RESULTS OF THE CONCERTED ACTION ON THE RETRIEVABILITY OF LONG LIVED RADIOACTIVE WASTE IN DEEP UNDERGROUND REPOSITORIES

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ABSTRACT

Disposal is generally defined as the emplacement of radioactive waste in a disposal facility without the intention of retrieval, and without reliance on long-term surveillance and maintenance. However, in recent years the issues of surveillance and retrievability have been considered as increasingly important in a number of countries. This has become apparent from, for example, public interaction and consultation. It seems that a staged decision-making process in which decisions are not irrevocable would reassure several stakeholder groups. This requires control and surveillance of the disposal process and the option to be able to reverse to previous stages if desired.

This paper presents the results of a 'Concerted Action' that was carried out as part of the 4th Framework Programme of the European Commission (1). The Concerted Action provided a forum to try to establish a clear interpretation and working definition of retrievability and to compare the approaches being adopted in the different countries. Each participant provided information relating to the national situation. Experts from organisations involved in the development of national disposal concepts for long-lived radioactive waste in nine European countries have participated. Through the use of a common methodology, a number of issues were investigated.

The methodology to discuss retrievability (consisting of a 'working definition' of retrievability' and a common time zone table for the development of a repository) developed within the group of experts is explained in this paper. An overview will be given of the work carried out by the group with respect to the five issues selected for investigation: retrievability and design, retrievability and safety, the socio-political aspects of retrievability, retrievability and monitoring and retrievability and safeguards. Finally the conclusions reached by the group are outlined.

INTRODUCTION

Most countries with a nuclear programme have performed studies for the disposal of long-lived radioactive waste. The development and the demonstration of the technology for disposal and the decision/licensing process is progressing, but in many countries it may still take several decades before disposal facilities for long-lived wastes will become operational.

The disposal concepts, under development in the different European countries, are based on their nuclear programmes, their national geological options and their waste management strategies. Therefore, there are substantial differences in concept and in detail from country to country. In order to achieve a common understanding of the issue of retrievability and its implications experts from nine European countries have been brought together to discuss the important issues.

It has become obvious that a strong preference towards maintaining or even enhancing the potential for retrieval, i.e. retrievability, of disposed radioactive waste is developing. In some cases this preference occurred during the process for siting and licensing a final repository for deep underground disposal of long-lived radioactive waste.

The arguments for retrievability that have been put forward represent quite different viewpoints and address quite different aspects. The most frequently used arguments are:

1. Safety and operational arguments
   - Disposal should be reversible in case something goes wrong with the emplacement of a package.
   - Retrieval of a waste package might be necessary in case a waste package malfunctions during or after emplacement.
   - Retrieval of waste packages might be necessary if the repository appears to be malfunctioning at a later stage.

2. Licensing arguments
   - Retrievability should be included in order to facilitate a staged decision and licensing process.

3. Societal arguments
   - Radioactive waste may contain potentially useful materials, which might become valuable in the future. It could be the wish of a future society to utilise such a resource.
   - Disposal decisions should not be irrevocable, in order to provide future generations the option to take their own decisions.
   - >From a sustainable society viewpoint, high priority is given to reuse of materials and to minimisation of the quantity of waste that needs to be disposed of. Views and/or technology for reuse of materials may be different in future.
   - The precautionary approach and the recognition of uncertainty speak in favour of retrievability.

4. Waste management arguments
   - Future new technology or scientific knowledge could – based on re-evaluation of the cost/benefit balance – motivate modifications in earlier disposal, or retrieval of disposed waste packages.
   - A repository that includes design features to keep the waste packages retrievable could offer better possibilities for control and surveillance of the waste after disposal.

5. Public acceptance arguments
   - A disposal concept might be better appreciated, when key decisions are reversible. Including retrievability might enhance the acceptance of geological disposal.

Implementation of retrievability will require (re-)consideration of design and design complexity, operational aspects, safety aspects, safeguards, costs, etc. This paper touches upon design and operation, safety, societal aspects, Nuclear Materials Safeguards, and monitoring.

A METHODOLOGY FOR DISCUSSING RETRIEVABILITY

Discussions on retrievability often take place at a conceptual level in which retrievability is broadly considered as an option, which makes it possible for current and future generations to reverse a decision to place waste packages in a repository, should they find that desirable. In order to structure the discussions within the Concerted Action a methodology consisting of a 'working definition' of retrievability and a common time zone table was developed.

The following working definition of retrievability was adopted:

The ability provided by the repository system, to retrieve waste packages for whatever reason retrieval might be wanted.

Under this definition retrievability is controlled by the following three basic conditions:

- Accessibility to the waste packages
- Confinement of the waste to the waste packages
- Technical feasibility of retrieving the waste packages

The design, construction, operation, closure and post-closure activities involved in the development of a deep underground repository were broken down into 13 different time zones. Table 1 gives the definitions of these time zones.

Table 1 Time zone definitions

1.	Interim storage at or near the surface
2.	Design and construction of the repository and completion of the first disposal cells
3.	Period of filling one disposal cell with waste package(s)
4.	Period of keeping the package accessible before backfilling and sealing the disposal cell
5.	Backfilling and sealing of the disposal cell
6.	Period of keeping the backfilled and sealed disposal cell accessible before backfilling the depositing tunnel
7.	Backfilling the depositing tunnel
8.	Period of keeping the access tunnel open, after having backfilled the depositing tunnel
9.	Backfilling of the access tunnel
10.	Period of keeping the access shafts open, after having backfilled the access tunnel
11.	Backfilling and sealing the shafts
12.	Post-closure phase with institutional control
13.	Post-closure phase without institutional control.

With respect to individual waste packages these time zones can be defined as either passive or active. In a passive period (such as the period after which a package has been placed in a disposal cell but before the cell has been backfilled) the three basic conditions for retrieval of that waste package essentially do not change. In an active period (such as the backfilling and sealing of a disposal cell) one or more of these three basic conditions are changed.

RETRIEVABILITY AND DESIGN

For all examined national concepts it can be stated that the effort needed to retrieve the waste packages increases as one progresses through the different time zones of repository development. Up to a certain stage in the development of the repository (and depending upon the specific concept), retrieval is technically relatively straightforward and can often be performed with equipment that is the same as, or similar to, that used to put the waste in place. At later stages, after successively more backfilling and seals have been put in place, specific technology may be needed either for the removal of this backfill or for the retrieval of the waste package itself. Although the effort needed in any time zone may be different for different disposal concepts, it was agreed that, in general, the existing disposal concepts are retrievable until well into the post-closure stage.

The retrievability of the current concepts can be enhanced by design modifications. These include the use of easily removable backfill and sealing materials, modification of the repository layout and the use of a liner between the waste package and first engineered barrier to allow easy retrieval. A second category of measures by which retrievability can be enhanced (or at least maintained at a certain level) involves the extension of the duration of passive time zones. So, by postponing measures that would reduce the accessibility of the waste packages (e.g. backfilling or sealing), easy retrievability may be maintained for a longer period of time. Extension of the duration of a passive time zone by a period similar to the originally planned duration of that time zone is generally considered not to require modifications to the repository design or to the technology to retrieve waste packages in that time-zone. However, for longer extensions it is likely that some degree of modification may be needed.

RETRIEVABILITY AND SAFETY

As stated above the retrievability of the current concepts can be enhanced by design modification measures or by postponing the closure of the repository. There is general agreement that any such

measures taken should not compromise the ability of a particular disposal concept to comply with the relevant criteria for operational or long-term safety. This would have to be demonstrated for a specific concept through a systematic analysis of the relevant issues for that concept.

For a number of concepts changes in repository design, such as modification of the disposal cell design to allow easy access to the waste packages for longer periods of time or to ensure the stability of the underground structures for longer times, are being considered to enhance retrievability. The current impression is that the impact of such design adjustments on the repository long-term safety and on the operational safety will be not significant.

Other design features that would enhance retrievability (e.g. removable backfill, high integrity containers) are not expected to have any detrimental effect on post-closure safety.

Postponing the closure of the repository or parts of it could have implications for both the operational and long-term safety. For a specific concept the following effects would have to be analysed with respect to long-term safety:

- Effects arising from prolonged repository ventilation and prolonged geosphere drainage.
- Effects connected with long-term stability of the host rock and durability of rock supports and repository seals.
- The risks associated with misuse or abandonment of the repository during the extended operational period - which highlights the need for a firm and sustainable control.

An analysis of the implications for operational safety should include the conventional and radiological risks for workers and the potential impacts on the public and the environment. There exists a general agreement that appropriate design measures and operational procedures can ensure operational safety.

SOCIO-POLITICAL ASPECTS OF RETRIEVABILITY

Many programmes have chosen a staged approach to the geological disposal of radioactive waste as the preferred option. It is intended to implement the disposal facility in such a manner that it provides flexibility to decide if and when it is appropriate to move from one stage to the next. Retrievability is an essential element of such a staged approach to deep disposal, in the sense that it allows to reverse one or more steps in the disposal process to be reversed and, if necessary, allows waste packages to be retrieved from the underground facility. In this sense retrievability is an important factor in the socio-political decision-making process.

Retrievability is also often considered to be part of an ethically responsible approach to waste management. However, although ethical considerations may be in favour of some level of reversibility in waste management decisions, they do not give any direct answer to the question of what level of retrievability one should incorporate into the various stages of implementation. Even if we leave options open for future generations, it is the present generation of implementers that has to decide on the ease of retrieval, the need for surveillance, maintenance and safety. This will require some judgements that will inevitably affect future generations.

RETRIEVABILITY AND MONITORING

A repository development programme is likely to involve a wide-ranging programme of monitoring. The aims of such monitoring will be diverse but, broadly speaking, the programme will be designed to demonstrate compliance with national or international regulations and to assist in the societal decision-making process.

Whatever the reasons for monitoring, if the monitoring data were to indicate a failure to reach the required standards, or if the data were to indicate that the repository systems behave in an

unacceptable way, this could bring about a need for corrective action. The ultimate corrective action would be waste retrieval. From this viewpoint retrievability is seen as secondary to monitoring.

There are, of course, reasons for providing retrievability that are unconnected to monitoring, for example to provide options for future generations. Here retrievability, rather that monitoring, is the primary issue with monitoring serving retrievability rather than the reverse. From this viewpoint there appear to be three ways in which monitoring can serve retrievability:

- First, by monitoring a range of parameters relevant to package integrity and waste accessibility, monitoring may be used to establish that the waste packages are retrievable, as well as how easy or complicated actual retrieval might be.
- Second, monitoring might be used to provide data to make it possible to take a decision to postpone closure of cells, depositing tunnels, access tunnels and access shafts, depending on the current time-zone.
- Third, monitoring may be used to demonstrate that the systems installed to allow reversibility of operations remain fit for that purpose.

RETRIEVABILITY AND NUCLEAR MATERIALS SAFEGUARDS

Repositories that will be used for the disposal of significant amounts of fissile materials are expected to be subject to international Nuclear Materials Safeguards. The current position of both Euratom and the IAEA is that spent fuel will remain subject to Safeguards measures as long as the Safeguards agreement itself remains in force and that the closure of a geological repository does not justify the termination of applicable Safeguards agreements.

At present considerable international activity is going on to formulate detailed requirements for practical Safeguards implementation for geological repositories. A central consideration is the 'timeliness of detection of diversion' – that is the Safeguards should ensure that countermeasures can be taken before the proliferator's goals are achieved. Any measures taken to enhance retrievability (i.e. which facilitate the retrieval of spent fuel for whatever reason) may therefore have implications for practical Safeguards implementation. In particular, keeping the access tunnels or shafts open for a prolonged period of time could imply the continuation of relatively intense Safeguards measures compared with what is needed for a backfilled and sealed repository.

CONCLUSIONS

The Concerted Action has resulted in a clear interpretation and working definition of the concept of retrievability. This has lead to a more common understanding of the meaning of retrievability and to a better understanding of how and to what extent retrievability has been or could be incorporated into the different disposal concepts.

The disposal process for long-lived radioactive waste has been divided into time-zones ranging from interim surface storage through the post-closure period. This methodology has enabled a structured approach, which has led to a better understanding of how retrievability varies between different disposal concepts and between time-zones within each disposal concept.

For most disposal concepts, confinement of the waste to the waste packages is unlikely to change significantly for hundreds or thousands of years. Waste packages become less accessible as the disposal process progresses through the subsequent stages in the disposal process (time-zones). Often a different technology for the retrieval of waste packages is needed when advancing from one time zone to the next one.

Measures to enhance retrievability should not compromise the ability of the disposal concept to comply with the criteria for operational safety or for long-term safety of the repository. Within this restriction, a number of organisations are examining ways in which retrievability can be enhanced. In

general, the design changes being considered are aimed at keeping easy access to waste packages for longer periods. One of the possible ways to achieve this is postponing backfilling, closure and sealing steps to a (much) later moment in the disposal process. Such measures could however result in an increased possibility of abandonment i.e. failure to close and seal the repository properly. This confirms the need to establish a strong institutional control during such periods.

Ethical considerations may thus be in favour of some level of reversibility in waste management decisions. However, they do not give any direct answer to the question of what level of retrievability one should incorporate into the various stages of implementation. Even if options are left open for future generations, it is the present generation of implementers that has to decide on the balance between ease of retrieval and the need for surveillance, maintenance and safety. This will require some judgements that will inevitably affect future generations.

Implications of retrievability on monitoring and on Nuclear Materials Safeguards have been examined. The implications will vary significantly between concepts. In all countries, participating in this Concerted Action, monitoring programmes are still under development at this moment.

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The participatin g organisations were NRG (NL); ANDRA (F), DBE (DE), ENRESA (E), NAGRA (CH), NIREX (UK), KARUWEEG (NL), POSIVA (FIN), SCK-CEN (B), SKB (S).

OUTLOOK

The topic of retrievability is currently receiving a lot of attention both nationally (e.g. at the Swedish National Council for Nuclear Waste, KASAM, and at the U.S Board on Radioactive Waste Management of the National Research Council) and internationally (e.g. at an ad-hoc group under auspices of the OECD NEA Radioactive Waste Management Committee (RWMC) and from the IAEA).

It is emphasised that the views expressed in this paper do not necessarily represent the views of the governments of the countries involved or of the organisations responsible for radioactive waste management.

REFERENCES

1. J.B. GRUPA, D.H DODD, J.P. HOORELBEEKE, J. ZIEGENHAGEN, J-L. SANTIAGO, P. ZUIDEMA, I. CROSSLAND, J. VRIJEN, J. VIRA, G. VOLCKAERT, T. PAPP, "Results of the Concerted Action on the Retrievability of Long Lived Radioactive Waste in Deep Underground Repositories," EUR 19145, European Commission (2000).