatures and radiation levels that will persist around spent fuel and high-level waste containers. In some geologic environments, it may be preferable to delay retrieval until the temperature and radiation have decreased.

The techniques and equipment needed for waste retrieval are similar to that already in use today in surface waste stores, mining and underground construction applications, and nuclear decommissioning, and no new or exotic technology is required. Some components of the technology required for retrieval in specific repository designs have been, or are now being, demonstrated, e.g., the cutting of waste containers from cement backfill by Nirex and the retrieval of spent fuel containers emplaced according to the KBS-3 concept by SKB. Such demonstrations should be encouraged in the various national and international research programmes. They contribute to technical confidence in the feasibility of waste retrieval and, also, to a wider non-technical confidence in the feasibility and the seriousness of the waste management organisations about retrievability. Although retrieval can be achieved with today’s technology, developments in potentially relevant technologies should be kept under review as these may yield improved methods of controlling and monitoring the underground environment over long periods and retrieving waste.

5.4 Institutional arrangements and planning for retrieval

For waste retrieval to be feasible, institutional arrangements have to be foreseen in order to ensure that:

- an appropriate level of technical ability to retrieve is maintained at each stage following waste emplacement;
- the methods for retrieval are defined, including retrieval under foreseeable component-failure and accident conditions; and

- periodic evaluations are made of the status of the repository, focussing on the operational safety and potential long-term safety and the appropriateness and need to either:
  - proceed with the next step towards repository closure;
  - maintain at the current step, including specification of repair or maintenance requirements; or
  - reverse a step, including retrieval of the waste if necessary.

5.5 Site and repository monitoring

Beginning in the period prior to construction, and continuing up to closure, monitoring of various site and repository parameters will provide information for safety assessment. This may include confirmation of natural site conditions, understanding of the response of the natural system to the presence of the repository, and the early evolution of the engineered elements. In many designs, measures to enhance retrievability, such as an extended open period, will modify site conditions and delay or prevent the conditions that are aimed at for long-term safety. The plan for monitoring related to performance should be carefully considered and reasoned arguments applied so that the relevance of measured parameters to eventual long-term safety is known.

During the operational period, and any extended open period that follows it, monitoring of rock stability, the underground environment, and waste-package conditions will be needed. Such monitoring is required to ensure operational safety, to detect any risk of incipient failure, e.g., of rock support systems, and to check whether the conditions for waste retrieval according to the given methods are still met. The results of monitoring will be used to plan maintenance and refurbishment of the various systems and underground elements. The results may also contribute to decisions on when to move to the next stage towards repository closure, as they will refine estimates of how long a given stage can be maintained without significant additional expenditure on maintenance and refurbishment. They may prompt backfilling of some underground openings, if it is revealed that an extended open period may lead to effects that could compromise long-term or operational safety.

Subsequent monitoring, which may include the monitoring of backfill conditions, may be carried out to follow the early evolution of the engineered barriers, and to check that the expected evolution towards stable physical and chemical conditions is underway. It could also be used to check whether or not the conditions for waste retrieval according to the available methods are met, should the decision to retrieve the waste be taken.

Spent fuel and other waste that is rich in fissile material would be subject to both monitoring for safety and to nuclear safeguards monitoring, to verify that no unlawful retrieval has taken place. During the operational period and any extended open period, this would be done by on-site administrative and surveillance measures as used at other nuclear plants. Monitoring could continue in the post-closure period using on-site and remote techniques, for example, acoustic techniques, aerial photography, and satellite imagery may be used to identify any drilling or mining activity aimed at retrieval. Monitoring by the national government in order to allay public concerns may continue beyond the times suggested by regulators on grounds of safety or need for safeguards.

5.6 Conclusions

If retrievability is claimed to various degrees, it will be necessary to ensure that retrieval is in fact feasible. This has technical and institutional implications, as well as possible R&D requirements.

Most repository concepts have a degree of intrinsic retrievability, i.e., the waste could be recoverable even if specific provisions to retrieve the waste are not implemented. Specific measures can also be taken to make retrieval easier and/or extend the period during which it can be conveniently achieved. Provisions for waste retrieval will be repository system specific and retrievability may be more difficult to maintain in some host rocks and repository concepts than in others. In all the mined repository concepts presently under consideration, waste retrieval would be technically possible, although some restrictions on access to the waste would apply in some host rocks, especially rock salt.

However, the technical complexity and cost of retrieval will tend to increase as progressive steps towards closure are taken. Alternative or variant methods for retrieval may need to be defined to take account of the conditions of the waste containers, backfill (if emplaced), and repository as this develops over time. Contingency plans should also be considered for accident situations that can be anticipated, e.g., varying degrees of rock falls and loss of primary emplacement/retrieval systems.

During the waste emplacement period and before extensive placing of backfill, waste retrieval could usually be achieved by the reverse use of emplacement systems. After placing of backfill, special techniques may be necessary to retrieve waste. Special measures would also be necessary to undertake mining and retrieval operations at the high temperatures and radiation levels that will persist around spent fuel and high-level waste containers. R&D should continue in technologies relevant to waste retrieval and, in particular, demonstrations of retrieval technologies should be encouraged in the various national and international research programmes.

For waste retrieval to be feasible, institutional arrangements must be made to ensure that: an appropriate level of technical ability to retrieve is maintained at each stage following waste emplacement; the methods for retrieval are defined, including retrieval under foreseeable component-failure and accident conditions; and periodic evaluations are made of the status of the repository. These evaluations should focus on the operational and potential long-term safety of the repository and the appropriateness and need to proceed with the next step towards repository closure, maintain at the current step, or reverse a step, including retrieval of the waste if necessary.

The claim of retrievability implies monitoring to check the continued feasibility of the waste retrieval option over the period for which it is claimed. This will include monitoring of the underground conditions, operability of equipment, and continued safe working environments underground. An extended period of opening related to retrievability may also provide opportunities for extended monitoring related to long-term performance and confidence in long-term safety.

6. IMPLICATIONS OF REVERSIBILITY AND RETRIEVABILITY FOR NATIONAL POLICY

6.1 Introduction

Development of a deep geologic repository is a significant national project and is expected to take place over a number of decades. During this time, experience will be gained both nationally and internationally and will be incorporated into the implementation of the project as it progresses. A stable and comprehensive national policy will provide a framework in which decisions can be made and a route map for the expected development that can be the basis for organisational and financial provisions. The practice of step-wise decision making, allowing for broad review and input at each decision step, is well established. In this approach, decisions can be reversed.

The policy that outlines the principles under which radioactive waste will be managed in a safe, environmentally sound, and cost-effective manner should address how reversibility should be implemented and include an indication of the degree to which retrievability should be considered for different waste types, taking account of possible resource values and other factors. The government also needs to ensure the financial, organisational, and regulatory arrangements to carry through the policy, as discussed below.

6.2 Financial arrangements

Incorporating reversibility and retrievability may have financial implications. These include the cost of changing designs to facilitate reversibility and retrievability and, more significantly, the costs of monitoring, safeguarding, and maintaining the repository and organisational frameworks for decades, if not centuries, if an extended open period is required.

The "polluter-pays principle", the goal of which is to minimise or eliminate economic externalities, is applicable to the costs of waste management. As the producer of nuclear wastes, the nuclear industry should estimate the costs of maintaining retrievability of wastes for some period of time, as well as the costs related to exercising a retrieval option to various degrees, and incorporate those costs in the pricing structure for its product (electricity). However, if maintaining retrievability becomes an open-ended commitment, dependent on the shifting tides of political will and public perception, the nuclear industry cannot reasonably predict its costs and, therefore, cannot reasonably price its product. In this case, because of the wide societal benefit associated with having an adequate supply of energy, an argument can be made for the government assuming responsibility for maintaining reversibility and retrievability after a fixed time. A governmental decision (or series of decisions over some number of years) to maintain a high level of retrievability or proceed with repository closure could then be taken in the context of the overall allocation of national resources.

6.3 Organisational arrangements

Organisational arrangements provide for institutional programmes, including arrangements for monitoring, as discussed in Chapter 5. They must also ensure that the technical expertise necessary for retrievability, including capability for dealing with radiological issues, is maintained nationally. This expertise is presently centred in the nuclear industry and associated regulatory and research institutions. In many countries, however, the continuation of the nuclear industry is in doubt, and government intervention may be necessary to ensure that an adequate level of experience is maintained.

6.4 Regulatory arrangements

Current international guidance and national regulations deal mainly with operational safety and the design targets for long-term (post-closure) safety. Relatively little consideration has been given to retrievability/reversibility or its implications. These may include a longer control and monitoring period, a more gradual relinquishment of control, and the associated decision-making system.

In a few countries, the possibility of retrieval is mentioned in legislation or regulation, e.g. in the United States, the Nuclear Waste Policy Act specifies three possibilities under which retrieval may be required. In Finland, legislation states that: “Disposal shall be planned so that retrievability of the waste canisters is maintained in order to provide for such development of technology that makes it a preferred option”. In general, however, guidelines are not given on how any requirement for retrievability should be implemented. Where retrievability is mentioned, there is usually an overriding requirement that any measures to enhance retrievability should not compromise long-term safety.

If national waste management policy requires retrievability, then regulatory requirements should be reviewed to check that they reflect the aspects of maintaining security and safety, including radiological protection and nuclear safeguards, both during possibly prolonged open periods and over the long term. In most countries, separate license applications will have to be made to permit various stages of development, e.g. construction, waste emplacement, backfilling and closure, and the operator’s application should state plans for the implementation of each stage. In this context, the operator may propose (or the regulator may require) retrieval as a fallback step, equivalent to shutdown procedures for nuclear reactors.

7. CONCLUSIONS AND RECOMMENDATIONS

To gain the necessary wide societal confidence in the engineered geologic disposal of long-lived radioactive waste, it is important to show that progress towards disposal will be made by a cautious and flexible step-wise approach, with opportunities for review, taking account of both technical and public interest matters. Flexibility of the decision-making process is not an objective in itself, but is good practice. It can contribute both to technical confidence in the ability to safely manage the waste and also to a confidence in wider audiences that an irreversible decision is not being made. Ultimately, if engineered geologic disposal, either in general or at a specific site, is found to be an unsatisfactory solution, then it must be possible to reverse steps towards disposal, and the waste management community must show that it is ready for this possibility.

Even if choices between management options are left open for future generations, the primary responsibility to solve the problem posed by radioactive waste still rests with the present generation. This generation has to decide on the balance between efforts made to maintain and monitor conditions in a repository and the resulting ease of retrievability. These decisions will have a bearing on the options available to, and burden placed on, future generations. We cannot anticipate the conditions or the ethical and practical judgements that may be made by future generations. Decisions to be taken today must be based on present-day values and understanding of ethical issues and other national concerns. Measures that favour flexibility in decision making are, however, consistent with the ethical principle that the needs and aspirations of future generations should be respected, including their freedom to make their own decisions.

The integration of reversibility in a step-wise repository development programme, which may include measures to enhance the retrievability of waste, presents opportunities to take advantage of advances in scientific knowledge and technology, as well as the ability to respond to changes in national policy, regulations, and social attitudes. Reversibility of decisions and retrievability of the waste must be coupled with other options, however, as reversibility implies reversal to follow some other course, and waste should not be retrieved unless an alternative, more acceptable, waste management solution is available. In particular, retrievability is not introduced to improve the long-term passive safety of a repository and is not a primary goal in waste disposal concepts, but only a preference that favours flexibility. The introduction of measures to facilitate retrievability does not lessen the need for thorough safety assessments and assurance of operational and long-term safety and security of a repository.

Waste retrieval is possible in all geologic formations considered for radioactive waste disposal today, but some disposal concepts may be more easily adapted to allow for more convenient and cost-effective retrieval, e.g., by delaying backfilling of repository access ways for an extended period following waste emplacement. Such adaptations of the repository design or operational plan are also likely to involve a cost. This must be balanced against the value that the additional flexibility gives, whether in terms of technical opportunities or social acceptance.

Retrievability should not be an excuse for indefinite delay of repository development decisions and is not a substitute for a well-designed repository that has a defensible basis for closure. Closure is a significant milestone in the development of a repository from technical, administrative, and social perspectives. It marks the transition from an underground facility from which retrieval may still be contemplated to a final disposal facility. Final closure should be performed when adequate confirmatory data have been collected to provide reasonable assurance that the facility will perform as intended, and public confidence is sufficient to warrant the associated discontinuation of the underground monitoring and increase in the difficulty of retrieval. The likelihood that waste would need to be retrieved after this step would be, thus, very low. Clear plans for repository development, including closure, must be made even if flexibility is allowed to future decision makers in their implementation of the plan.

Largely because of the large margins of passive safety built into an engineered geologic repository, no circumstances have been identified that would require urgent retrieval of waste. Thus, even if a decision was someday made to retrieve waste, there would always be time to implement an orderly programme of waste retrieval, and time to construct any facilities necessary for waste storage prior to investigating alternative disposal routes.

If retrievability is claimed, certain practical requirements must be met to assure its feasibility. The technical complexity and cost of retrieval will tend to increase as progressive steps towards closure are taken. During the waste emplacement period and before extensive placing of backfill, waste retrieval could usually be achieved by the reverse use of emplacement systems. After placing of backfill, special techniques may be necessary to retrieve waste. Special measures would also be necessary to undertake mining and retrieval operations at the high temperatures and radiation levels that will persist around spent fuel and high-level waste containers. R&D should continue in technologies relevant to waste retrieval and, in particular, demonstrations of retrieval technologies should be encouraged in the various national and international research programmes. Such demonstrations contribute to technical confidence in the feasibility of waste retrieval and also to a wider non-technical confidence in the feasibility and the seriousness of the waste management organisations about retrievability.

For waste retrieval to be feasible, institutional arrangements must also be made to ensure that: an appropriate level of technical ability to retrieve is maintained at each stage following waste emplacement; the methods for retrieval are defined, including retrieval under foreseeable component-failure and accident conditions; and periodic evaluations are made of the appropriateness and need to proceed with the next step towards repository closure, maintain at the current step, or reverse a step, including retrieval of the waste if necessary. Monitoring will also be required to verify that the conditions under which retrieval could be performed still exist.

The governmental policy that outlines the principles under which radioactive waste will be managed in a safe, environmentally sound, and cost-effective manner should include an indication of the degree to which retrievability should be considered for different waste types, taking account of possible resource values and other factors. The government also needs to ensure the financial, organisational, and regulatory arrangements to carry through the policy.

The financial implications of reversibility and retrievability include the cost of changing designs to facilitate retrievability and, more significantly, the costs of monitoring, safeguarding, and maintaining the repository for decades, if not centuries, if an extended open period is required. Whereas the nuclear industry can set aside funds for a defined plan of repository development, including a period of monitoring and control, governments may have to take on this responsibility if maintaining retrievability is to become an open-ended commitment. The decision to devote substantial sums of money to maintain retrievability should be taken in the context of the overall allocation of national resources.

The government must also ensure that organisational arrangements are in place to maintain the technical expertise necessary for retrievability, including capability for dealing with radiological issues. This expertise is presently centred in the nuclear industry and associated regulatory and research institutions. In many countries, however, the continuation of the nuclear industry is in doubt, and government intervention may be necessary to ensure that an adequate level of expertise is maintained.

In most countries, regulatory guidelines have not yet been given on how requirements for retrievability, if any, should be implemented. Where retrievability is mentioned, there is usually an overriding requirement that any measures to enhance retrievability should not compromise the passive long-term safety of a repository. If national waste management policy requires retrievability, then regulatory requirements should be reviewed to check that they reflect the aspects of maintaining security and safety, including radiological protection and nuclear safeguards, both during possibly prolonged open periods and over the long term.

In most concepts, waste retrieval will become more technically demanding as stages towards closure, e.g., progressive filling of disposal vaults and access ways and placing of seals, are taken. Although waste retrieval may be possible at all stages, including after closure, it is suggested retrievability should be considered mainly in the period before closure and, for example, R&D should be focussed on the possibilities for retrieval in this period. Similarly, institutional arrangements and plans for retrieval of the waste should be focussed on the period preceding closure. Retrieval after repository closure, although technically possible, will require substantial resources to re-establish above- and below-ground facilities and access to the waste. If the need to reverse course is carefully evaluated with appropriate stakeholders at each stage of repository development, a high level of confidence should be achieved by the time a closure decision is taken that there are no technical or social reasons for waste retrieval.

Reversibility of decisions is increasingly included in the step-wise decision-making process that is foreseen for engineered geologic disposal. The implications of retrievability of the waste within disposal strategies, and the desirability (or not) of including specific measures to enhance retrievability, are currently being considered within the national programmes of several countries. Consensus on the meaning and value of reversibility and retrievability may develop in time and it is hoped that this document will contribute to this development. Still, it must be recognised that for issues such as this, that combine technical, policy, and ethical aspects, the solution adopted in any country must, above all, be fitted to the specific technical disposal system of that country and also be acceptable within the national policy framework.

REFERENCES

EC, 2000. Grupa, J.B., D.H. Dodd, J.-M. Hoorelbeke, B. Mouroux, J.M. Potier, J. Ziegenhagen, J.L. Santiago, J. Alonso, J.J. Fernández, P. Zuidema, I.G. Crossland, B. McKirdy, J. Vrijen, J. Vira, G. Volckaert, T. Papp, and C. Svemar, 2000. *Concerted Action on the Retrievability of Long-lived Radioactive Waste in Deep Underground Repositories*, European Commission Project Report EUR 19145 EN.

IAEA, 1972. *The Structure and Content of Agreements Between the Agency* and *States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*. Information Circular INFCIRC/153 (Corrected). International Atomic Energy Agency, Vienna.

IAEA, 2000. Retrievability of High Level Waste and Spent Nuclear Fuel. Proceedings of an International Seminar organized by the Swedish National Council for Nuclear Waste in co-operation with the IAEA, Saltsjöbaden, Sweden, 24-27 October 1999. IAEA-TECDOC-1187. International Atomic Energy Agency, Vienna.

NEA, 1995. *The Environmental and Ethical Basis of Geological Disposal*: *A Collective Opinion of the NEA Radioactive Waste Management Committee*, Nuclear Energy Agency of the OECD, Paris.

NEA, 1999a. *RWMC Strategic Plan*. Nuclear Energy Agency of the OECD, Paris.

NEA, 1999b. *Confidence in the Long-term Safety of Deep Geological Repositories: Its Development and Communication*. Nuclear Energy Agency of the OECD, Paris.

NEA, 1999c. *Progress Towards Geologic Disposal of Radioactive Waste*: *Where Do We Stand?* Nuclear Energy Agency of the OECD, Paris.

Annex 1

ETHICAL PRINCIPLES UNDERLYING REPOSITORY PLANNING AND DEVELOPMENT[*]

Ethical principles applied to general environmental issues have been debated in both international and national fora. For example, the UNEP Rio Declaration and the UNESCO Declaration are the result of diplomatic and political co-operation among States. A relevant document has been produced by the American National Academy of Public Administration (NAPA) at the request of the United States Department of Energy to study how the public administration could take account of the rights and interests of future generations when making decisions. The Academy proposes an approach based on four principles (see Box 1). It is recognised that each of these principles has its limits. Responsible decision making seeks to achieve a balance between the application of the four principles.

Ethical consideration of the long-term safety implications of radioactive waste disposal involves consideration of responsibilities *vis-à-vis* future generations in a way that is quite unusual and beyond the normal considerations for individuals and sub-groups living today. One important concern is to avoid, or limit, harm to future generations, based on the consideration that these future generations may not have the capability or understanding to take actions to protect themselves. According to this view, the fundamental principles underlying repository planning and development may be summarised as follows:

- The generation producing the waste is responsible for its safe management and the associated costs.
- There is an obligation to protect individuals and the environment both now and in the future.

---

[*] This annex draws on (Pescatore, 1999).

- No moral basis exists for economic discounting of future health and risks of environmental damage.
- Our descendants should not be exposed to risks that we would not accept today. Individuals should be protected at least as well as they are today.
- The safety and security of repositories should not be based on the presumption of a stable social structure for the indefinite future or on a presumption of technological progress.
- Waste should be processed in such a way as not to be a burden for future generations.

Box 1

NAPA PRINCIPLES ON RIGHTS AND INTERESTS OF FUTURE GENERATIONS (NAPA, 1997)

- *The Trustee Principle* – Every generation has obligations as trustee to protect the interests of future generations.
- *The Sustainability Principle* – No generation should deprive future generations of the opportunity for a quality of life comparable to its own.
- *The Chain of Obligation Principle* – Each generation's primary obligation is to provide for the needs of the living and succeeding generations. Near-term concrete hazards have priority over long-term hypothetical hazards.
- *The Precautionary Principle* – Actions that pose a realistic threat of irreversible harm or catastrophic consequences should not be pursued unless there is some countervailing need to benefit either current or future generations.

Although actions by future generations (such as waste retrieval) are not excluded, these principles give no basis for facilitating such actions in repository planning. In this vein, the 1995 RWMC Collective Opinion (NEA, 1995) concluded that the "geological disposal concept does not require deliberate provision for waste retrieval after site closure. Interventions will, in principle, never be needed after the repository closure since the disposal concept requires that the presence of waste may safely be forgotten, after a period of institutional control to prevent early inadvertent intrusion."

The 1995 RWMC Collective Opinion (NEA, 1995) also pointed out that "Retrievability is an important ethical consideration since deep geological disposal should not necessarily be looked at as a totally irreversible process completely foreclosing possible future changes in policy". Indeed, more recent ethical considerations indicate that, in addition to the abovementioned principles, repository planning and development should respect the needs and aspirations of future generations, including the freedom of future generations to make their own decisions:

- Although future generations should not be unduly burdened, we should not unnecessarily limit the capacity of future generations to take over management control, including the ability to recover the waste.
- We are responsible for passing on to future generations our knowledge concerning the risks related to waste.
- There should be enough flexibility in the disposal procedure to allow alternative choices.

These developments are reflected in the international Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (IAEA, 1997). This states one of its objectives as: "to ensure that during all stages of spent fuel and radioactive waste management there are effective defences against potential hazards so that individuals, societies and the environment are protected from harmful effects of ionizing radiation, now and in the future, in such a way that the needs and aspirations of the present generation are met without compromising the ability of future generations to meet their needs and aspirations".

The implication is that, in order to respect the needs and aspirations of future generations, whether near or far into the future, the possibility that they may wish to pursue other options, including retrieval of the waste, should be considered in repository planning. Future generations may, for example, have access to new technologies and may have a different perception of acceptable risk.

For future generations to profit from such flexibility, it must be assumed that a stable society will continue to exist and that:

- they will appreciate the flexibility of the options left open to them;
- they will make good use of these options, and
- they will continue as responsible societies, making judgements according to ethical principles similar to those of today.

These assumptions are, however, optimistic and flexibility may become a burden if it requires maintenance of the knowledge and technical expertise to allow for specific interventions. Furthermore, future generations may make bad, as well as good decisions. Thus, as indicated, for example, by the conclusions of KASAM – the Swedish National Council for Nuclear Waste (SKN, 1988), a balance has to be stuck between the principle of avoiding undue burdens on future generations (Box 2, first point) and the principle of respecting their needs and aspirations (Box 2, second point).

Box 2

THE KASAM PRINCIPLES (SKN, 1988)

- Our generation, which has had the benefit of nuclear energy, must also take the full responsibility for the radioactive waste (nuclear waste and spent nuclear fuel), and not leave an undue burden to coming generation. This also means that a repository shall not be dependent for its long-term safety on monitoring or maintenance by future generations.
- In a world where knowledge is increasing with time, and where value judgements are changing, future generations shall be given the freedom to make their own decisions with regard to utilisation of resources for safety and long-term protection. Furthermore, a repository should not be designed so that it unnecessarily impairs future attempts to retrieve the waste, monitor or repair the repository.

REFERENCES

IAEA, 1997. *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. INFCIRC/546. International Atomic Energy Agency, Vienna.

NAPA, 1997. Deciding for the Future: Balancing Risks, Costs, and Benefits Fairly Across Generations, National Academy of Public Administration, Washington, DC, June.

NEA, 1995. The Environmental and Ethical Basis of Geological Disposal: A Collective Opinion of the NEA Radioactive Waste Management Committee, Nuclear Energy Agency of the OECD, Paris.

PESCATORE, C., 1999. "Long-term Management of Radioactive Waste: Ethics and the Environment". Nuclear Energy Agency of the OECD, Newsletter, Vol. 17, No.1, Paris.

SKN, 1988. Ethical aspects of nuclear waste. Some salient points discussed at a seminar on ethical action in the face of uncertainty in Stockholm, Sweden; September 8-9, 1987, SKN Report 29.

Annex 2

PARTICIPANTS IN THE AD HOC GROUP ON REVERSIBILITY AND RETRIEVABILITY

BROWN, Peter A.	Natural Resources Canada (NRCan), Canada
RUOKOLA, Esko	Finnish Centre for Radiation and Nuclear Safety (STUK), Finland
MOUROUX, Bernard	French Radioactive Waste Management Agency (ANDRA), France
BRENNECKE, Peter	Bundesamt für Strahlenschutz (BfS), Germany
SAKUMA, Hideki	Japan Nuclear Cycle Development Institute (JNC), Japan
DODD, David H.	Radiation and Environment (NRG), The Netherlands
RUIZ LOPEZ, Carmen	Consejo de Seguridad Nuclear (CSN), Spain
TOVERUD, Öivind	Swedish Nuclear Power Inspectorate (SKI), Sweden
ZUIDEMA, Piet	National Cooperative for the Disposal of Radioactive Waste (NAGRA), Switzerland
HARRINGTON, Paul	U.S. Department of Energy (USDOE), United States of America
PESCATORE Claudio	OECD, Nuclear Energy Agency
SUMERLING, Trevor	Safety Assessment Management Ltd., United Kingdom
VON MARAVIC, Henning	European Commission, DG Research, International Organisation

ALSO AVAILABLE

NEA Publications of General Interest

2000 Annual Report (2001) *Free: paper or web.*

NEA News
ISSN 1605-9581 Yearly subscription: € 37 US$ 45 GBP 26 ¥ 4 800

Geologic Disposal of Radioactive Waste in Perspective (2000*)*
ISBN 92-64-18425-2 Price: € 20 US$ 20 GBP 12 ¥ 2 050

Radioactive Waste Management Programmes in OECD/NEA Member countries (1998)
ISBN 92-64-16033-7 Price: € 32 US$ 33 GBP 20 ¥ 4 150

Radioactive Waste Management

Using Thermodynamic Sorption Models for Guiding Radioelement Distribution Coefficient (KD) Investigations – A Status Report (2001)
ISBN 92-64-18679-4 Price: € 50 US$ 45 £ 31 ¥ 5 050

Gas Generation and Migration in Radioactive Waste Disposal – Safety-relevant Issues (2001)
ISBN 92-64-18672-7 Price: € 45 US$ 39 £ 27 ¥ 4 300

Confidence in Models of Radionuclide Transport for Site-specific Assessment (2001)
ISBN 92-64-18620-4 Price: € 96 US$ 84 £ 58 ¥ 9 100

Nuclear Waste Bulletin – Update on Waste Management Policies and Programmes, No 14, 2000 Edition (2001)
ISBN 92-64-18461-9 *Free: paper or web.*

Features, Events and Processes (FEPs) for Geologic Disposal of Radioactive Waste – An International Database (2000)
ISBN 92-64-18514-3 Price: € 25 US$ 24 GBP 15 ¥ 2 900

Regulatory Reviews of Assessments of Deep Geological Repositories – Lessons Learnt (2000)
ISBN 92-64-05886-9 Price: €34 US$ 32 GBP 20 ¥ 3 400

Strategic Areas in Radioactive Waste Management – The Viewpoint and Work Orientations of the NEA Radioactive Waste Management Committee
(2000) *Free: Available on web.*

Stakeholder Confidence and Radioactive Waste Disposal (2000*)*
ISBN 92-64-18277-2 *Free: paper or web.*

The Role of Underground Laboratories in Nuclear Waste Disposal Programmes (2001)
ISBN 92-64-18472-4 *Free: paper or web.*

Order form on reverse side.

ORDER FORM

OECD Nuclear Energy Agency, 12 boulevard des Iles, F-92130 Issy-les-Moulineaux, France
Tel. 33 (0)1 45 24 10 15, Fax 33 (0)1 45 24 11 10

E-mail: nea@nea.fr**, Internet: http://www.nea.fr**

Qty	Title	ISBN	Price	Amount
		Total		

☐ Payment enclosed (cheque or money order payable to OECD Publications).

Charge my credit card ☐ VISA ☐ Mastercard ☐ American Express

(Prices include postage and handling fees).

Card No.	Expiration date	Signature
Name		
Address	Country	
Telephone	Fax	
E-mail		

The NEA wishes to express its gratitude to the Government of Japan
for facilitating the production of this report.

本報告書の作成に関し、日本政府の協力に謝意を表する。

OECD PUBLICATIONS, 2 rue André-Pascal, 75775 PARIS CEDEX 16
Printed in France.