Preface

This report is the seventh in a series of state-of-the-art reports on nuclear waste, officially submitted by KASAM to the Swedish Government. Previous reports have been submitted in 1986 (ISBN 91-38 09767-2), in 1987 (ISBN 91-38-009938-1), in 1989 (ISBN 91-38-12264-2), in 1992 (ISBN 91-38-12749-0), in 1995 (ISBN 91-38-13952-9, SOU 1995:50) and in 1998 (ISBN 91-38-20933-0, SOU 1998:68).

As usual, KASAM attempts to examine a number of topical issues in the debate which should be presented so that they can be easily understood. Besides the Swedish Government, the reports are aimed at politicians and communities which are involved in the siting of a repository for spent nuclear fuel, environmental organizations and other interested parties.

Since there is also a considerable interest in nuclear waste issues abroad, and much of the discussion is of common interest to many nuclear power-producing countries, this report has been translated into English. The 1998 report is also available in English, whereas earlier reports have been published in Swedish only.

KASAM, the Swedish National Council for Nuclear Waste, spring 2001:

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KASAM herewith submits its state-of-the-art report for 2001 to the Government.

Stockholm, May, 2001

Camilla Odhnoff
Chairman, KASAM

Contents

Summary

The search for a suitable site for a repository for spent nuclear fuel is an issue that, to a large degree, involves both politicians and the general public. This particularly applies to the municipalities which are directly affected by the siting process. **Chapter 1** provides a description of how, in three of the feasibility study municipalities, the interest and involvement of the local communities have been stimulated. It is worth emphasizing that the municipalities have chosen different ways of achieving a dialogue with the public. This is the result of the fact that the municipalities and municipal governments have considerable scope for taking different initiatives in their own municipalities.

Chapter 2 deals with the issue of retrievability of nuclear waste from a deep geological repository. This chapter is largely based on material presented at an international seminar for experts that was held at Saltsjöbaden in October 1999. The seminar was organized by KASAM together with the International Atomic Energy Agency (IAEA), Vienna. The background to the seminar was that, in recent years, KASAM had noted an increased interest in the question of the retrievability of nuclear waste from geological repositories. The growing interest does not primarily come from the engineering and scientific community. Instead, it has its roots in a doubt or reluctance from parts of the general public, who do not accept the idea that a repository can be abandoned after closure and no longer need human supervision. Views have also been expressed that today's waste could be viewed by subsequent generations,

with improved knowledge and a greater imagination, as a raw material for not yet developed processes. Therefore, many people believe that the repository must be supervised, at least for a period, and that it must be possible to retrieve the deposited material, if wished. In some countries, requirements on retrievability are already included in laws and ordinances, while in other countries, more of a "wait-and-see" approach is adopted. For many of the system solutions discussed in different countries, the retrievability requirement does not entail any essential difficulty, since many systems, such as the proposed KBS-3 system in Sweden, are based on a successive process, achieved in stages, and where each stage can be reversed.

Chapter 3 provides a description of the Swedish bedrock and properties, aimed at non-experts. This subject is of particular interest, since Swedish bedrock has for some time been considered to be a feasible geological environment for eventually hosting a repository for spent nuclear fuel. Most of the Swedish bedrock is 1,500 – 2,000 million years old. This can be viewed in relation to the age of the Earth, which is about 4,600 million years old. Over thousands of years, the bedrock has been exposed to different types of influences, including glaciations, which have caused fractures in the rock (a separate chapter was devoted to fractures in the bedrock in KASAM's previous state-of-the-art report, SOU 1998:68). In chapter 3, the stability of a repository in the bedrock is discussed from a geological perspective.

Chapter 4 presents an analysis of current knowledge about groundwater in crystalline bedrock. The groundwater is the underground part of the natural water cycle. Groundwater volumes, composition, flow rates and flow paths are of central importance to the final disposal of nuclear waste, in the short-term perspective when the repository is being constructed and in the long-term perspective, when the conditions in the bedrock – in connection with canister damage – are of importance for the dissolution and migration of various radionuclides to the biosphere. In this chapter, special interest is devated to the importance of the soil layer for groundwater transport in the bedrock, the mixture of groundwater of varying chemical composition, origins and ages, the occurrence of bacteria at great depths as well as the development and usefulness of different models for understanding and calculating groundwater flow and radionuclide transport in the bedrock.

Bentonite, which plays an important role in the proposed KBS-3 concept is a type of clay. The intention is to surround each individual copper canister with bentonite when it is placed in the deposition hole in the bedrock. The bentonite fulfills many functions. One is to prevent water from reaching the canister and another is to prevent or retard the outflow of water which may contain radioactive substances, following canister damage. The bentonite must also act as a "trap" for bacteria which could otherwise cause copper corrosion. The bentonite must also act as a buffering cushion between the canister and the rock, absorbing minor rock movements and, thereby, preventing canister damage. In **Chapter 5**, an evaluation of the role of the bentonite is presented and a physical and, above all, chemical explanation is provided for bentonite performance and properties. Certain critical properties are identified and, in some cases, additional studies are proposed in order to improve our understanding of this fascinating and interesting clay.

Chapter 6 gives an insight into the problem of extrapolating the properties of a material over a period of time, the length of which exceeds the time during which actual long-term tests can be conducted in a laboratory. The extrapolation of material data from laboratory experiments is a major scientific challenge when it comes to the canister that SKB is planning to use for the final disposal of spent nuclear fuel. The outer shell of the canister, which is expected to be manufactured from pure copper, will be exposed to active corrosion and creep for several hundred years in the beginning of the final disposal period. In relation to the long future of the repository, this is a very short time but, nevertheless, a very long time compared with the time in which materials investigations can be conducted in laboratories.

A fundamental idea behind the proposed KBS-3 concept for the final disposal of nuclear waste is that the waste canister should be intact and contain the radioactive waste for as long as it can present a danger to mankind, animals and the environment. However, the analysis also includes different scenarios describing what would happen if a hole should form in one or more canisters for any reason (manufacturing defects, corrosion or other damage), long before this is expected. In order to assess the impact of such events, it must be possible to calculate how the radioactive substances leak out of the canister, through the bentonite and how they are then transported through the bedrock. Radionuclide transport is expected to occur very slowly and most of the radioactive substances will adhere to surfaces along the way (in the bentonite or the bedrock). The radioactive substances that reach the biosphere, where man, animals and plants live, are particularly important since they could harm living creatures. To understand the link between a possible radioactive release which reaches the groundwater or ground surface and the radiation doses that humans and animals could be exposed to, models of the biosphere must be developed. An overview of different types of biosphere models is presented in **Chapter 7.**

The final chapter, **Chapter 8,** provides an overview of how the nuclear waste issue and nuclear waste are handled in a number of countries and describes the work being conducted within this area by a number of international organizations, the IAEA and OECD/NEA, as well as within the EU. This chapter is more comprehensive and detailed than in previous state-of-the-art reports. A consistent trend is that greater weight is given to non-technical issues, such as the structure of the decision-making process, public acceptance, retrievability of the waste etc. in both national and international contexts.

1 Feasibility study municipalities in dialogue with the public: The examples of Nyköping, Oskarshamn and Tierp[1,2]

1.1 Introduction

The construction of a repository for spent nuclear fuel has a tangible local dimension. It is not enough for the nuclear power industry to be able to develop a method that the competent regulatory authorities and Government consider to be sufficiently safe and for the industry to propose a site that these consider to be suitable. The general public must also have confidence in the process that results in the decision. Ultimately, the general public must also have confidence in the solution to the final disposal issue that society has decided upon. This especially applies to public groups that are particularly affected by the issue, namely, those living in the part of Sweden (region, municipality, neighbourhood or vicinity) where it is intended that a repository should be built. It can be said that government

[1] This chapter was written by Director General, Olof Söderberg, expert adviser of KASAM and also the Special Advisor on Nuclear Waste Disposal, Ministry of the Environment, Sweden. Much of the information in this chapter was presented at an OECD/NEA Workshop on Investing in Trust – Nuclear Regulators and the Public (Paris, November 29 – December 1, 2000).

[2] During the period of 1995 – 2000, SKB conducted feasibility studies in the municipalities of Nyköping, Östhammar and Oskarshamn. During the period of 1998 – 2000, SKB also conducted feasibility studies in the municipalities of Tierp, Hultsfred and Älvkarleby. These six municipalities, located in three different counties (Uppsala, Södermanland and Kalmar), are known as the feasibility study municipalities. In the early nineties, SKB also conducted feasibility studies in the municipalities of Storuman and Malå (located in northern Sweden). Municipal referenda were held in 1995 and 1997, respectively, and resulted in majority votes against further investigations in these two municipalities.

and regulatory decisions do not only have to meet legal requirements, they must also have democratic legitimacy.

During the nineties, the site selection process has successively become more distinct. This has occurred through an interaction between the municipalities concerned, the Swedish Nuclear Fuel and Waste Management Co (SKB), the regulatory authorities and the Government. The new regulations of the Environmental Code (1998:808) have also helped to provide greater clarity.

This chapter focuses on how the locally elected political leadership of three of the feasibility study municipalities – Nyköping, Oskarshamn and Tierp – have tried to ensure that future decisions made by these municipalities are based on adequate knowledge and to ensure that elected municipal representatives reflect the opinion of the citizens. Due to the limited space available here, this discussion focuses on three municipalities. However, the three municipalities illustrate three different ways of dealing with the issue.[3] The work presented here is based on events occurring from the mid-nineties up to mid-November 2000, namely, the time when SKB announced its proposal for site investigations (see below)

Between 2006 and 2008, SKB plans to submit an application to the Government and obtain a government decision for a licence, under the Environmental Code and the Act (1984:3) on Nuclear Activities to, at a certain site in Sweden, start the construction of a repository[4] for spent nuclear fuel. The ultimate choice of a

[3] A broader analysis, including the municipalities of Hultsfred, Älvkarleby and Östhammar will be provided in a report to be published by the Special Advisor on Nuclear Waste Disposal (M 1999:A) in 2002. The report will deal with the work within all of the feasibility study municipalities and county administrative boards concerned and the intention is to cover the development of the process until the spring of 2001.

[4] Nowadays, in most contexts, SKB uses the term "deep repository". This term is not used in legal acts and other legislation. Instead, such instruments refer to "final disposal". The regulatory authorities and the Government aim to consistently use the term "final disposal" or "repository" to designate the facility to be constructed. Even if a "deep repository" is intended (and is designed) to be the final site where the spent nuclear fuel will be deposited ("repository"), SKB's terminology implies that mankind will be able, in the foreseeable future and for some reason, to retrieve the spent nuclear fuel deposited in the

repository site will be based on *feasibility studies* in 5–10 municipalities, on *site investigations* at a minimum of two sites and on a *detailed characterization* at a minimum of one site. A government decision of 1995 states that SKB must apply for permission from the Government to conduct the detailed characterization, since this "is a stage in the construction of a nuclear facility which is intended to be a repository for nuclear fuel and nuclear waste".[5]

During the nineties, it has been generally understood that municipalities affected by the site selection work have a special status in the decision-making process. Vital decisions cannot be made without public insight and the participation of the municipalities' democratically-elected representatives. This unique position is reflected in the regulations of the Environmental Code on consultations with the municipality – and the concerned local population – in order to prepare the Environmental Impact Statements (EIS) and other documents to be used as a basis for decision-making.

SKB's site selection work is based on the assumption that it is possible to find a site that fulfills regulatory safety requirements for a repository and that this site is suitable for industrial establishment as well as located in a municipality where the public is not negative to the construction of such a facility.

The applicable legislation does not require that SKB should have the permission of the state or the municipality to conduct feasibility studies or site investigations. Licensing under law is only needed to conduct a detailed characterization at a particular site. However, SKB's work on feasibility studies and site investigations, assumes that the municipality, in some way, has given its consent for these studies and investigations.

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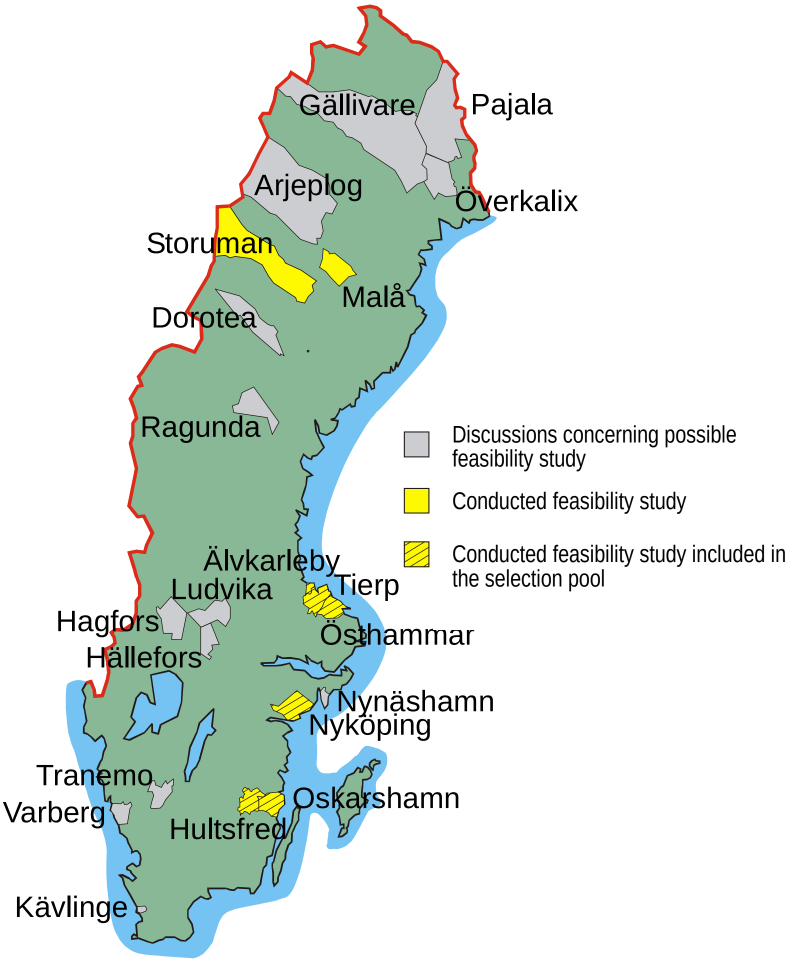
repository. The term "deep repository" also denotes the construction of the repository at considerable depths (400 – 700 meters) in the bedrock.

[5] Government decision (Ministry of the Environment) of May 18, 1995 (Supplement to the Programme for Research etc. concerning the Handling and Final Disposal of Nuclear Waste etc.)

Nuclear activities are already established in the municipalities of Nyköping, Oskarshamn and Östhammar. Based on general studies conducted on Swedish bedrock, SKB established contact, in 1995[6] with the three municipalities discussed in this chapter and others and requested permission to conduct feasibility studies there. All three municipalities gave some form of positive answer. In the case of Oskarshamn, this was after almost one year of considerable deliberation. A few years later, SKB noted that several municipalities were interested in having feasibility studies conducted within their own municipalities. In the light of the general geological studies commissioned by SKB, the outcome was a "Yes" to participation in feasibility studies by Östhammar's northwestern neighbouring municipalities, Tierp, in 1998, and Älvkarleby, in 1999, as well as by Oskarshamn's western neighbouring municipality, Hultsfred in 1999. The map of Sweden on the following page shows the municipalities where SKB has held in-depth discussions[7].

[6] At that time, the Government had stated that it expected SKB to base a future application to construct a repository for spent nuclear fuel on 5–10 feasibility studies, at least two site investigations and one detailed characterization.
[7] SKB has publicly stated that it had in-depth discussions concerning the possibility of conducting feasibility studies with the following municipalities in 1995 (in addition to the above mentioned eight): Arjeplog, Dorotea, Gällivare, Hagfors, Hällefors, Ludvika, Nynäshamn, Ragunda, Pajala, Tranemo, Varberg and Överkalix.

Municipalities, involved in in-depth discussions with SKB concerning possible feasibility studies



Source: SKB

Based on the result of the feasibility studies and on other information, SKB announced, on November 16, 2000, that the company wished to conduct site investigations, including exploratory drilling in the municipalities of Oskarshamn, Östhammar and Tierp. SKB's plans also include a closer investigation of how transportation to a repository in the municipality of Tierp can be arranged via Skutskär (municipality of Älvkarleby) and how transportation can be arranged to a repository within the municipality of Nyköping via Oxelösund. However, exploratory drilling within the municipalities of Älvkarleby and Nyköping will not be conducted. SKB assumes that the municipalities concerned can state their positions on the company's plans by the end of 2001.

Municipalities affected by the studies conducted by SKB in order to find a site for a repository for spent nuclear fuel can obtain financial support from the state from the Nuclear Waste Fund.[8] Under the basic regulation, the Swedish Nuclear Power Inspectorate can grant compensation for a maximum of SEK 2 million per year and municipality.[9] The amount may be used by the municipality for information that the municipality itself provides to its own residents and to improve knowledge (competence development), especially among those who are elected to represent the municipality on this issue. Competence development includes measures to stimulate the general debate on all issues relating to the final disposal of nuclear waste. Municipalities are allowed to use funds from these contribution to provide financial support for activities conducted by groups of citizens who are particularly involved in related issues, such as opinion groups who are critical to SKB's activities.

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[8] The nuclear power companies are obliged to pay a certain fee per kWh of generated electricity. These fees are accumulated in the Nuclear Waste Fund. The assets of this state Fund are intended to cover all of the costs of the handling and final disposal of the spent nuclear fuel and of decommissioning the nuclear power reactors.

[9] In addition, the Government can grant further compensation. This has been done through government decisions in November 2000 with respect to the municipalities of Hultsfred, Oskarshamn, Tierp and Älvkarleby.

1.2 A problem?

In a representative democracy such as Sweden, with a high voting participation, it may seem to be self-evident that the municipal councillors and municipal board should be regarded as legitimate representatives of the municipality and, thereby, of the local population. However, is this "formal" approach enough when it is a question of deciding on issues relating to the siting of a repository for spent nuclear fuel? How do the representatives of the municipal council who have been elected by the local population ensure that the contact between themselves and the population is such that the decisions made by them reflect the predominant opinion of the local electorate on this particular issue? And how do these elected representatives thereby contribute to creating and maintaining trust in the democratic decision-making process? Let us assume that, alongside the established political parties, there are also groups of citizens who claim that they reflect a truer picture of public opinion than the local politicians appointed in the general elections, namely, within the framework of the democratic and representative system. How do the local politicians handle such a situation? What conclusions could SKB come to if this situation arises?

The municipalities of Nyköping and Oskarshamn have been facing these issues since 1995. In the case of the municipality of Tierp, during the second half of 1998, the municipality had to select a strategy for participating in site selection work and to, immediately afterwards, implement this strategy.

1.3 Interaction between municipal representatives and the public[10]

1.3.1 Nyköping

Nyköping was one of the municipalities with nuclear activities that was contacted by SKB in spring 1995 (cf Section 1.1). The reaction of the local politicians can be summarized in the following way. There are no legal regulations requiring SKB to request permission from the municipality or government authorities to conduct a feasibility study. For this reason, there is no reason for the municipal council or municipal councillors to, at this stage, handle or discuss the issue. At the same time, the municipality's representatives informed SKB that they were not negative to the company's plans. If SKB wanted to conduct the feasibility study, the municipality planned to set up some form of a working group which would follow and review SKB's work as well as provide SKB with information. The municipality's reaction can, therefore, be characterized as a *passive consent.*

The municipality established its own feasibility study organization, which initially consisted of an *Information and Review Group,* comprising representatives of each political party represented on the council. The task of the group is to represent the municipality in dealings with SKB. A representative of the largest political party chairs the group. The chairman has been given a kind of *political responsibility* for the municipal handling of the matter. Early in 1996, a *Reference Group* was also set up. The chairman of the Information and Review Group was also the

[10] The interaction described in this section is designed, in practice, to also meet the requirements of the European Council Directive 85/337/EEC, amended through Directive 97/11/EC) and those of the Aarhus Convention (ECE/ECP/43; Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters). The Convention has been signed by Sweden and 34 other states as well as the EU, but has not yet been ratified by Sweden. No official Swedish translation has been published, although a detailed description of the content of the Convention is available in Swedish in two papers written by Dr. Jonas Ebbesson.

chairman of the Reference Group. Representatives from twenty associations and organizations in the municipality involved in local nature and culture preservation activities as well as representatives from business and trade unions were invited to participate in the Reference Group.

The representatives of almost all of the parties in Nyköping largely agreed that this was a suitable method of handling the issue. However, criticism was expressed by a minority comprising representatives from the Green Party and the Left Party.

SKB completed and successively published different background reports which were presented and discussed by both the Information and Review Group and by the Reference Group. A preliminary final report on the feasibility study was completed in May 1997. SKB was given the opportunity to present the report at one of the municipal board's meetings. At that presentation, only a few questions were raised by the councillors.

SKB's aim in first preparing a preliminary version of the feasibility study reports was to provide the municipality and public with an opportunity to express their views before a final report was prepared. In December 1999, more than two years later, the municipality decided on its statement of opinion. SKB's final version of the feasibility study report was presented at the beginning of November 2000.

Attendance of meetings of the Reference Group was low. In late 1996, two of the most critical participants decided to leave the Group claiming that participation was meaningless, since the elected politicians of the municipality did not take their arguments seriously. Meetings of the Reference Group were rare. However, recently, initiatives have been taken to revitalize the Group.

The Information and Review Group played a key role in the contacts between the municipality and SKB. Municipal staff provided secretariat services to the Group. When SKB's preliminary feasibility study report was presented in May 1997, the

Information and Review Group decided to give a few independent consulting companies the task of reviewing the report. The consultants' review was completed at the end of 1997. The consultants found that SKB's preliminary feasibility study report was of a high professional standard, but that certain issues should be studied further.

SKB had originally counted on being able to prepare a final feasibility study report in summer 1998. However, the Information and Review Group considered it necessary to obtain information for the municipality's decision through a broad review process. Political parties, organizations, associations and companies within the municipality, neighbouring municipalities and some government authorities at a regional level were given the opportunity to state their opinions. The public was also encouraged to do so. It took just over a year to implement this review process. It then took almost another year for the Information and Review Group to formulate a statement of opinion which, in December 1999, was also the municipal board's statement of opinion. The statement required that, among other things, SKB should describe in greater detail other siting alternatives in the municipality besides the Studsvik area.

1.3.2 Oskarshamn

1.3.2.1 A special position with regard to nuclear waste

When SKB contacted the municipality of Oskarshamn in 1995, the locally elected political leadership realized that it had to adopt a position in the light of certain conditions which made the municipality unique in Sweden. The prime conditions were:

- The municipality had, already in 1978, allowed SKB to construct the Central Interim Storage Facility for Spent Nuclear Fuel (CLAB) near to the nuclear power plant located on the Simpevarp peninsula (CLAB has been in operation since 1985);

- At the end of the eighties, the municipality had allowed SKB to construct the underground Äspö Hard Rock Laboratory on the Simpevarp peninsula. However, this was under the condition that the Laboratory would never be used as a repository for nuclear waste;
- In 1992, SKB had presented plans to expand CLAB and to construct an encapsulation plant next to CLAB.

The plans to expand CLAB and to construct an encapsulation plant led the municipality to the conclusion that municipal competence in the nuclear waste management area would have to be developed so that the municipality could participate on an equal footing in the licensing of these projects. The municipal representatives felt that, at least, they should be able to detect weaknesses in various arguments and claims that the industry might put forward. After an application was submitted, the Government granted funds in 1994 for competence development and the municipality started the Local Competence Development Project (LKO Project).

From the early eighties, Environmental Impact Assessments (EIA) were increasingly demanded in connection with major construction projects. Formal regulations requiring the preparation of Environmental Impact Statements (EIS) were introduced in 1991 in the Natural Resources Act which was applicable at that time. Of particular interest in this context was the basic approach that the proponent of a large project would be obliged to consult with those affected by the project and take their views into consideration already at the planning stage. The locally elected political leadership felt that the new legislation should be used to ensure that the municipality gained full insight into SKB's plans and the possibility of affecting these plans.

In 1994, the municipality took the initiative and formed a local/regional body called the *EIA Forum for CLAB and the*

Encapsulation Plant.[11] The chairman was a senior civil servant from the County Administration in Kalmar and the County Administrative Board provided secretarial services. The EIA Forum also included municipal representatives, representatives from SKB, the Swedish Nuclear Power Inspectorate and the Swedish Radiation Protection Institute. The rules of procedure for the Forum stated that the purpose of the Forum was to achieve the mutual exchange of information and to ensure that the basis for the EIS that SKB was to prepare would be as sound as possible. The key concept was openness. It was also established that the Forum would have no decision-making authority and that the participants would not be bound by any conclusions drawn by the Forum.

1.3.2.2 Interaction

As a result of the municipality's history of nuclear activities (cf 1.3.2.1), both elected politicians and staff were considerably knowledgeable about the nuclear waste issue and were well-prepared to deal with new issues when they were approached by SKB in May 1995 about conducting a feasibility study.

The municipal response to SKB was carefully prepared. During the summer of 1995, the municipal council arranged information meetings for the public. During the remainder of 1995 and the first part of 1996, two advisory groups of politicians worked in parallel on the issue. Both groups comprised representatives for all of the political parties represented on the council; the difference was that one group comprised senior politicians while the other comprised young politicians. Both groups organized information meetings for the public. Special experts from Sweden – and abroad – who were known critics of SKB's work, were invited to some of the meetings to present

[11] The name was subsequently changed (see Section 1.3.2.2).

their views. Brochures and other information material were prepared and distributed to households.

At the municipal council meeting in August 1996, both of the groups presented their conclusions. On this occasion, there was a broad discussion in the council about various issues relating to a feasibility study. Once these were dealt with by the municipal executive committee, the council decided in October 1996 that SKB would be allowed to conduct a feasibility study providing that certain conditions were fulfilled. Some of these conditions targeted the Government rather than SKB. In the decision document, the municipality emphasized its authority to make independent decisions. The document made it clear that a feasibility study had been "allowed" by the municipality. Furthermore, the decision document also made it clear that the municipality had in no way made a decision concerning a possible future proposal of SKB to conduct a site investigation within the municipality at a later stage. If the issue of a site investigation was broached by SKB in the future, the municipality considered that it would be free to decide on the matter at that time.

After more than a year of deliberations, the municipality decided to set up its own feasibility study organization.[12] The *municipal council* is a reference group and is thereby ultimately responsible for the municipality's participation in the work. The municipal executive committee is responsible for day-to-day decision-making. The LKO Project (cf. 1.3.2.1) and associated experts are the resources for six working groups (6-8 members in each) each focusing on different subject areas. Four of these were the same as those used by SKB's feasibility study organization, while a fifth group was responsible for information and a sixth for issues relating to the encapsulation plant and the link between that project and the feasibility study.

[12] This organization for the municipality's work in connection with the feasibility studies still largely remains.

In October 1996, a minority, consisting of Centre Party and Green Party representatives, had voted against the municipal council's decision to allow SKB to conduct a feasibility study. However, once the decision had been made, both of these parties also became fully involved in the municipality's feasibility study organization.

The six working groups had two main tasks, namely to develop competence within the group and within the council as well as to present to SKB the municipality's views during the feasibility study. The chairman and one member were also members of the municipal council (all of the political parties had a representative in at least one group). The other members were appointed by the council from citizens who did not represent a political party but who were considered to represent different sectors of society and opinions. The aim was to also ensure that women and youth were well represented in the working groups. The members of the working groups were expected to have good contacts with different parts of the local population.

Work within the groups started in August 1997 with different forms of competence development. For almost a year, the groups held regular discussions with SKB representatives as the company prepared various reports.

The mandate of the EIA Forum between the municipality, SKB, the regulatory authorities and the county administrative board, described in Section 1.3.2.1, also extended to the feasibility study and it changed its name to *EIA Forum for Studies of Final Disposal Systems for Spent Nuclear Fuel in Oskarshamn Municipality.* The name *EIA Forum in Kalmar County* was usually used. In this Forum, which still meets about once every second month, the municipality raised various questions and requested clear and exhaustive answers from SKB. The expression "stretching SKB" was coined and used as an illustration for what took place. SKB has obviously aimed at providing clear answers to all questions raised and, in discussions within the EIA Forum, has demonstrated sensitivity to requests and viewpoints expressed by the municipal representatives.

At a municipal council meeting in June 1999, SKB presented the preliminary version of the feasibility study report.

The municipality's review of the preliminary feasibility study report was made by the municipal feasibility study organization. However, the areas of responsibility of the different working groups were somewhat changed. External experts, apart from those already included in the LKO Project, were no longer considered necessary. It was emphasized that "the regulatory authorities are our experts". In parallel with the group's work, the municipality implemented a traditional review process where about 100 reviewing bodies were invited to participate. About 30 statements of opinion were submitted. Before a draft of municipality's review statement was prepared, the municipality requested that SKB should comment and respond to all of the critical comments and questions that had emerged during the review process.

In March 2000, based on the interaction described between the municipal council, the local population, the competent regulatory authorities and, to a certain extent, SKB, the municipal council made a decision on the municipality's review statement on SKB's preliminary feasibility study report. The municipality found that the feasibility study largely gave a clear view of where facilities could be sited and of the consequences of such a siting. At the same time, the municipality requested that certain supplementary information be provided and stated that if Oskarshamn became a candidate for an encapsulation plant or repository, the municipality would demand a thorough EIA, a clear decision-making process and a solid basis for decision-making.

1.3.3 Tierp

Since it shared borders with Östhammar, the municipality of Tierp was able to follow the progress of the feasibility study in Östhammar (cf Section 1.1). In April 1998, SKB informed the locally elected political leadership that certain areas near to the border of Östhammar could be of interest for closer study. Subsequent detailed discussion resulted in a letter from SKB to the municipality of Tierp about conducting a feasibility study in the entire municipality.

The municipal representatives dealt with the request quickly. By June 1998, the municipal council had unanimously voted for a positive response to SKB's proposal. No conditions were attached to the decision.

During the remainder of 1998, a plan of action for the municipality's handling of the feasibility study was formulated. The plan was adopted by the council in February 1999, but with a reservation from the representatives of the Green Party.[13] The plan of action stated that the municipality would have such a high level of ambition "that, if the conditions after the completion of the feasibility study are fulfilled, the municipality could proceed to the next step of the site selection process". With this level of ambition, the plan of action demanded deep and broad work in the following areas: information, gaining the acceptance of the population, evaluation and competence development. The aim was to achieve the participation of the citizens based on knowledge and the ability to critically review SKB's work.

The municipality set up its feasibility study organization consisting of *the working committee of the municipal executive committee,* a political co-ordinator and a *reference group* of 14 members. The *political co-ordinator* chairs the group which also

[13] The Green Party representative also participated in the unanimous municipal vote in June 1998. After the local elections in September 1998, new Green Party representatives took over.

includes representatives from all of the political parties on the council, local representatives of the Society for the Conservation of Nature, trade unions, industry, parents of small children and, SOS-Tierp, a local opinion group highly critical both to SKB's activities and to the municipality's decision to allow SKB to conduct the feasibility study. Two municipal staff members, a project manager and an information specialist assist the reference group. The task of the group is to closely follow SKB's work and to express the municipality's views to SKB.

During the course of less than one year, SKB prepared a number of background reports which were intensively discussed at meetings between the company and the reference group. A preliminary feasibility study report was presented in February 2000. SKB requested the municipality's viewpoints on the report.

The municipality reached an agreement with Umeå and Gothenburg Universities whereby these bodies would review the entire preliminary report. However, only the section in the report that dealt with long-term safety was subjected to an in-depth review by both universities.

The municipality also sent the report to groups, organizations and political parties within the municipality as well as to neighbouring municipalities and county administrative boards for review. About 35 statements of opinion were received from these bodies. Ten were received from individual and small groups. A consultant was hired to participate in the work within the reference group on preparing a proposal for the municipal review statement. The municipal council dealt with the issue at its meeting at the end of November 2000.

The tone of the municipality's review statement on the preliminary feasibility study report is highly critical. The municipal working committee stated that "a municipal decision which can entail the siting of a geological deep repository for radioactive waste in a municipality is of such exceptional importance in the long and short term that the municipality must place particularly high demands on the impartiality and comprehensiveness of the basis for decision-making". At the proposal of the municipal board, the municipal council decided to propose that SKB should supplement the feasibility study report and stated that "a decision to participate in any continued work requires such a supplementary final report".

For some years, the three municipalities of Tierp, Älvkarleby and Östhammar have interacted on different issues. The three municipal boards have recently formed a joint body, *Northern Uppland co-operation on the Nuclear Waste Issue (NUSKA).* In time, the practical consequences of this new organization will be revealed.

1.4 Information and competence development in the municipalities[14]

1.4.1 Nyköping

During the initial phase of the feasibility study, the municipality arranged information meetings for the general public at different sites, including in one of the neighbouring municipalities. The meetings were visited by a limited number of individuals (estimated at about 50–150). It was considered necessary to use other methods to reach out to the public. An information brochure was printed and distributed to all households. The brochure described SKB's plans and the role of the municipality. The response from the public was subdued apart from a small but highly critical group (see Section 1.5.1). In 1998, the municipality took the initiative to start study groups on the feasibility study issue. About 120 citizens participated and

[14] In parallel with the information activities and competence development conducted by each municipality, SKB conducts an extensive information programme in all six feasibility study municipalities. This chapter only deals with activities organized by the municipalities themselves, even if they are, to a certain extent, conducted in co-operation with SKB.

several of these later participated in the review process for SKB's preliminary feasibility study report (see Section 1.3.1). Through advertising and additional brochures, the municipality encouraged the population to express its views on the feasibility study and the nuclear waste issue to the Information and Review Group. From 1998 – 2000, a number of lectures by experts were arranged for the public on the content of the Environmental Code, the Act on Nuclear Activities and the Radiation Protection Act as well as on a wide variety of topics such as transmutation methods, the decision-making process, marine biology, archaeology, safety after closure, rock and continental ice-sheets, microbiology and impact on the groundwater.

In co-operation with SKB, the municipality arranged 80 bus trips to SKB's facilities in Oskarshamn, mainly CLAB (the Central Interim Storage Facility for Spent Nuclear Fuel) and the underground Hard Rock Laboratory. Two of these trips were arranged for municipal councillors. The members of the Information and Review Group made study trips to other countries such as Finland, France, Germany and Switzerland.

The municipality's web site was also used. The minutes from the Information and Review Group's meetings were accessible at the site. The public has been encouraged to use the web site to pose questions and make comments. Special efforts have been made to involve the youth in Nyköping in issues relating to the feasibility study.

1.4.2 Oskarshamn

Since 1994, the municipality has conducted extensive information and competence development work on various aspects of the nuclear waste issue. This work has focused on the elected representatives on the municipal council and the members of the working group as well as on the general public. The municipal executive committee has on different occasions emphasized that thorough considerations can only be made by the elected representatives if they have a deep understanding of the issues involved. However, as is described in Section 1.5.2, such an understanding must also be combined with the knowledge and values held by the public.

In the 1999 activity report for LKO, an integrated view of activities conducted over a five-year period, 1994 – 1999 is provided. A total of about 400 activities are reported. Examples include meetings, seminars and exhibitions arranged by the LKO itself. Furthermore, the members have taken part in meetings and seminars arranged by others, participated in study trips in Sweden and abroad as well as published information brochures. A large number of citizens have visited SKB's facilities on the Simpevarp peninsula. Extensive documentation is accessible on the municipality's web site.

1.4.3 Tierp

During the first part of 1999, information meetings were arranged for the public in all five metropolitan areas in the municipality. Basic information was provided by representatives for SKB, the Swedish Nuclear Power Inspectorate, the Swedish Radiation Protection Institute and the Ministry of the Environment. Only a few individuals attended these meetings. At this stage, the municipality also provided financial support for a public meeting organized by SOS-Tierp (see Section 1.3.3). A panel debate in August 1999 attracted an audience of one hundred.

From autumn 1999, lectures and seminars given by experts were held for the members in the reference group with the aim of developing their competence. The competence development work also included study trips for all of the members to Oskarshamn and to Finland. Some of the members also participated in study trips to France and Germany.

More active information work targeting the public started when SKB, in February 2000, presented the preliminary version of the feasibility study report. The meetings were held in five of the municipality's metropolitan areas. Attendance by the public had varied, depending on where the meetings were held in relation to the areas that SKB identified in the study. The municipality also took the initiative to start a "school project" in co-operation with the regulatory authorities, SKB and SOS-Tierp. Study trips for the public were arranged to SKB's facilities in Oskarshamn. About 800 people took part in the trips. The municipality's web site is an important information source where all of the municipal documents relevant to the feasibility study work are easily accessible.

1.5 Elected representatives and "concerned groups"

1.5.1 Nyköping

As described in Section 1.3.1, the majority of the elected politicians in Nyköping did not consider that there was any reason to discuss the subject of SKB's feasibility study on the municipal council. The view seems to have been that the issues should only be raised if and when the feasibility study resulted in a request by SKB to conduct a site investigation in the municipality.

So far, the local population has shown limited interest in SKB's feasibility study. However, some opposition has been noticed, primarily from locally-active organizations. The most active group, Rädda Fjällveden (Save the Fjällveden Area), was formed more than 15 years ago when SKB conducted exploratory drilling in the Fjällveden area as a part of SKB's study site investigations. Another group which is critical to SKB's work is a local historical society in Tystberga, located near to one of the areas identified as the main siting alternative in

SKB's preliminary feasibility study report. Both groups are opposed to SKB's siting work and to the actions of the municipality. At the end of 1996, Save the Fjällveden Area ceased participating in the municipality's reference group (cf Section 1.3.1). This group also asked the municipality for extensive financial support to conduct its information activities. However, their requests were denied, with the exception of certain minor amounts to compensate for the cost of meetings. The group has appealed, without success, to the county administrative board, the Swedish Nuclear Power Inspectorate and the Government with respect to the municipality's decisions. Members of these opinion groups have accused leading politicians of an undemocratic handling the feasibility study issue by not putting the issue on the municipal council's agenda. Members of the group have also stated that they completely lack confidence in the elected municipal politicians.

At present, it is difficult for an outsider to judge the extent to which these highly critical statements reflect the attitude of the local population as a whole (see also Section 1.6). However, the fact remains that there is a deep mutual distrust between the elected politicians in Nyköping and these groups. In its justification for its proposal in November 2000 for certain investigations to be conducted concerning the possibility of siting a repository in the municipality of Nyköping (cf Section 1.1), SKB has not dealt with this issue.

1.5.2 Oskarshamn

This municipality gives three main reasons for its deep involvement in the nuclear waste issue.

- The municipality is in a special position. Spent nuclear fuel from all of the Swedish nuclear power reactors is temporarily stored in CLAB. If no solution or site is identified, the fuel will remain in the municipality's "backyard". As long as the final disposal issue has not been resolved, there is a risk that this temporary storage will be prolonged, which is unacceptable to the municipality. Municipal representatives often point out that "the problem cannot just be voted away";

- Active participation of the municipality will contribute to a better result. The industry and regulatory authorities have numerous experts in natural science and technology but their insight into the reactions of the public and their knowledge of the essence of the local society is limited. The municipal representatives and the local population are in the best position to judge current and future needs. Only through active participation by the municipality can this knowledge be shared by implementers and regulators and included in the overall basis for future decision-making;
- An important bonus effect is probably increased respect for the political system and its ability to handle multi-facetted societal problems. According to the representatives for Oskarshamn municipality, a passive municipal strategy could be detrimental, since this could lead to distrust of the ability of the representative democratic system.

The final point demonstrates a conscious intention to avoid a situation where a group of citizens claim that their arguments are not taken seriously by the elected politicians or, even worse, that these politicians do not even listen to their arguments. The local politicians in Oskarshamn seem to be able to act from a platform of trust (see also Section 1.6).

1.5.3 Tierp

As mentioned in Section 1.3.3, the critical group, SOS-Tierp, was formed shortly after the municipality's decision to allow SKB to conduct a feasibility study. Some of the population in the vicinity of the areas identified by SKB as of potential interest have also demonstrated a critical attitude.

SOS-Tierp has maintained a high profile from the beginning. In September 1999, the group applied to the municipal board for financial support for a local information project on the nuclear waste issue. Following discussions, support was granted.

In its justification for the decision, the municipal executive committee stated that SOS-Tierp's aim is to evaluate the nuclear waste issue from a critical standpoint regarding method and the site selection process. This actively contributes to the comprehensiveness of the feasibility study. With its commitment and knowledge, the group plays a vital role in forming public opinion in the municipality (see also Section 1.6).

It can be noted that one of the most detailed review statements on SKB's preliminary feasibility study was submitted by SOS-Tierp in September 2000. A comparison between this statement and that submitted by the municipality of Tierp in November 2000 shows numerous similarities. Representatives for SOS-Tierp have publicly expressed that they believe that the statement of the municipality was influenced by SOS-Tierp's criticisms. However, the extent to which the critical attitude of the opinion group is held by the local population is uncertain (see also Section 1.6).

1.6 The "true" representatives of the public

In discussions concerning the public's participation in the planning of major projects, the following types of question are often raised: Who is the public? Who should participate in the planning and decision-making process? Who are the "true" representatives of the public? Can a system of representative democracy ensure public participation or can this only be achieved outside the system? Another reason to focus on these kinds of questions is the fact that the role of environmental organizations, primarily local groups, has been particularly emphasized in the bill behind the Environmental Code.

In all of the Swedish feasibility study municipalities, the locally elected political leadership made considerable and admirable efforts to deal with the problems associated with information on the nuclear waste issue and competence development. There is a clear commitment to establish a solid basis for both elected representatives and the public to make informed decisions.

The municipal efforts are facilitated by SKB's policy to be represented by the corporate management and/or high-level executives in connection with all meetings with the municipalities. The approach adopted by SKB in recent years is of equal importance: SKB does not come to the municipalities with complete solutions to various problems. Instead SKB puts forward ideas that require a common discussion in order to arrive at a solution. "Dialogue" seems to have replaced "information" as SKB's main strategy in its relations with the municipalities.

The fact that the regulatory authorities have gradually realized that they must be active and visible in the municipalities has also probably strengthened the municipal representatives position. Regulatory activities are not limited to occasionally providing information. These activities comprise continuous contact maintained by senior staff. The regulatory authorities can thereby actively demonstrate that they are looking after the interests of the public and that they are accountable to the public.

The three examples provided in this chapter show that the representative democratic system has different ways of dealing with the nuclear waste issue at the municipal level, in a way that also inspires the confidence and respect of critical opinion groups.

It is quite clear that the elected politicians in *Nyköping* have worked with the intention of establishing an open decision-making process and ensuring that all viewpoints are thoroughly considered. However, their efforts have been met by greater mistrust from those who are critical to SKB's activities than is the case in the other two municipalities. Some of the local critics have chosen not to co-operate with the municipality within the municipal feasibility study organization. Instead, they have expressed their viewpoints via the local media. At the same time that they have distanced themselves from participating in joint working groups, they have demanded that the municipality should provide substantial financial support for their activities. These demands have been rejected by the municipal politicians – and this has result in a growing divide between the critics and the elected municipal representatives. To an outsider, there would appear to be limited possibilities, at least at present, of improving the situation through dialogue.

A deeper analysis of the situation is necessary in order to establish how deep and widespread this distrust is and why it exists. However, it should also be pointed out that opinion polls show that more than two-thirds of the inhabitants of the municipality appear to be willing to accept further investigations (cf Section 1.2). This would indicate that the strength of the negative opinion is limited. Nevertheless, the dismissive attitude of the Nyköping politicians to the idea of handling the feasibility study at municipal council level leaves them vulnerable to criticism.

In *Oskarshamn*, there seems to be no doubt about who should be considered to be representatives of the public. The municipality's, and thereby the elected political representatives', deep involvement in the feasibility study issue does not appear to be called into question.

One reason for this situation may be that the municipality's attitude, since SKB's site selection process started, has been to make firm and distinct demands on the company and its owners and to only accept satisfactory answers to questions raised. From the very beginning, the municipality also demanded openness in the decision-making process. Openness and respect have also, subsequently, characterized SKB's attitudes to the municipal representatives. This open attitude has given the elected politicians of Oskarshamn the chance to show their electorate that the municipality's views and criticism actually do affect the company's plans and activities.

These circumstances may have helped to create and maintain a situation where the local population trusts its elected representatives. A contributing factor to this trust may have been the fact that the political parties, once the decision to permit the feasibility study had been made, agreed not to exploit the issue in local party politics. The outcome of this seems to be that no-one has found any reason – or even thought of – questioning the democratic legitimacy of those who have been elected to express the municipality's views to SKB.

Another factor that should be remembered is that more than four-fifths of the population of Oskarshamn appears to be positive to the idea of SKB continuing its investigations in the municipality (cf Section 1.2). This is the highest percentage for all of the feasibility study municipalities.

The representatives for Oskarshamn municipality sum up what they call "the Oskarshamn model" by the following seven points[15]:

- Openness and participation: all cards on the table, real influence;

[15] The model was applied to an actual case. In 1998, Oskarshamn gave its permission under the Natural Resources Act and the Act on Nuclear Activities to the expansion of CLAB. This was achieved after an EIA which was more extensive than that required by the legislation at that time.

- The EIA is our platform: We help to prepare the basis for decision-making but we make our own decisions independently;
- The municipal council is our reference group: A competent reference group that is accountable to the voters;
- The public is a resource: A transparent process and concrete proposals mean involvement and influence;
- The environmental groups are a resource: The environmental groups and their experts make an important contribution to the work;
- SKB is "stretched" for clear answers: We must have knowledge in order to ask difficult questions and we must have clear answers to our questions;
- The authorities are our experts: SKI and SSI participate throughout the process and we make our decisions in the light of their views.

Work within the municipality of Oskarshamn has gained international recognition and has led to municipal representatives being invited to present the municipality's work at various seminars and conferences in recent years. In September 2001, the municipality will be hosting an EU seminar where representatives from various European municipalities which are or have been involved in the siting of facilities for nuclear waste disposal will exchange experiences.

The conditions in *Tierp* are characterized by the existence of two force fields. The one comprises the elected politicians who would like the municipality to continue to play a role in SKB's siting process. The other comprises a dedicated opinion group which questions the fact that the municipality has granted SKB permission to conduct a feasibility study and questions fundamental parts of the final disposal method (technical solution) that SKB has selected. In spite of this, the two force fields seem to be able to maintain a working relationship.

It would seem that the critics in Tierp feel that they have been treated fairly and have been shown respect by the municipal politicians. The democratic legitimacy of the politicians has therefore never been called into question in the public debate.

As mentioned above (Section 1.5.3), the extent to which the critical attitude of SOS-Tierp reflects the attitude of the population as a whole is unclear. However, there are certain indications that the doubt and criticism regarding SKB's work have become more widespread during the second half of 2000. For example, the elected municipal council, in its review statement at the end of November 2000 concerning SKB's preliminary feasibility study report (see Section 1.3.3) supported sharply worded criticisms of parts of the report. The municipal representatives have also publicly criticized SKB for not waiting for a couple of weeks before identifying sites for investigation in order to give the municipal council time to decide on its review statement on the feasibility study report.

At the same time, an opinion poll from May 2000 showed that 71 per cent of the inhabitants were positive to further investigations in the municipality. However, the corresponding figure obtained six months earlier was higher (77 per cent). Tierp is the only of the six feasibility study municipalities where the percentage of "those positive" has decreased between the two opinion polls.[16]

[16] SKB ordered the opinion poll. According to the opinion poll, more than 70 per cent of the inhabitants in all of the six feasibility study municipalities were positive to further investigations in their own municipality (answer to the question "Do you think that SKB should be allowed to conduct a site investigation, namely exploratory drilling, for a deep repository for spent nuclear fuel in the municipality?"). In the case of Nyköping, the figure in May 2000 was 75 per cent and, in the case of Oskarshamn, 85 per cent. Six months previously, the corresponding figures were 67 per cent and 83 per cent, respectively.

2 Retrievability of nuclear waste from geological repositories[1]

2.1 Introduction

This presentation is mainly based on papers presented at an international seminar at Saltsjöbaden, Sweden, held in October 1999 and the discussions that took place at that occasion (ref. 1). Some more recent material has, however, also been used (ref. 2).

The seminar was organised by KASAM – The Swedish National Council for Nuclear Waste – in co-operation with the IAEA. The title of the seminar was ”Retrievability of HLW and Spent Nuclear Fuel”, but some material on LLW and ILW was also accepted, since some of the issues connected to retrievability are very much the same.

All the papers were invited and included contributions from a number of European states, such as Belgium, France, Germany, Netherlands, Sweden, Switzerland and United Kingdom, along with Canada and United States.

Retrievability was discussed for repositories in various geological host formations, such as different rock types, salt and clay.

The first half of this chapter contains a general discussion on various aspects of retrievability, whereas the second half gives an overview of how retrievability is looked upon in some individual countries.

[1] This chapter has been edited by Dr. Tor Leif Andersson, Secretary of KASAM.

2.2 Some definitions

In IAEA terminology

- *Storage* is emplacement above or below ground with intention of retrieving the waste at sometime in the future, in order to implement another, yet to be defined, management option;
- *Disposal* is emplacement with no intention of retrieving the waste, although retrieval is technically possible.

With this terminology, disposal is intended to be permanent and to be the concluding step of waste management, whilst storage is intended to be temporary and only an intermediate stage in waste management.

The following definition is presented in a recent report from the European Commission Concerted Action on the retrievability of long-lived radioactive waste in deep underground repositories (ref. 2) and is very much in line with the outcome of the discussion at Saltsjöbaden:

- *Retrievability* means the ability by the repository system to retrieve waste packages for whatever reason retrieval might be wanted.

It is important to keep in mind that there is *no intention* to retrieve built into the term retrievability, just that it would be possible to do it.

2.3 Retrievability at different times

The effort needed to retrieve waste packages would be very much dependent on when in the handling chain an actual retrieval would be initiated.

A rather extensive description – with 13 different time-zones – is given in the recent European Commission report just mentioned.

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

Similar lists of time-zones were presented at the Saltsjöbaden seminar, although not that extensive.

A general conclusion is that the earlier in the chain a retrieval would be initiated, the easier it would be. Also, it was concluded that even after a full closure of the repository, it would generally be possible to recover the waste packages, even if there would be some restrictions for some of the presented systems. These restrictions are mainly connected to the durability of the waste container and to the temperature in the near zone around the waste packages.

For the retrieval of the waste packages from a closed repository, a re-opening of the closed (refilled) shafts and tunnels would be one option. Another option would be to open up new access ways through a new system of shafts and tunnels in order to recover the packages ”from another side” so to speak.

2.4 Why retrievability?

The discussion on retrievability has come up during the latest few years as a result of the ongoing R&D and planning work for the disposal of HLW and spent fuel.

Generally speaking one can say that there is a tendency to a shift in how to look at the issue of retrievability. Traditionally, the approach has been to present the best possible solution for a good repository, with such properties that, once the waste or the spent fuel has been placed there and the repository has been closed and sealed, then nobody would have to worry about it any more. This generation would then have taken full responsibility for the waste it has generated in such a way that future generations would not need to pay any attention and would not be exposed to any significant risk of being hurt by the waste. Those who are used to this traditional, more technically based approach, may find it a bit surprising to note that there is a increasing interest in retrievability, i.e. in possibilities to recover the waste and get it back again.

Which are the driving forces behind this shift? Not surprisingly, there is a number of arguments – quite different in nature. Some of them will be addressed here.

2.4.1 Man is not perfect

The design and construction of a final repository for HLW or spent fuel is a major undertaking in itself. It includes a number of components and materials, about which the knowledge is extensive but still limited. It was noted by KASAM as early as in 1987 that since Man is not ”unfoolproof”, which is a fault but also a key to development and progress, there must be a possibility to repair a repository if it – for some reasons – does not work as expected. This would mean that the waste should be retrievable. The question about how one would get such information about a malfunction is of course another problem, which will be discussed later here.

2.4.2 The waste may turn into an asset

Somebody has said that waste is what you have when you have no more imagination. It is hard to imagine how spent fuel would be utilised in a country without an ongoing nuclear energy programme, in a world with very low uranium prices, with export limitations for plutonium etc. But times may change. The remaining energy content of the spent fuel is quite impressive and may be of interest in a possible future with new attitudes, new generations of people and new generations of nuclear reactors. The spent fuel also contains a number of other elements – mainly produced by fission – such as rare earth metals, palladium, rhodium, technetium etc., which may become of strategic interest for use in future technologies.

2.4.3 The society may feel that there is an even better way to take care of the waste, by a modified repository design or by quite another method

In the discussions with the public, a fear or at least a reluctance is often expressed towards any action that is definite and irreversible. The argument is usually that – taking into account the rapid development of science and technology – one would expect better solutions to come up for the waste within the nearest 50–100 years. And then it should be possible to take benefit from such a development and make an improved arrangement for the waste.

Perhaps one could say that implementers, authorities and others working with the radwaste issues originally believed that the public would appreciate that the waste would be disposed of in a way that it could be forgotten. But gradually it has turned out that the public may not like to see the waste being placed totally ”out of sight”. It would rather prefer to have an option to retrieve it.

The general opinion at the seminar was that it is very unlikely that the waste will be retrieved from a repository, just to be placed in another one, as long as the first repository works as expected. But such a decision would, of course, need to be taken by the future generation under consideration.

2.4.4 Ethical considerations

Ethical considerations are often very much based on value judgements rather than on hard facts. Not surprisingly, therefore, very different (even contradicting) conclusions and proposals can be claimed to be ”ethically correct”. This became very evident in the ethics session, which contained three papers, two from Sweden (ref. 1i and 1k) and one from the Netherlands (ref. 1j). The Dutch paper was a short presentation of a report that had been produced by some environmental groups on request by the Government – the so called METRA-study. The METRA-study had two main objectives

- To identify the social and ethical considerations underlying retrievable disposal;
- To interview a number of environmental organisations with the aim to record opinions and feelings that play a role in the acceptance of retrievable disposal.

Some conclusions from the METRA-study are that

- Since the time scale for radioactive waste to be a potential hazard amounts to as much as hundreds of thousands of years, it is beyond comprehension. It is then unrealistic to expect that the present generation can take responsibility for such long periods. This would also be in agreement with the ”rolling present” as introduced by NEA in its Collective Opinion on the environmental and ethical basis of disposal of radioactive waste, in which a postponed decision is advocated. During a period of reflection, the waste is stored and available in a form that enables to process it with more advanced technologies. Not only the waste is passed on to future generations but also the resources and the technical abilities to manage the waste in a environmentally responsible way;

- If there should be no difference in detriment between the present and future generations, then a retrievable disposal should be the preferred option also for future generations. Consequently, this would call for a permanent retrievability. For such a system, geological formations such as clay and salt would be less suitable, due to the plastic deformation. Therefore, a permanent retrievable disposal facility at the surface is the recommended option. But since it is recognised that both the stability of the institutions charged with the management of the waste and the stability of the society as a whole are questionable for the long term, the conclusion is that no real solution can be offered.

The METRA-study also notes that there are fundamental differences of view on the ethics regarding disposal of radioactive waste between the regulator (representing the official position) and representatives of environmental organisations. In one view it is considered ethical to emplace the waste in a (retrievable) underground repository in order to create a fail-safe situation. In the other view it is found more ethical if each successive generation would decide for itself what the best possible method is, manage the waste such as to keep all options open and pass the know-how, the technology and the resources to enable that.

On the principle of retrievability itself there seems to be an agreement between the ”official position” and the authors of the METRA-report to the extent that it is acceptable from an ethical point of view. However, no consensus exists yet on a practical implementation of this concept. Permanent retrievability is an illusion if one accepts that long-term safety conditions of the repository should not be compromised.

Another observation made in the study is that there is a beginning of a dialogue between the official bodies and persons representing environmental and social organisations and that a significant part of the latter groups are determined to remain involved in the further discussion.

Whereas the Dutch paper, from its ethical analysis, concludes that no solution can be offered, the Swedish paper by Anne-Marie Thunberg (ref. 1i) offers a way forward. Anne-Marie Thunberg is a member of KASAM and she is one of the pioneers in introducing an ethical way of thinking in the radwaste area. Some leading principles are that risks and burdens should be shared among generations in an equitable way. The generation which has the advantages shall also have the consequences of the risks and burdens it has created, Also resources and advantages should be shared among generations in an equitable way. Offering a ”freedom of action” for the future generations is equally important as minimising the risks and burdens transferred to them.

In an absolute meaning there is no right or wrong decision to make in the radwaste issue. We have spent fuel to take care of and we must make our best, based on the knowledge and experience we have now. It would, however, be wrong to make decisions which are unrevokable (which cannot be cancelled).

To have a significantly prolonged period of storage at the surface would mean passing on burdens and risks to future generations in an unacceptable way. The conclusion in Anne-Marie Thunberg’s paper, which also includes a very useful historical overview of the development of the ”ethical thinking” on the radwaste area, is that we can hardly advance further than to manufacture an interactive waste management system, allowing us to involve present and future generations in an open, flexible, and non-preconstrained decision making process. In such a process, retrievability presents itself as an inescapable dimension – taken into consideration both the human being as a responsible subject, including the time scale relevant for society as well as for man, and the character of knowledge, especially in relation to long-term effects. She also ends her paper with a question: Is it not also an inescapable dimension, in such an open process, that we provide for a repository which is designed to be finally closed? Her own answer to that question is that it is our obligation towards future generations to give them also this possibility, in order to really guarantee them a reasonable freedom to act. The problem is that the freedom to chose final closure is restricted to one generation, either ours or someone in the future.

An important aspect is also brought up in another Swedish paper by Jensen and Westerlind (ref. 1k) who works for the Swedish authorities. They remind us that ethical consideration is always a societal concern, which is an integrated part of laws and regulations. Treatment of ethics as a separate part in the decision making process is therefore always debatable.

They also mention that the term retrievability often is proposed to cover mainly positive qualities such as the option of later changes to the repository or a new disposal concept. However, as ICRP and others have pointed out, it also implies the possibility of a number of more negative qualities, such as

- Operational exposures;
- Continued risks of accidental releases;
- Financial provisions to cover operating costs etc.;
- Continued reliance on institutional control,

which all may impose some burdens on future generations.

2.5 Long-term monitoring

The state of technology on acoustic remote monitoring of rock and concrete structures for nuclear waste repositories was presented by R.P. Young (ref. 1l). Excavation activities and thermally induced damage can be detected by such techniques, as has been demonstrated in some underground rock laboratories.

The acoustic techniques work very effectively in hard rock, somewhat less effectively in plastic rocks, but they certainly offer a very interesting option for doing non-intrusive monitoring of the near field and also for keeping the site under control, to reveal any energy releasing activities, like drilling, excavation, blasting etc. Therefore such methods may have a role not only for the supervision of the performance of the repository during the first decades but also for the safeguards system in the future.

By such techniques, information can be obtained about where a damage is taking place, about the extent of the damage, about the damage mechanism etc.

The detectors should preferably be placed in the sub-surface a few metres below the surface, in order to get a good contact with the rock and avoid the weathered upper few metres. The lifetime of the detectors is expected to be up to about 50 years.

2.6 Cost considerations

Geological disposal of nuclear waste is considered by many to achieve a permanent protection for man and its environment. The extremely long time-scale has drawn the attention to the need for society to plan far ahead into the future. This is perhaps the first time so much of thought and debate is being devoted to the burdens and benefits which a technology may bring to generations in a far future.

There are complex legal issues connected with the ownership of radioactive wastes from their time of production to their final disposal. These differ from country to country. In the USA, the situation is rather straight forward, since it is foreseen that the Government will take title to spent fuel from the utilities and with this title goes all future responsibilities. If the Government is also the repository implementer, the situation is rather clear. It will be more complicated if a third party – for example a dedicated waste management organisation outside the Government – is the implementer. In many countries it is very clear that the ownership and the responsibility for the waste stays with the producer of the waste, i.e. with the nuclear power companies. In either case, it seems obvious that Governments will finally take over the waste and the responsibility for it, at some time after it has been emplaced in a repository, which has been closed and sealed.

The following conclusions were made in a paper by Charles McCombie (ref. 1m).

- It is important that responsibilities be clearly allocated throughout the life of any project which extends over very long times. The explicit attention being paid to this question in radioactive waste disposal makes this a pioneering issue; it will become relevant also for other activities with far future influence;
- For as long as the existence of the repository implementing body can be assured, there is no real problem of assigning responsibility. The producers of the wastes, e.g. electrical utilities, may have a longer expected lifetime. In this case some responsibility may revert to these waste producers at long times;
- It is straight forward to arrange financial measures which can ensure that monitoring programmes are funded for as long as future generations choose to monitor. For retrieval, adequate funding can also be made ready, but it is less clear that tying up resources, in case one has to deal with very low probability events, is a sensible strategy;
- At very far future times, responsibility for a closed and sealed national repository must revert to the Government of

a State. If international repositories are realised, sharing of future responsibilities between host and customer countries can be regulated by Treaties;

- In all cases, it is the ethical responsibility of current generations to try to minimise burdens or responsibilities passed on to future generations. Repositories should be designed, sited, operated, closed and financed in a manner best suited to achieve this goal.

The cost related implications of a retrieval were also discussed in a separate paper by Olof Söderberg (ref. 1n).

A general problem is to apply the ”polluter pays principle” for extremely long time periods, during which the organisation under consideration may cease to exist. In some countries funds are being built up in order to assure that money is available for a proper final handling of the spent fuel, incl. its final disposal in a repository, and in such cases there should be no problems, as long as the size of the fund is large enough to allow for the work to be done. A special problem will occur if one would decide to retrieve the waste from the repository. Some financial systems may provide funds also for such a retrieval, at least if it takes place early in the process, i.e. before closure of the repository.

In Söderberg’s paper it is suggested that if a retrieval is carried out after a 10 year demonstration period (such a period is expected to be part of the Swedish process), it seems clear that the ”polluter pays” principle and the principle of “today’s generation carrying the costs” can be applied. Several other retrieval scenarios – with retrieval at different times and for various reasons - are also discussed in the paper. For a retrieval about 50 years after the closure and sealing of the repository, the situation would probably be quite different, since the Government – in connection with the sealing – is presumed to have declared that the former nuclear utilities have met their responsibilities as defined by the (Swedish) legislation. Such a declaration would probably mean that the responsibility for the content of a repository has shifted from the nuclear companies to the state. Such a retrieval would consequently have to be paid for by the generations living at that time. It is concluded in the paper that the line has to be drawn somewhere. It would simply not be reasonable for our generation to provide financing for situations which – based on thorough considerations – are regarded as very unlikely to occur.

The stability of funds was also discussed and a general remark is of course that the stability of a fund is dependent on the stability of the society. Guarantees are only given in a very general way and the only real guarantee is the stability of the economy in the country under consideration as well as in its economical surroundings. Government bonds are usually regarded as safe papers, but there are also countries, in which such papers have lost their value.

The risk of intrusion in the fund was also mentioned, and some meant that such a risk might be larger than the risk of human intrusion into a deep geological repository.

2.7 Safety and safeguards

Safeguards include those control measures that have been agreed upon by many nations in order to prevent non-peaceful use of nuclear material and nuclear development.

An overview of safeguards aspects on geological repositories was given in a paper by A. Fattah, IAEA (ref. 10).

A State usually has an obligation to safely store any nuclear material, which is considered unsuitable to re-enter the nuclear fuel cycle, isolated from the biosphere. Also, physical protection has to be accounted for, to prevent inadvertent access to such material. In addition to these two criteria – which are fully under the State's jurisdiction – a third criterion reflecting international non-proliferation commitments needs to be addressed. Under comprehensive safeguard agreements a State concedes verification of nuclear material for safeguards purposes to the IAEA. The IAEA can thus provide assurance to the international community that such nuclear material has been used for peaceful purposes only as declared by the State. All these three criteria constitute a unit. None can be sacrificed for the sake of the other, but compromises may have to be sought in order to make their combination as effective as possible.

Safeguards can – according to Article 11 of the safeguards agreement – be terminated only when the material has been consumed or diluted in such a way that it can no longer be utilised for any nuclear activities or has become *practicably irrecoverable.* Therefore, such safeguards for nuclear material in geological repositories have to be continued even after the repository has been back-filled and sealed. The effective application of safeguards must assure continuity-of-knowledge that the material in the repository has not been diverted for an unknown purpose. The nuclear material disposed in a geological repository may have a very high and very long-term proliferation risk because the inventory is substantially large. Change in social, environmental and other scenarios might demand recovery of nuclear and other material from the repository sometime in the future.

Article 35 of the same agreement states that ”where the conditions of Article 11 are not met, but the State considers that the recovery of safeguarded nuclear material from residues is not for the time being practicable or desirable, the IAEA and the State shall consult on the appropriate safeguards measures to be applied”. The Legal Division of IAEA has, however, made the interpretation that Article 35 does not permit the IAEA to terminate safeguards where the conditions of Article 11 are not met.

The question may be raised if spent fuel might be withdrawn from the nuclear fuel cycle, by being classified as ”consumed”, ”diluted” or ”practicably irrecoverable”. Spent fuel in any form of interim and retrievable storage facilities remains accessible and the nuclear material can be recovered. Spent fuel stored for a long time becomes even more easily recoverable as radioactivity decreases considerably after several decades, making plutonium extraction more feasible.

The possibility to recover nuclear material exists even after closure of a permanent geological repository and any country which emplaces spent fuel could at any time retrieve it. The same technology, skill and effort are required for emplacement as well as retrieval and advancement in mining technology will make it even easier. Should a State intend to divert material contained in fuel elements and deposited permanently in a geological repository, there is no conceivable way of making the material irrecoverable.

The IAEA has taken the initiative to develop an international consensus on the future policy of safeguards for spent fuel placed in geological repositories. In 1988 an advisory group meeting on *Safeguards Related to Final Disposal of Nuclear Material in Waste and Spent Fuel* was held in Vienna with 17 Members States and the Euratom participating. The meeting recommended that: ”Spent fuel does not qualify as being practicably irrecoverable at any point prior to, or following placement in a geological repository, or even after closure of the repository, and the IAEA should not terminate safeguards on spent fuel.”

Further meetings were held in order to provide guidance to identify safeguards measures beginning with the planning and design phase, in particular to indicate the requirements to be used for the application of safeguards.

The safeguards systems must meet rigorous systems specifications and standards in order to function for a very long time period with little or no service. Since emplaced spent fuel cannot be re-verified, other methods must be used to ensure that no material is being diverted. The safeguards systems for a repository will be based on an integrated safeguards verification system (ISVS) and design information verification (DIV) to confirm than no nuclear material is removed by any declared or undeclared routes. It will also be based on maintenance of continuity-of-knowledge on the nuclear material content.

An ISVS will be applied to verify transfer, flows and inventory of the spent fuel disposal containers and to maintain continuity-of-knowledge on the nuclear material. It should be comprised of elements of containment and surveillance (C/S), monitoring and non-destructive assay (NDA) systems, as well as DIV along with geophysical, environmental and radiological systems. An ISVS should have the capability of functioning, as far as practicable, in automated, remote control and remote data transmission modes.

In parallel, a programme for the Development of Safeguards for Final Disposal of Spent Fuel in Geological Repositories (SAGOR) was launched by the IAEA in order to foster technical advancement. The mission of SAGOR has been to ensure that the safeguards systems developed for the final disposal of spent fuel effectively meet the objectives of IAEA safeguards (ref. 1p).

The final reports of the SAGOR project were published in 1998. They include safeguards approaches for the spent fuel conditioning facilities, operating repositories and closed repositories. For each facility type, the diversion paths and detection points are included, in addition to the description of needed R&D efforts.

It is stated that the conditioning facility will offer the last possibility for a real verification of fuel data. Thereafter it will become difficult, in practice impossible to assess. At the conditioning facility conventional safeguards measures can be used.

For the operating repository the reliability of C/S measures (i.e. Control & Surveillance) is of crucial importance. Loaded transport containers will arrive and empty ones will leave the repository, in which also excavation work will be going on in parallel to emplacement activities in different parts of the repository area, and this may be going on for as long as 50 years or more. This will of course not simplify the safeguards work. Design information verification (DIV) may have to be implemented periodically to give assurance to the correctness and completeness of the declared activities and design of the repository.

In the closed repository, diversion of nuclear material requires excavation. Possible diversion paths that have been identified in the SAGOR work include excavation of the original or new shafts and tunnels, excavation from other mines, tunnels or caves. Therefore, the surface area including original shafts need to be monitored in addition to the area around the repository. Both on-site inspection and remote monitoring may be considered.

The model safeguards approach include

- unannounced random visual inspections by applying geophysical techniques;
- satellite or aerial monitoring;
- active or passive seismic monitoring;
- application of other potential measures, e.g. environmental sampling and information analysis.

The safeguards approach does not require the possibility to directly verify the presence of the nuclear material. The verification measures are directed to the integrity of the repository site rather than to the inaccessible material itself.

It is obvious that if we conclude that the waste in a deep geological repository is retrievable – even if a real retrieval would be a large and costly undertaking – then one also has concluded that the material is **not** practicably irrecoverable, and hence it will be subject to continued safeguards.

A paper by Toverud and Wingefors from the Swedish Nuclear Inspectorate (ref. 1r) concludes that there may be a number of possible reasons for retrieval of spent nuclear fuel from a repository and they range from technical to purely political.

The concluding remarks in the paper from the Inspectorate are:

- It cannot be excluded that the repository will not perform as intended during the operational phase. Therefore, the repository design should take retrievability of waste packages into account. Demonstration of such retrieval should be regarded as a condition for siting or construction of a repository;
- It must be considered that waste packages should only be retrieved when arrangements have been made for their subsequent safe management;
- Future generations may wish to retrieve the spent fuel from the repository. Disposal methods and repository design should consider this and not make such retrieval unnecessarily difficult. On the other hand, any measures taken to facilitate retrieval must not significantly impair the long-term safety of the repository. It may have to be shown that both these aspects have been adequately considered;
- Retrievability must always be discussed in such a way that it is clear that the reason why retrievability is included in the design and planning is **not** any doubt concerning the safety of the repository.

2.8 Placing the issue in a perspective

In a keynote paper in the opening session (ref. 1a), the director of the Division of Radiation and Waste Safety, IAEA, Mr. Abel J. González gave a background to the issue of retrievability issue. He also made an effort to look at the issue in a very wide perspective. Some of his points will be quoted here.

2.8.1 Polarised opinions

On the one hand, the collective opinion of waste management experts is, and has been for many years, that the problem is not particularly difficult to solve technically; that we already have mature disposal technologies that can assure the long term safety of all radioactive waste; and, thus – and this is particularly important in this context – that we can free future generations from the responsibility for managing our waste.

On the other hand, there is a widespread and deeply rooted perception in the general public and its political representatives that the management of radioactive waste poses a tremendous problem that the nuclear industry has consistently failed to acknowledge, and for which there is no adequate solution.

This divergence of views is perhaps strongest and most apparent in the context of geological disposal, particularly of high level waste, and is therefore central to the issue of retrievability.

This conclusion is very much in line with what has been said already in section 2.4. In addition, however, Mr. González emphasised that by introducing the issue of whether the disposal should be retrievable, experts are not facilitating a common understanding of their position. On the contrary, they have now created another pole of divergence among the experts themselves. The reasoning of the sceptics is simple: if disposal is so safe, why does it need to be retrievable?

2.8.2 Release, discharge and waste (proper)

Without underestimating any problems, it may be useful to make some comparisons between different kinds of radioactive waste that have been generated by mankind. Radioactive waste has been discharged as effluents into the environment, where is has been dispersed. Such waste is generally termed ”release” or ”discharge” and has not always been considered as waste (proper). Such waste is not retrievable from the place where it was disposed of: the global environment. The most dramatic examples are the remains from atmospheric nuclear weapon tests, which have been dispersed into the environment in an uncontrollable and irresponsible manner. They are the result of 2 408 nuclear weapon tests, of which 541 with a total yield of 440 megatons took place in the atmosphere and 1867 with a total yield of 90 megatons in the geosphere. The activity of waste already disposed of in this way is dramatic if considered in isolation. According to estimations from the United Nations Committee on the Effects of Atomic Radiation (UNSCEAR), more than 2 000 EBq (or 2000 x 10^{18} Bq) of fission products have been discharged into the atmosphere and dispersed globally as a result of atmospheric nuclear weapons testing alone. The corresponding figure from underground testing is another 500 EBq.

These are not the only cases of free disposal of radioactive waste in the environment. There have been continuous releases to human habitats from installations of the military nuclear fuel cycle. Again the amounts are staggering: alone the discharge of three Russian military production centres are astonishingly high: from Tomsk 42 EBq have been discharges into the nearby river; from Krasnoyarsk 17 EBq; and from Mayak 4 EBq.

By comparison the releases from the Chernobyl accident of about 0.1 EBq seem minuscule.

Is this vast amount of radioactive waste comparable with the amounts of nuclear waste to be placed in repositories? Surprisingly enough, it is. The waste under consideration at the Saltsjöbaden seminar is the solid or solidified waste being kept ”contained”, i.e. isolated from the environment. All this is termed waste (proper) and, because of our inability to communicate information, it has been understood by many as being the only real waste. Its total activity compares well with that from waste already discharged into the environment, although comparison can be tricky i.a. due to the different radioisotopic composition. An estimation of the activity of all the solid waste produced in nuclear power reactors can be estimated to be around 10 000 EBq.

In summary, an unknown amount of radioactive residues that is estimated to be much larger than 3 000 EBq has already been discharged uncontrollably and irrecoverably into the environment, mainly by the nuclear weapon states. By comparison, we are now dealing with radioactive waste amounting to 10 000 EBq, safely contained and waiting for an orderly and controllable disposal. For this we have so many discussions on what actions to take, how deep to build the repository, in what type of host rock, how to protect the waste with more sophisticated covers and now whether or not to make such a disposal retrievable.

The intention with the above comparison is certainly in no way to advocate the free release into the environment of the waste proper that is awaiting disposal, only to give some additional perspective to the issue and a framework for the discussions.

2.8.3 A difficult information problem

According to Mr. González, the public should be clearly informed that, while our problem is limited to a few tens of tonnes of waste per year generated by an electricity production plant of one thousand megawatts, if the same plant is fuelled with conventional fuel, it will produce several million tonnes of waste, of which six million are green house gases, nearly one hundred thousand are noxious sulphuric and nitric acids, and nearly half a million are ashes, which incidentally are rich in radionuclides – of course of natural origin.

To deal with this volumetrically limited problem we have developed a sophisticated technology, perhaps believing that this will assure public acceptance. The result was probably the opposite. Technology is, of course, the bedrock of safety for geological disposal. But the evidence of the past two or three decades is that technology alone cannot deliver public support. There are a number of additional means by which public support can be developed. The first – and perhaps the single most important step in gaining public acceptance of geological disposal – is simply to construct and operate geological repositories safely. The second is genuine public involvement in the decision-making process or what in fashionable terminology is called stakeholders' involvement.

2.8.4 "Mediators and judges"

A quote from Hans Blix, former Director General of the IAEA, who chaired one of the sessions of the seminar, may be useful to keep in mind for anybody working with the radwaste issue. "Remember the difference between a mediator and a judge. A mediator must always seek a middle ground, which makes both parties satisfied. A judge must always seek the truth, and the truth is not necessarily in the middle."

2.9 An overview of how retrievability is looked upon in some countries

This chapter puts the emphasis on retrievability aspects. For a broader overview of the nuclear waste management programmes in different countries, reference is made to chapter 8 of this book.

2.9.1 Belgium (ref. 1e, 2)

In 1998 the Belgian Government made a formal statement concerning the disposal of LLW, in which the implementer was asked to develop a "reversible" solution. Similar requirements may later on also be made for the disposal of HLW or spent fuel, but at present there is no formal or informal position of the

Government known concerning the retrievability of ILW, HLW and spent fuel.

Geological disposal in the Boom Clay at Mol is being studied as a reference concept for ILW, HLW and spent fuel. In the reference concept, the underground infrastructure consists of a series of disposal galleries in two separate fields, one for heat-emitting and one for non-heat-emitting waste. The galleries are connected to transport galleries which in turn are connected to shafts leading to the surface. The clay layer is about 100 m thick. The waste will be emplaced in the middle of that layer, at a depth of about 230 m.

The galleries in the Belgian concept will have a diameter of about 2 m and have a concrete lining. The waste packages will be placed in horizontal disposal tubes made of stainless steel, and the space between the disposal tubes and the gallery lining will be backfilled with pre-compacted blocks made of a mixture of bentonite, sand and graphite. The total length of a gallery will be about 200 m.

In general terms, retrievability can be incorporated in the system in three different ways

- In the design of the repository one can integrate requirements for prolonged reversible waste handling capabilities. A first condition is met by using high-integrity long-lived waste containers;
- By postponing the stepwise closure of the repository, the period of easy access to the disposed waste is extended;
- By using easily removable backfilling and sealing materials, access to the disposed waste can be restored without great effort.

The design lifetime of the vitrified waste overpack is about 300 years and of the spent fuel container about 2 000 years. As long as the disposal tube and the waste container remain intact and as long as the tube can be accessed, reversible waste handling is possible (i.e. there is retrievability).

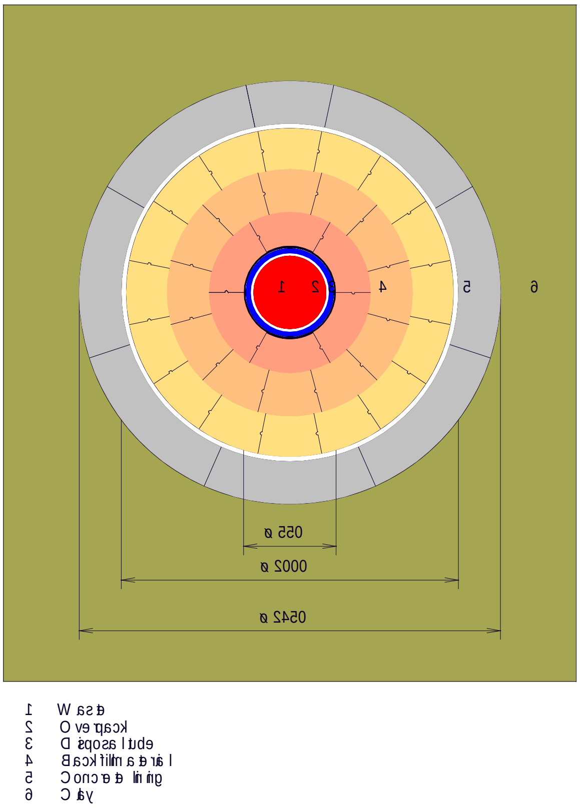
Presently, it seems reasonable to keep a deep repository in the Boom Clay, if needed, open for about 100 years. If longer periods would be asked for, enhancing some of the design requirements could in principle accommodate this need. However, the safety aspects of such a further postponed closure would also need to be addressed.

In an open repository a series of processes can affect the long-term confinement capacity

- Chemical processes: The presence of oxygen may create problems with corrosion of waste containers and disposal tubes and the Boom Clay may be acidified by oxidation reactions;
- Hydraulic processes: Transport of clay water to the galleries may lead to a desaturisation of the host rock;
- Mechanical processes: There may be convergence of the clay around the galleries. Also, galleries will have to withstand higher pressures as long as they are kept open;
- Thermal processes: Thermal profiles in the host rock will largely depend on how the ventilation is arranged.

These processes are not expected to create insurmountable problems for a repository in the Boom Clay which stays open for 100 years, but each of them will need further research to confirm this. Especially the question of aerobic corrosion of the waste containers could be a difficult one.

It is concluded that although an extended open repository seems to be feasible from a safety point of view, final closure remains an absolute safety requirement. The risks for major changes in society which could result in a breakdown of the active management of the open repository could lead to an abandonment of the repository. Therefore, the duration of the open phase should be limited to a reasonable period of time.



In the Belgian concept for the disposal of high-level vitrified waste (from reprocessing), the galleries (in the clay) will have a diameter of about 2 m and have a concrete lining. The waste packages will be placed in horizontal disposal tubes of stainless steel and the space between the disposal tubes and the gallery lining will be backfilled with pre-compacted blocks made of a mixture of bentonite, sand and graphite. Retrievability may be achieved by using high-integrity long-lived waste containers, by postponing the stepwise closure of the repository and by using easily removable backfilling and sealing materials. (Ref. 1e)

2.9.2 Canada (ref. 1h)

The Canadian proposed system for disposal of the spent reactor fuel would be a network of horizontal tunnels and disposal rooms, excavated deep in the rock, with shafts extending from the surface to the tunnels. The repository would be built at a depth of 500–1 000 m in the Canadian Shield. The spent fuel would be placed in containers made of titanium or copper and designed to last for at least 500 years. The containers would be placed in the disposal rooms or in boreholes drilled in the floor of the rooms. Each container would be surrounded by a buffer material, likely containing clay. Each disposal room would be backfilled and sealed with clay or cement. All tunnels, shafts and exploration boreholes would be ultimately sealed in such a way that the disposal facility would be passively safe, hence not depending on institutional controls to ensure long-term safety.

The Atomic Energy of Canada Ltd (AECL), which is the implementer, has stated that it would take 60 to 100 years to build and fill the repository, seal it and decommission it. During that period, monitoring and retrieval would be possible. AECL also stated that, during that period, the decision to close the facility could be delayed as long as future generations desired. It also indicated that, after decommissioning, retrieval would be more complex and expensive. An independent study has later on concluded that it would still be possible to retrieve the wastes from a decommissioned facility, although it is estimated that the process would take 5 to 15 years depending on the nature of the intervention required.

In 1989 an environmental assessment panel was appointed by the federal Minister of the Environment to conduct a public review of AECL's concept. One of the tasks given the panel was the examination of the criteria by which safety and acceptability of nuclear fuel waste management should be evaluated. The panel stated that to be considered acceptable a concept must meet the following criteria:

- Have broad public support;
- Be safe both from a technical and social framework;
- Have been developed within a sound ethical and social framework;
- Have the support of Aboriginal people;
- Be selected after comparisons with the risks, costs, and benefits of other options; and
- Be advanced by a stable and trustworthy proponent and overseen by a trustworthy regulator.

After a number of sessions and hearings, the panel, in its final report in 1998, concluded that there was not sufficient public support to proceed with the proposed concept, although it had judged the concept to be, on balance, safe from a technical perspective at this stage of development. The panel added, however, that the concept had not been demonstrated to be safe from a social perspective. It recommended that the government adopt a step-by-step approach in seeking broad public support on the best approach for the long-term management of these wastes before getting on with site selection for a particular facility. The government of Canada responded to the panel report in December 1998, endorsing most of the recommendations.

The panel noted that conceptions of safety and acceptability are greatly influenced by an individual's or a group's perception of risk. As there is often little correlation between experts and the public perception of risk, it is not surprising that there are disparate views of what is safe and acceptable. The conceptions of safety, risk and acceptability are coloured by each individual's or community's perspectives.

Some participants who rely more on science and technology to predict the future and adapt to change, generally believe that today's science and human knowledge should be able to meet the challenge of building a waste facility that would guarantee the protection of human communities for a period lasting at least 10 000 years. They noted that there is no known successful institutional control that has lasted for such a long period of time. They therefore believe that it is preferable to trust the natural protection offered by deep geological formations and the natural environment combined with a disposal system designed by humans that could be sealed in complete safety forever. This would remove from unstable societies the responsibilities of managing this hazard. Some participants among this school of thought, however, believed that access to the repository should be retained for as long as society might wish to recuperate the wastes. Their faith in the technical safety of the concept relies on their interpretation that the concept incorporates sufficient flexibility at the site selection stage and implementation stage to correct any inadequacies from a technical and engineering perspective. Design as you go is an acceptable approach.

For other participants, who do not have confidence in the ability of science and engineering to resolve problems of this nature, an important characteristic of nuclear waste is the risk they represent for thousands of years, a risk that transcends scientific predictions. From their point of view, it would be presumptuous to believe that current scientific tools are exempt from major failures. Science, they believe, cannot predict everything and safety is not just a matter of probabilities and meeting standards and regulations. For the public, safety is rather the opposite of danger; it is protection against harm. Hence, as imperfect as society may be, it must keep surveillance and control over the repository in order to intervene in the future and apply corrective measures to unforeseen events that could become catastrophic. According to them, it would be irresponsible to expose current and future generations to a catastrophe caused by a lack of adequate monitoring capability or effective access to the waste.

The division between these schools can be observed in the evaluation conducted by the panel members in using their criterion for flexibility in assessing safety. The scientists on the panel believed that the concept as described by AECL offered limitless flexibility to allow corrections in ”design as you go”, an acceptable engineering practice, and also to delay decommissioning and final closure to accommodate whatever extended monitoring stages future generations might require. Such flexibility should be retained. The social scientists on the panel, however, did not believe that there was sufficient flexibility in the concept to guarantee its safety. They tended to agree with participants in the review that a system of early detection of failure, inside the repository or close to it, should be incorporated in the disposal concept. Such a system would provide forewarning and trigger appropriate action, including retrieval if deemed necessary, in the event that a series of unexpected events were to thwart passive safety. In accordance with its criterion for flexibility, the panel agreed that safety from a social perspective would be improved if AECL's concept was modified to include better monitoring technologies and more effective retrievability possibilities, thus striking a balance between passive safety and active institutional control.

On the issue as to whether the public wanted a sealed, walk-away disposal facility or would prefer monitored, retrievable long-term storage, the panel concluded that in the light of the evidence presented to them during the review, AECL's proposal would have to be modified to include better post-closure monitoring and retrieval technologies. Such modifications would not only help provide the degree of security to earn public confidence; they would also satisfy the need to strike a balance between minimising the responsibility placed on future generations and maximising their choices.

2.9.3 France (ref. 1d, 2)

In 1991, a law was passed in France, in which three main research directions for the management of high-level and long-lived radioactive waste are defined. This work will form the basis for a decision in 2006. One of the research directions concerns a study of the possibilities of "reversible or irreversible" disposal in deep geological formations, notably through work in underground research laboratories. The reasons for reversibility are many, but they are essentially based on the principle that future generations should have the possibility of re-examining the current decisions and have a freedom of choice. During 1997, there were public inquiries for the construction of underground research laboratories and the implementer ANDRA took note of public interest and of the elected representatives' insistence for a study of reversible geological disposal.

It may be noted that the term ”reversible” is used in the material from France. In this connection it may be regarded as synonymous to ”retrievable”, i.e. the possibility of retrieving the disposed waste packages safely.

In 1998 the French Government confirmed the decision to carry out the research in two underground laboratories. The Government mentions that the ”architecture of the repository must also provide for the logic of reversibility”. In August 1999, the Government issued the implementing decree for the construction and operation of the underground research laboratory at the Meuse/Haute-Marne site in eastern France. According to the decree, the research to be performed within the laboratory should aim at providing data required to ”the design, the optimisation, the respect of the reversibility and safety, of a potential radioactive waste repository”.

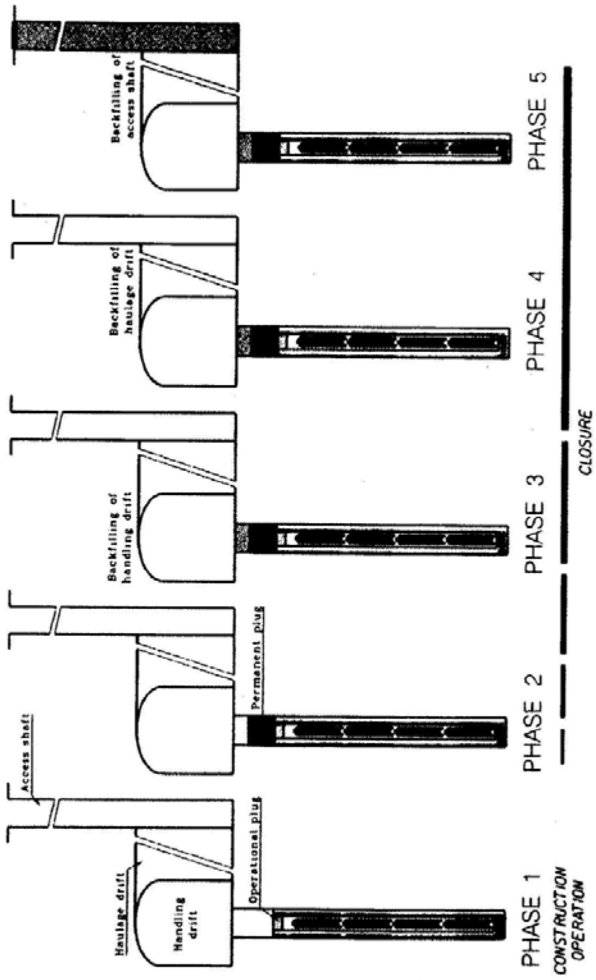
A repository will consist of a shaft leading to deep underground access drifts and then to further handling drifts. The handling drifts give access to vertical or horizontal cells (silos, vaults, boreholes and tunnels) where the waste packages are emplaced. A series of identical cells containing similar waste constitutes a ”disposal module”. After the construction and operation phases, there will be a step-by-step closure of the cells, the modules and the repository itself. At the current stage of the research programme, the selected preliminary design options include the possibility to retrieve the waste packages during the operational phase. This means that there is an ”initial retrievability of the repository”.

In order to ensure ”initial retrievability” of a repository during the operation phase, different factors are taken into account in the design, such as:

- With a high degree of modularity it will be easier to adopt specific reversibility requirements;
- A few cm of clearance between the waste packages and the engineered barriers will facilitate a retrieval of the waste packages from the cell;
- The sizing of the excavations, that of the support systems of packages and that of the steel liner of swelling engineered barriers should guarantee the mechanical stability of the system and the steadiness of the clearance between the packages and the engineered barriers;
- For vitrified waste, the potential adoption of an overpack facilitates the retrieval and also provides great mechanical strength of the packages and a high-level corrosion resistance;
- Shielded handling equipment and shielded operational plugs ensure the radiological protection of the operators;
- Additional remote handling equipment is defined for a potential retrieval;
- Means to ensure general operating conditions are provided, such as for instance adequate ventilation .

The next steps of the research programme will include

- Assessment of the technical possibilities in each successive disposal phase for accessing and retrieving waste packages safely;
- Assessment of the possibilities of delaying the partial or total closure of the repository with respect to the long-term safety.



The French concept is based on a phased approach. During the operation phase (phase 1), all movements are reversible and the various structures are open. This state can be maintained for many years. During phases 2-5, a step-by-step closure of the repository cells, the modules and the repository itself will take place. Retrieval remains possible during all phases, although with an increasing degree of effort. (Ref. 2)

2.9.4 Germany (ref. 1q, 2)

In Germany, the final disposal of radioactive waste is the task of the Federal Government. Final disposal in deep geological formations is regarded to be the best solution for radioactive waste elimination, and is anticipated for all kinds of radioactive waste, including spent fuel. Since 1977, much of the work in Germany has been devoted to a salt dome located near the village Gorleben, which has been considered as a preliminary site for a repository, based on an extensive site selection programme.

The Gorleben repository concept contains two shafts down to the salt dome, in which the waste will be emplaced at a depth between 800 and 1 400 m. The waste packages and the disposal fields must be designed to ensure that a temperature limit of 200C at the cask-salt rock interface will not be exceeded. Only one salt dome is expected to be used.

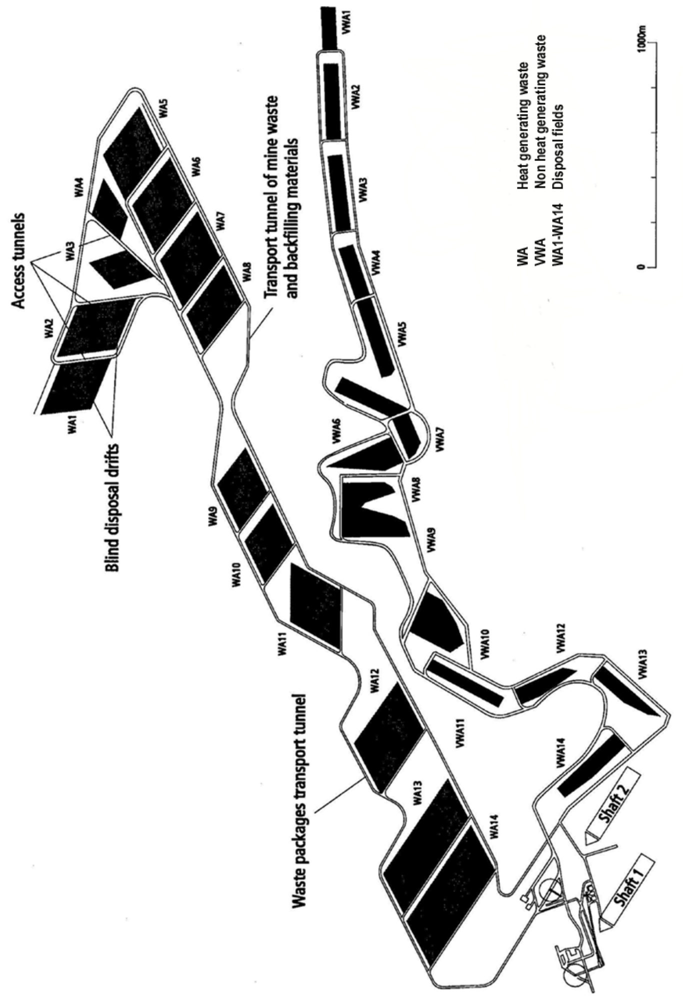
Different variants are considered for the disposal of heat generating waste. Spent fuel is expected to be placed in POLLUX-casks. A POLLUX cask is a self-shielding multi-purpose cask for disposal of spent fuel. It has a length of 6 m, a diameter of 1.6 m and a weight of 65 tonnes, when loaded with spent fuel.

The favoured concept for the Gorleben repository anticipates disposal of radioactive waste in different mine sections at a depth of about 840 m; heat generating waste including spent fuel in one and non-heat generating waste in the other section.

The Gorleben concept has been developed according to the present legal regulations and does nor include any retrieval intentions. With the planned repository design, there will be only very restricted possibilities to recover waste packages during the operational phase.

Retrievability has so far been studied in Germany only in the context of safeguards requirements. Temperature field and thermomechanical near-field calculations demonstrate that retrieval from the closed and sealed repository is possible with the state-of-the-art mining technology. Nevertheless, spent fuel packages recovery would require excavating a new retrieval mine.

Retrieval is only possible at a time and a place where the temperature limit of 100C is not exceeded in the repository area. According to calculations, about 40 years after the start of the emplacement (or 70 years after discharge from the reactor), the surface temperature at the first two POLLUX casks situated at the outer end of a marginal drift will already have dropped below 100C. There will be no full retrievability within the nearest 150 years, but after 150 years about 500 casks will be retrievable and after 1 000 years, all will be retrievable, with regard to the temperature conditions.



The German Gorleben repository concept is based on disposal in a salt formation at a depth of about 840 m., with heat generating waste and non-heat generating wastes in different sections. For the heat generating waste, retrieval may not be possible at all times, due to too high temperatures in the repository area during the first few hundred years. (Ref. 1q, 2)

2.9.5 The Netherlands (ref. 1j, 2)

The most studied option for the disposal of radioactive waste in the Netherlands is a mine type of repository in salt formations deep underground in the northern part of the country. Due to opposition of the local population and environmental groups, the suitability of these salt domes could not be confirmed by site investigations. As a temporary solution the government decided for long-term storage in an engineered facility.

In 1993, the Government published a policy on disposal methods for highly toxic wastes, including radioactive waste, in a position paper. It stated that non-retrievable storage and disposal methods for such wastes are not in accordance with criteria for sustainable development and should therefore be rejected. In the same year also the suitability, in principle, of deep underground salt formations for disposal of radioactive waste was reconfirmed by the Parliament.

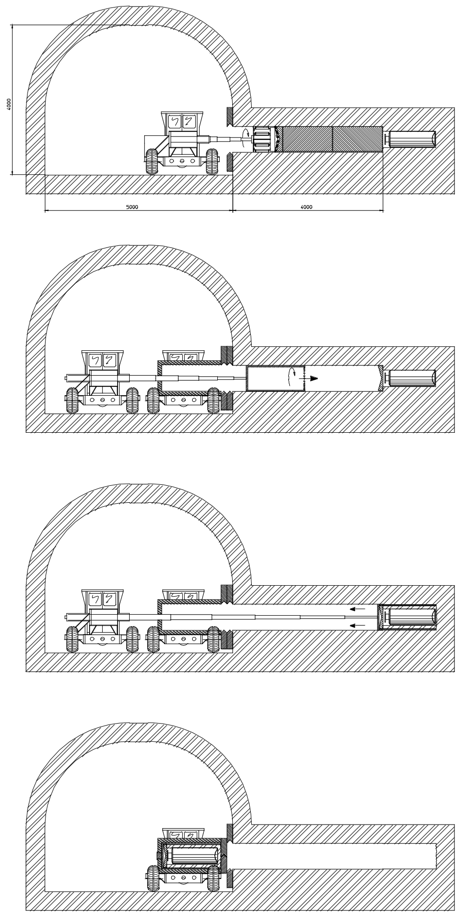
CORA is the national research programme overseeing and co-ordinating all research related to radioactive waste disposal. Its objectives are the following

- To broaden the scope to other relevant host rock materials (than salt). In particular, the suitability of tertiary clay is to be taken into account;
- To further explore the impact of the principle of retrievability of radioactive waste and in particular focus attention on
  - feasibility of construction of a retrievable repository in different host rock materials and time-dependence of the structural requirements;
  - safety implications of various retrievable options on the long-term containment function;
  - additional investment cost and maintenance costs of retrievable repositories in different host rocks;
- To investigate the possibilities of extended surface storage of radioactive waste;

- To maintain and possibly intensify the international co-operation in research related to radioactive waste disposal by participating in international projects.

The METRO-I and the TRUCK-II concepts are both based on vitrified high level wastes from the reprocessing of the spent fuel from the two nuclear power plants in the Netherlands. Within METRO-I, a new design for a repository in salt has been developed. Within TRUCK-II, a design for disposal in clay has been worked out.

The retrieval method for the METRO-I concept envisages the use of a standard drill to remove the rock salt plug and a ”core-drill” to remove the waste container and a thin layer of surrounding rock salt. These operations are assumed to occur under rather normal conditions, i.e. the conditions in the repository allow for a standard preparation and carrying out of the retrieval activities. Also in the TRUCK-II concept a retrieval is expected to be based on existing technologies.



In the Netherlands, concepts for disposal in salt as well as in clay have been worked out. The figure shows a retrieval procedure for waste packages (vitrified waste) placed in salt. The salt plug (about 3 m long) will first be removed by use of a standard drill. Then a "core-drill" will be used to remove the waste container and a thin layer of surrounding rock salt. (Ref. 2)

2.9.6 Sweden (ref. 1c, 2)

The prime responsibility for the management and the disposal of the radioactive waste in Sweden lies with the reactor owners. The reactor owners have formed a jointly owned company, SKB, to carry out the necessary actions.

The Swedish legislation does not include any requirements for retrievability.

The KBS-3 concept which is the main track, along which SKB is working for the spent fuel, is a deep repository in hard rock, with shafts, access tunnels and deposition tunnels. The waste packages (thick walled copper canisters with an iron insert) will be placed in deposition holes drilled in the floor of the deposition tunnels, and surrounded with a bentonite buffer. The repository is expected to be located at a depth of about 500m. The deep repository is planned to be built in two stages. In the first stage, approximately 10 % of the total amount of spent nuclear fuel (about 400 canisters) will be deposited. This initial period is planned to start around 2015 and last for about 5 years, after which the experience will be evaluated. If the result of that evaluation is that continued deposition is suitable and acceptable, the entire repository will be built and the activities will continue until all waste has been deposited.

The present repository design has been developed to get a system with a very high and provable safety level, with no intention of retrieval and without the reliance on surveillance and maintenance. Nevertheless the system exhibits a high degree of retrievability. An important part of the decision making under uncertainty is the feasibility of taking a step back in the decision sequence, if one would like to do so. The concept of retrievability can be extended into a general reversibility of any action taken in the waste management process. The possibility to reverse any action would then correspond to a retrievability in the operating phase, the possibility to take back the waste from the repository would be retrievability in the post-closure phase.

SKB has the opinion that no actions shall be taken during handling, and no arrangements shall be made that will unnecessarily hinder retrieval, nor shall any actions be taken to enhance the retrievability if they will impair the capacity of the repository to comply with the safety regulations.

As long as the spent fuel is kept in the interim storage (pool storage CLAB), it is of course fully retrievable.

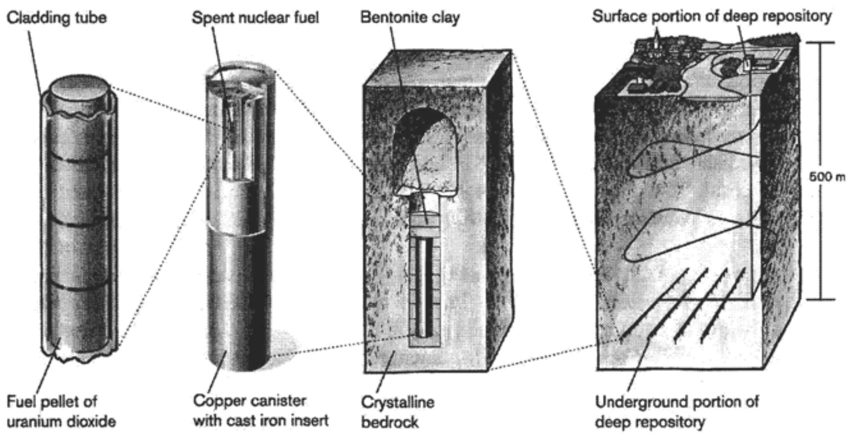
Before disposal, the fuel will be dried and encapsulated in copper canisters with a cast-iron insert. A cast iron lid will be bolted on the insert and a copper lid will be welded on the canister. Techniques for retrieving spent fuel from a sealed canister will be developed in order to be able to cope with situations like canister damage during the handling etc., and these techniques will be useful also for any possible retrieval for other reasons.

When a canister has been deposited in the repository, it can be retrieved by just reversing the depositing stage, as long as the bentonite has not swelled too much. If such a swelling has taken place, the bentonite must be removed by a special technique, which is being developed. Spraying with salt water under high pressure may be an option for that.

Techniques for the removal of the backfilling of a deposition tunnel have already been tested.

When it comes to retrieval after backfilling of transport tunnels and shafts, the situation will be very much dependent on how much time has elapsed sine the backfilling was made. New equipment might have to be purchased and enhanced ventilation may be required because of the increased rock temperature. A logical limit for any intentional action is in practise given by the time during which the information regarding waste and site is preserved.

The fact that the concept is based on a canister with a very long life time, is supposed to be of great advantage for a safe retrieval of the canisters.



The Swedish KBS-3 concept – based on disposal at about 500 m depth in crystalline rock - has a high degree of retrievability thanks to the step-wise procedure. A waste package (copper canister) can be retrieved by just reversing the depositing stage, as long as the bentonite around the canister has not swelled too much. If swelling has taken place, the bentonite must be removed by a special technique, which is being developed. Spraying with salt water under high pressure may be an option for that. (Ref. 1c)

2.9.7 Switzerland (ref. 1g, 2)

In Switzerland, the legal requirement is that the repositories should provide the required level of safety without requiring active institutional control. Thus, even for short-lived low and intermediate-level wastes, an underground repository must be provided.

A site selection procedure that started more than 20 years ago gradually narrowed the number of options down to a total of four sites, which were included in the final evaluation. Based on the results of these investigations, Wellenberg in the community of Wolfenschiessen in the canton of Nidwalden was selected for recommendation to the Government in 1993. The selection process was attested by a political commission and also reviewed by the federal safety authorities.

The main advantage of Wellenberg is its large volume of compact, low-permeable marl host rock, which gives a lot of freedom in the design of a repository.

An application for a licence was submitted to the Government in 1994. Parallel to the federal licensing procedure, cantonal and community licences for the underground investigation need to be applied for. Since part of the repository entrance would be constructed outside zones foreseen for industrial purposes, the zone planning of the community must be adapted, a change that required a vote by the community assembly. The vote turned out to be affirmative by slightly more than 70 %.

Since also mining concessions could be affected by the repository, a cantonal vote was needed and the outcome of that was negative for the Wellenberg project. About 52 % of the votes were against. The canton of Nidwalden has eleven communities with a total population of about 35 000.

The steps taken by the project (GNW – Genossenschaft für Nukleare Entsorgung Wellenberg) since the negative outcome of the cantonal vote are to announce its willingness to restrict the concession application to exploratory drift and to present a project where the retrievability issue has been taken into account. These measures were also asked for by the Cantonal Government.

It turned out that the fact that waste would be emplaced in the caverns and the empty space backfilled more or less immediately thereafter had given many of the public a feeling of irreversibility and ”loss of control” over the waste. GNW therefore has suggested that backfilling of the caverns should take place much later – after a time span of two or more generations. The waste will be emplaced in the repository constructed to provide the necessary geological long-term safety, but the caverns will remain open and controlled until future generations decide to terminate controls, backfill the caverns and close and seal the repository. This idea has been investigated thoroughly during 1996–1997, taking into account technical as well as long-term safety aspects. The results were published in 1998 and presented to the safety authorities and to the Federal and Cantonal Governments and other involved parties. The response was positive and GNW now expects that the combination of high societal decision flexibility and uncompromised passive long-term safety will facilitate the necessary political steps forward to the implementation of the repository.

2.9.8 United Kingdom (ref. 1s, 2)

The HLW in UK will be in form of reprocessing waste. It is envisaged that vitrified HLW will be stored for a minimum of 50 years before disposal, in accordance with Government policy. A review of that policy is, however, expected to start shortly.

Nirex is responsible for providing the UK with environmentally sound options for the disposal of ILW and a small amount of certain LLW. Nirex has examined the feasibility of incorporating an extended period of relatively easy retrievability within its concept for an underground repository for such wastes. During a period of interim underground storage, the repository would remain open to provide access from cranes and other machinery to the vaults so that the waste remained retrievable.

The design philosophy that Nirex has adopted aims to provide flexibility by offering options for a continued maintenance and refurbishment programme. This would enable future generations to extend the period of underground interim storage, if they so desired, while retrieval remained possible. The following factors need to be considered when designing for extended storage in an underground facility:

- All areas, except the vaults, must be accessible by people for maintenance. In the vaults, the radiation levels would prevent access by people and all operations there would be carried out remotely;
- The vault environment must be controlled to maintain the sound condition of the waste packages, by controlling the temperature, humidity and chloride levels. These systems would need to continue performing effectively for the period during which the wastes were stored. If they had to be designed to operate for longer than 100 years, they would need to be accessible for maintenance;
- In terms of vault integrity, initial concepts were developed on the basis of repository closure following a waste emplacement period of about 50 years. However, 100 years is considered an acceptable design life for the kind of rock support system that would be required. For periods longer than about 100 years, it would be necessary to gain access for maintenance of rock support system.

Should a period of prolonged underground interim storage be the preferred option, the following factors would also need to be considered:

- During a waste emplacement period of about 50 years, wastes could be retrieved from the vaults by simply reversing the systems used to emplace them. Interim storage could be extended by a further 50 years, during which time it should remain reasonably straightforward to retrieve the wastes;
- To keep the vaults open beyond about 100 years, it would be necessary to arrange for all repository systems and equipment to be accessible for maintenance. Where practicable, equipment should be designed so that it could be removed from the vault for maintenance, the only exception being rock support, groundwater management systems and fixed in-vault equipment such as crane rails;

- Further work is being carried out to confirm the viability of the above options for extending the interim storage period. That work will include consideration of issues such as container corrosion, wasteform degradation and vault maintenance to identify constraints on the duration of the period.

Should a decision be taken in due course to backfill and seal the vaults, less reliance would be placed on rock support systems and groundwater management within the vaults could be ceased. The cement-based backfill would provide alkaline conditions that would afford protection to waste packages by inhibiting container corrosion. Retrieval would still be feasible following backfill but with increased difficulty.

2.9.9 United States (ref. 1f)

The Nuclear Waste Policy Act, as amended in 1987, defines the requirement for retrievability and provides the reasons for which retrievability may be required. It states that any repository to be approved as a result of the Act shall be designed and constructed to permit the retrieval of any spent fuel placed in such repository. It also states that such retrieval should take place during an appropriate period of operation of the facility. This latter requirement defines retrievability as a pre-closure activity. Reasons for which retrievability is justified under the Act include public health and safety, environmental concerns, and recover of economically valuable contents of spent nuclear fuel. The period of retrievability will be as specified by the Secretary of Energy at the time of design, and it will be subject to approval or disapproval by the Nuclear Regulatory Commission (NRC).

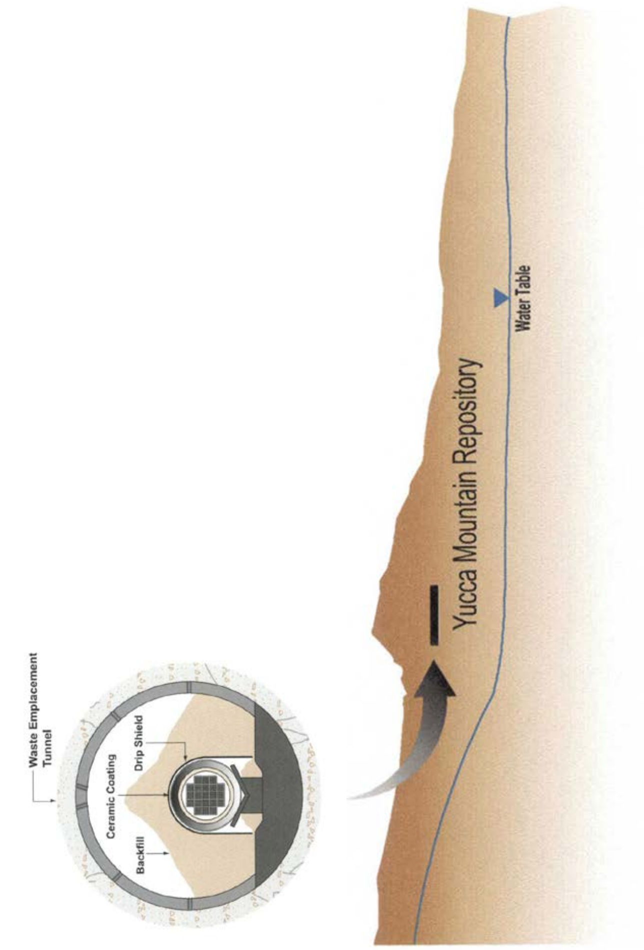
Concerning regulatory requirements, the NRC has stated that the waste must be retrievable on a reasonable schedule, starting at any time up to 50 years after start of emplacement, unless a different time period is approved by the NRC. A reasonable period is defined as the period that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

The US approach to retrievability envisions that the waste be retrievable at any time during the preclosure period. The regulatory minimum for retrievability is 50 years from start of emplacement, but the Department of Energy (DOE) intends to maintain a retrieval capacity throughout the preclosure period.

The concept for the proposed repository at Yucca Mountain includes horizontal emplacement drifts located in the unsaturated zone, approximately 300 m below the mountain surface and approximately 300 m above the water table. Different types of waste packages will be used for different type of wastes. For example, the waste package for spent PWR fuel will be a cylinder, approximately 1.6 m in diameter and 5 m long. It will have an inner wall of stainless steel and an outer wall of alloy 22, each of them 50 mm thick. The waste packages will be placed after each other (like the wagons in a train) on special fundaments at the floor of the drifts. The recent design change has focused on reducing performance assessment uncertainties through achieving a cooler design than proposed earlier. An example is that emplacement drift centerline spacing has been increased from 28 to 81 m to provide a sub-boiling region between drifts for water drainage. Other features, such as a drip shield over the waste packages and backfill to protect the drip shield, have been added to provide defence in depth in reduction of the amount of water contacting the waste packages during the postclosure period.

The emplacement drifts are to remain open until closure of the repository. This provides numerous performance benefits, because heat and moisture can be removed during the preclosure period, thereby lowering the postclosure temperatures and slowing the increase in relative humidity upon closure. One can say that the preclosure period is not to enhance retrievability but does improve performance, and the resultant extension of the retrievability capability is a secondary effect.

With the amended design, the temperature of the drift wall is required to remain below boiling and retrieval conditions are enhanced. Because of the lower rock temperatures, stresses in the rock and the risk of premature drift failure are reduced. Since the drifts are to remain intact and open during the preclosure period, retrievability would be accomplished though reversal of the emplacement process under normal conditions. The main components of the emplacement equipment, such as locomotives, shielded waste package transporter and emplacement gantry, can still be used under such normal conditions. An abnormal retrieval condition would occur when this equipment cannot be used, most likely due to drift wall collapse. Under such circumstances several additional operations would need to be added to the sequence, including clean up and removal of fallen debris, stabilising the drift, restoring the tracks, repositioning waste packages etc. Cooling would be required to lower the temperatures from near-boiling to human-accessible and portable radiation shielding may be required to permit access to those packages which cannot be remotely retrieved. Due to the double-ended nature of the emplacement drifts, retrieval can be accomplished from either end.



The concept for the proposed repository at Yucca Mountain includes horizontal emplacement drifts in the unsaturated zone, about 300 m below the mountain surface and about 300 m above the water table. The waste packages will be placed after each other on special fundaments at the floor of the drifts. By choosing enough distance between adjacent tunnels, the temperature level can be kept below 100C, which would make retrieval possible. (From ref. 3)

2.10 Some conclusions

As mentioned before, during the latest few years there has been a shift in the discussion **from** final repositories which would be closed and sealed and nobody would need to care anymore **to** repositories from which it shall be possible to retrieve the waste packages. Very briefly spoken the old view was based on technology and the new view is based on public perceptions. Technicians may feel that they capitulate to the public by accepting retrievability and, even worse, they may have a feeling that the safety of the system is questioned. A mixture of technical facts and know-how and a feeling for value judgements with the public will no doubt provide a way forward.

Retrievability seems to be possible always, as long as one has sturdy casks. An actual retrieval of waste from a sealed repository may be done by removing the backfill or by getting access to the waste packages via new access roads. The costs for retrieval from a sealed repository are expected to be high and it is not anticipated that such a retrieval will be proposed as long as a repository works well.

Retrievability may never be allowed to compromise the safety of the repository. In most cases, retrievability is achieved during the operation stage by using a step wise procedure, with each of the steps being reversible.

For some systems, such as the German one, retrievability is not possible at all times, for instance due to too high temperatures around the waste packages. In such cases retrieval would be possible only after some decay time has elapsed. In some cases one may get around such temperature problems by increasing the distance between adjacent waste packages, as has been suggested for instance for the US system.

Monitoring of a repository may be of interest for different reasons. During an initial demonstration period one may wish to monitor the function, but there may also be a need to ”guard” a repository for a long time to make sure than nobody takes illegal access to the waste, i.e. safeguards precautions. At the seminar, mainly acoustical methods for supervising a repository area were described. The present state-of-the-art in acoustical monitoring makes it possible to detect any physical activities such as drilling, blasting etc. in the area by using detectors installed in the rock around the repository area.

Safeguards can, according to Article 11 of the IAEA safeguards agreement, be terminated only when a material has been consumed or diluted in such a way that it can no longer be utilised for any nuclear activities or has become *practicably irrecoverable.* Therefore, safeguards for spent fuel in a geological repository need to be continued even after the repository has been back-filled and sealed, in particular if the waste in the repository is claimed to be retrievable.

2.11 References

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