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Retrievability of high level waste and spent nuclear fuel

Proceedings of an international seminar organized by the Swedish National Council for Nuclear Waste in co-operation with the International Atomic Energy Agency And held in Saltsjöbaden, Sweden, 24–27 October 1999

KASAM

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FOREWORD

The possibility of retrieving spent nuclear fuel or reprocessing HLW placed in geological repositories is an issue that has attracted increased attention during the past few years, not only among technical experts but also among politicians at different levels, environmental organizations and other interested representatives of the public. Some arguments for retrievability often mentioned in the discussions are, for instance, that:

- it must be possible to take remedial actions if it would appear that the repository does not perform according to expectations;
- new technologies or new economic conditions may lead part of the waste, particularly spent fuel, to be considered a useful resource;
- new technologies may be developed which can make the radioactive waste less dangerous or even harmless.

The Swedish National Council for Nuclear Waste (KASAM) decided to convene an international seminar on this issue at Saltsjöbaden, a town close to Stockholm, Sweden, on 24–27 October 1999.

During the planning of the seminar, KASAM informed the IAEA about its intentions and asked for some form of support. In consideration of the significant interest in the issue of retrievability in a number of IAEA Member States and within the Secretariat, KASAM's invitation was accepted and the IAEA decided to co-operate in the organization of the seminar. As a result of that decision IAEA staff members participated in the seminar and the IAEA agreed to publish the proceedings in the TECDOC series.

The intention of the seminar was to obtain an overview of how the issue of retrievability is looked upon in different countries and also to have an opportunity to discuss — among experts — how important areas, such as public acceptance, safety, safeguards, funding, etc. are connected to the retrievability issue.

The aim of the seminar was not to produce any consensus statements on retrievability, but rather to initiate broader thinking and to stimulate the discussion in the countries concerned and in international organizations within this area. For that reason much time was devoted to discussions, which have also been covered in this publication.

The IAEA officers responsible for this publication were E. Warnecke and F. Gera of the Division of Radiation and Waste Safety.

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SUMMARY

An international seminar on retrievability of high level waste and spent fuel was held at Saltsjöbaden, Sweden, in October 1999. The seminar was organized by the Swedish National Council for Nuclear Waste (KASAM) in co-operation with the IAEA. This publication includes the presented papers (all of them invited), an edited record of the discussions as well as some concluding remarks.

The seminar addressed a wide range of aspects on retrievability, as reflected in the session titles:

- Session 1: International review and some national updates on retrievability;
- Session 2: Public acceptance;
- Session 3: Ethical aspects;
- Session 4: Long term monitoring and cost considerations;
- Session 5: Safety and safeguards aspects;
- Session 6: Concluding remarks.

This summary consists of a condensed version of the concluding remarks presented by the rapporteurs and other participants in Session 6.

Session 1 included, in addition to an international overview, national reports from a number of countries planning repositories in different geological host materials. The presentations — from Sweden, France, Belgium and the United States of America — paid particular attention to how retrievability is included in the disposal systems.

It was noted that retrievability is being considered actively in a number of countries in studies, in repository design and in experimental demonstration work. Attention is also being paid to the legal and regulatory aspects of retrievability. The issue of minimizing burdens on future generations versus maximizing their freedom to choose was also discussed and it was concluded that for some disposal systems there is no contradiction whereas in other cases a conflict may exist between the two objectives. The extent to which one can satisfy both these premises is an important issue.

Provisions designed to facilitate retrievability can decrease the reliability of isolation barriers and thus be counterproductive in respect to overall safety, but this is not necessarily true in all cases. Certain features — such as long lived containers — are good for both.

Retrievability is always possible but cost and risk are affected by when and how it is done. Current technology is considered sufficient, but demonstration would be useful, even if not required.

The issue of nomenclature is important and not sufficiently clear. Retrievable, recoverable, reversible, reparable, postponable, irrecoverable, are examples of words used in discussions about retrievability; there is an obvious need for clear definitions.

Retrievability seems to be a feature of many national programmes. It is explicitly addressed and to some extent being programmed into them. The potential downside of this is that the more work that is done on enhancing retrievability, the greater is the danger of reinforcing the perception that retrieval will be necessary.

From **Session 2** the following conclusions were reached:

The perceived risk is very important. It is difficult to convey actual risk or calculated risk to the general public. Communities with previous experience of nuclear activities may accept a disposal facility more easily; in any case broad public support is required. The level of transparency in the information is very important.

Retrievability options appear to aid in the discussion, but such options could also be detrimental. It was also noted that the a step-by-step approach — with a possibility to reverse each step — may be the best way to achieve public acceptance.

Early and continuous public participation is essential.

In **Session 3**, very different views were presented in two papers from Sweden (A.-M. Thunberg) and the Netherlands (METRA-study). Both papers present questions, doubts and reflections.

The Swedish paper concludes that we have to act now and our action must be based on the knowledge that is available today. There is always some degree of uncertainty, which is unavoidable. A passive attitude is not defensible. Long term safety must be the primary concern, if such a goal would be inconsistent with other values. A quote from the paper: "The price we seem to have to pay is to act under the premises of uncertainty, while not being able to use this uncertainty as an excuse for not acting at all".

The Dutch paper was a presentation of a report prepared by an environmental group on ethical aspects related to retrievable disposal of radioactive waste — The METRA study. The paper concludes that "There are fundamental differences in view on the ethics regarding disposal of radioactive waste between the regulator (representing the official position) and the 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 disposal method is, manage the waste such as to keep all options open and pass on the know-how, the technology and the resources to enable that." The Dutch paper also makes the observation that there is a beginning of a dialogue between the official bodies and persons representing environmental and social organisations and that at least a significant part of the latter groups have shown a determination to remain involved in further discussions.

S**ession 4** included a description of geophysical methods for monitoring. Basically, such techniques have been known for a long time, they are very effective in hard rock, somewhat less in plastic rocks. They 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.

Session 4 also addressed the issues of liabilities, responsibilities, financial commitments, etc. in the different options. Generally, after closure of the repository, according to present legislation, the operator will be released from further responsibility. With the option for a future retrieval of the waste, questions on continued responsibility, costs, and funding need to be taken care of. Some participants expressed doubts about the possibility to transfer information, responsibility and funding over very long periods of time.

Session 5 covered the two important areas of safety and safeguards. It was concluded that safety has the highest priority, without any doubt, and shall not be compromised by safeguards, retrievability or anything else. Safety comprises radiological and conventional (mining) safety. Also, it is necessary to distinguish between safety during the operational phase (regarding the staff as well as members of the public) and post-operational safety.

For "normal" scenarios (including waste emplacement, backfilling of disposal rooms, closing of drifts and accesses), it was concluded that repositories can be built, operated and closed safely.

For "retrievability scenarios" different situations can be identified. In one of them, which could be termed the "reversibility" scenario, disposal of the waste is done in the same way as in the normal scenario above, but provisions are made to allow reversal at every step. The safety case is very similar to the normal scenario. An adjustment of the repository layout may be necessary, for instance in order to limit the maximum temperature in the repository. Adjustments may also be needed in the waste package design in order to maintain mechanical stability or chemical durability, in particular when it comes to HLW glass blocks, which may require less elaborate packaging. There is also a need for development of technologies, for example equipment for waste retrieval. Radiological safety has to be ensured, i.e. radionuclide releases from contaminated or leaking waste packages have to be addressed and, as necessary, additional engineered features have to be built into the concept.

Another retrievability scenario could be termed "full retrievability", which would mean that the disposal rooms are left open for an extended period. That situation corresponds to a new repository condition, which needs to be addressed by a new safety assessment. In this case all the issues discussed above are more crucial and need very thorough consideration. A particular issue is the stabilisation of open rooms, which otherwise might collapse as a consequence of the temperature increase and this may result in conventional accidents. Some of the experts expressed the opinion that "full retrievability", as described above, is not consistent with the IAEA/ICRP principle of optimisation, because exposures are not "as low as reasonably achievable".

Regarding feasibility, the opinion of the experts at the meeting was: yes retrievability is feasible, although it is difficult to achieve, additional measures have to be taken into account and it is more expensive. The safety case for "full retrievability" has not yet been fully assessed, neither theoretically nor practically, for example, in demonstration experiments in laboratories, pilot plants or underground research laboratories.

Concerning safeguards, it was concluded that the spent fuel conditioning plant has to undergo safeguards inspection. Open disposal rooms also have to be inspected. It would be desirable to monitor closed rooms prior to closure of the repository, by geophone measurements or other remote control measures. After closure of the repository, land surveillance of the repository site, for example by satellite systems, would be a suitable measure to ensure that there is no diversion of fissile material.

No conceptual approach for dealing with retrieved waste was presented at the seminar.

It is very important to have an integrated approach to radioactive waste management, from the generation of the waste through to its disposal, including items such as safeguards or retrievability, in order to avoid conflicting requirements. The work on safeguards shows in principle that co-operative work can lead to reasonable concepts which suit both — those who deal with safety and those who deal with safeguards.

OPENING ADDRESS

A.J. González
Director of the Division of Radiation and Waste Safety,
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Presented by E. Warnecke

It is both a personal pleasure and great honour for me to address you today. I am grateful to the Swedish National Council for Nuclear Waste, KASAM, for allowing me the unique opportunity to open this Seminar which touches on two controversial themes: the disposal of radioactive waste and whether such a disposal should be retrievable or not. You may have invited me just because I have an executive position at the International Atomic Energy Agency (IAEA), which is the only organization in the UN family with specific responsibilities in the themes addressed by the Seminar. However, I would also like to think — perhaps a little presumptuously — that you also invited me because you are interested in simply hearing the opinion of an expert who has dedicated his professional life to the protection of human beings against the detrimental effects of ionizing radiation.

This is a meeting on *retrievability* of radioactive waste disposal, but, in the current international context, this is synonymous with having a meeting on the *safety* of radioactive waste disposal because, I would go as far as to say, there can be no waste disposal unless there is universal agreement on its safety. And, if there is no waste disposal, the discussion on whether the disposal should be retrievable becomes a discussion on *the sex of the angels*. My presentation, therefore, will mainly address the safety of radioactive waste disposal in general with some links to the particular issue of retrievability. It will not be a formal position of the international organization I represent — the IAEA — but rather my candid professional opinion on this controversial subject.

Opinions on radioactive waste often seem to be rigidly polarized:

- 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 the context of this seminar — 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 so is central to the subject of this seminar.

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?

Our challenge is to narrow these gaps in perception, and to work towards solutions that are both technically sound, logically coherent and, furthermore, enjoy broad public acceptance. The future of waste disposal must be both safe and acceptable; otherwise there will be no future for waste disposal, nor for its retrievable variant; neither will there be much future for the nuclear technologies that generate the waste.

In my opinion, a crucial step in meeting this challenge is to obtain a *de facto* international consensus on safe and acceptable solutions. I will revert to this theme at the end of my presentation.

The only particularity of radioactive waste in relation to any other type of human waste is that radioactive waste is a source of ionizing radiation which may cause radiation exposure to humans and consequently harm their health. In principle, therefore, the safety of radioactive waste is no different, as a conceptual issue, to the safety of any other radiation source. Current practice, however, has tended to highlight a somewhat different and rather curious picture in relation to waste safety. The "safety" of innumerable radiation sources is not necessarily questioned by society — for instance, those sources of natural origin and those created artificially by man for use in medicine. Conversely, the "safety" of radiation sources associated with nuclear power in general, and, in particular, the "safety" of radioactive waste disposal has overstepped all rational considerations. Indeed, it has become a kind of religious quest with all the trappings of dogma that such a religion calls for. This "religious" approach to the safety of radioactive waste disposal has in turn prompted a counter-reaction among those who are convinced, sometimes genuinely convinced, sometimes because of vested interests, that nuclear power can be a safe and sustainable source of energy for mankind and that its radioactive waste can be safely disposed of. This counter-reaction, usually headed by the nuclear industry, has also tended to be dogmatic.

"Believers" and "non-believers" in the feasibility of the safe disposal of radioactive waste appear to be sincere in their conviction that the other side is heretical — even sacrilegious. Neither side seems prepared to make any kind of compromise or to even try and understand the other's standpoint. Allow me to express candidly my perspective of these two divided camps looking at the situation from a distance. The vast gorge between them represents the most important — perhaps even the sole — issue requiring attention within nuclear power today. Should all interested parties be unable to resolve this problem, I must stress again, there may not even be a future for the one subject of this Seminar nor a future for nuclear power as an alternative, sustainable source of energy.

As perhaps the vast majority of attendees here today, I feel a member of one of those two "camps" — the camp that believes in the feasibility of the safe disposal of radioactive waste. The organization that I represent also shares this view. I am therefore far from being an impartial bystander. However, perhaps because I am democratic (in the sense that the ancient Greeks used the term), it worries me that our "creed" is shared by a relatively small number of believers — let us say a few thousand around the world — who constitute an assembly of self-proclaimed rationalists. Our opponents — those who are convinced that radioactive waste is a real evil which cannot be handled safely by man — make up a much larger congregation. In fact, they probably represent the rest of humanity. It is a relief to me that many who make up this vast majority are irrational in their line of argument or simply ignorant of the facts. But this sense of relief is limited because, ultimately, the decision-making process in a democratic society depends on that vast majority rather than on our seemingly correct but minority opinion.

Perhaps our best approach in endeavouring to face the formidable challenge posed by those in the opposing camp is to absorb their sense of rationale into our own. I therefore propose the necessity of a self-critique and reform of the faith in which our group believes. Otherwise, it would be hypocritical of me to debate with you about a future which has poor prospects. We must be prepared to change our approach in an effort to close the gap in understanding between all *stakeholders* to use a term which today is "*à la mode*".

In my view, we have before us a dilemma with the following two premises: either we continue to defend our rationale *in extremis* with all the potentially damaging results we have experienced up to now; or we attempt to conduct an introspective examination of our rationale in the light of what seems to be the opinion of the majority in the hope that our beliefs will be better understood and accepted. I opt for the second premise, namely that we should look inward and examine our rationale, constantly keeping the majority opinion in mind. I will therefore try to be faultfinding and to play the devil's advocate of our approach even though — I stress — I personally agree with many of the general conclusions reached by our camp. My proposals will hinge on reforming my own faith, not because I am a self-critical masochist but because my faith is the one that I can best understand and rationalize. I am also convinced that such a change is necessary to effect a reform of beliefs in the opposing camp, although I recognize that it is not necessarily sufficient in itself.

The first problem that we have to face is that of perspective information. Have we conveyed the right message to the stakeholders on what our problem is? Have we provided the right perspective to it? Or is it because of our mental concentration on high level waste and sophisticated disposal technologies that we have in fact obscured the issues?

Let us start our retrospective analysis by asking ourselves: what is the idealization of the term radioactive waste among those who hear it?

It is a fact that human beings have artificially produced radioactive materials and substances for the benefit of mankind and also for military purposes. Large amounts of these materials have become unusable remains, as in all industry since industrialization began. In this case the peculiarity of the remains is their radioactivity. These radioactive remains — in solid, liquid or gaseous form — are what we term *radioactive waste.* Just a small volumetric fraction of this waste is that referred to in the title of this Seminar and is subject to disposal, whether retrievable or not. Such type of material has already been freely released into the environment. At this stage, let me be provocative: do you really believe that this is the picture that we have transmitted? Are you truly convinced that the public is aware that mankind has released freely into the atmosphere large amounts of radioactive substances whose radioactivity is of the same order of magnitude as that accumulated in the waste 'proper' that we plan to discuss in this Seminar? Are you yourselves aware of this fact?

It is a generally hidden fact that a substantive part of the radioactive waste generated by mankind has already been discharged as effluents into the environment where it was dispersed without any noticeable health effect. This waste, which in technical jargon is termed *release* or *discharge*, has not always been considered as waste *proper*. In practical terms, 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, I would say, irresponsible manner. They are the result of 2408 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 estimates from the United Nations Committee on the Effects of Atomic Radiation (UNSCEAR), more than 2000 EBq (or $2000 \cdot 10^{18}$ Bq) of fission products have been discharged into the atmosphere and dispersed globally as a result of atmospheric nuclear weapons testing alone. There have also been large releases into the geological environment as a result of underground nuclear testing: just another 500 EBq or $500 \cdot 10^{18}$ Bq. Semipalatinsk in Kazakhstan is a big dumping area for some of this waste and nobody seems to care. This covers a large area about the size of Austria. All attempts by the United Nations merely to quantify the problem have failed because of an apparent lack of interest. Alone in one part of this vast area, in Dagelan, there are more than 600 kilograms of plutonium.

And these are not the only cases of free disposal of radioactive waste in the environment. There have been continuos releases to human habitats from installations of the military nuclear fuel cycle. Again the amounts are staggering; alone the discharges of three Russian military production centres are astonishingly high: from Tomsk $42 \cdot 10^{18}$ Bq have been discharged into the nearby river; from Krasnoyarsk $17 \cdot 10^{18}$ Bq; and from Mayak $4.4 \cdot 10^{18}$ Bq.

By comparison the releases from the Chernobyl accident of about 10^{17} Bq seem minuscule.

Furthermore, a relatively large amount of waste has been deposited in various parts of the world as ***residues*** from previous operations. Examples include waste remaining from tailings of the mining and milling of ores that contain naturally occurring radioactive materials and also from accidents, unregulated operations, and other military activities, like military transports etc. The total global activity of residues has not yet been fully quantified but is enormous — particularly of residues from military operations.

Is this vast amount of radioactive waste comparable with what we are concerned with in this Seminar? Surprisingly enough, it is.

The waste referred to in this 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, or as some people believe, the real devil. Its total activity compares well with that from waste already discharged into the environment, although comparison can be tricky *inter alia* due to the different radioisotopic composition. The estimation of their activity is straightforward. Each GWa (gigawatt–year) of electrical energy produced by nuclear power generates around three EBq of radioactive waste, which decays approximately by one order of magnitude of activity by every order of magnitude of time in years (i.e., after one year 0.3 EBq per GWa remain after 10 years; 0.03 EBq per GWa remain after 100 years, etc.). The cumulative electricity generation by nuclear power is around 4000 GWa. Therefore, the total activity of solid waste from this source 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 3000 EBq has already been discharged uncontrollably and irrecoverably into the environment, mainly by the nuclear weapon states. This swift disposal does not seem to have produced noticeable health effects. By comparison, we are dealing with radioactive waste amounting to 10 000 EBq safely contained and waiting for an orderly and controllable disposal. This is the cause of our trouble. For this we have so many discussions on what actions to take, how deep to build a repository, in what type of host rock, how to protect the waste with more sophisticated covers, and now *whether or not to make such disposal retrievable!* All that after we, the same people who are so deeply concerned about the ethical consequences of our actions, have freely released into the environment, without any control whatsoever, basically the same amount of activity. I am convinced that when our grandchildren compare these actions either they will have to laugh at our naivety or perhaps lament our hypocrisy.

But a more interesting aspect, again usually hidden from the public and from many specialists, is that all the activity of radioactive waste produced by humans, however great, is minute in comparison to the global activity of natural radionuclides. These were produced when our solar system was created and have been continuously produced by Mother Nature from the beginning of time and released into the environment. The amount is so large that it defies quantification. Earthquakes, volcanic eruptions and solar flames are foundries for huge amounts of radioactive materials. Only in the city of Ramsar in Iran, Nature's continuous release of mineral water rich in radium is generating radiation doses to inhabitants of the area which are more than one hundred times higher than the dose limits to members of the public from nuclear activities. Moreover, over millennia, the global inventory of natural radioactive materials has changed dramatically. The radioactive materials created artificially by man represent only a tiny proportion when compared to the global inventory of radioactive materials and even to changes occurring naturally.

It is surprising that comparative evaluations of inventories of man-made radioactive waste versus natural changes in the global inventory of radioactive materials have not been used more effectively as a plausible safety indicator. Assessment of future natural changes in the global radioactive inventory can be made within the uncertainties associated with other natural phenomena which are usually much easier to predict than man-made events. I ought to emphasize one particular point, however. Something that is troubling or harmful is not automatically acceptable because it compares favourably against its "natural background". The fact that there is a huge natural inventory of lead in the Earth's biosphere does not make the release of effluents containing this harmful element permissible; the fact that the incidence of "natural" cancers or genetic defects is surprisingly high does not legitimize the artificial induction of these diseases. However, the unavoidable background dose from natural radiation sources and its global variation are accepted reference points which offer a perspective to those additional doses caused by human activities. There is, therefore, no reason to discard the use of the global inventory of radioactive substances and its expected fluctuations in relation to radioactive waste. The conclusion I draw is, firstly, that more effort should be devoted to the assessment of changes occurring in the natural inventory of radioactive substances and, secondly, that we must develop a line of logic so that we can use the information we have on this natural inventory to put the radioactive substances produced by Man into perspective.

Please do not construct from my words a wrong moral: in no way do I advocate the free release into the environment of the waste proper that is awaiting disposal. This action, if feasible, would be as irresponsible as nuclear weapon testing. My only intention is to give some logical perspective to the actions that we are taking and a framework for our discussions. What all the fuss is really about is disposing irretrievably the small volume of waste that we have generated and that we will generate in the foreseeable future.

My moral is that for good or for bad (and I firmly believe that it was for bad!), we have historically treated discharges, residues and waste (proper) as different and independent entities and, in turn, different from the "radioactive waste" generated by Nature. Moreover, the experts dealing with all these entities usually belong to different "schools" of thought. As a result, the safety approaches applied have not always been inter-consistent and are hardly ever inter-dependent. Discharges have traditionally been the exclusive domain of the so-called *"radiation protection community"* who have applied to them safety criteria fully consistent with the ICRP International System of Radiological Protection. Waste (proper) has been treated as a special radiation source by another group of experts — the so-called "*radioactive waste community"* — who have developed *ad hoc* safety criteria. Residues, whether of artificial or natural origins, were *de facto* ignored until recently when, under environmental clean-up demands, *ad hoc* criteria were evolved by a number of national agencies and other interested organizations including the ICRP and the IAEA. The divergent methods used for handling discharges, residues and waste (proper) have not helped us in our efforts to communicate on the waste safety issue. Those who are critical of radioactive waste disposal see this inconsistency as a confirmation of their fears, and, admittedly, little has been done in the expert community to allay these concerns. Examples are abundant: a relatively small dose limit is recommended for discharges, whereas amazingly sophisticated theoretical calculations have been made for using this dose limit for *long term* disposal of waste (proper); then again, much higher levels than those relating to dose limits are recommended for residues. Of course, there are good explanations for this apparent incongruity, but they appear baffling and paradoxical to those outside our community and perhaps to many inside.

My examination of this issue leads me to a very simple conclusion. Discharges, residues and waste (proper), whether manmade or the creation of Nature must be treated conceptually as a unity and communicated to the public. Their safety must have a common conceptual denominator. The scientific and technical communities dealing with them should come together and unify their language, concepts and criteria. At the IAEA, we have already started moving in this direction and we hope that others will follow our lead.

This brings me to a different issue on this general matter of perception and communication. I would like to formulate the issue with a question which, for some in the audience, may seem sacrilegious: is the quantity termed radiation dose the correct indicator for *long term* safety of waste disposal?

The impact of current radiation exposure on health and on the environment is customarily quantified in terms of the quantity ***radiation dose***. The reasons for using this quantity in radiation protection are twofold: (i) it corresponds approximately to the expected deleterious effects not only on human health but also on other species; and, (ii) it is relatively straightforward to measure or to assess. However, the use of radiation dose as an indicator for the *long term* safety of radioactive waste disposal is flawed because none of the reasons for using the quantity for radiation protection purposes applies in this case. Firstly, radiation doses are not assessable with any certainty for periods of time longer than a few hundred years. The assumption that future generations will continue to live as we do and that environmental structures and patterns will not change is simplistic and does not bear up to any serious analysis. Secondly, with the expected progress of molecular therapy, it is by no means obvious that the level of radiation dose will continue to be a reasonable indicator of the probability of suffering health effects from radiation. The assumption that diagnostic and therapeutic medicine will be worse in the future than it is now is again not plausible.

In spite of these facts, "assessments" of waste and health impact have unfortunately already been carried out *over one million years* (!) and, believe it or not, they continue to be carried out by members of our community. These *long term* "assessments" are damaging our credibility and the case for safety of waste disposal. They cannot be regarded as a serious scientific endeavour to predict the future on the basis of present day living patterns and they alarm members of the public.

The usual argument to justify this curious behaviour has been: “If we do not use dose, what can we use?” This sounds to me like a declaration of defeat because we appear unable to find a suitable indicator to demonstrate the *long term* safety of waste disposal, we feel compelled to fall back on the use of a non-plausible indicator. We should stress that it is not true that the basic ethical foundation of the ICRP System of Radiological Protection does not stand unless we use dose. The principle of justification is more comprehensive than taking only dose into account. The basis of the principle of optimization is to select the protection option which is judged to be the best under the prevailing circumstances and not the option that delivers certain doses. The deontological principle of individual limitation has its roots in the protection of Man as an individual rather than as a species, and therefore dose is not the sole indicator for achieving this principle.

Again I kindly ask to you not to misinterpret my words and derive a wrong moral. My critique is not a plea to abandon the use of the quantity radiation dose. Rather it is as an appeal to rationalize its usage and to search for complementary safety indicators for the long term. In summary, we should try to stop the wrong use of dose as a major indicator of the long term safety of repositories. We should also seek a simple clarification of the aim and purposes of the System of Radiological Protection for the long term. This might include a generalization of the System’s principles, whereby we stress that indicators other than dose are legitimate for long term radiation protection purposes. We should also explore further the System’s application in a variety of circumstances, including those which may be perceived as being harmful to human health and welfare in the distant future.

Let me move quickly to another confusing issue: the technological sophistication that we have imposed on the treatment of radioactive waste.

Firstly, and just to put our problem in perspective, let us agree on the physical volume of waste. In fact, the physical volume of the waste preoccupying us is more than modest amount. This is another important issue which has not been properly communicated by us. The total volume of the so called *high level waste* produced annually from all operating nuclear power plants world-wide is around 4000 cubic meters — probably equivalent to the volume of this Seminar premises. The volume to be produced over the next 30 years is estimated at 120 000 cubic meters, comparable to the size of a football stadium. For purposes of comparison, it is interesting to note that the amount of waste characterized as hazardous under the Basel Convention that controls its transboundary movement is 400 000 000 tonnes. This is a basic message that we have failed to transmit, namely that the modest volume of radioactive waste is a logical outcome of the efficiency of nuclear energy. One kilogram of wood can provide to us just one kW·h of energy. One kilogram of coal is able to produce 3 kW·h, and 1 kilogram of oil can generate 4 kW·h. It is convenient to remain in the antigroup which states that one kilogram of uranium can generate the astonishingly large amount of fifty thousand kW·h in an open cycle and up to three million five hundred thousand in a closed cycle!

The public should be clearly informed that, while our problem is limited to 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 ash, 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 I believe public support can be developed. The first — and in my view 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*.

But should we not ask ourselves first the following questions. Technology for what? And why? Is it technology for "concentrate and contain" in a repository rather than "dilute and disperse"? Is it technology for immediate action or for "wait and see"?

The answers to these questions seemed intuitively straightforward until a few years ago. They were obvious to our community of believers. Our opinion, however, seems to be now moving in a different direction. In a sense, the underlying theme of this Seminar implicitly gives answers to these questions and curbs discussion of alternative options. The Seminar is intended to provide a forum for discussion on the retrievability of waste from geological repositories. That is, this Seminar has assumed the decisions taken by our community, namely: (i) that to "concentrate and contain" is definitively better than to "dilute and disperse" into the environment; and (ii) that, apparently, disposal actions should not necessarily be taken today, because the "wait and see" option, now sophistically called *retrievability* is perhaps a feasibly better option.

Although it may be felt a little out of place for the first speaker of the Seminar, I would like — with your permission — to play the Devil's Advocate and explore what somebody who disagrees with our viewpoint might say about our line of argument. Kindly allow me to indulge in my reflections; I hope they might resurface in your memory at some later date. The very first question that such a Devil's Advocate would pose would be *Why*? Why should we prefer "concentrate and contain" to "dilute and disperse"? Why is it ethically better for future generations to inherit a deadly legacy of a very low (but finite) probability caused by deterministic effects following an intrusion into a repository, rather than committing individuals of the present and near future generations to an extremely low probability of stochastic effects? Why concentrate waste in order to achieve the smallest volume of repository, and not allow for some geometrical "dilution" within the repository in order to make deterministic effects unlikely in case of intrusion? If we believe that our disposal option is so safe, why should it be retrievable?

The answers to these questions are not as easy as they might appear on the surface. For those adherents of our faith — that is to say for all the thousands of experts at work in this field — the choices have been disputable. Some judge that the "dilute and disperse" option — for instance into deep seawater — is ethically questionable and politically unacceptable. And so we stand firmly by our remaining option of "concentrate and contain": the residues should remain concentrated in what we now call high level waste and disposed of as far away from mankind as possible where hopefully they can and shall be forgotten. For others in the community of experts, the "wait and see" option has no appeal because we already have a solution and therefore do not need to delay a decision. Such a delay would result in unnecessary radiation doses and industrial hazards, in particular mining hazards, that can and should be avoided. Finally, the question remains: to find a place for the retrieved waste if such a decision is taken. Although these experts have elaborated a sophisticated reasoning, it unfortunately does not seem to be shared by others inside our community, and this Seminar is proof of that. Their questions are also straightforward. Why can't we wait before undertaking irretrievable disposal, at least until a wider consensus is reached? Why isn't the option of retrievable disposal explored more carefully? These questions and many others are voiced by those who either view the disposal of radioactive waste with complete scepticism or with a feeling that our science has not yet reached a sufficiently advanced level for such definitive decisions to be made. Added to all this is the unfortunate fact that the answers we have offered in the past have never been as convincing as they should.

My thoughts on this matter are that we need to examine with scrutiny the basic technical decisions that we have taken but not implemented. We have to revisit, with an open mind and critical spirit, all the alternative options and combinations of such options. I am personally convinced that, after such re-examination, we may arrive at the same conclusion that our community shared until few years ago, namely that *the best option under the prevailing circumstances is to dispose the waste and dispose of it in a non-retrievable way in a geological repository,* but perhaps with some improvements in current methods of design which prevent potential deterministic effects following human intrusion. But I also strongly believe that we shall arrive at this final conclusion — whatever it may be — only after the extensive participation of expertise not only from our own community but also from those opposing our views, and not only from our own discipline but also from other sciences such as ethics and politics.

In summary, I have endeavoured to present the confusing background to our discussions. Against it, believers and non-believers on the safe disposal of radioactive waste have constructed their own particular rationale — sometimes incorporating elements of dogma. As already mentioned, I will carry out a critique solely on the constructions of the party to which I belong — namely, that of the believers. Let us now briefly summarize the curious rationale just outlined.

- Firstly, we have decided to make a distinction between *discharges*, *residues,* both natural and artificial, and *waste* (proper), and to treat them separately and not necessarily according to the same safety approach.
- Secondly we have decided to judge the impact of the waste produced by the generation of nuclear electricity in isolation and independently from the radioactive waste already released into the environment by human activities and, more important, without considering the vast amount of radioactive substances released by Nature into the environment.
- Thirdly, we have decided to use as a major indicator of the long term safety of radioactive waste the theoretically assessed value of the radiation dose that is attributable to its disposal. We have decided to use this indicator to judge the impact of radioactive waste disposal on human health and the environment not only for the present and near future but also for inconceivably long periods of time into the distant future.
- Fourthly, we have decided that, of the alternative disposal options, *"concentrate and contain"* should be selected because, although the option *"dilute and disperse"* is ethically better, it is not politically feasible. We also decided furthermore that *"wait and see"* is not an acceptable option but still we discuss retrievability.

With all these inconsistencies, we should not be surprised that our audience is so confused!

But this is not all:

- Lastly, and most significantly, we have decided that the ultimate responsibility for ensuring the safety of radioactive waste management rests with the State which has produced the waste and that decisions on their disposal should be national decisions.

I would now like to address this last important issue: public confidence and support might be strengthened by international co-operation to achieve international understanding and comprehension, and, ultimately, international consensus.

The safety of radioactive waste management has always been and remains first and foremost a national responsibility. But I would caution against the temptation to regard it as an entirely national issue. I will give four reasons why I believe that the international dimension can play a crucial role, particularly with reference to the safety of geological disposal.

Firstly, decisions concerning the geological disposal of long lived waste necessarily involve those countries in the vicinity of a waste disposing country. These apply even for those countries that could place a repository far from any national border with the intention of precluding transboundary impacts.

Secondly, on a philosophical level, these decisions have implications that extend far into the future, much further than even the most durable of national institutions. Just as decisions that could affect citizens of a State other than that in which the decision is taken necessarily take on additional considerations. Thus decisions that could affect people many generations into the future have an extra dimension that transcends conventional national decision-making. As we have no way of building intergenerational consensus on ways of dealing with this, international consensus seems to offer a possible substitute.

Thirdly, the reality is that a traditional orthodoxy, that waste should be disposed of in the country in which it is generated, is increasingly being challenged. In recent years it has become clear that, in many parts of the world, international options for the management of waste are being investigated, whether as a purely commercial proposal or as an exercise in finding the most suitable sites.

Fourthly, international co-operation can offer a variety of opportunities for improving safety by sharing expertise and experience. A given country might expect to build at most one or two repositories in the next 50 years, so the pooling of experiences seems to be essential. Perhaps, as in the case of waste management, international co-operation can also be a way of building confidence that a high level of safety is being achieved and that the technology and methods being applied are well established and reliable.

Within this framework let us ask ourselves how international co-operation, and particularly the work of the IAEA, can contribute towards the goal of safe and acceptable waste disposal? In order to answer this question, I shall refer to the IAEA's functions, role and work.

Firstly, permit me to remind you that the IAEA is essentially based on three pillars sustaining its duties. *The verification of peaceful uses and security of nuclear material* is probably the best known: it is the one that has given the IAEA the nickname of '*the nuclear watchdog of Vienna'*. The *transfer of technology* that the IAEA fosters is another well known pillar. But it is the less known of the IAEA's functions promoting safety, the pillar which is becoming more essential for nuclear energy.

Since its creation in 1957, the IAEA has exercised two basic statutory functions forecast by its founders, namely:

- establishing standards of safety for the protection of health against the effects of ionizing radiation, and
- providing for the application of these standards at the request of a State[1]. With these statutory functions, the IAEA is unique among international organizations.

These IAEA functions have been instrumental in the emergence during the 1990s of what might be called a *de facto* international regime on nuclear and radiation safety, and which encompasses the safety of radioactive waste disposal. The regime includes three key elements:

- **legally binding international undertakings among States**;
- **globally agreed international safety standards**; and
- **international provisions for facilitating the application of those standards**.

I will discuss each of these aspects in turn as they relate to radioactive waste disposal.

Let us start with the binding international undertakings among States or, in legal terms, international conventions. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention) is an incentive convention that establishes commonly shared safety objectives and sets out specific obligations of contracting parties aimed at achieving those objectives. Adherence to these national obligations is monitored by means of an international process of peer review by the other contracting parties. Every three years, each Contracting Party must prepare a report on the measures it has taken to meet its obligations under the Convention, and each national report is distributed for review by all of the contracting parties. The three-year cycle culminates in a Review Meeting, in which each national report is discussed in turn, along with the comments and questions on the report from other contracting parties.

The first review meeting for a parallel convention, the Convention on Nuclear Safety, was held in April this year, and the general feeling was very favourable. Not only was the rigour of an international peer review considered to be valuable in enhancing the credibility of national nuclear safety programmes, but the element of self-assessment inherent in preparing for the Review Meeting was considered by many countries to have been equally important. The success of the first review meeting bodes well for the Joint Convention, and the experience gained will be used to improve the whole review process for both conventions.

The Joint Convention was opened for signature two years ago, and we now have about half the ratifications needed for it to enter into force. While the effectiveness of the Joint Convention will depend on the involvement of as many countries as possible, I would particularly like to emphasize the importance of ratification by those States with large nuclear programmes. The Convention on Nuclear Safety received a significant boost in credibility earlier this year when the country with the most nuclear power plants — the USA — became a Contracting Party. Ratification of the Joint Convention by the major nuclear players would have a similarly symbolic importance.

[1] Statute of the International Atomic Energy Agency, Article III.A.6.

Let me now turn to the question of international safety standards. It is well established that repositories must be sited, designed, constructed and operated according to national laws and regulations. However, public acceptance of the adequacy of those laws and regulations will certainly be made easier if they are consistent with international consensus on standards of safety.

Unfortunately, geological disposal is perhaps the only area of safety standards in which the level of international consensus seems to have actually decreased in recent years. In many parts of the world, the development of geological repositories has reached an impasse. This has led to a trend towards reconsidering some of the basic orthodoxies of geological disposal. I have already mentioned some tentative movements away from the concept that waste should be disposed of in its country of origin. Another example, related to the very subject of this Seminar: the irreversibility of geological disposal — traditionally regarded by experts as an advantage — seems now to be a particular cause of unease for many. As a response to these concerns, some countries are beginning to study how repositories might be designed to facilitate retrieval of waste if, for whatever reason, society decided at some later time to do so. It is not my intention to pre-empt your debates on this controversial issue at this early stage in the Seminar, but let us be clear that the predominant technical view has always been that such retrievability is not only unnecessary, but probably also undesirable from a safety point of view. If allowing for retrieval would compromise safety or safeguards, it would be our responsibility to oppose it, but somehow the concerns that people feel about this issue need to be addressed.

To move the debate forward: the IAEA promotes the concept of an international 'forum', composed of experts from a wide range of disciplines, to consider the various technical, economic, social and ethical issues surrounding safety standards for the disposal of high level waste, including the issue of retrievability, and how progress might be made towards a solution which is both technically and publicly acceptable.

Safety standards must reflect the realities of the situation to which they are addressed. In the case of geological repositories — or indeed any other means for managing long lived radioactive waste — this raises questions about using estimates of radiation dose as the basis for standards. The dose of radiation is a quantity that has the advantage of being widely accepted in areas of safety concerned with the past, the present and the near future, but it has serious limitations as an indicator of the impact of a geological repository in the far future. However, any alternative indicators — such as estimates of radionuclide concentrations or fluxes — will need to be credible, and one of the most likely ways of achieving this credibility will be through international acceptance. The IAEA is also active in this field, supporting the investigation of alternative indicators of repository performance for long time-scales.

I will now turn to an area that represents a substantial amount of the IAEA's work in safety, and which we classify as **"providing for the application of safety standards**". This 'umbrella' category includes providing direct safety assistance to Member States, rendering safety review services, fostering information exchange, promoting education and training, and supporting research and development. Of these, there is only time to mention two briefly: safety review services and information exchange.

The IAEA offers a wide range of safety review services available to its Member States on request. The purpose of these services is to give the requesting State access to a range of expertise and experience from other IAEA Member States. Repository safety assessment is one important area in which this kind of service can offer a way of showing that the methods used and assumptions made are sufficiently robust and defensible to withstand the scrutiny of an international group of peers. In recent years, the IAEA has provided such reviews to a number of Member States including a joint review — together with the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development — of the safety assessment for WIPP (the Waste Isolation Pilot Plant; near Carlsbad, New Mexico, USA).

Another aspect of providing for the application of safety standards is fostering the international exchange of safety related information. This includes the production of a large and diverse range of publications on safety issues and, increasingly, the use of electronic media in the collection and dissemination of information. It also includes the most direct, face–to–face exchange of information, both at major international conferences and also a wide range of smaller international meetings and seminars on more specialized topics such as this. I would draw your attention to two particular events related to waste management: an International Symposium on Restoration of Environments with Radioactive Residues in Arlington, Virginia, starting on 29 November, and an International Conference on the Safety of Radioactive Waste Management to be hosted by the Spanish Government in Córdoba next March. I kindly invite you to attend these events where a large international audience will discuss many of the issues tackled by this seminar.

Outlook

Many in our community are beginning to give up all hope of a future for the disposal of radioactive waste. I have heard with increasingly alarming frequency many despairing comments in this vein. Despite the fact that I have tried in my presentation to share a number of critical ideas with you, I do not wish to create a pessimistic impression. On the contrary, I am optimistic but with my feet firmly planted on the ground of realism. I refuse to continue repeating robot-fashion that the *problem of radioactive waste disposal is solved*, that the *only issue is the lack of understanding from the public*, and other such dogmatic statements. My basic grasp of reality tells me that the situation is far more complex.

I would like to leave this podium on a note of *realistic optimism*. In the long saga of radioactive waste disposal, although we are at the bottom of a slope of negativity, I sense a reaction to the many years of disapproval and an ascent towards positivity. The trend towards internationalization of the problem is evident. The IAEA became a *de facto* catalyst and focus for an international regime on the safety of radioactive waste. Professional radiation protection organizations, such as the ICRP, are becoming more involved and committed to providing guidance on the topic despite their previous silence (ICRP has just issued a publication specifically on radioactive waste and is in the process of preparing another).

New issues and challenges are influencing the IAEA's safety activities, including its waste safety standards programme. It will be important to achieve international consensus on key issues in the years ahead and to clearly define priorities for future co-operative work. One of today's most important issues is whether disposal should be retrievable. We look forward to the contribution of this seminar to the solution of this dilemma.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER OPENING ADDRESS

Q: Have there been any polls made on the issue of waste disposal?

A: I am not aware of recent polls on waste disposal. It has to be noted that the results are always changing and pros and cons can just vary from country to country and from time to time. The point that Mr. González wants to make is that there is a discrepancy between the experts who are actively working on the subject of disposal — these are the "believers". They are dealing with the actual work, they know what they are convinced that they can say: The solutions that we have found, that we have tested and that we have assessed, are safe. On the other hand the public is not necessarily convinced by such experts statements, in particular as the experts are often discredited in the public for being not neutral and that is the point, that has to be made and that has to be challenged.

Chair: It is always a challenge to deal with the public. As an old politician I would like to quote Brecht, who said that he rather wanted another people. He was also a believer in democracy.

C: I would like to comment on the first question. My feeling is, that in Sweden the public opinion on disposal is more like 50–50 %. I do not really see this big gap and think it is a too simplistic description, with the experts on one side and the public on the other side.

Q: You made a distinction between waste proper and other kinds of waste in the beginning of the speech. One type that was not proper was the waste in the former Soviet Union. Did you say something on the Agency's view on that kind of waste? Will something be done about it or is it just to stay there as a bad example?

A: In the former Soviet Union waste that has been discharged or distributed into the environment by accident. The Agency has no authority to take action in any country unless the country requests the Agency to provide help. In addition, the Agency provides help through seminars, conferences, publications etc.

In the case of Russia, the Agency has not been requested to help in the clean-up of existing sites, although Russia immediately requested the Agency to help when the accident at Tomsk reprocessing plant happened in 1993.

Mr. González' opening address addresses the situation at the Semipalatinsk weapons test site in Kazakhstan. The Agency was requested to provide help in this case and published a report on the preliminary assessment and recommendations for further study[1]. In contrast to the IAEA findings at the French weapons test site at Mururoa and Fangataufa[2] the radiological situation at Semipalatinsk[3] is different as heavily contaminated areas were identified where action should be taken (e.g., restriction of access). Further studies and activities are needed and dealing with such a situation is a challenge.

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[1] International Atomic Energy Agency, The Radiological Accident at the Reprocessing Plant at Tomsk, IAEA, Vienna (1998).

[2] International Atomic Energy Agency, The Radiological Situation at the Atolls of Mururoa and Fangataufa, Radiological Assessments Reports Series, IAEA, Vienna (1998).

[3] International Atomic Energy Agency, The Radiological Conditions at the Semipalatinsk Test Site, Kazakhstan, Radiological Assessments Reports Series, IAEA, Vienna (1998).

INTERNATIONAL REVIEW AND SOME NATIONAL UPDATES ON RETRIEVABILITY

(Session 1)

RETRIEVABILITY: AN INTERNATIONAL OVERVIEW

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Abstract

Using available information from the published literature and material obtained from a network of contacts, a short introductory overview of international developments in the field of retrievability of emplaced nuclear waste was produced for the Swedish National Siting Co-ordinator for Nuclear Waste Disposal. This examined the issue in terms of a number of basic questions: Definition, Need, Design Implications, Safeguards for Fissile Material, Public Acceptability and Safety Assessment. The report was submitted in February 1999, and acted as a catalyst for the organisation of an international seminar by KASAM, the Swedish National Council for Nuclear Waste (these proceedings). This paper describes the report contents, and points to the invited papers at the seminar which expand on and update the limited descriptions in the original report.

1. INTRODUCTION

This paper is based on a report produced for the then Swedish National Siting Co-ordinator for Nuclear Waste Disposal, examining the situation as regards the development and possible implementation of retrievability as an integral part of a disposal concept for nuclear waste [1]. Because of the short work period involved, between October 1998 and January 1999, the report was at best only an overview, designed to provide a broad picture of current plans. In the event, the report served as the catalyst for this seminar to be organized.

It had become clear, from monitoring of many national programmes for siting of final repositories for radioactive waste disposal, that the potential or otherwise for retrievability of emplaced wastes is the one issue in particular which is repeatedly raised during public consultation and interaction.

Although even those repositories which may be constructed over the next decades will operate for many decades more and be sealed only after a long term monitoring phase, there is little operational pressure to finalise retrievability concepts [2]. However, as siting processes require detailed conceptual designs to be developed, as do the associated safety assessment exercises, it is becoming increasingly recognised that the potential for retrieval must be examined now. The presentations in this seminar serve to demonstrate how the issue has developed.

For example, as is reported elsewhere [3], a major collaborative investigation, or ‘Concerted Action’ which began in March 1998, is currently underway under the auspices of the EU (Directorate General XII), involving implementing agencies from the various Member States.

As McCombie and Zuidema have pointed out [2], *‘the technical and (much more problematic) the societal processes for decision making concerning methods for remediation,* *up to and including retrieval...have nowhere been completely defined'*. This report was therefore a contribution to that effort, intended to serve as background to these other studies when they appear.

The report included some limited review of the technical aspects of retrievability, with especial regard to the issue of Safeguards, as it relates to the long term monitoring of fissile material, whilst at the same time incorporating information regarding public perceptions of retrievability where possible. Ethical issues concerning responsibilities of present and future generations were also included where appropriate.

As well as describing the developments in a selection of national programmes, the report was structured around a number of basic questions, as briefly outlined below. Other papers at this seminar will provide up to date information on individual programmes.

2. WHAT IS RETRIEVABILITY?

As in many similar cases relating to geological disposal issues, it is helpful to make a comment regarding basic terminology. It is necessary to distinguish between 'retrievability', which is the theoretical ability to recover wastes however difficult that may ultimately prove to be, and 'retrieval', which is the actual act of recovery. Implementing agencies tend to refer to 'retrievability' as an unlikely and probably unnecessary option, whereas the public tends to express concern about how 'retrieval' could actually be carried out.

As pointed out by McCombie and Zuidema [2], deep geological disposal was developed to remove wastes permanently from the human environment, utilising multiple barriers, to ensure that they remain isolated from the human environment and inaccessible to Man for the very long timescales needed to allow for the natural decay of their radioactivity. Indeed, in 1996 the IAEA defined a geological disposal facility as '*one where there is no intention to retrieve the waste'* [4].

This has led to the development of various euphemisms in those countries examining or actively pursuing the issue, as described below. These include *'Very Long term Interim Storage'* and *'Reversible Geological Storage'* in France, and *'Monitored Geologic Repository'* in the USA etc.

As demonstrated by the papers at this seminar, discussion regarding retrievability of nuclear wastes tends to focus on deep geological disposal, as proposed for either high level waste (HLW) or spent nuclear fuel, although several countries propose some form of co-disposal of long lived intermediate level waste (ILW or TRU in the USA).

The French National Assessment Agency (CNE) has suggested there could be little or no justification for development of a retrieval capability in the case of low-level waste (LLW), because of the lack of any re-usable resource value, but did accept the fact that it might ultimately prove necessary because of public concerns [5]. Indeed, proposals have also been made recently in various LLW Compacts in the USA regarding development of so-called 'Assured Isolation Facilities' following the intense public reaction to plans for near-surface disposal of these wastes.

Whilst the nuclear waste industry would claim that retrieval of emplaced wastes is theoretically possible at any time during the operational lifetime of a repository, up to and including final sealing, some present disposal concepts are designed to specifically rule out the possibility, and incorporate immediate backfilling of disposal rooms, tunnels or boreholes, whilst others envisage leaving some or all of these open until a final closure decision is made at some date in the future.

As explained by others, in the **United Kingdom**, for example, Nirex have to date divided the timescale for potential retrievability into 3 [6]:

1. *Following emplacement of (L/ILW) packages, but prior to being surrounded by cementitious backfill.*
2. *Following cementitious backfill placement but prior to access ways being sealed.* Here retrieval would be more demanding but is regarded as relatively straightforward [7].
3. *Following sealing of access ways and after shaft sealing and repository closure.* Clearly, as time moves on, the difficulty of the task would increase due to degradation of the of the waste packages and loss of information [7].

The Netherlands assume that waste disposal takes place as a step-wise process:

- Facility construction;
- Waste emplacement;
- Repository operation as an 'underground waste storage facility', possibly for a period of up to several hundred years;
- Repository closure.

The time period for overall retrievability is currently open to debate in the Netherlands. The 'Commissie Opberging Radioactief Afval' (the CORA Commission), is supporting research into this matter at present. The time basis is referred to as a 'rolling present' scenario [8], in which regular decisions are made as to whether the underground waste storage facility should remain 'open' or be 'closed'. The period between each decision will depend on social and economic developments, the life expectancy of the equipment in the repository and the costs of the maintenance and monitoring activities. In the latest concept a period of 25 years is assumed. CORA envisages a period as long as 200 years before final closure as being a reasonable maximum. Study is underway of scenarios in which the existing surface storage facility at Borssele, operated by the Central Organisation for Radioactive Waste (COVRA), remains operational for up to 300 years before development of the underground waste storage facility.

As mentioned in several presentations, regulations governing some national disposal programmes have always included a period during which the wastes, as emplaced, can be observed, monitored and if necessary retrieved, but the timescales have generally tended to be measurable only in decades, which is long for human activities but negligible in terms of relevant containment periods [2]. For example, the USA Nuclear Regulatory Commission (NRC) stipulates that access must be maintained for up to 50 years following the start of repository operations.

The public, on the other hand, often regards potential retrievability as synonymous with a guaranteed ability for retrieval, and as an 'insurance policy' designed to allow the rectification of problems in the future. It does not often draw the distinction between pre-closure and post-closure periods.

3. WHY SHOULD RETRIEVABILITY BE NECESSARY?

Various reasons may be envisaged for the retrieval of nuclear waste/spent nuclear fuel once it has been placed in a deep geological repository, not all of which are safety-related, such as:

- Removal in the event of an accident or following recognition of poor performance;
- Removal for implementation of transmutation or other new technology;
- Removal for monitoring and disposal concept validation purposes;
- Removal to allow for implementation of an improved emplacement or overall disposal concept;
- Removal as part of work associated with assessment model validation (maybe in an underground rock laboratory or URL).

4. WHICH COUNTRIES ARE ACTIVELY EXAMINING RETRIEVABILITY AS A MANAGEMENT OPTION?

Whilst the papers at this seminar describe in some detail the situation in most of those countries now recognised as examining retrievability, the initial report summarised those programmes where information was obtainable.

Belgium

In 1994 ONDRAF/NIRAS announced a list of 98 potential sites for a near-surface L/ILW facility. By mid-1996 only one community had expressed any interest in even beginning investigations, so the siting process was suspended, and an independent review instituted of the whole effort and criteria employed, and analysis of the comparable costs of near-surface storage, deep disposal or long term storage.

The 'Altsurf Project' report did not recommend whether final disposal or a system of monitored storage is to be preferred. ONDRAF/NIRAS has now developed a new workplan to examine the possibilities.

As de Preter [9] points out, retrievable disposal concepts are also under consideration for deep disposal of HLW and spent fuel in the Boom Clay.

Canada

The disposal concept examined in detail by the CEAA Panel in 1996/7 did not propose any specific enhancement of retrievability. Both methods proposed during the hearings (steel or KBS–3 type canisters) envisaged the immediate backfilling of emplacement tunnels, once full. However, AECB regulations stipulate that retrievability should be feasible during the lifetime of the disposal vault, and therefore the issue did surface as an issue in many presentations to the panel, and was reflected in the Panel's report [10].

France

Until 1998, deep geological disposal was the only concept under consideration, as laid out in the Nuclear Waste Act of 1991. Three research strands were to be followed and reported on in 2006, after which a decision on future actions would be made by government.

These were:

- Partition and Transmutation;
- Waste packaging and effects of long term surface storage;
- Development of at least two underground laboratories, in different geological media. This was to include the study by ANDRA of the feasibility of reversible or irreversible disposal.

In February 1998 it was announced that legislation was to be introduced to also allow research into shallow disposal of HLW to be carried out as well, and in June it was allocated 15% extra funding, to be increased by a further 20% in 1999.

So as to enable this additional research to begin as soon as possible, CEA was instructed to review the concept of shallow disposal by the end of 1998. However, before this CEA began work on the so-called ‘Very Long Term Interim Storage’ Project (ETLD), which will absorb more than 50% of its total waste management research budget.

CNE also examined the scientific basis and reliability of reversibility for all disposal concepts and in late June 1998 recommended major changes to the French disposal strategy, including separation of non heat-generating plutonium-contaminated wastes from HLW. They would be placed in a deep repository, but with retrievability ensured for around 300 years. The HLW, on the other hand, would go into ‘subsurface storage’, with continuous monitoring and assured retrievability.

The ETLD Project at CEA is designed to develop potential concepts for these various proposals. In the December statement giving approval for the development of an underground laboratory in the Meuse Department, CEA was instructed to research the feasibility of developing a shallow storage facility in subsurface caverns in marl in the Gard region, probably at Marcoule.

Details of ANDRA’s proposals for retrievable concepts are outlined by Hoorelbeke [11].

Netherlands

In 1984 a long term research programme into disposal options was agreed and a research commission set up under the direction of the ILONA Committee, which advises the responsible government department.

Following the ILONA reports, and to comply with the principle of sustainable development, the government said in 1993 that it ‘wished’ that any wastes disposed must remain retrievable for extended periods, so as to allow for monitoring and recycling if new technologies are developed.

A co-ordinating committee (CORA) was set up in 1995 to examine retrievable disposal possibilities, following the ILONA reports. These included:

- long term above ground storage;
- retrievable storage in rock salt (identified as preferred host rock); and
- retrievable storage in clay.

The CORA programme encompasses now more than 20 projects, amny dealing directly with retrievability. These are scheduled to end by mid 2000.

Three possible scenarios are envisaged, potentially in any combination:

- indefinite above-ground storage;
- 100 years above-ground storage, then transfer to an underground retrievable facility; and
- extended above-ground (up to 300 years), then 200 years in a retrievable underground facility, followed by final closure after around 600 years.

These concepts are described further in this seminar by Selling [12].

Sweden

As explained by several speakers in this seminar, SKB's current plans envisage a two–stage process in which a limited inventory (around 400 canisters) of spent fuel is emplaced in a fully-retrievable form at the final candidate repository site, probably around 2008, with a period of observation and evaluation, as part of a staged decision-making process. Only after this period of so-called 'demonstration disposal' will the full scale repository be developed, following further licensing and evaluation of alternatives. The retrievability of these canisters is seen by SKB (and the regulators) as an explicit design criteria. In this seminar Papp [13] and Jensen [14] describe this from the standpoints of the implementer and regulator respectively.

Switzerland

NAGRA, the implementing agency, had originally envisaged immediate backfilling of emplaced L/ILW waste containers and disposal rooms. However, due to the the negative cantonal vote at Wellenberg in a referendum in 1995, incorporation of some form of retrievability has become one of the major means by which NAGRA and the government have sought to regain public confidence.

HSK (the regulator) envisage no problem as regards 'delaying the closure of the repository for a time period short enough that the passive safety barriers are not compromised'.

United Kingdom

In accordance with the IAEA, UK regulations define disposal as '*emplacement of waste without intent to retrieve it at a later time...* ". However, UK Nirex has developed a concept for the deep geological disposal of L/ILW which incorporates use of a so-called 'soft grout', which can be re-excavated if possible One of the reasons for this was to respond to the perceived public concern over irreversible disposal.

Due to the cancellation of the proposed RCF at Sellafield, plans to carry out in-situ experiments on this grout have been indefinitely postponed, although Nirex has taken out a patent on the formulation of the material. McCall [15] describes the latest Nirex plans in this regard.

United States of America

Following continued problems in developing new near-surface disposal facilities for LLW, a concept known as an 'Assured Isolation Facility' has become increasingly discussed. This facility would be above-ground and fully monitorable and retrievable. This is being examined at the present time by several of the so-called 'Compacts' to see if it is licencable under the Low Level Waste Policy Amendment Act.

As regards HLW/spent fuel, under current regulations, the NRC requires access to the waste in a repository for a minimum of fifty years after emplacement starts, for the purpose of safeguard and safety verification.

When the report was produced, the latest concept for the proposed facility at Yucca Mountain in Nevada incorporated methods for maintaining the easy access required by the NRC. These resulted in the use of the name: 'Monitored Geologic Repository' for the proposal examined in the 'TSPA-VA' that was submitted by DOE to Congress in December 1998. Further changes were announced in mid–1999 and are described by Harrington [16].

5. WHAT ARE THE DESIGN IMPLICATIONS OF RETRIEVABILITY?

The IAEA list a number of factors which can potentially influence the ease with which emplaced wastes (in this case specifically spent fuel) could be recovered [4]. These include:

(a) Host rock

Stable, self-supporting crystalline rocks are less problematic than salt which flows and soft clays which require support. The need to maintain access drifts and galleries for long term maintenance and monitoring, as well as for possible retrieval, means that some degree of convergence will take place. This will be greater for salt and soft clays.

Belgium has yet to finally decide which rocktype to use for shallow disposal; if retrievability is adopted, it may impact on that choice. HLW is to be put into the Boom Clay at Mol, but retrievability has not been proposed there, at least to date, although as mentioned above, de Preter [9] outlines the latest situation.

France has looked at clay and crystalline, but the shallow storage concept is still some way behind the deep one. Clay is the only rock approved for further work to date, and ANDRA has produced several borehole/silo combination design concepts, which are described by Hoorelbeke [11].

The Netherlands is well along the development path, with retrievable designs in salt completed, and one for clay nearing completion. They incorporate staged sealing of short horizontal boreholes, with tunnel access maintained throughout. Selling [12] gives more details.

The situation in Germany as regards potential design options to incorporate retrievability, although not covered in the original report, is described by Brennecke [17] as also being well advanced.

The latest conceptual design for US host rock, tuff, will incorporate the use of support shields to maintain the 50 year access required by NRC, which means that access can actually be maintained for up to 300 years.

(b) Depth of emplacement

This can also affect the rate of closure of tunnels etc. Where this necessitates the provision of a tunnel liner, retrievability potential is considerably enhanced, as in the USA.

It is assumed in the Netherlands that several phases of re-excavation will be necessary to maintain access over the required period. French research in the planned unerground laboratories will dictate the final depth in each rocktype, given the mandate to incorporate retrievability.

(c) Repository design and layout

Certain layouts would inhibit later access, especially those which envisage immediate backfilling. Designs incorporating emergency escape routes may be necessary if retrievability is to be made possible.

Several concepts envisage the need to re-excavate tunnels etc., and to continue long term maintenance programmes. The Canadian designs included details of the equipment which would be needed to actually retrieve waste canisters; the Swedish requirement for demonstration disposal means that it would also be developed, but then may well be discarded once full operations began.

(d) Type of backfill material used

Bentonite blocks are designed to swell and could become difficult to remove, whereas other possible materials exist which could be more easily excavated. The Nirex 'soft grout' is the only example so far of a custom-made material which could actively facilitate retrieval.

The Dutch designs allow for use of salt plugs which could be removed and allow ready access to the rock surrounding an emplaced canister, with a special shutter arrangement to provide radiation shielding.

NAGRA are beginning to develop concepts for allowing retrieval of waste packages from horizontal caverns, leaving access above partially backfilled areas, and maintaining machinery etc., using a range of excavation tools.

(e) Type of container used

The thickness of shielding would affect retrievability options due to proximity constraints for workers, although a long lived robust container with radiation shielding would make it simpler.

Many of the concepts designed to at least allow some form of retrievability incorporate the use of massive containers, so as to guarantee their integrity over the periods proposed (usually around 1–300 years). Some plan to use the massive transport canisters (the Dutch, for example), whilst the USA are currently researching the possible use of drip shields and some form of container covering. Those where borehole emplacement is envisaged must be able to withstand possible remining or drilling.

(f) Temperature in the repository

This is also affected by depth, and at elevated levels could preclude human entry, or even some types of machinery. It can also be affected by the level of passive ventilation that is maintained following completion of disposal activities. Decay heat from emplaced wastes must also be taken into account, due to the potential for 'thermal shock', which has the potential to alter ground conditions with time.

The USA have developed the idea of a 'thermal strategy' in which waste heat actually prevents water entering the tunnel after emplacement. This can have deleterious effects though on the ability to retrieve the waste, as it can damage services etc. As Harrington [16] points out, latest concepts have proposed a 'cooler' repository option.

The Dutch are concerned that temperature will limit access for maintenance and retrievability, and specify a minimum salt plug and pillar between disposal areas.

(g) Special measures to aid recovery or hinder human access

This includes things which range from provision of high resolution near-field monitoring to deliberate destruction of shaft equipment and not retaining archives etc., together with removable borehole seals, emergency escape routes etc.

The degree of retrievability required obviously has an impact on the design. If it is to be 'totally retrievable', then there must be free access to the disposal tunnels etc., with only limited bentonite plugs etc. in the holes themselves. The degree of ventilation is of course another important factor affecting accessibility, so it may be necessary to reduce this and close off the roadway, but not actually remove the ability to restore full ventilation and access. This of course necessitates maintenance and even replacement of all underground environmental systems, in case they are needed. Of course this access may be required at exactly the most unfavourable period, when radiation and tunnel temperatures are at their peak.

Once some form of backfilling starts in the roadways, wastes are then only in a 'semi-retrievable' form. The repository maybe now becomes, in effect, a secure long term storage facility.

Once a facility is closed, it enters into a 'low-retrievability' state, in that access is limited. It could be made even less available by processing of the waste.

Various methods for waste retrieval have been envisaged, albeit in general terms, and some of these are discussed in the report as regards specific national proposals. Suffice it to say here that some form of core drilling, standard mining or over-tunnelling, and some special techniques yet to fully developed, appear to be the most practical means, depending on whether wastes are emplaced in horizontal or vertical boreholes or within disposal rooms. Some form of shielding and remote operation also appears to be a prerequisite.

The report examined the design proposals and implications put forward by those countries identified. The papers in this seminar provide more detail.

6. WHAT IS THE IMPACT ON SAFEGUARDS?

The requirement for maintenance of Safeguards to prevent diversion of fissile material to weapons production should, according to a 1988 IAEA Working group, continue even after it has been sealed in a deep repository.

In general, there has to be a reason for Safeguards to be terminated, or at least relaxed. Under normal circumstances, relaxation is only allowed if it can be shown that the wastes in question have been consumed, diluted in a way to make the contained material no longer available for weapons production or that they have become ‘practically irrecoverable’.

A whole session at this seminar is devoted to this issue, in conjunction with other safety-related matters, with major input from the IAEA. The Agency has in the past specified that design information should be supplied to it by waste disposal implementing agencies before any emplacement takes place, so as to allow it to develop a system of ‘Design Information Verification’ (DIV). Wastes such as vitrified HLW and other conditioned wastes could likely be excluded from Safeguards after their transfer to the final disposal canister in the conditioning or encapsulation plant. Spent fuel, on the other hand, would remain subject to them until final emplacement, and even then, design considerations come into play regarding the question of when, if ever, to relax the regime.

7. WHAT HAS PUBLIC REACTION BEEN LIKE?

Whenever radioactive waste disposal is discussed by the public at large, the potential for making irreversible decisions always comes to the fore, and usually broadens into discussions of ethics and decision making, whilst exploring the unknown wishes of future generations.

The starting position for this debate was originally clear, and was laid down by several international consensus documents, albeit produced by nuclear-oriented organisations, such as the Nuclear Energy Agency (NEA) and the IAEA. These concluded that responsibilities to future generations were better discharged by final disposal, rather than relying on long term storage, as we cannot predict the stability of future generations [18].

That said, they actually also commented that *‘retrievability is an important ethical consideration since deep geological disposal should not necessarily be looked at as a totally irreversible process’*, and concluded that stepwise implementation of disposal would leave open the possibility of adaptation in the light of scientific progress and societal acceptability.

Many in the nuclear industry accept that they have had little success in communicating the basic concept and benefits of deep geological disposal to the general public [2] and that many people actually misunderstand the ‘*laudable, ethical objectives’* of a system which does not require active monitoring and from which retrieval need never be necessary. It is accepted however that this is often interpreted as meaning that monitoring is unlikely actually to be carried out and that retrievability is actually not possible.

In the past, the industry either ignored public criticism or opposition to geological disposal, or regarded it as an ‘information problem’. However, following numerous setbacks in terms of siting programmes, which have in some countries even extended to the issue of the development of underground laboratories, it has begun to advocate a more open discussion of the issue, but one which accepts that public concerns must be taken seriously.

In its recent review of waste management issues [19], the EU identifies the initial motivation for introducing retrievability as a political one, *'since it is thought to be a positive influence on the public acceptance of a repository on a particular site'*. This view is echoed in France, where an unnamed utility official commented recently that retrievability was '*the political price to pay'* for obtaining public acceptance for development of an underground laboratory [20]. Similarly, in the UK, Nirex clearly acknowledges that the main reason that it has commissioned work on retrievability is because it may *'have a bearing on public acceptance of deep disposal.knowledge that the process of disposal is reversible should allay unfounded, but nonetheless genuine, fears about "getting it wrong".* [6]. Retrievability is regarded as a 'safety net' [7].

As far as environmentalists are concerned, Greenpeace, for example, advocates an immediate cessation to the production of nuclear wastes. For those which do exist, however, *'there exists no technical solution whereby the net detriment to human health and the environment can be guaranteed to be zero for the long term future...The only possible approach...is therefore to retain them on land and to manage them in failsafe conditions according the maximum in:*

- *safety;*
- *security (from terrorism and theft);*
- *containment;*
- *accessibility (to allow inspection and maintenance);*
- *monitorability (to ensure the early detection of any failure to meet the above criteria); and*
- *retrievability (in the event of the detection of any such failure)* [21].

Meanwhile, the public is caught in the middle of the debate, often unsure of where to turn.

As Riverin [10] describes, retrievability surfaced during the EIS Hearings in Canada in 1996/97 as an issue of major public concern. AECL themselves also gave details of how the issue (together with monitoring) was raised during the public consultation period prior to the preparation of the Environmental Impact Statement. A significant proportion of people felt that retrievability was an important factor, with between 60–70% of those surveyed expressing concern about the waste being inaccessible following repository closure, especially if local or regional monitoring were to highlight some problem with the containment system [22].

The reaction of the public to NAGRA's proposals in Switzerland, albeit for L/ILW, and described by Kowalski [23] demonstrates how difficult it can be for an implementer to move forward with a proposal if the public does not feel happy with the ethical and technical balance.

Since the original report was written, the British House of Lords has published the findings of its wide-ranging Inquiry into nuclear waste management. Retrievability and ethical issues were major topics. The Consensus Conference held in May 1999, and described in this seminar by Hiett [24], again showed just how important these issues are in the minds of the public.

A session at this seminar is devoted to discussion of the ethical framework of the retrievability issue.

8. OTHER ISSUES

The original report did not explicitly deal with the cost implications of incorporating retrievability (to whatever degree) or the specifics of which monitoring techniques could be used to determine the need for it. Three papers, Young [25], McCombie [26] and Söderberg [27] have been invited to encourage discussion on these issues, which are being recognised as major drivers in this debate.

The report also pointed out that retrievability itself had not featured in any major safety assessment work to date, being equated more with some form of deliberate human intrusion. As it becomes more important in the future it is likely to become a scenario in its own right.

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QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

C: The term "practically irrecoverable" is not used by the IAEA in connection with waste disposal, only in connection with safeguards! The Agency uses the term "disposal" for something which is not intended to be retrieved. That does not preclude that somebody else will later decide to retrieve it. The IAEA Waste Management Glossary of 1993 is recommended.

The IAEA document "Waste Management Safety Fundamentals" also provides some guidance with reference to retrievability. It states that the overall safety should not be compromised and also that no unnecessary burdens should be put on future generations. It is an interesting philosophical question whether retrievability is a burden on future generations or not.

A: I agree. But there seems to be a dichotomy of words used by different sections of the IAEA and also by others. This is true also for different countries and even for different organisations within an individual country.

Chair: It makes a big difference if you look on the possibility to retrieve from the view of the waste managers or from the view of the safeguards regulators. If there is a possibility to retrieve, then one must continue with the safeguards for a very long time.

C: You said that it is more difficult to foresee technical development compared to social development. Coming from a university department where we are doing work, trying to look into the future, I do not agree with you. Technical developments appear to be easier to extrapolate from the present knowledge compared to how people will behave or how they would want to organise their societies. The technology for transmutation, for instance, has been discussed since the seventies.

Chair: The time span from when something is known by the scientists until it transpires in the broader community can be quite long.

C: In your list of reasons for retrieving, I did not find deliberate retrieval to get resources back. Many people think that recovery because of the energy content is maybe the most plausible reason for wanting to get the material back within one hundred years.

A: It was included in a sense. I assumed that if you develop transmutation or a new technology, then you would want to recover it. Some of the plans are actually considering further segregation of the waste material that may not be reusable.

Chair: When Camilla Odhnoff called me about this seminar she made a comment, which I would like to quote and which we should keep in mind: “Waste is what you have when you have no more imagination!”

You mentioned the attitude of the public and environmental organisations. Was there a change in their attitudes between the stage when we were talking about non-retrievable waste disposal and the new stage when we offer an option to retrieve.

A: A lot of the hard line environmental organisations have always said that deep disposal is not the answer and that they would prefer long term monitored surface storage. But there are also others within the same area who would like to see a deep disposal in combination with a monitored surface storage. Many of the opponents are not too impressed by the records of the nuclear industry. I know that the nuclear waste management industry of today has a lot of problems being associated with the nuclear industry and even with the military industry and gets a lot of grief from that. But the public looks at statements made 25, 30 or 40 years ago. “Do not worry, leave it to us, we know what we are doing etc.”. Now the children of that generation is saying the same thing again, and people wonder if they can take the words as true or if they should colour them with a bit of past knowledge. My experience with organisations and the public is that people want to know that it is managed safely, but they also have a fear back in their mind that if you walk away from it and something goes wrong, there is nothing anybody can do to put it right. I am not saying this is a valid argument, but that is an argument a lot of people have. It may well be that, if you introduce retrievability as an area of discussion, at the end of the discussion more people will accept that it is not necessary. I do not know, but if the industry just pats the public on the head and says “Do not worry!”, then it leaves the area of uncertainty in the public and I think they like to think that a connection to the waste should continue.

Chair: The technical people may be inclined to say that this may be valuable material in the future, that future generations should want to use and we should not deprive them of that opportunity. Some of the sceptics would say they have doubts about our ability to arrange a final repository in a proper manner and therefore would prefer that we do not seal it completely, and maybe also there will be better methods of doing it in the future. So the motivations of different groups may be very different.

C: Very often seminars like this gather people of the same “faith”. One should broaden the faith and include different points of views.

Chair: That is true. But there is some legitimacy in having people of reasonably similar thinking to clear out between themselves what they think. Of course, consensus building in society is desirable. But one should also keep in mind the difference between a mediator and a judge. These are two different functions. A mediator will seek a middle ground in order to get acceptance from several sides and no more controversy. A judge will have to judge on the basis of legislation, or of what is considered to be the truth. And the truth is not necessarily in the middle.

CONCERTED ACTION ON THE RETRIEVABILITY OF LONG LIVED RADIOACTIVE WASTE IN DEEP UNDERGROUND REPOSITORIES — PROGRESS TO DATE

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Abstract

Within the EURATOM Framework Programme: Nuclear Fission Safety, a Concerted Action on the retrievability of long lived radioactive waste in deep underground repositories is being carried out. This Concerted Action commenced on the 1st of January 1998 and involves experts from nine different European countries. The Concerted Action will be completed by the 31st of December 1999. This paper gives a brief overview of the objectives of the Concerted Action, the work programme that has been defined to meet these objectives, the work performed to date, and the remaining work programme.

1. INTRODUCTION

The European Commission is funding a Concerted Action on 'the retrievability of long lived radioactive waste in deep underground repositories'. This Concerted Action commenced on 1 January, 1998 and will be completed by 31 December, 1999. The Concerted Action is being co-ordinated by NRG (NL) and KARUWEEG (NL) is acting as scientific secretary and editor for the Final Report. The other participants in the Concerted Action are ANDRA (F), DBE (D), ENRESA (E), NIREX (UK), POSIVA (FIN), SCK–CEN (B) and SKB (S). Since January 1999 NAGRA (CH) is also participating in the Concerted Action.

The objective of the Concerted Action is to establish a clear interpretation and working definition of the concept of retrievability. To meet this objective a work programme has been defined — see Section 2 below — and is now well underway. The results of this work programme will be presented to the European Commission by 31 December, 1999 together with the participant's opinions on the form in which these results should be published. This paper (or "progress report") gives a brief overview of the objectives of the Concerted Action, the work programme that has been defined to meet these objectives, the work performed to date, and the remaining work programme.

It should be emphasised that the report describes work that is still in progress and that is based on concepts that are currently under development.

2. OBJECTIVES AND WORK PROGRAMME

The objective of the Concerted Action is to establish a clear interpretation and working definition of the concept of retrievability with the view to come to a more common understanding of the meaning of retrievability with respect to the final disposal of radioactive waste. The concerted action will result in a report containing: an inventory of the views of all participants on retrievability; a clarification of specific aspects of retrievability and a list of the common opinions with respect to retrievability. To meet this objective the Concerted Action has been divided into three Work Packages:

Work Package 1 (1 January 1998 — 31 October 1998)

The objective of this task was to obtain an inventory of views with respect to retrievability and waste disposal: all partners provided and evaluated the relevant information from their country. In the final meeting of Work Package 1 the results were used to define the full scope of Work Package 2 and the targets of the working groups for the tasks in Work Package 2 (see section 3 below).

Work Package 2 (1 November 1998 — 30 September 1999)

Specific aspects of retrievability, identified and specified in Work Package 1, have been investigated in separate task groups, in particular with respect to in what ways they can be further clarified. Task groups were set up to investigate:

- Retrievability and the different time zones of a repository;
- The influence of retrievability on the safety of the repository;
- Socio-political factors;
- Retrievability and monitoring.

For each task a task group leader was identified who then defined the work to be done and who co-ordinated the input from the different participants. Although participation in each task group is optional in practice all participants are participating in all task groups.

Work Package 3 (1 October 1999 — 31 December 1999)

The Final Report, describing the results obtained in the first two Work Packages, will be written. At the final meeting the last draft of the final report will be discussed in detail, as well as the question of whether the results of this project could form the basis for a report on retrievability in the Euradwaste series.

3. STATUS MID–1999

The results of Work Package 1 have been bundled into a working document. The bulk of this working document consists of the country specific annexes provided by each of the participants. Each country annex gives information on the following subjects:

- The reference disposal concept(s) under consideration;
- The background to any interest in retrievability in that country and how, if at all, retrievability has been defined (either formally or informally by the government, waste management organisation or others);
- The participants views on the technical, safety and economic issues associated with retrievability;
- Any relevant R&D activities currently being carried out.

Representatives of many of the countries participating in the concerted action will give presentations that cover some or all of the above points listed above at the present seminar. For these details the reader is referred to the relevant paper.

The preliminary analysis of the different country annexes indicated that there were significant differences between the participating countries with respect to the origin of interest in retrievability, the position of the government and/or waste management organisation and the thinking on technical, safety and economic issues. There were also differences in the terminology used by the different participants in the concerted action — not only with respect to retrievability specific aspects but also with respect to repository design and operation. It was noted that these differences were a complicating factor for analysing the country annexes. It is the intention that the country annexes will be updated once the work for Work Package 2 has been completed and that these, in their final form, will be attached to the Final Report.

The working document resulting from Work Package 1 was used to finalise the work programme for Work Package 2. In addition considerable effort was spent on discussing how, whilst respecting national differences, a greater harmonisation in the presentation of the country specific information could be achieved. Such a harmonisation should facilitate the carrying out of the work for Work Package 2 and the writing of the Final Report (Work Package 3). In this respect, it was agreed that before starting work on Work Package 2 a common approach for the breakdown of a disposal operation into time zones should be developed to provide a framework for analysing those issues which were selected for Work Package 2. The time zone breakdown, agreed upon by the participants is given below. This time zone breakdown will be modified as necessary as the concerted action proceeds.

(a) Interim storage at or near the surface;
(b) Design and construction of the repository and completion of the first disposal cells;
(c) Period of filling a disposal cell with waste package(s);
(d) Period of keeping the package accessible before backfilling and sealing the disposal cell;
(e) Backfilling and sealing of the disposal cell;
(f) Period of keeping the backfilled and sealed disposal cell accessible, before backfilling the depositing tunnel;
(g) Backfilling the depositing tunnel;
(h) Period of keeping the access tunnel open, after having filled the depositing tunnel;
(i) Backfilling of the access tunnel;
(j) Period of keeping the access shafts open, after having backfilled the access tunnel;
(k) Backfilling and sealing of the shafts;
(l) Post closure phase with institutional control; and
(m) Post closure phase without institutional control.

This common time zone breakdown was then used when carrying out most of the tasks for Work Package 2. These tasks, as finalised following the discussion of the results from Work Package 1, were defined as follows:

Task 1: Retrievability and the different time zones of a repository

In this task, which was lead by ANDRA, the meaning of retrievability in the different time zones of a repository was investigated. The goals of this task were:

- to describe the effect of retrievability in the disposal concepts on design, construction and operation;
- to describe the retrieving methods, foreseen for the different time-zones of the disposal concepts; and
- to discuss the demonstration of retrievability concepts.

For this task each participant provided the following input:

- a breakdown of their country's disposal concept into the time zones given above; and
- an analysis of the different time zones considered in their concept on the basis of the following: the technical effort needed to retrieve in each time zone; the extra knowledge that is needed to achieve retrievability; the technological and scientific knowledge that is needed to support strategic waste management decisions.

On the basis of this information there will be some discussion on the demonstration of reversibility or retrievability concepts.

Task 2: Influence of retrievability on the safety of a repository

In this task, which was lead by ENRESA, the implications of retrievability on the safety aspects of a repository were investigated. Each participant analysed their disposal concept (using the time zone breakdown) for aspects where retrievability would influence safety and in what way. This analysis was done in a qualitative way.

For this task each participant provided the following input:

- Identification, for each time zone, of the different retrievability enhancing measures (with respect to design, construction and operation) which could have some influence on the repository's operational and long term safety;
- An analysis of the implications of retrievability for operational safety (based on the retrievability enhancing measures) — e.g., the long term stability of repository structures or doses to facility workers;
- An analysis of the implications of retrievability for long term safety (based on the retrievability enhancing measures) — e.g., as a result of the use of modified backfill materials or keeping the (parts of) the repository open for longer periods (ventilation effects, repository abandonment).

On the basis of this information some common conclusions will be, where possible, drawn with respect to retrievability and repository safety.

Task 3: Socio–political factors

This task, which was lead by NAGRA, addressed issues such as: credibility/confidence building; communication of definition and interpretations for implementing; communication of objectives for retrievability; verifying unique definition of retrievability; and the possible effects of retrievability on public acceptance. The emphasis in this task was on making an inventory of this type of information, which was provided by the different participants, rather than trying to analyse the information in detail or provide a 'common view' on these issues.

Task 4: Monitoring

This task, which was lead by NIREX, aimed to clarify further the need for monitoring in deep geological disposal and investigate the links between monitoring and retrievability. A number of different classes of monitoring were defined: monitoring for radiological protection, environmental protection and operational safety; inspection of retrieval systems; monitoring of the waste and its surroundings from within a repository; monitoring of the waste and its surroundings from boreholes and monitoring of the waste and its surroundings by remote sensing.

For each class a description of the monitoring activity was given and attention was paid to the reasons for monitoring in the context of retrievability, the possible impact of the monitoring activity on long term safety and a possible influence on a waste retrieval decision. In addition attention was given to the limitations of monitoring and the time scales over which the various classes of monitoring could be implemented.

In addition to the above four tasks a limited amount of attention has been given to the issue of safeguards and retrievability with regard to the disposal of spent fuel. The current safeguards policy with respect to spent fuel disposal, implementation aspects and repository abandonment have been discussed.

4. REMAINING WORK PROGRAMME

The work for Work Package 2 is currently being finalised. The last three months of the Concerted Action will be dedicated to producing the Final Report. This Final Report will be presented to the European Commission together with the participant's opinions on the form in which these results should be published.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: In one of your slides you showed a set of timelines. Is this for one project or is this for a combination?

A: This is a range based on what came from different participants in the project. It is also important to note that you can be busy with several phases of a repository project at the same time. You can be placing waste packages in one area at the same time as you are building new access drifts or emplacement tunnels in another area.

Q: Every package that is going to be disposed of is very robust. Do you ever expect to see any result of the monitoring during the institutional control period, and if you do see a release, what are the threshold levels for remediation?

A: I am not aware of any defined action levels or intervention levels. When I made the point about the limitations of monitoring, I tried to emphasise that one should not develop a monitoring programme before thinking about what to do with the results. Certainly, a lot of people in the group felt that one would not "see" anything anyway by the monitoring. Others were saying well, but the fact that you are not seeing anything is also important information.

Q: Do you feel that the lack of regulators and other parties in your group was a shortfall in your available information?

A: It is not an issue that has been discussed. Personally, I do not think this was a major problem, given the objectives of the group and the phase in which the thinking is in most countries.

Chair: In this project called Concerted Action, is there an ambition of achieving any convergence in action or is it only a mapping and comparison? What is its objective? I was often struck, in the IAEA, that for safeguards there are agreements with states, which gives the Agency right to go in and inspect, but for the field of safety there are no such rights. The Agency gives services on safety and the way it has proceeded is through exchanging information about safety and trying to pick up best ideas. This will of course lead to a certain convergence also and one might well say that we all have an interest in making sure that safety in nuclear power is good everywhere in the world. And the same certainly applies to nuclear waste. That certainly justifies an exchange of information, perhaps even going a step further in justifying a mutual influence and perhaps some convergence, leaving a fair amount of latitude. I was wondering if the Commission had such an ambition?

A: When calling it a discussion forum, I meant that it is not a research project funded by the Commission. The project builds on what the participants bring in to the meetings. But it is also more than a discussion forum in the sense that we have a contract with the Commission, which states certain objectives and results. It is not our objective to force harmonisation. The objective is to identify some common elements and to explain differences. By analysing the issues we can perhaps provide a framework in which these issues can be investigated further, possibly within a follow-up project or within national programmes. It was a useful discussion for everybody participating, when people could bounce ideas off each other. But the report should, as stated in the contract, be fairly descriptive rather than prescriptive.

Chair: One is still at an early stage of the discussion on retrievability and if one is to learn from each other and exchange information and experience, then perhaps one of the first efforts would be to agree on a common terminology.

A: Yes, that aspect is important as is also the aspect that the national programmes are in different phases and have their own interests, their own interactions with their own regulators etc.

STEPWISE DECISION MAKING AND OPTIONS FOR RETRIEVAL IN THE SWEDISH KBS-3 CONCEPT

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Abstract

The long time aspect of radioactive waste management have resulted in the adoption in Sweden of an ethical principle that requires present generations to manage radioactive waste in a way that will not burden future generations, and at the same time avoid to unnecessarily hinder future generations to retrieve the waste or take actions to change the disposal system. The present Swedish repository design has been developed to get a high and provable safety and to get a robust repository. A consequence of this has been a high barrier integrity that gives the system a high retrievability. The development of a repository system is a step-wise process, as much of the information on repository performance will only become available as the steps are carried through. In such work, retrievability can be extended also to other steps in handling or conditioning, i.e. indicating a general ability to reverse any step taken. At each decision-step, the confidence in achieving a safe repository has to be balanced against the commitments the step involves. An important factor in this balance is the feasibility of steping back in the process. Thus, reversibility/retrievability are valuable systems characteristics in decision-making under uncertainty. It is generally agreed that the retrievability option should not be used as an excuse for developing a repository with lower safety levels than otherwise would have been required. In fact, such an action is in practice equivalent to an intentional transfer of burdens to future generations.

1. THE DISPOSAL CONCEPT

The prime responsibility for the management and disposal of radioactive wastes produced in the 12 Swedish reactors lies with the reactor owners. Together they have formed a jointly owned company, Svensk Kärnbränslehantering AB (SKB), to carry out the necessary actions.

The Swedish system, see Fig. 1, is based on the following fundamental principles:

- Operational waste with short and medium half-life is disposed of as soon as possible after arising. A final repository, SFR, is in operation close to the Forsmark Power Plant.

- Spent nuclear fuel is stored 30 to 40 years before being emplaced in a deep repository without reprocessing. A central interim storage facility, CLAB, is in operation close to the Oskarshamn Power Plant. The siting process for the deep repository has started.

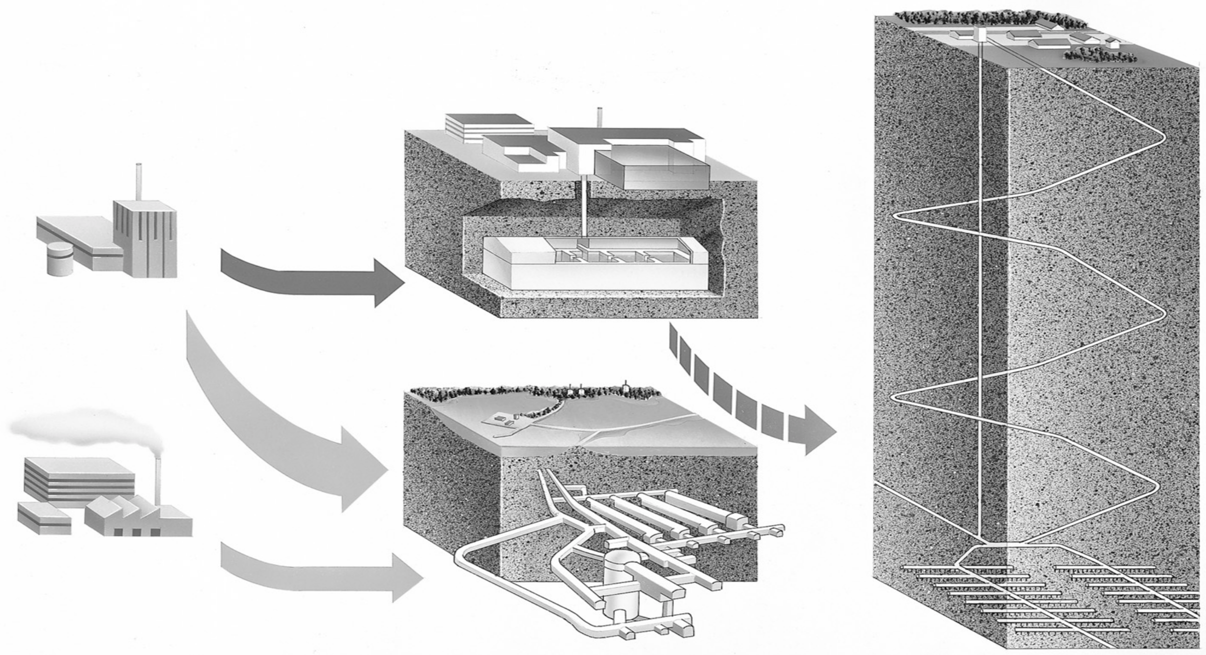

FIG. 1. Spent nuclear fuel (dark arrow) is stored in a central interim storage facility before disposal in the deep repository. Operational wastes from reactors and other sources (light arrows) are deposited in the SFR facility.

In order to achieve long term safety, the disposal system is based on three safety levels — isolation, retention and dilution. The first is the **isolation** of the spent nuclear fuel from the biosphere. It is achieved by encapsulating the spent nuclear fuel in long lived copper canisters in a beneficial environment. In the next safety level, the repository has the function to **retain** and **retard** the transport of the radionuclides should the isolation be broken, thus allowing them to decay before reaching man and his environment. Thirdly, by proper site selection, transport pathways and **dilution** conditions in the biosphere can be influenced by site selection so that any radionuclides that escape will only reach man in low concentrations.

The long term safety of the deep repository is based on passive multiple barriers so that the degradation of one barrier does not substantially impair the overall performance of the disposal system. The materials used in the repository are selected with a view to the possibility of verifying their long term stability and performance in the repository with experience from nature. For the same reason, the thermal and chemical disturbance that the repository is allowed to cause in its surroundings is limited.

The repository is planned to be situated at a depth of about 500 m, depending on conditions at the selected site. From a tunnel system deposition holes are bored in which copper canisters with spent nuclear fuel are emplaced and surrounded with bentonite clay. The tunnels will be backfilled with a mixture of bentonite and quartz sand or other suitable material. See Fig. 2.

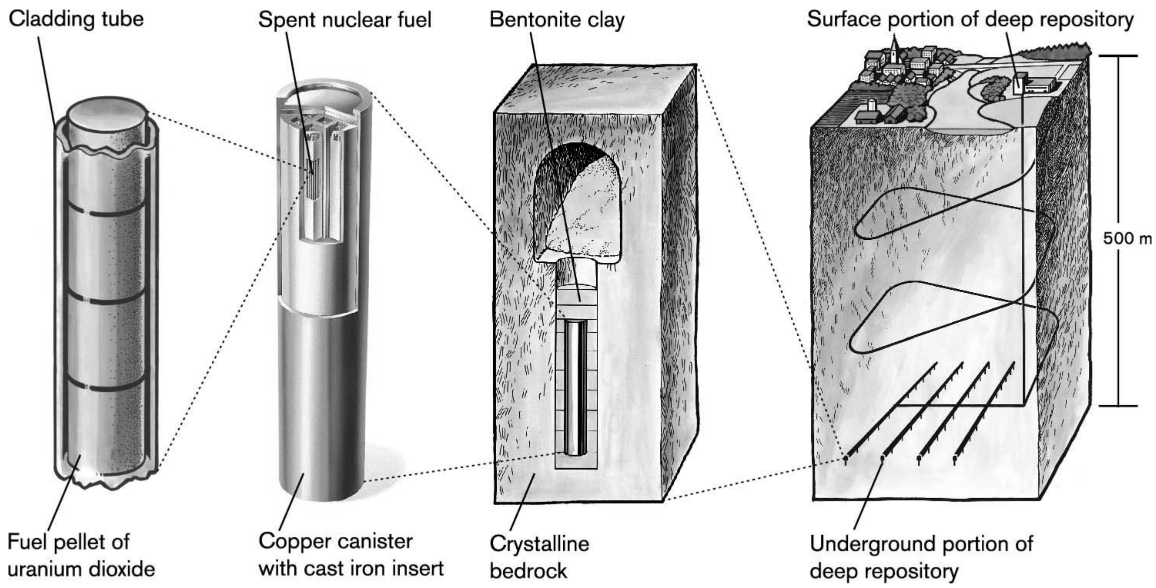

FIG. 2. The spent fuel is encapsulated and deposited about 500 m down in the bedrock.

The deep repository is planned to be built in two stages. In the first stage, approximately 10 % of the spent nuclear fuel, i.e. about 400 canisters, will be deposited. This initial disposal period is planned to start around 2015 and last for about 5 years, after which the experience gained will be evaluated.

If the result of the evaluation is that continued deposition is suitable and acceptable — which is the expectation — the entire repository is built (stage 2) and the activities continue until all waste has been deposited. The total quantity of spent nuclear fuel that is generated by the present day Swedish nuclear power programme up to the year 2010 is estimated to around 7000 tonnes.

2. OBJECTIVES OF RETRIEVABILITY

Due to the long time spans that have to be handled in radioactive waste management, decisions in this area are often strongly influenced by ethical aspects. The established moral or ethical traditions in a country will have a large impact on how an issue like "decision-making under uncertainty" is handled. It will also have an influence on how opposing ethical principles are balanced.

Two such principles often discussed in Sweden are:

- Our generation, that has had the benefit of nuclear power, must also take the full responsibility for the radioactive waste, and not leave an undue burden to coming generations.
- In a world where knowledge is increasing with time, and where values judgements are changing, coming generations should be given the freedom to make their own decisions, for instance with regard to long term protection and utilisation of resources.

As a result of such discussions the issue of retrievability has come in focus.

Subsequently, the adoption of the two-stage strategy for developing the spent fuel repository had as a direct consequence that the feasibility to retrieve the waste after the first step must be shown. This demonstration will be a part of the safety assessment for getting the permission to deposit waste in the repository.

Retrievability in the second stage has only been discussed as a moral and ethical issue. Extensive discussions both in Sweden /KASAM: Etik och kärnavfall, SKN Rapport 28 mars, 1988, in Swedish/ and internationally/NEA: The Environmental and Ethical Basis for Geologic Disposal, A Collective Opinion of the NEA RWMC, Paris/ have resulted in the following Swedish view on deep geologic disposal:

(a) The repository shall not be dependent for its long term safety on monitoring or maintenance by future generations. This is not to say, however, that the repository cannot be monitored for a period after disposal of the waste or closure of the repository.
(b) The repository shall not be designed in such a way that it unnecessarily impairs future attempts to change the repository or to retrieve the waste.
(c) Information regarding the waste, the disposal system and the site should be preserved for the future as well as can reasonably be achieved.

No formal requirements on retrievability have yet been established in Sweden. The general view is that retrievability is good as long as it is not impairing the safety of the repository. Furthermore, a sealed repository with proven retrievability is often considered safer than a prolonged interim storage requiring surveillance and control over long times. The Nuclear Power Inspectorate intends to stipulate requirements for retrievability in its future regulation (The Swedish Nuclear Power Inspectorate's Evaluation of SKB'sRD&D–progamme 98, SKI Report 99:30).

3. CONCEPTUAL ISSUES OF RETRIEVABILITY

Retrievability can be defined as a practical possibility to take back the radioactive waste deposited in a repository and to transfer it to a safe storage facility. That is, it should be possible to localise and identify the waste packages, to retract them from the repository and to handle and transport them. Although the cost and effort needed is important for the practicality of retrieval, the term retrievability has been used to indicate the *possibility in principle* to retrieve.

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. A consequence of this has been that the system also exhibits a high retrievability. Thus there is no contradiction between isolation (no intention of retrieval) and retrievability (having the capability of to retrieve).

Development of a repository system will always be a step-wise process, and much of the basic information regarding the repository performance will only become available as the steps are carried through. At each decision step in the repository development process, the ability to understand and quantify the achievable safety has to be balanced against the commitments to site or system that the step involves. Important in this balance and in decision making under uncertainty is the feasibility of taking a step back in the decision sequence. Here the concept of retrievability can be extended into a general reversibility of any action taken. The possibility to reverse an 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.

Other factors of importance when making decisions under uncertainty are e.g. how flexible the system is to changes in knowledge or technology and when alternative options for the system development are closed. To make it possible to adapt the repository system to better knowledge, alternative options should be kept open as long as reasonable. At the same time, the safety of the repository system should be as robust as possible, i.e. not very sensitive to uncertainties in site-data or barrier performance.

Obviously, retrievability has a coupling to issues like non-proliferation and control of nuclear materials.

4. TECHNICAL ASPECTS

Due to the long development and operational period of a spent fuel repository, SKB regards the retrievability/reversibility to be important. It is the opinion of SKB that no actions shall be taken during handling, and no arrangements shall be made that will unnecessarily hinder retrieval, nor shall actions be taken to enhance the retrievability if they will impair the capacity of the repository to comply with the safety regulations.

In the planned Deep Repository the spent nuclear fuel is in principle retrievable through all stages of the disposal process. The cost and effort involved with the retrieval will vary through the different stages. In this section the different stages in the Swedish disposal process are identified and actions needed for backtracking/retrieval at each stage are discussed.

In interim storage

After about a year the spent fuel is transferred from the reactor sites to the central interim storage facility, CLAB. Here the fuel is stored in water-cooled pools in the same way as at reactor sites. No conditioning is made and the fuel is fully retrievable.

After encapsulation

Before disposal in a deep repository the fuel will be dried, and encapsulated in canisters. The canister consists of a cast-iron insert with purpose-made channels for the intended fuel type. The insert takes 12 full length BWR– or 4 PWR–elements. A cast iron lid is bolted on to provide a leak-tight enclosure for the spent fuel during the encapsulation process. The insert is inside a corrosion resistant copper canister. After a copper lid has been welded on, the iron insert is completely encased in the outer copper canister. Substantial testing is made to control the tightness of the canister.

In case of defects in the canister or the welding, or if the canister is deformed during the handling or transport, the various steps have to be backtracked. A full retrieval after encapsulation requires that the canister lid is cut off, that the insert is opened, and that the fuel elements are transferred back to the pools. All the actions except the actual cutting of the copper lid can be made using the normal equipment in the encapsulation facility. Equipment and the procedure for opening a defect canister will be tested at the canister laboratory.

In the repository

When a canister is deposited in the repository, it is placed in a purpose-made hole in the tunnel floor, and surrounded by blocks of compacted bentonite-clay. When groundwater is absorbed by the bentonite the clay starts swelling and forms a plastic barrier around the canister protecting it mechanically and creating a buffer zone with very low hydraulic conductivity. In case something goes wrong in the deposition operation, the canister can be retrieved with the deposition–machine.

If the clay has started swelling the friction might be too large for simple lifting of the canister. A series of canister retrieval tests including remote handled methods for removal of the bentonite and the transfer of the canister into a radiation shield are running in the Äspö–HRL. The radiation levels outside the canister (max. 500 mGy/h) will only allow very limited activities around an unshielded canister.

Temperature restrictions require a minimum distance of around 6 m between two canisters in the same tunnel — giving a total tunnel length of 30–40 km. Each deposition tunnel is 0.25 to 1 km long. When all canisters in a tunnel have been emplaced, the tunnel is backfilled and the tunnel opening to the central tunnel is plugged. Should retrieval be required at this stage the tunnel plugging and the backfill has to be removed.

TABLE I. STAGES FOR THE SWEDISH DISPOSAL OF SPENT NUCLEAR FUEL

Stage	***Planned activities and its consequences on retrievability***
Interim storage	The spent fuel is stored in water–cooled pools. The fuel elements are fully retrievable.
Encapsulation	Fuel elements are placed in a cast-iron insert inside a copper container. A bolted iron lid and a welded copper lid seal the canister. For retrieval the weld must be cut open, the iron lid unbolted, and the fuel transported back to the pools. The cutting of the weld will be tested at the Canister Laboratory. In other operations the encapsulation equipment is used in the reverse.
Deposition	The canister is placed in a deposition hole and surrounded by compacted bentonite. If no substantial swelling has occurred due to water uptake the deposition operations can be reversed.
Extended operation	The deposition tunnels above the canister positions are backfilled, and the openings to the transport tunnels will be plugged. For access to the canisters the plugs and the backfill must be removed. If the bentonite buffer around the canister has swelled special methods must be used to free the canisters from the deposition holes. Such methods will be developed and tested at the Äspö–HRL.
Post closure institutional control	The whole repository will be back-filled and the accesses will be plugged. A period of institutional control is expected but the duration is not decided. If the interval between the back-filling and the retrieval operation is long special safety precautions will be required when excavating the tunnels.
Long term storage	After the institutional control has been discarded and the information regarding the waste is assumed to be lost, the retrievability will depend on the geophysical information that can be registered on surface.

Depending on the actual layout of the repository the different tunnels will be backfilled and at the final closure all tunnels and shafts will be sealed. With regard to the long term retrievability after the closure of the repository, no specific guidance has been given in Sweden. Since the repository concept is based on very long lived canisters no leakage due to corrosion is expected. Thus a retrieval operation during a reasonable period of institutional control is quite feasible. Depending on the period of closure various safety precautions are required for the re-excavation. The time limit for any intentional action is in practice given by the time period during which the information regarding waste and site is preserved.

Other long lived nuclear waste in Sweden, e.g. internal parts from the maintenance or decommissioning of nuclear reactors or some types of research waste, are planned to be disposed in concrete in a separate part of the repository. The conditioning and packaging of these waste types is made to allow normal handling, transport and disposal activities. The packages are thus considered to be retrievable up to the back-filling and closing of the repository. The radioactivity is small compared to the spent fuel and no specific requirements for post-closure retrievability of the packages has been posed nor for retrievability of the waste from the waste packages.

Due to the high geometric stability of the repository no specific features have been introduced to simplify the pinpointing of the waste packages or the retrieval of them. Nor have any barriers or safety measures been introduced with the purpose to reduce the retrievability. If specific arrangements are introduced to further simplify retrieval, new safety evaluation must be made to balance the benefit of that action to its cost or other detriments.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

C: Tönis Papp has asked me to make some comments about what we have done at the Swedish Nuclear Power Inspectorate (SKI) on the regulations. Since we left our review of SKB's RD&D programme 98 to the Swedish Government in April 1999, SKI has prepared a preliminary draft on regulations of HLW, which has been sent to SKB, to the reactor owners and to other organisations for comment. At SKI we have also discussed with our internal lawyers about the possibility to include retrievability in future regulations. According to the existing law, the Nuclear Act, it presently looks like retrievability could not be put as a demand on the industry in future regulations. However, retrievability will possibly be subject to close discussions between SKI and SKB in the future.

Q: You intend to remove the bentonite with salt water. Is the assumption then, that the bentonite may be contaminated, so you will have to treat it as a radioactive material, or do you just monitor the slurry as it comes off and then remediate it if necessary?

A: Yes, we will definitely have to monitor it. We believe that we can make canisters and welds that are of such quality that a reasonable retrievability period will be available. As always, there will be monitoring both of the direct radiation from the canister and of possible contamination of the clay taken away with the salt water.

Q: It is interesting to note that the same features which give you long term safety also give you easier retrievability. That seems to be a happy circumstance for the Swedish case. I suppose, that would not be true for a repository in salt.

A: No, you are right. We have tried to talk about this a little philosophically, also in the Concerted Action in Brussels (c.f. David Dodd's paper), whether one can say that a higher safety automatically will give a higher degree of retrievability. I do not think one can easily make such a conclusion. Generally, most of the factors which give you a high safety will also be beneficial for the retrievability. But suppose, for instance, that we would make the disposal in deep boreholes 4–6 kilometres deep, or something like that, instead of the method we now propose. The intention would then be to put the spent fuel in a rather small canister, with much less shielding around, and trust that the geological barrier would give the protection. There you can say that retrievability of such a canister would be much more difficult. Maybe just the effort to retrieve it would break such a container, and one would not say that safety and retrievability go hand in hand. But in a system where you have a high integrity of the barriers, the fact that the barriers are not changed in some way simplifies the process of taking it out, because then you know what system you have, what quality, exactly which positions you have etc.

Q: How about thermal effects on retrievability? If you dispose of heat generating waste, you heat up the host rock and the environment of the canisters. Can you retrieve at all times, in accordance with your concept, with temperatures below something like 100^{o}C or do you have only a limited time slot in which you can retrieve?

A: In our proposed system, when we have put down a canister and back-filled, then the temperature will go up, within twenty years it is somewhere close to 90^{o}C. We have this limit of 90^{o}C in order to keep away from a 100^{o}C situation, where we would get evaporation, salt-enrichment etc., which would complicate the safety assessment quite a lot. So one of the primary reasons for us to do this repository in this way was to keep away from the problems of high temperatures. If we would like to recover the spent fuel twenty years after the temperature peak, then it would require a period of cooling and ventilation. This could be done with the same salt water as is used in order to take away the bentonite. We could bring in cold water and thereby reduce the temperature. There might also be a need for higher ventilation, but we do not see any problems in principle with that.

Q: But if the rock is heated up to 90^{o}C, there will be stability problems in the rock, I suppose?

A: The temperature limit is given at the connection between the bentonite and the canister. The maximum temperature at the surface between the bentonite and the rock would be somewhere between 75 and 80^{o}C, and it will peak at a somewhat later time. But the heating might cause changes in the mechanical stresses, and normal precautions will be needed when you are going down for re-excavation.

PHASED REVERSIBILITY UNDER THE CURRENT FRENCH DISPOSAL CONCEPT

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Abstract

The French law of 30 December, 1991 and the implementing decrees provide for taking into account the reversibility in the study of geological disposal. This takes place within the framework of a 15 year research program. The research in this field implies both the assessment of technological possibilities for retrieving waste packages safety from the repository and the assessment of the consequence of delaying the closure of the repositories on the long term safety. This research program aims at proposing to the decision makers, by the year 2006, an open range of relevant options with regards to reversibility.

1. INTRODUCTION — THE FRENCH CONTEXT

The French law of 30 December, 1991 concerning the management of high level and long lived radioactive waste defined three main research directions [1]. 15 years of research are considered to prepare choices and decisions for 2006.

One research direction consists in studying the possibilities of reversible or irreversible disposal in deep geological formations, notably through the creation of underground research laboratories.

The reasons for the reversibility of a geological disposal are manifold: they are essentially based on the principle that future generations whether near or far should have the possibility of re-examining our current technical decisions or solutions to manage high level and long lived waste, and should consequently have a freedom of choice. These reasons were widely discussed during the drafting of the law of 30 December, 1991. During the 1997 public inquiries for the construction of underground research laboratories, ANDRA has taken careful note of public interest and of the elected representatives' insistence for the study of reversible geological disposal.

In 1998, following the French Government's request to the National Reviewing Committee (CNE) for a report on reversibility, ANDRA explained to the Committee what the scientific and technical implications of a reversible repository might be during its construction, operation and closure [2]. ANDRA sought more particularly to define at which moments, under which conditions and with what ease or difficulty, it would be possible to access and retrieve radioactive waste packages disposed of deep underground.

The report of the CNE pointed out in particular ethical issues which connect the acceptability of decisions to their reversibility [3].

On the 9 December, 1998, the French Government confirmed the decision to carry out the research in two underground laboratories and in the "logic of reversibility". The Government noted the CNE's definition of "reversibility" which consists in the possibility of retrieving the disposed waste safely and providing an important advantage for the society. In its decision, the French Government mentions that the "architecture of the repository must also provide for the logic of reversibility" [4].

On the 3 August, 1999, the Government issued the implementing decree for the construction and operation of the underground research laboratory on the Meuse/Haute–Marne site in the East of France. According to this decree, the research to be performed within the laboratory aims at providing data required to "the design, the optimization, the respect of the reversibility and safety, of a potential radioactive waste repository".

Another demand of the French Government is to pursue the research on the possibilities of geological disposal in granite rock on a new site to be selected.

2. THE PHASED APPROACH

The basic objective of a geological repository is to ensure the protection of human beings and of the environment. The safety of such a repository must be guaranteed over long periods of time. Safety requirements are naturally strict on the issue. They must not be challenged by further hazardous technical solutions concerning the reversibility of disposal.

Schematically speaking a repository consists of shaft leading to deep underground access/haulage drifts, and to further handling drifts. These handling drifts give access in turn to vertical or horizontal cells (silos, vaults, boreholes and tunnels) where waste packages are emplaced. A series of identical cells containing similar waste constitutes a "disposal module".

As such, the life-cycle of a repository (Fig. 1) starts with the construction and operation phases (Phase 1), followed by the step–by–step closure of the cells, the modules and the repository itself, each step corresponding to a successive disposal phase (Phases 2, 3, 4 and 5).

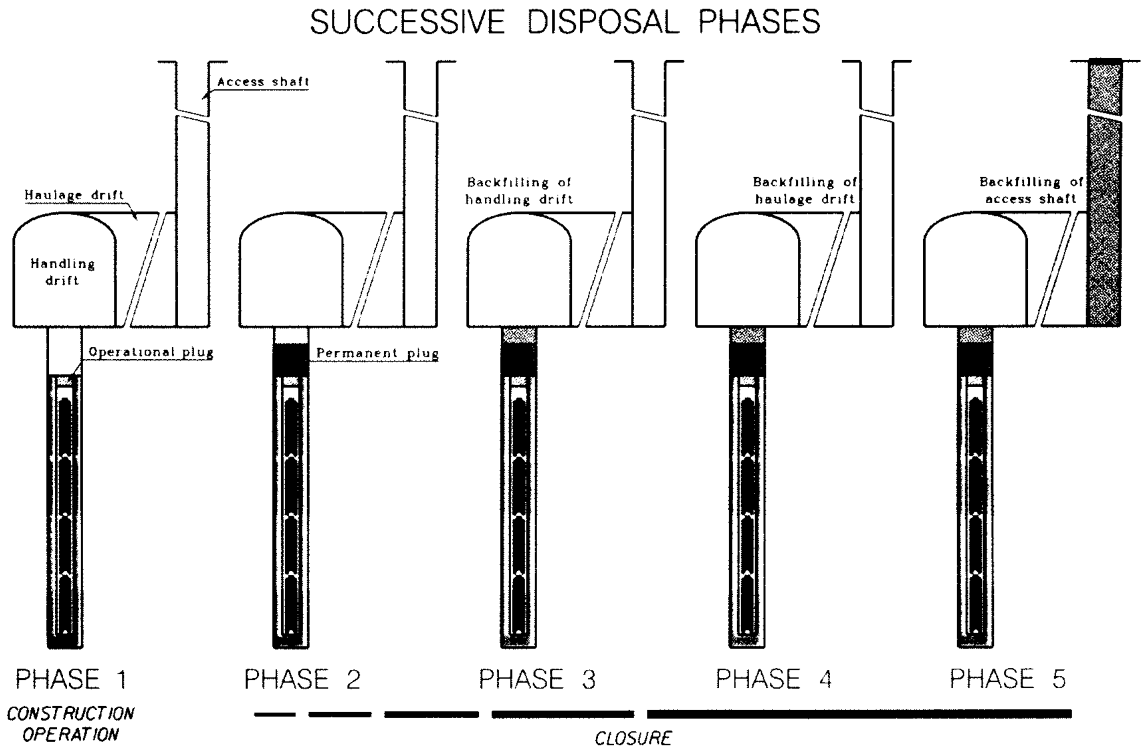

FIG. 1. Successive disposal phases.

3. THE CRITERION REVERSIBILITY IN THE DESIGN OPTIONS

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 without jeopardizing long term passive safety" it is the "initial retrievability of a repository" or "initial reversibility".

Practically in the argilites of the Meuse/Haute–Marne site, different options of disposal cells are designed with respect to the type of waste (see Fig. 2):

- Transuranic no heat emitting waste packages are planned to be disposed in horizontal tunnels. Their length is about one hundred meters and their diameter six meters. An option based on larger section caverns is also being studied. For both options, the "engineered barriers" placed between the waste packages and the argilite are made of concrete.
- Heat generating vitrified waste packages are disposed in shorter horizontal tunnels. Their length is about 25 meters and their diameter 2.5 meters. A swelling clay based buffer material is envisaged around the packages. Vertical borehole option is also being studied.
- For the option of disposal of spent fuel, the packages can be placed in the bottom half section of a horizontal drift, the upper half section being devoted to handling operations. To constitute an engineered barrier, options on concrete and swelling clay are both being considered.

In order to ensure the "initial retrievability" of a repository during operation phase without jeopardizing long term safety, different factors are taken into account in the design of a repository. For instance:

- The modularity of a repository contributes to the "logic of reversibility": the higher the modularity, the easier it is to adopt specific reversibility requirements as the state of each module may differ along with the successive life-phases of the repository.
- A few centimetre's clearance between the waste packages and the engineering barriers are provided within the range of design options. This clearance facilitates the retrieval of waste packages from the cells.
- 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 waste packages and the engineered barriers.
- As for high level vitrified C wastes, the potential adoption of an overpack facilitates the retrieval of waste packages. An overpack provides a great mechanical strength of 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 to potentially retrieve the packages in the case of horizontal disposal tunnels.
- Lastly, means to ensure general operating conditions which are favourable to accessing and retrieving packages are provided, e.g., for instance adequate ventilation.

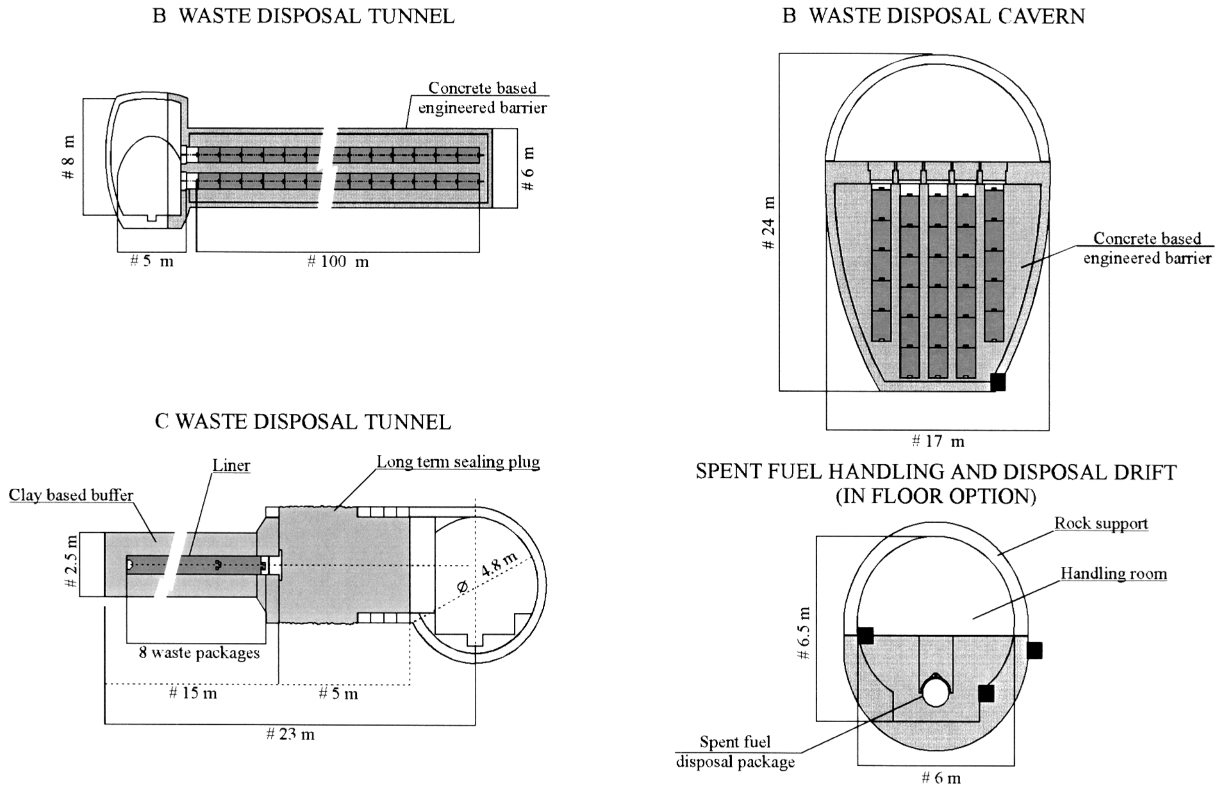

FIG. 2. Design options of waste disposal cells in argilites.

4. NEXT STEPS TO DEFINE REVERSIBILITY TO ANDRA'S RESEARCH PROGRAM

On the basis of the preliminary design options, the pursue of the study of reversibility in the next steps of the research programme implies both:

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

This research should aim at putting–across any relevant data showing the realistic flexibility in managing a geological repository.

4.1. The assessment of technological possibilities of retrieval relating the successive disposal phases

After each successive closure step the access to the waste package is less and less easy due in particular to the amount of material to remove. The study consists in describing for each step the available or potential equipments and processes to retrieve the waste package, for instance by removing backfill and bulkheads from shafts, drifts and cells, and repairing rock supports.

However, the retrieval of waste packages is generally considered as feasible in all cases, at least as long as the memory of the location of the repository is kept.

The assessment of the possibilities of delaying the successive closure steps

Assessing the possibilities of delaying the closure of disposal cells, handling or access drifts without consequences on long term safety suggest, first of all, identifying the phenomena, which could have an impact on the stability and integrity of the repository components.

These phenomena could be triggered by the excavation of the repository cavities, by the emplacement of heat emitting waste packages, then by backfilling and sealing of the repository cavities and drifts. They can consist, for instance, in mechanical, thermal or hydraulic discharges and recharges, in the corrosion or alteration of waste packages, engineered barriers, rock–supports and the rock itself. They lead to an evolution of the state of the cavities, such as the collapse of the clearance between waste package and engineered barrier.

Studying these phenomena, particularly through experiments on the argilite within the underground research laboratory enables the assessment and modelling of their kinetics. This modelling makes it possible to describe the evolution of the repository in its successive life-phases. Therefore, the influence of the delaying of the closure steps on the repository can be assessed.

With regard to safety, the phenomena analysis is a basis to the definition of additional scenarios, resulting from the potential delaying of closure steps.

The phenomena analysis also contributes to define a monitoring programme appropriate to the stepwise closing process.

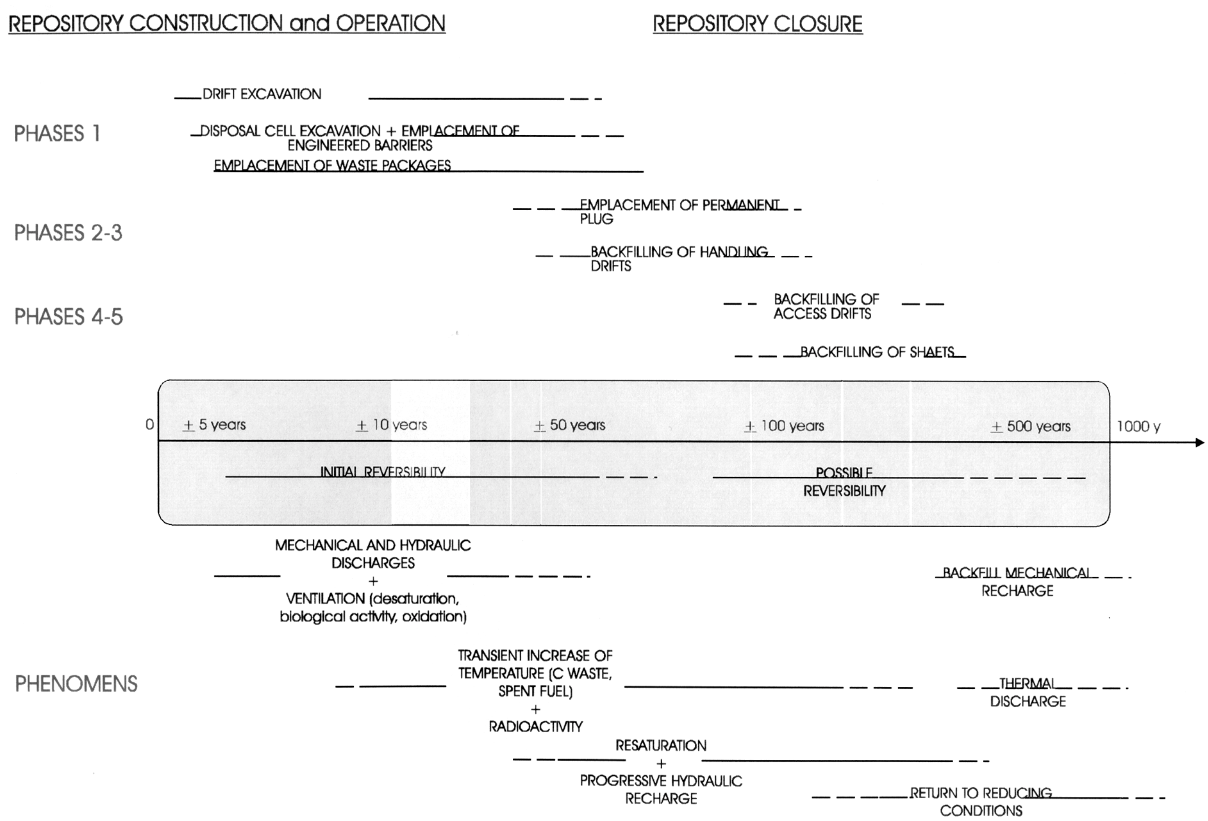

FIG. 3. Reversibility and life phases of the repository.

5. CONCLUSION

a) Studying reversibility means turning a political demand into a technical and scientific approach.
b) By distinguishing successive phases within repository's life span, one can describe how retrievability evolves with time.

- This allows to forecast the times when retrievability demands new technical means and specific set-ups regarding safety.
- Scientific and technical legibility contributes to:
  - Building up confidence in repository design; and
  - Proposing to the decision makers, by the year 2006, an open range of options with regards to reversibility.

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QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: Is this ethical principle also applied to other types of waste, for example hazardous waste?

A: The 1991 law, which is the first one to provide for reversibility, says that we have to study both reversible and irreversible options for nuclear waste. This law provides for reversibility in any geological disposal of any kind of waste. This has had an impact on the geological disposal of chemical waste in France, which has to be reversible. The first packages are now underground and this is made according to a reversible process. But the law addresses only the geological disposal, not the above ground disposal.

Q: You mention a monitoring programme based on some phenomena you have identified by performance assessment modelling and URL (Underground Research Laboratory) research. We also heard this morning that we do not expect any results related to safety from the monitoring programme. Could you comment on that and also on the time span you are including in the study. Are we talking about decades or centuries?

A: A common safety indicator is the dose from the released radionuclides. But we do not expect the radionuclide release to start before hundreds or thousands of years. We can monitor in the repository phenomena like mechanical deformation, increase in temperature, hygrometry in the clay buffer etc. These phenomena occur at relatively short scale and they are directly connected to the modelling of the evolution of the repository.

Q: You showed a figure in which is indicated a period of initial reversibility up to maybe 50 years, followed by another period of possible reversibility extending up to about 500 years. Is 500 years based on any systematic consideration of the host rock formation or is it only an illustrative figure based on your present feelings?

A: The figure you refer to is addressing the reference case, which means a life cycle of a repository without the enhancement of reversibility. Based on this reference case, we are studying the possibilities to postpone some closure steps and to prolong some intermediate phases. The figure 500 years indicates an order of magnitude in the phenomenological approach and, on the other hand, it is also mentioned in the French basic safety rule as the acceptable duration for the ”memory” of the repository.

Q: Coming back to the earlier question about what you can monitor, I am rather worried about all these things that you claim that you can monitor. I am afraid that people will monitor them because they are measurable and not because they are relevant. One big danger is that we monitor transient effects which do not have a long term effect. Don’t you think there is a real danger with the monitoring of the whole repository system? One danger is that you will monitor irrelevant things. Another danger is that if you try to use the monitoring as a test of how well you understand the system, then the test will be too strict, because you do not have to understand the system as well as that.

A: My point was monitoring with regard to reversibility, so I am addressing a time scale of several decades, maybe a few hundreds of years. I am not addressing the long term safety in terms of potential long term release of radionuclides. My presentation points out the possibilities of monitoring. These are very open and there is no decision for the time being.

Q: In principle you say that future generations should have a choice of freedom and that is why you provide retrievability. But suppose that future generations would have preferred the freedom to have nothing to do with the waste and with the closure of the repository. Which were the arguments in France in the discussion of these two types of freedom, when you arrived at the conclusion to give them the freedom of choice in terms of retrievability but not to give the choice of not having to do anything with the disposal of today’s waste?

A: It is not a yes or no situation. Our generation or maybe the next one will start the operation phase, but then the kinetics of the decision process is in the hands of the next generation and so on. It is a step-wise disposal process with the possibilities to decide at each step, but the decision is in the hands of the people who will have to decide at that time.

Q: Can they also decide not to go along with your planned monitoring programme over 100 years?

A: Yes, they can decide that. The only thing we do is that we make research in order to know what is feasible or not from a technical and scientific point of view.

Q: I noticed that you have some plans for spent fuel disposal. Is that only MOX-fuel or are you also preparing for once through spent fuel disposal?

A: The research addresses mixed oxide fuel and also uranium oxide fuel.

Q: Does that mean that there is a policy change on reprocessing in France?

A: No, this is research. We want to know if it would be feasible to dispose of spent fuel. The idea is that if we would like to consider to dispose some percent of the spent fuel, or maybe more, in the long term, everything should be open. That does not mean that any decision has been taken in one sense or another.

Chair: It is interesting to note that a country like France, which is in the main geared to reprocessing and taking care of plutonium, also looks equally at the question of retrievability as those countries which go for spent fuel disposal. After all, we all know that for spent fuel there is still a great energy potential. And yet, those who have already extracted it look for other potential values in the waste. This is a point worth retaining.

Another reflection is on the relation to other types of waste. You mentioned that in France there are similar ideas on retrievability for other types of waste than nuclear. But it occurred to me that one may say that the discussion within the nuclear sphere perhaps is far ahead of discussions in relation to other wastes. In the opening speech yesterday, it was said that it is useful to compare what we are doing in the nuclear sphere with what is being done in other spheres. It gives a useful perspective to what we are dealing with.

RETRIEVABILITY IN THE BELGIAN DEEP DISPOSAL CONCEPT IN CLAY

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Abstract

While radioactive waste disposal implies that there is no intention to retrieve the waste, retrievability refers to the potential to retrieve the waste. So, retrievability can be an integrated element of a disposal solution. The different reasons for considering retrievability in the development of a disposal solution are discussed. Amongst them, the precautionary principle takes an important place. The development of a disposal solution should be in the first place safety-driven. The use of robust, high-integrity waste containers or overpacks contributes directly to safety, but also to the enhancement of the retrievability. Indeed, as long as the first barrier is intact, safe waste retrieval is in principle possible. By extending the period of easy access to the waste, *i.e.* by keeping the repository open during a longer period than needed for waste disposal operations, safety and retrievability goals can become contradictive. Indefinitely postponing the decision to close the repository enhances the risk of unforeseen perturbations of the disposal system and the risk of abandonment. This pleads of course for limiting the duration of the open phase to a reasonable period of time. Otherwise, the advantage of a prolonged open repository, as a means to prolong retrievability of the waste, is cancelled by the increasing risks of a system whose safety relies on societal, political and decisional stability, and not on a robust, passive multi-barrier system.

1. INTRODUCTION — WHY IS RETRIEVABILITY BEING CONSIDERED?

The objective of disposal is to dispose of the waste in a safe manner and in such a way that long term safety is not dependent on continuous active measures. The objective of disposal is not to retrieve the waste after some time. If the latter were the case, it would be more appropriate to keep the waste in storage.

However, disposal and retrievability do not have to be conflicting concepts. While disposal implies that there is no *intention* to retrieve the waste, retrievability refers to *the potential to retrieve* the waste after emplacement.

Although the first challenge in developing a radioactive waste disposal system is to demonstrate convincingly that all safety requirements can be met, several reasons can be put forward to integrate retrievability in disposal concepts.

- In the safety demonstration exercise we are inevitably confronted with scientific uncertainties concerning long term and irreversible impacts on the environment. Although severe or unacceptable impacts are extremely unlikely for a properly sited and correctly designed repository, absolute proof of it cannot be given. The precautionary principle states that in such a case appropriate preventive actions should be taken. It is important to emphasise that any preventive measure should be proportional to the risks of irreversible damage. So, in all precaution considerations due account has to be given to the safety margins of a disposal system. The robustness of the disposal system, supported by the multi-barrier concept and defence–in–depth requirements, is an essential element in this evaluation. The precautionary principle is essentially a moral obligation to decide and to progress in a responsible and cautious way. A stepwise decisional process of radioactive waste disposal, with the possibility in each step to undo previous decisions, can be such a responsible and cautious way. So, accommodating the potential to retrieve the radioactive waste in the disposal concept can be seen as a direct application of the precautionary principle.

- A second argument for retrievability deals with our incapability to judge whether radiological risks that we consider to be acceptable or even insignificant, are also acceptable for future generations. Future generations might want to correct our actions, if they consider the related risks too high.
- A similar argument is that future generations might want to re-use our disposed waste. A reversible disposal system that allows for a safe retrieval of the waste fits that argument. It can, however, also be argued that in that case the risks of retrieving the waste are at the expense of the future generations, because they decide to retrieve knowing both the benefits and the risks.
- Finally, retrievability is closely related to risk communication problems. In discussions with non-technical audiences, all safety demonstration exercises are hampered by the problem that calculated risks and perceived risks are different notions. It is thought that a stepwise and flexible decisional process can be a way to solve this problem. Irreversible situations or decisions do indeed negatively affect perceived risks.

There are currently no laws or policy statements requesting retrievability of disposed high level radioactive waste in a deep repository in Belgium. However, the issue of retrievability was introduced in a policy statement of the government (16 January, 1998) on the disposal of low-level waste on the surface or in a deep repository.

After this general description of the main motivations to integrate retrievability in the Belgian deep disposal concept, the remainder of the text will focus on the technical elements in the disposal design that contribute to or enhance the retrievability of the disposed waste. The relationship between retrievability and long term safety is also dealt with.

2. RETRIEVABILITY IN THE BELGIAN DEEP DISPOSAL CONCEPT

Optimizing the design, the construction, operation and closure of a deep repository has to be in the first place safety–oriented. The main objective of a radioactive waste repository is to provide passive safety. Incorporating elements of retrievability in the disposal system is a means to develop and realise a safe solution in a responsible and cautious way. It is, however, not an objective that should be optimised. Optimization of a deep repository in terms of retrievability would lead to a surface or subsurface storage solution.

In general terms retrievability can be incorporated in a disposal system in three different ways:

- In the design of the repository one can integrate requirements for prolonged reversible waste handling capabilities. A first condition for reversible waste handling 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. Although this may be a technical element of retrievability, it is felt that it does not really affect the perceived retrievability. Retrieval of the waste from a closed repository is no longer considered by the general public to be realistic, probably because a closed repository is seen as an accomplished fact.

The Belgian repository design for the deep disposal of high level radioactive waste (vitrified waste from reprocessing or spent fuel) bears a series of intrinsic retrievability features, which were not intentionally designed. They stem from safety considerations.

The overpacked waste forms are placed in a long (several tens of meters) disposal tube (a cross-section of a disposal gallery for high level vitrified waste is given in Fig. 1). Before placing the waste canisters in the disposal tube, the space between the disposal tube and the disposal gallery lining is backfilled with precompacted blocks of a swelling clay/sand mixture. The use of a disposal tube allows to separate the construction phase of the disposal gallery, including the backfilling with precompacted blocks, and the emplacement of the waste itself. The overpacked waste forms are pushed one after another in the disposal tube, which has no long term safety function.

The design lifetime of the vitrified waste overpack and of the spent fuel container are respectively about 300 years and about two thousand years. The primary function of the container is to provide physical containment during the transient phase of the repository, principally the thermal transient phase. Steels that are corrosion resistant in the disposal environment have been identified (a.o. austenitic stainless steels). Although further confirmation of this corrosion resistance is required, the performance of this overpack/container barrier opens the perspective of a very long physical containment of the waste, which contributes significantly to the reinforcement of the multi-barrier concept, as well as to the intrinsic retrievability of the disposal concept. 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 perfectly possible.

Increasing the design lifetime of the waste containers, of the disposal tube and of the access infrastructure (transport galleries and shafts) can further enhance the intrinsic retrievability characteristics of the disposal system. These technical design elements make it possible to postpone the decision for stepwise closure of the repository in view of an extended accessibility. For example, after emplacement of the waste canisters in the disposal tube and after a provisional closing off of the disposal tube, it may be decided to keep the transport galleries and shafts open for a longer period of time than strictly necessary for repository operation.

At present it seems reasonable to keep a deep repository in the Boom Clay, if needed, open for about one hundred years. If for retrievability requirements longer periods are asked for, enhancing some of the design requirements could in principle accommodate this need. However, one has to be aware that by further postponing repository closure an increasing number of elements that complicate, or even jeopardise, the long term safety objective will be introduced. This is discussed in the next point.

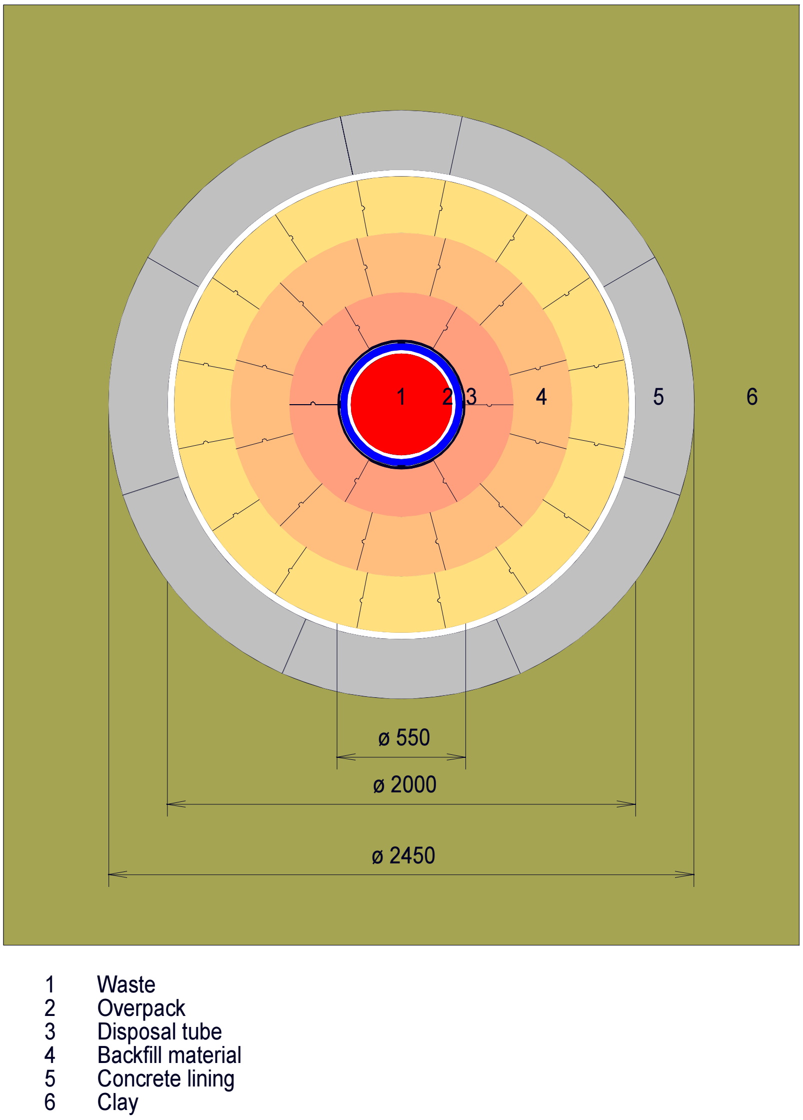

FIG. 1. Cross-section of a disposal gallery for high level vitrified waste.

3. THE INTERACTIONS BETWEEN RETRIEVABILITY AND SAFETY

If stringent retrievability requirements would be imposed on the Belgian deep repository for high level radioactive waste, it is clear that the disposal tube and the waste containers will play an essential role. Their design lifetime and capability for reversible waste handling operations will have to be checked very carefully.

Equally important will be the question during which period of time the transport galleries and shafts can remain open. During this open phase of the repository active surveillance and maintenance will be necessary. The high temperatures and relative humidities in the underground will have implications for the ventilation system.

In an open repository a series of processes can affect the long term confinement capacity of the disposal system:

- Chemical processes: the presence of oxygen may create problems of aerobic corrosion of waste containers and disposal tubes and will acidify the Boom Clay by oxidation reactions.
- Hydraulic processes: continuous transport of clay water to the galleries, leading to desaturation of the host rock.
- Mechanical processes: the question of convergence of the clay around the galleries; also, disposal gallery seals will have to withstand high differential pressures as long as the transport galleries remain open.
- Thermal processes: thermal profiles in the host rock will largely depend on ventilation regimes.

None of these processes seems to create insurmountable problems for a repository in the Boom Clay that remains open for one hundred years. Each of them will need further research to confirm this statement. Especially the question of aerobic corrosion of waste containers could be a difficult one.

Although an extended open repository seems to be feasible from a safety point of view, final closure of the open repository remains an absolute safety requirement. Due to unexpected major changes in society a breakdown in the active management of the open repository could occur, resulting e.g. in the abandonment of the open repository. This pleads of course for limiting the duration of the open phase to a reasonable period of time.

Otherwise, the advantage of a prolonged open repository, as a means to prolong retrievability of the waste, is cancelled by the increasing risks of a system whose safety relies on societal, political and decisional stability, and not on a robust, passive multibarrier system.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: Can you please tell us a bit more about what you mean by pressurisation of seals?

A: If you place the waste in the disposal galleries, you will have to close the galleries with a preliminary, a temporary or a final seal. An important element is the swelling of the backfill material and this has been developed such that the total swelling pressure is less that the total lithostatic pressure, otherwise it would start to fracture the geological barrier. If you put the seal at the end of the disposal gallery and there is no backfilling in the access galleries, this seal will have to withstand the same swelling pressure and I do not have the technical elements yet to say that this is feasible, in which way it could be done and how it can interact with the other barrier functions of the system. So this is an open question, which should be looked at carefully.

C: I like very much the first part of your paper. I think you have hit on basically all the important points in the debate about retrievability between industry and regulators and political decision makers, in a very structured way. That first part of your paper could be used as a starting format for a discussion about what we are really dealing with in the wider perspective on retrievability.

Q: I was puzzled by your very last conclusion, that retrieval after closure is not an issue. How can you come to that conclusion, from the rest of your presentation? I thought that, for many people, that is the issue, whether you can retrieve after closure.

A: I would like to make a comparison with another problem in waste management and that is the difference between technically calculated risks and perception of risks. Technically evaluated retrieval after closure is one thing, but perception by a lot of people and mainly by the people that are concerned about this issue, is another thing. I do not think it is possible to convince a large population, the general public, of the fact that retrieval in a closed repository is technically feasible and that it is part of a decision process. I think that people will be convinced that, once the repository is closed, it is an accomplished fact and nobody will ever come back to that decision.

C: I think it is a dangerous approach to mix technical analysis with research results on perceived public perceptions. You should really limit yourself to the technical assessment of options and leave this worry about the perception to the decision makers.

A: I do not agree at all on that! The main part of our work is to develop technical solutions, but we have to take into account the acceptance of such solutions. I have experience of my own from site selections and from development of concepts and if you do this in a very technical way and do not look outside, then you may run against a wall and lose everything. If you have a discussion with the broad public, there is the possibility that you can develop your solution, I mean the solution of your company and of the public.

C: Still I think it is a dangerous process. If you make a technical assessment of options, you will most likely conclude that the safety of an open repository is lower than that of a closed repository. Therefore, your technical judgement should lead you to conclude that the repository should be closed as soon as possible, as soon as technically feasible. If your idea of the perception of the public causes you to change this conclusion, it is a disturbing element in the process. It should be kept in mind that perceptions are changing; what is the perception today will not entirely be the perception of next generation.

A: As I showed in the reference decisional scheme for a repository in Belgium, the intention is to close it as quickly as possible after waste emplacement. So we do not disagree on that point.

C: In Phil Richardson's paper this morning, it was mentioned that the public demands retrievability. So that question is already on the table. I do not really understand the comment. If the industry does not want a retrieval or see it as hazardous to retrieve, they should not go along with this.

Chair: The starting point may be a little different. You talked about a much shorter period of retrievability than some other speakers this morning.

A: The main reason here is based on technical considerations and also on decisional considerations. If no decision can be taken about closing a repository after say 50–200 years, then I do not think such a decision will ever be taken.

C: It is also interesting that many of the uncertainties that we have seen, may be resolved within a period of 50–100 years, for example the questions on energy future and on transmutation. That period of 100 years is quite interesting, when it comes to leaving a slack in time for final decision to close the repository.

RETRIEVABILITY AS PROPOSED IN THE US REPOSITORY CONCEPT

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Abstract

The Nuclear Waste Policy Act states that any repository shall be designed and constructed to permit retrieval. Reasons for retrieval include public health and safety, environmental concerns, and recovery of economically valuable contents of spent nuclear fuel. The Nuclear Regulatory Commission requires that waste must be retrievable at any time up to 50 years after start of emplacement. The US Department of Energy intends to maintain a retrieval capability throughout the preclosure period. Possible preclosure periods range from a minimum of 50 years to as much as 300 years. Repository closure includes sealing all accessible portions of the repository, including ventilation shafts, access ramps and boreholes. Drip shields will be installed over the waste packages. Access to the repository after closure is not intended. The proposed repository includes horizontal emplacement drifts located in the unsaturated zone. The emplacement drift centerline spacing is 81 meters to provide a subboiling region between drifts for water drainage. A drip shield covers the waste packages. All emplacement drifts remain open until closure of the repository, providing performance benefits such as removing heat and moisture during the preclosure period and lowering postclosure temperatures. This does not impede retrieval, permitting a reversal of the emplacement process to accomplish retrieval under normal conditions. The preclosure period is therefore not to enhance retrievability, but does improve performance, and the resultant extension of the retrievability capability is a secondary effect. Information must be provided from the performance confirmation program to support a regulatory decision to close. Closure would isolate the repository from the accessible environment, preclude preferential flowpaths for water into the mountain, and minimize the possibility of inadvertent intrusion.

1. BASIS FOR US CONSIDERATION OF RETRIEVABILITY

1.1. Legislative requirements

The Nuclear Waste Policy Act, as amended in 1987, defines the requirement for retrievability and provides the reasons for which retrievability may be required. Section 122 of the Act 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 nuclear 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 preclosure activity. Reasons for which retrievability is justified under the Act include public health and safety, environmental concerns, and recovery 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).

1.2. Regulatory requirements

The Nuclear Regulatory Commission requirements are given in Title 10 of the Code of Federal Regulations (CFR), Part 60 and draft Part 63. These regulations establish a minimum period during which retrieval must be possible. 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.

2. DURATION OF CAPABILITY FOR RETRIEVAL

2.1. Preclosure period

The US approach to retrievability envisions that waste be retrievable at any time during the preclosure period. The regulatory minimum for retrievability is 50 years from start of emplacement, but the DOE intends to maintain a retrieval capability throughout the preclosure period. The actual duration of the preclosure period for a repository has not been determined, but is subject to several inputs.

Recent project activity has addressed the issue of uncertainties in both natural and engineered system performance. It has been determined that cooler temperatures during both the preclosure and postclosure periods reduce uncertainties in modeling the system behaviors, and are also beneficial to repository operations. A design change has recently been approved which incorporates a cooler design [1]. The previous design resulted in emplacement drift rock wall temperatures well above boiling both before and after closure. The revised design maintains the rock below boiling during the preclosure period, although closure at 50 years would result in rock temperatures above boiling. The revised design is also capable of maintaining rock temperatures below boiling throughout the postclosure period by extending the preclosure period. There are therefore several conceptual preclosure periods.

The minimum preclosure period is that necessary for compliance with the NRC regulations, and is 50 years from the beginning of waste emplacement.

The second potential preclosure period is that length of time that would result in sufficient heat removal so that the repository host rock would remain below boiling after closure. Under the current design concept, a preclosure period of approximately 125 years is required to maintain the repository rock walls below boiling after closure.

The third potential preclosure period results from a repository concept that defers the closure decision to future generations. The US concept does not preclude extending the preclosure period to allow future generations to make the decision when to close, and to continue to monitor and acquire performance data to support such a closure determination. The repository is being designed to permit a preclosure period of 300 years, with reasonable maintenance. This approach is directly responsive to public input. Public concerns have been expressed that closure in relatively short periods does not provide adequate assurance of safety.

2.2. Accessibility after closure

The US concept of repository closure includes sealing all accessible portions of the repository, including ventilation shafts, access ramps and boreholes. Drip shields will be installed over the waste packages, and the emplacement drifts backfilled. Access to the repository after closure is not intended.

3. DESCRIPTION OF REPOSITORY LAYOUT

3.1. Open drifts in unsaturated zone

The concept for the proposed repository at Yucca Mountain includes horizontal emplacement drifts located in the unsaturated zone, approximately 300 meters below the mountain surface and approximately 300 meters above the saturated zone. The recent design change has focused on reducing performance assessment uncertainties through achieving a cooler design than that proposed in the Viability Assessment (VA). The spent fuel loading has been reduced from 85 to 60 MTHM per acre. The emplacement drift centerline spacing has been increased from 28 to 81 meters to provide a subboiling region between drifts for water drainage. The maximum power per waste package has been reduced from approximately 19 KW to less than 12 KW. The preclosure ventilation rate has been increased from 0.1 cubic meters per second (CMS) per drift to 2 to 10 CMS. Other features, such as a drip shield over the waste packages and backfill to protect the drip shield, have been added to provide defense in depth in reduction of the amount of water contacting the waste packages during the postclosure period.

3.2. Drifts open until closure

The emplacement drifts are to remain open until closure of the repository. This provides numerous performance benefits in this emplacement concept, primarily removing heat and moisture during the preclosure period, lowering the postclosure temperatures and slowing the increase in relative humidity upon closure. Other benefits include facilitating the measurements taken during the performance confirmation period, after loading the waste packages into the drifts. With respect to retrieval, this provides the benefit of not impeding retrieval, permitting a reversal of the emplacement process to accomplish retrieval under normal conditions. The preclosure period is therefore not to enhance retrievability, but does improve performance, and the resultant extension of the retrievability capability is a secondary effect.

4. METHODS OF RETRIEVAL

4.1. Drift conditions during retrieval

Under the cooler conditions of the revised design, the temperatures inside a drift during the preclosure period are reduced. During the preclosure period, the drift wall now 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. Further cooling will be necessary for human entry into the drift. The increased confidence in drift stability is of interest, due to the higher radiation field in the drift resulting from the use of thinner, more corrosion resistant waste packages as compared to the previous design concept.

4.2. Retrieval under normal conditions

Because the drifts are to remain intact and open during the preclosure period, retrievability would be accomplished through reversal of the emplacement process under normal conditions. The main components of the emplacement equipment include the primary and secondary transport locomotives, a shielded waste package transporter, and an emplacement gantry.

4.3. Retrieval under abnormal conditions

An abnormal retrieval condition would occur when the equipment and operating sequence stated above cannot be used, most likely due to drift wall collapse conditions that would preclude the use of the remotely operated waste package gantry. Under these circumstances several additional operations would be added to the sequence, including clean up and removal of fallen debris, stabilizing the drift, restoring the tracks, repositioning waste packages, and control and removal of breached or damaged waste packages. In these abnormal circumstances, waste package retrieval from the drift is not limited to the gantry operation. Other equipment pieces have been identified which can perform the operation successfully. Waste package skirts are fitted with holes allowing grappling in the event that lifting of the supporting bases is not possible. To perform these activities, it is anticipated that cooling would be required to lower the temperatures from near-boiling to human-accessible temperatures, and that portable radiation shielding may be required to permit access to those packages which cannot be remotely retrieved.

Generally, preparation for retrieval under abnormal conditions would be the same as stated for the normal operation, with the exception that a unique retrieval plan would be developed as required for each case. Due to the double-ended nature of the emplacement drifts, retrieval may be accomplished from either end.

5. CLOSURE OF A REPOSITORY

5.1. Closure authority

The decision to recommend closure will be based upon completion of an appropriate preclosure performance confirmation monitoring program. To receive approval to close a repository, the DOE must submit a license amendment to the NRC. Information must be provided from the performance confirmation program to support a regulatory decision to close. The intent is to ensure that an adequate basis exists for understanding the postclosure performance of a repository prior to performing closure activities.

5.2. Closure activities

When approval is granted, closure would commence and require a number of years to accomplish. The drip shields would be emplaced over the waste packages, backfill emplaced over the drip shields, additional backfill emplaced in access ramps and potentially in perimeter and ventilation drifts, and seals installed in all penetrations to the surface of the mountain. These would include all access shafts and ramps, ventilation shafts, and boreholes. The intent of the closure activity is to isolate the repository from the accessible environment, preclude preferential flowpaths for water into the mountain, and minimize the possibility of inadvertent intrusion.

6. SUMMARY

Retrieval of spent nuclear fuel from a geologic repository is a regulatory requirement. A design is being developed for a proposed repository, which has the capability to retrieve any or all emplaced spent nuclear fuel. Reduction of uncertainties affects the duration of the preclosure period. Retrieval under normal conditions would be accomplished through the reversal of the emplacement process, but abnormal retrieval is also possible. The extended monitoring capability proposed for a repository does not degrade repository safety. Retrieval activities could be initiated at any time prior to repository closure.

REFERENCE

[1] US DEPARTMENT OF ENERGY, Civilian Radioactive Waste Management System, *License Application Design Selection Report*, Report No. B00000000–01717–4600–00123 REV 01, US–DoE, Las Vegas, Nevada, USA (1999).

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: You said that the rock would boil?

A: That has become shorthand for the boiling of water in the rock, for us that is 96^{o}C.

Q: In France, Belgium, Sweden and so on, one seems to regard the retrievability or the postponed closure as something which is disturbing the long term safety, and one does not seem to be very happy with this additional requirement. In the USA, you seem to be happy with this requirement of retrievability, since it gives you 50–300 years to make your final safety case and to cool a bit more than before. In Switzerland, for instance, we would not be allowed to place anything in the repository before the final safety case has been made, and we are worrying about leaving it open 50 years or 100 years or even 30 years in order not to jeopardise the long term safety. Have I understood this correctly?

A: What I said initially was that performance is driving the design and then the design supports a pre-closure ability, not the other way around! We would not expect to hold a repository open simply for retrievability. We have to make a safety case before we can even get a licence to construct. We go through two licensing evolutions, prior to construction and prior to emplacement. Once we have substantially completed construction, we go back to the NRC to get a licence to receive and handle waste. At that point, we have to show them that the construction activities were in compliance with the safety case we made initially. The closure period comes in to ensure that the safety cases that we made on the basis of modelling, on testing, on our assumptions as to what would actually happen in a loaded repository, were true. That is why that performance confirmation period is there, to allow us to collect sufficient data. So we are not allowed to postpone the safety case until we have already built, constructed, loaded and sat on a repository for fifty years or more. We have to make that safety case before we can even get a construction authorisation.

Q: You said that performance is driving the design. What is the purpose of the backfill and drip shield or so-called Richard’s Barrier in the total systems performance assessment? If it does not play any role, why then bother to put them in there?

A: They do play a role, at post-closure, not at pre-closure. For those who are not familiar with that: A Richard's Barrier is a dual layer backfill, where you have a coarser material, like a gravel, underneath a finer material, like a sand, and the intent of that is to keep the water wicked within the sand such that it will not go into the coarser gravel material underneath and you can then divert down a sloped interface between them. We decided that there would be an inordinate amount of difficulty in trying to install such a device and then demonstrate in a regulatory environment that it is really going to work as you expect it would for the period of time that you are interested in. So the Richard's Barrier as a dual layer is gone. But we do have the drip-shield and the backfill. The waste package with its outer surface of Alloy 22 is susceptible to some corrosion mechanisms at elevated temperatures, so the intent of the drip-shield is to keep the water off of the waste package during that period of elevated temperature. It is made out of Titanium, a different barrier material, another defence in depth mechanism, should we have misunderstood some of the failure mechanisms, but the drip-shield would keep the water off of the waste package during the waste package elevated temperature regime of a couple thousand years. The backfill is on top of the drip-shield to provide mechanical protection to it, from rock falls. One of the things we are doing is trying to determine just how large a rock can fall. Earlier estimates had had them as large as fifteen tons, we are now down to about seven and a half tons. Again, it is a fairly substantial rock, so the intent of the backfill is to provide a cushioning mechanism on top of the drip-shield.

Q: Could you please say something about the intermediate storage facilities and what kind there are, and why there are no national ones?

A: I do not know that there are any real intermediate storage facilities. What I said is that each of the reactors has storage capacity and some of the reactors have had to go to dry storage because they have used up there pool capacity. There is no other high level waste or spent nuclear fuel storage facility. High level waste comes to us from the other Department of Energy facilities, at Hanford, Savannah River etc. Some of them are already reprocessing some of the reprocessing waste. You have heard of the Hanford tanks, I am sure. There they have not yet started. At Savannah River they have, so they are going to create high level waste canisters, and they are building storage facilities on their sites for storage of those until a repository is ready to accept it. I say a repository because we have not yet finished site characterisation. We do not know yet that we will even recommend Yucca Mountain for a repository site. The DOE waste stream includes high level waste from reprocessing and also DOE spent nuclear fuel from the various DOE test reactors, production reactors and some commercial fuel that DOE has taken title to. The large majority, ninety percent of what would come to a repository, would come from the commercial power plants.

Q: I would like to reflect on your remark about the safety indicators and would like to mention to you that the IAEA has prepared — on the basis of consultations with international experts — a report on this. The report is available here at this meeting, so you may choose to look at the report on indicators others than dose and risk. I would also like to ask you a question regarding your third bullet statement "Normal retrieval is reverse of emplacement". It seems very simple but if you have temperatures of say 100°C you have changed the situation very much compared to the emplacement situation. Temperatures of 100°C leads to quite a complicated system because of the thermo-mechanical reactions and probably the breakdown of rock stability. What is your experience in this area with respect to the tuff?

A: We convened an expert panel on rock mechanics to address that specific question. The first meeting was in fall of 1998 and then the panel reconvened in spring 1999. As you might surmise, there is not a great deal of experience with tuff, with elevated temperatures, so the experts were highly reluctant to try and prognosticate how long we can expect tunnel integrity. One thing that they did agree upon though, was that the liner, the concrete liner, was more than would be necessary. They thought that probably you could get by with rock bolts and wire mesh for a period of up to around 100 years before having to go back and do some substantial remediation reinforcement. They did not expect that you would have significant failure, but rather it would be a general unravelling of relatively small pieces of rock coming out. So we have another panel of sub-surface construction experts, who have taken the position that steel sets or some sort of liner, if not concrete then steel with lagging, is a more appropriate solution, that is why I said earlier that we would probably end up with a combination of the two depending upon the specific rock. We are doing extended thermal tests; you may know that we had a single element heater test, we had a large block test, we are in the middle of a drift scale test, where we have heated up about eighty metres of drift with several different types of ground support to repository temperatures. These are even actually higher than the temperatures we are looking at now, just to see what would happen to water movement within the rock, to the host rock itself, and we used that data to support the safety case. One comment is that the horizon of rock, that the test is in, is representative of only about fifteen percent of the overall repository rock. There is another much larger area called the lower lithophisal, that most of the repository horizon would be in. We have not run heater tests in that yet. We have recently completed a tunnel that went over to that particular rock and one of the things for the future is to do thermal testing in there, just to balance the large scale test against what we find from that lower lith.

PUBLIC ACCEPTANCE

(Session 2)

REPORT FROM THE UK CONSENSUS CONFERENCE ON RADIOACTIVE WASTE MANAGEMENT, MAY 1999

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Abstract

A Consensus Conference took place in the UK in May 1999 to address the issue of Radioactive Waste Management. Sixteen members of the public were invited, at random, to take part in the conference, and initially were unaware of the topic. After two preparation weekends, the citizen's panel held a two day conference at which they cross examined expert 'witnesses' on issues which they felt to be relevant to the topic. The remit of the panel was as follows: "The Consensus Conference is to focus on the effective and publicly acceptable long term management of nuclear waste in the UK, both civil and military, concentrating particularly on intermediate and high level waste. This will be considered by the citizens' panel in their capacity as members of the public, taking into account what they see as the relevant issues." Following the conference itself, the panel produced a report on their findings and conclusions. Retrievability was just one of the many areas that the panel covered. In relation to the area of public acceptance for long term management of radioactive waste, the recommendations of the panel were as follows: "In conclusion the panel was unanimous that in order for a solution to be publicly acceptable, the waste MUST remain accessible and monitorable to give future generations a chance to deal with the problem if/when a solution is found".

1. WHAT IS A CONSENSUS CONFERENCE?

A Consensus Conference is a forum at which a citizens' panel, selected from members of the public, questions 'experts' (or 'witnesses') on a particular topic. The Panel then assesses the responses, discusses the issues raised and reports its conclusions at a press conference. A distinctive feature of this approach is that the citizens' panel is the main actor throughout: it decides the key aspects of the debate, including the choice of questions and selection of the witnesses, and formulates its own conclusions. At the end of the conference, the panel produces a report outlining its conclusions and recommendations, which is circulated to key decision makers in the government and industry and to other interested parties.

Despite the title 'Consensus Conference', the citizens' panel is not forced to reach a consensus, but rather is encouraged to explore the extent to which they are able to agree. Experience shows that citizens' panels take an independent line and give a unique insight into the way in which issues are perceived by members of the public who have had the opportunity to fully consider the evidence. The citizens' panel's decisions and observations are not binding on the various parties it consults as part of the process, or any other body, but the conclusions of panels in the past have proved influential in the subsequent development of policy.

Consensus conferences are especially suited to dealing with controversial issues of public concern at a national level, which are often perceived as being too complex or expert dominated. Past consensus conferences have tended to focus on issues of science and technology, but this approach is equally well suited to other issues which require careful consideration by informed members of the public.

The main aim of the consensus conference is to influence the policy making process by opening up a dialogue between the public, experts and politicians. Through informed and structured debate on issues that are often complex and contentious, areas of public concern are identified along with recommendations as to how they may be examined and resolved. A consensus conference promotes constructive links between industry, government, academia and the public and expands the availability of accessible, accurate information. Through wide media coverage, it acts to advance public understanding of the topic and policy alternatives.

Funding for the conference came from The Office of Science and Technology, the Natural Environment Research Council and Nirex. The conference was organised by UK CEED (Centre for Economic and Environmental Development).

2. HOW WAS THE CITIZEN'S PANEL CHOSEN?

A panel of between 10–20 people is selected to reflect a variety of socio-demographic criteria, such as gender, age, education, occupation and geographical location. Panel members should not have any significant prior involvement of the conference topic — they are taking part in their capacity as citizens, not as specialists or professionals. The panel is too small to be a statistically representative sample of the population but should nevertheless represent a genuine cross-section of the general public, reflecting a wide a range of views as possible.

Recruitment of the citizens' panel was undertaken by an independent market research company, using random selection techniques. Four thousand people, randomly selected from the national electoral register, were invited to take part in the consensus conference as a member of the citizens' panel. They were asked to give up their time voluntarily to attend the two preparatory weekends in March and April and the four days of the conference in May. At this stage, the subject of the consensus conference was not mentioned. Just over 120 people responded expressing their interest. They were then contacted again, given details of the conference topic and asked to confirm that they were still available for the necessary dates. Around 70 people responded. From this group of people the 16 members of the panel were selected, essentially at random, whilst ensuring that there was an even balance of men and women with a mix of educational backgrounds and that regions throughout the country were represented. Of the 16 people who originally agreed to take part, one did not attend the first preparatory weekend and so the panel remained with 15 members.

3. WHAT PREPARATION DID THE PANEL HAVE?

Before the first preparatory weekend in March, the panel were provided with a document called the 'Introductory Material' which was intended to be, as far as possible, a balanced and 'neutral' introduction tot he area.

The panel then attended two preparatory weekends. The panel were provided with further information from the organisations who contributed to the introductory material. At the second weekend, the panel focused on selecting the witnesses and formulating the questions, which would form the basis of the Consensus Conference itself.

Throughout the entire process the panel were facilitated by an independent facilitator.

4. THE REMIT

The panel were asked to submit a report on the following remit:

"The Consensus Conference is to focus on the effective and publicly acceptable long term management of nuclear waste in the UK, both civil and military, concentrating particularly on intermediate and high level waste. This will be considered by the citizens' panel in their capacity as members of the public, taking into account what they see as the relevant issues."

In order to understand the remit, the panel focused on two areas as being of the most importance: what is *publicly acceptable* and what is meant by *long term*?

With little debate, the gut reaction of the panel was that for the solution to radioactive waste management to be publicly acceptable, it must be left in an accessible, monitorable and retrievable state. It should not be out 'out of sight out of mind' and future generations should be allowed the chance to deal with the problem if/when a solution is found.

The panel debated at length regarding the terminology used. We felt that the term 'sustainable development' was not at all clear and would not be understood by many members of the public. Additionally the thought of burying the waste deep and closing it off seems to be in contradiction to the term 'sustainable development'. The panel felt that it was incredibly important to leave the waste accessible, and this seemed to be the most common sense approach, and was the one area in which the panel reached a consensus.

The panel also debated at length some of the other terminology such as disposal versus storage. The word disposal was felt to be too final. Burial also implied an 'out of site out of mind' attitude. The panel felt that the public would understand the concept of the word storage, and that this would be publicly acceptable. Storage also implies retrievability.

There was also some lengthy debate about what the experts meant by deep and shallow. Asking how deep is deep is like asking how long is a piece of string. Although the panel could not reach a consensus, there was a feeling that within the industry 'deep' automatically meant disposal, or final closing off, and this should not necessarily be the case.

With regard to public awareness and public acceptance, the panel felt that in the UK the industry was making an effort to be more transparent in its decision making. The topic of radioactive waste is a very contentious one, and the consensus conference proved that ordinary members of the public are quite capable of listening to the evidence and forming some kind of opinion, in order to help industry and government gain an idea of how the public might feel about certain solutions. Indeed it would be naïve of the experts to push ahead with a solution that is not publicly acceptable.

5. CONCLUSIONS OF THE CONSENSUS CONFERENCE

During the course of the conference, the panel considered the many issues involved in the radioactive debate, from transportation and military use, to the continuation of nuclear power and reprocessing. The issue of retrievability was the one area where, even after hearing and reading all the evidence, the panel remained united and firm. Indeed, it has been difficult to write a presentation about retrievability, as this was the one area that required little debate, and seemed to be a common sense recommendation that everybody agreed with. To quote from the panels' report:

"In conclusion the panel was unanimous that in order for a solution to be publicly acceptable, the waste MUST remain accessible and monitorable to give future generations a chance to deal with the problem if/when a solution is found".

Whilst the panel had a limited time to look at all the evidence, there was a general feeling at the conference that this was the most 'common sense' approach to take. As a panel, we certainly hope that the experts take our views as members of the public into account when formulating any future policies.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: You said that you did not change your opinion during the work in the committee?

A: On the issue of retrievability, our views did not change. We felt all the time that the repository should remain open and accessible. Some people's views did change on things like continuation of nuclear power, safety and transportation issues during the process, but on the issue of retrievability we stood fast.

Q: Would you please tell us something about the group dynamics that took place. Was somebody elected a chairperson or did a sort of natural leader emerge who had very strong views and sort of towed the rest with them?

A: We had an independent facilitator throughout, who was extremely good, to the point that even now I do not know his views on the subject. He made sure that everybody, from the loudest person to the quietest person, actually got to have their say. A lot of the work we did in order to produce the report was done in smaller groups and I guess natural leaders emerged within those smaller groups, but again the facilitator was there to make sure that everybody had their say.

Q: Is the statement of the group in your last slide "unconditional"? Did you discuss what kind of confidence you would need, in order to shed some green light to projects aiming at final disposal and did you discuss if that project would possibly give more options to future generations than just remaining in a kind of interim storage "fashion kind of activity".

A: We were fairly limited with the time. We had the two preparation weekends and the two days for the conference and then it took from nine o'clock in the morning until three o'clock the following morning to actually write the report. We certainly tried to discuss as many issues as we possibly could. I think the perceived risk is such that we would feel more comfortable with it being left accessible. It would be interesting for the panel to reconvene, now that we are informed members of the public and we know a little bit more, to look at specific issues but you have to remember that retrievability was one of many, many issues that we covered in that short time. Does that answer your question?

Q: Yes, partly, but I am extremely interested in this need to build confidence in final disposal as such. In what areas, for instance, did you see this confidence should be mostly built or developed? Is it the geosphere or what type of scientific or technical area?

A: I can only speak for the experience in the UK, for example in schools they have programmes to make the children aware of Aids and drugs and things like this. I think if the whole issue of nuclear waste should be brought up among people at a younger age and be more in the public domain for talking about.

Chair: I realise that it will to be difficult to put you on the spot and make you think as a member of the public again, but in light of some of the kind of conversations that were held this morning, in some of the technical options it might be an increase in risk if you allowed for retrievability or you design for retrievability depending on the type of geology or the type of technology. If there were an increased risk, do you think that your panel would still think that retrievability is a necessary option for the acceptance of waste disposal? I know, you did not discuss this, I am putting you on the spot, I apologise for that.

A: I have to speak just for myself here and not for the rest of the panel. I think it is more publicly acceptable that you allow the future generation in 50 or 100 or 2000 or 5000 years time a chance to do something with it. I think it is all about perceived risks — the perceived risk being that it is better to leave the waste accessible.

Q: In the early part of your speech you said something like: for the waste disposal to be acceptable to the public, it has to be monitorable and retrievable. I was thinking about "being acceptable to the public". Did you, after this educational process where you became an informed citizen, regard yourself to be part of the public? Did you answer these questions with regard to what people would need or did you answer the questions with regard to what you would need?

A: We went through the whole process with our eyes as wide open as possible, and a lot of what we went with was the kind of gut feel, common sense side of things. I appreciate now that I am an informed member of the public, albeit to the level that I am. I can only say that, having spoken to friends and colleagues in my circle outside of the consensus conference, everybody seemed to be in general agreement with that, with the limited information that is available. I think we answered as lay members of the public.

Q: I am interested in the kind of responsibility that the group felt. Could you say something about that, what kind of role did the group take on, so to speak? Was it all individuals discussing or did you feel a pressure to have a consensus within your group? Did you feel that was a natural role, whatever it was you tended towards?

A: The group dynamics were rather amazing. It was a real experience to be a part of. We were fifteen very different people. I think it started off with what we had read in the local newspaper or whatever, and you go with your views. But when you come into the group, the group dynamics really take over and very strong relationships are formed. That is not to say that people were rail-roaded by the loud leaders. In fact we did not reach an overall consensus on one of the major issues and we actually wrote in the report that one or two people did not agree with this. Everybody did get a chance to have their say. We did not feel pressurised to make a consensus.

Q: Do you have any advice how to give information to the public or groups representing the public?

A: The first thing I would say is that we need plain English. A lot of the experts love great big long words and mathematical equations, and things like that do not mean anything to a member of the public. It needs to be explained in the simplest of terms, although it is a very complex issue. I think the consensus conference process has proved that it is possible to get the message across, but it does need to be done in a plain and simple way.

Q: You mentioned that the majority that responded was educated to degree level. Do you think it would be an even more challenging task to try and take this down to perhaps a primary or high school education level and explain it on those terms or do you think that explaining it on the terms that you understood would be adequate to the rest of the general public?

A: The majority of people that responded to the questionnaire were educated to degree level but they did some manual intervention in the end so, in the fifteen of us, I guess probably half were at degree level and half were not, so we were a very varied group. How it could be presented to school children? I am sure something can be done, I am sure it is not that difficult. We do deal with Aids and drugs in a very mature way for young children, and I think it is naive to think that they would not understand it.

C: In Switzerland, we have also had several such consensus conferences on very different subjects. We do not only have elections, but we are also voting in referenda very often. Therefore, we have always felt that it is nonsense to make such consensus conferences, since we know what the public meaning is. We know what the public think of, for instance, nuclear energy, or waste. Then somebody has said: well the public is uninformed, let us make a conference, a consensus conference and then we will get an idea of what is the impression of the informed public. And we have realised that there is no difference between the non-informed public and the informed public: I still do not know if this is a question that two weekends of some information on lower level and higher level, is too little to make any difference or if we are not able to pass the information correctly. We have found exactly the same as you have said, that your gut impression, your gut idea did not change during the whole process, which took several months. So I can confirm this, but why is it so?

A: I cannot explain why I did not change my mind on the retrievability issue.

Chair: But I think you made the point that if we want to change the attitudes of the public it is a generational thing, it is not something we can do in two weekends and if we want to inform — and we have to inform at a level that does not look like propaganda — it is not the industry coming in and saying, trust us, we are right. It is also not the anti-nuclear or green forces coming in and saying that nuclear is completely bad and you should never believe anyone. It is the opportunity to inform or educate, whatever the proper English term might be, the general population. Perhaps you should start with the students, because it will take maybe a generation for the acceptance to be there and to make these long term difficult decisions. We talk about inter-generational equity. We should not preclude the opportunity for them to either utilise or remediate some of the benefits or sins of the past, so it may take a long time. I think you are right, a week-end or two is not going to change the gut response of most people, because they will feel as though they have not had a time to assimilate and digest.

A: I do not know if you have actually read the report of the Consensus Committee, but we were actually quite proud that both sides — industry and the greens — were a bit surprised by the report and that both sides agreed with many aspects of the report. I do not think they could have predicted what we actually came out with.

C: Just a small comment. I think in the list of things that were just discussed, you have to remember that in some cases the uninformed or the informed public or whoever it is, might just be right.

WHY DO EXPERTS NEVER HAVE THE ANSWER TO THE PUBLIC?

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Abstract

The Oskarshamn municipality is located on the Swedish south east coast and has about 27 000 inhabitants. Oskarshamn is hosting three nuclear reactors, the Interim Storage Facility where the spent fuel from Sweden's reactors is stored, the Äspö Hard Rock Laboratory for underground research and the Encapsulation Laboratory where the welding technology is being developed. The industry is currently planning to apply for licensing of a disposal system for spent nuclear fuel between 2005 to 2010. Since 1992 Oskarshamn is a candidate municipality. Extensive efforts have been taken by the political leaders to initiate a public dialogue. A working model has been developed for the municipality work with seven policy statements **(Openness and participation** everything on the table — real influence. **EIA our platform** — development of the basis for a decision by parties together decisions independently. **The Council our reference group** competent elected officials responsible towards the voters. **The public — a resource** — concrete plans and clear study results a pre-requisite for public engagement and influence. **The environmental groups — a resource** — the environmental groups and their experts give us valuable contributions. **Stretching of SKB to clear answers —** we build competence so we can ask the difficult questions — we ask until we get clear answers. **The competent authorities our experts** — the authorities visible throughout the process — our decision after statement by the competent authorities. The goal is to have a completely open process with all facts on the table in order to be able to take decisions on "good grounds" should the question for the next step in site selection be put to the municipality from the industry. The paper describes the work in Oskarshamn related to spent nuclear fuel and also reflects on the issue of retrievability from a public perspective.

1. INTRODUCTION

The Oskarshamn municipality is located on the Swedish south east coast and has about 27 000 inhabitants. The municipality is economically strong and employment is high. In total the municipality has about 13 000 jobs. The largest employers are SCANIA (1700 employees) OKG Nuclear Power company (1100 employees) and the regional hospital (600 employees).

Oskarshamn is hosting three nuclear reactor blocks, the Interim Central Storage Facility — CLAB where all the spent fuel from Sweden's reactors is being stored, the Äspö Hard Rock Laboratory for underground research on disposal technologies and the Encapsulation Laboratory where the welding technology for the waste canisters is being developed.

Sweden's total amount of spent nuclear fuel to be finally disposed is estimated to be 8000 tons. Today 3000 tons is already in storage at the CLAB facility. The industry is currently planning to apply for licensing of an encapsulation plant and a final disposal site between 2005 to 2010.

In 1992 the Swedish Nuclear Fuel and Waste Management Co — SKB announced that their preferred site for an encapsulation plant was in direct co-location with CLAB. At the same time SKB initiated feasibility studies for a final disposal site in two north Swedish municipalities. In 1995 a direct request was sent to Oskarshamn where SKB asked for permission to carry out a feasibility study. In 1996 the municipality said yes to a feasibility study with a number of conditions. The feasibility study is now almost complete and a preliminary report is under review by the municipality.

During the discussion within the municipality about the encapsulation plant and the related Environmental Impact Assessment scoping study and the feasibility study the municipality has been actively engaged in the issue of the final disposal of the nations waste. A special project and local working groups have actively been following SKBs work and influenced its content. The municipality council with elected members has taken on the task as reference group for the municipality.

Extensive efforts have been taken to initiate a dialogue with the public — especially the young members — and the neighbouring municipalities. A working model has been developed for the municipality work with seven policy statements. The overall goal is to have a completely open process with all facts on the table in order to be able to take decisions on "good grounds" should the question for the next step in site selection be put to the municipality from the industry.

In Sweden the municipalities can veto the siting of nuclear facilities so the position of the municipalities is strong. Oskarshamn however has a particular situation as all the waste will be stored at CLAB. If all Swedish municipalities say no to the final disposal facility for Oskarshamn this will mean a yes to continuos storage in a temporary facility. The municipality has strongly objected to that the CLAB facility is turned into more than a short term solution like it was licensed to be.

2. THE OSKARSHAMN MODEL AND ORGANISATION OF THE WORK

The Oskarshamn Model is based on a seven policy statements and is forming the platform for the municipality engagement in the nuclear waste programme and is also used as a working structure for those engaged in the local working groups and the council politicians. The first policy statements were developed in 1992 and has been continuously discussed and developed since then:

The Oskarshamn model

(a) **Openness and participation**
Everything on the table — real influence.

(b) **EIA our platform**
Development of the basis for a decision by parties together,
decisions independently.

(c) **The Council our reference group**
Competent elected officials responsible towards the voters.

(d) **The public — a resource**
Concrete plans and clear study results a pre-requisite for public engagement and influence.

(e) **The environmental groups — a resource**
The environmental groups and their experts give us valuable contributions.

(f) **Stretching of SKB to clear answers**
We build competence so we can ask the difficult questions — we ask until we get clear answers.

(g) **The competent authorities our experts**
The authorities visible throughout the process,
our decision after statement by the competent authorities.

3. PUBLIC ACCEPTANCE AND THE ROLE OF EXPERTS

In our discussions locally we often refer to the evolution of decision making in the industrialised society. This model also applies well to the municipality history and the siting of the reactors and the CLAB facility.

Pre 1970 in Sweden industry and industrial facilities were mainly seen as progress and well paid work for people. Neither industrial decision makers, nor politicians on national and local level made much effort to consult the public and the public did not demand influence. The role of the experts was not questioned and experts were widely respected by the public.

In the seventies environmental concern started to grow and a critical nuclear debate grew fast. In Sweden this debate reached its peak in 1981 with a national referendum on the nuclear issue. Experts were not given much credit in the eyes of the public.

In the past decade a more open decision making where the public is invited to share the decision has been discussed and to some extent also practised. Experts have been given a more limited role as it becomes clear that decision making contains many aspects where the experts have a role but in balance with other players.

There are many areas in nuclear waste management that traditionally have been handled by experts but where values in reality is playing a large role. Examples of such questions are: What time span shall the performance assessment calculation cover? Is it important to include analysis of what will happen after an ice age? How shall human intrusion be handled in performance assessment?

In the end these are value related judgements where the experts can not and shall not give the answer. These kind of judgements are rather for the politicians to make. In order to make these decisions the politicians however need to understand the public values. The experts can of course provide basic information — and that is often required — but they can also influence the issue by including their values. Examples of this is that the experts can decide to end the analysis at a certain time or decide not to include human intrusion.

4. THE PRAGMATIC PUBLIC

Because of the proposals to site major facilities to Oskarshamn the nuclear waste problem has been on the agenda for almost a decade. The politicians have shown sincere interest to understand, debate and form a dialogue with their voters — the public. The public however has many things on their mind and urgent daily problems to solve. Few are prepared to set aside an evening for a seminar or a discussion.

Some see the lack of public engagement as a lack of opinion — this is a great mistake — the public has very strong opinions when asked. The problem is that traditional arrangements usually do not lead to the public[1]. The conclusion is to get the public opinion you have to go to the public.

In Oskarshamn numerous activities have already taken place and are planned to take place during the final part of 1999. From these activities we can already see a number of issues and opinions raised by the public in Oskarshamn. In early 2000 these activities will be summarised by the local working groups and reported to the municipality council.

Examples of opinions raised are:

- It must be clear that the KBS–3 method is safe and that the critical objections are fully addressed.
- It is not responsible to postpone actions waiting for some technical miracle — it is also not responsible to take actions if the technology is not ready and proven.
- It is not acceptable that CLAB becomes a long term facility.
- The municipality with the best conditions (geology) should act responsibly. If the best rock is here we should accept.

5. CAN PHASED DEVELOPMENT AND RETRIEVABILITY PLANS LEAD TO INCREASED ACCEPTANCE? — EXPERIENCE FROM OSKARSHAMN

The topic of this seminar is retrievability. The topic also includes the possibility of a stepwise decision making process as proposed for example by SKB in Sweden. What has been the political and public reactions towards these topics in Oskarshamn? Very minor.

From the discussions we can only conclude that both the politicians and the public are assuming a number of fundamental prerequisites for approval or rejection of SKBs proposals:

- The final disposal method must be safe or it should be rejected. The competent authorities are expected to approve or disapprove the method.
- The rock must be the best possible. Again the competent authorities are expected to approve or reject.
- People put the highest faith in themselves. When asked in polls a large majority says that they should take the final decision themselves to accept or reject a facility.

[1] This is not to say that this is always the case. When the public has become involved in an issue, traditional arrangements have a role. Some of the seminars arranged by the municipality on specific issues, such as the impact of ice ages, have been well-attended and stimulated dialogues between scientists and laymen.

The phased decision making process with continuos evaluations and new decisions before proceeding to the next step may by many experts be seen as a guarantee for cautious decision making on good grounds. For the public and local decision makers it is not seen exactly the same. Mainly two concerns have been raised:

- the initial phase where only 5 to 10% is allowed must not by any means be less stringent because it is not a license for the whole repository. The licensing should thus not be any different than if it was for the whole repository including sealing of the repository and long term monitoring;
- after the first 5 to 10% of the spent fuel has been disposed an evaluation shall take place. What can be evaluated after such short time?

Furthermore, more emphasis on retrievability should impact the safety assessment. Traditionally, the scenarios that form the basis for modelling and calculations have largely been of a technical character. However, if the backfilling of the repository is to be postponed to an unknown future, scenarios where the repository is left open should be given much more attention. We have thus not yet seen the full consequences in terms of safety of the retrievability concept.

6. SUMMARY AND CONCLUSIONS

From the Oskarshamn experience as a candidate municipality for major facilities for spent fuel encapsulation and disposal it can be concluded that the political leadership and the public agree that a solution for the spent fuel should be worked out now and that it is not responsible to wait for possible future technical miracles. The fact that the municipality is hosting the interim storage CLAB is putting at focus the alternative of not working out solutions for the nuclear waste problem and finding sites for the required facilities. This would be an unacceptable situation since the waste would continue to be near surface in a temporary facility requiring extensive supervision on a daily basis.

From the Oskarshamn perspective, phased licensing or retrievability has not been raised as any major issue. It is not clear if this can be seen as a permanent position towards the issue of retrievability or if has to do with the fact that the Swedish programme is still in an early siting phase and as the final licensing stage will come closer the issue will be given more focus?

The degree of retrievability is an issue where public values must have a major role. It is not up to the experts to give the answer. Sometimes experts tend to make unfounded value judgements on behalf of the public, and we should be careful and avoid this in the discussion on retrievability. Experts can provide technical and scientific information about relevant issues, but which are the ***relevant*** issues can never bed decided by the experts alone. This rests with the public and the political decision makers.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: You said that one of the objectives of this process is acquiring the best site for the repository or to identify the best host rock. This, I am afraid, is a very unrealistic objective, because you will never be sure you have identified the best site or the best rock. A realistic objective is to find an adequate site and adequate host rock. But I am very much in favour of your statement, that CLAB is not a “solution”, because being a storage facility it must be replaced by a final solution sometime possibly soon. If you were to discover that a candidate site with adequate fissure exists in the territory of your community, what do you think would be the attitude of the public in relation to the proposal to take the waste from CLAB and put it in the repository?

A: The public generally says that the waste should go to the best site. If we have the best site here, we should accept it. I think what they are saying is that they are not willing to tamper with safety. The highest ranking parameter, that for selecting the next round of at least two sites should be safety. For the public that means geology, I think.

Q: When you say "the best site", do you mean the best site among the candidate sites? That is not a best site in absolute terms, because the best site in absolute terms will never be found.

A: I know that, but when you ask people, this statement always comes up. This is a very dangerous material, that we have generated. We must find a solution for it, and as we cannot predict a hundred thousand years into the future without uncertainty, we must have the best possible solution. That includes the best possible geology.

Q: You are a technical person and you are an advisor to the Oskarshamn. I realise people say this all the time, they want the best for all concerned. What do you say, when Oskarshamn comes to you and says that? Do you tell them that this is an unrealistic thing to request or do you say that it is a good thing to ask, and that you will push SKB to prove it to them?

A: First of all, being an advisor, if I would start to make judgements on their behalf, I would no longer be an advisor to them, because I would take stands on this and that issue. We bring in SKI and SKB's experts, and let them explain and give the different aspects of the issue.

C: A follow-up on that issue. I would say that many times this same argument has been put forward also from the SKB's side and presented like this: There should not be an other, obviously better site available. When I have used this, it has also been accepted. So sometimes I have a feeling that the meaning of the best site is "among available sites", or among the sites studied. You should not make an obviously bad choice.

A: I think that, for a majority of the people, there is definitely a sort of a balanced attitude, but there are those who are very critical and they are very much involved. And they want to push this "best" to the limits because they want to see the site be disqualified on those grounds.

Q: Regarding the conclusions of the two presentations from UK and Sweden, there is quite a big difference. In the UK experience there was this imperative, that it must remain accessible in monitoring, and monitorable to give the future generation a chance to deal with the problem. And on the other side you have the experience from Oskarshamn where you have this "act now, do not wait for a technical miracle". Can you somehow try to explain this and do you have any idea what causes the differences between these two perceptions?

A: I think it means a lot that Oskarshamn has had nuclear reactors since the early seventies. You have 1000 people out of 27 000 working there, which means that there are another 3-5000 people involved in one way or another. I think the knowledge about nuclear aspects in general is very good. I asked a taxi driver there once what he thought about nuclear waste, and he said: "I know, by own experience, that if something would happen at the plant, there would be an alarm going out, and I would know that right away, so I think I can trust them”. It is a tremendous difference if you instead look at Storuman and Malå — two municipalities in northern Sweden with very little experience of nuclear industry. Oskarshamn has this experience since the seventies, and now they have had a nuclear waste debate going on for eight years, and a very strong engagement by the local politicians. The awareness, I think, is very high in Oskarshamn.

Q: I can confirm that the same behaviour can be seen in Finland. Communities who have a long experience of nuclear have this kind of attitude. In your presentation, you mentioned that you keep asking questions until you hear clear answers. What does that mean? Does it mean that clear answers are those that people want to hear? If they are pre-determined to oppose nuclear energy or if they are pro-nuclear they want to hear a certain kind of answer which to their mind is “clear”.

A: I think that “clear” in this connection means “understandable”. We keep asking until we get understandable and respected answers.

Q: I agree to some extent, although safety cannot be condensed into two or three figures. You say that public and citizens are themselves experts especially in matters that are related to a general amenity, for instance, when judging what is significant and what is not. It is of course justified that people can decide what is significant, not only experts. But many things are relative, like the weight of my wife which is fine to me, but not to her. So how can an expert contribute to a process like this, when there is a whole spectrum of what is significant and what is not?

A: The implementor in any country has worked over decades on his concept. He has done a lot of research, he has had many discussions with the regulators, there is much of common understanding there already, a sort of a “Stockholm perspective”, if you put it in Swedish terms. And then you come out to the municipalities and the public and say that we have now for more than three decades studied this problem and here is the solution, which you should accept, because it is well-founded, it has been reviewed by our regulators, and now the only thing we need is a piece of rock in your municipality. That is one extreme. The other possibility is that you come out to the municipality and say we have studied this, we have a lot of experience, we have a lot of expertise, we have a lot of data and facts, but there are also a lot of things we do not know. And now to complete this solution, we need to find a site, which we think we can find together. In the siting process we will be influenced by you and guided by you to a solution. We have no real pre-notions how this will be done.

But I think you should let yourself be guided in a three-cornered situation with the local decision makers, the public and the goal. It has been said in Oskarshamn by the politicians, several times, that they would like to take this decision, without a referendum if possible (but if a referendum is necessary that would also be OK). But they say that they can never go to a final decision unless they have a qualified majority.

Q: Would you please try to qualify on the distinction between people living in a municipality which has nuclear energy since a long time, and those who have not. Does it in the first case depends on to what extent, or if, they have positive and negative experiences? Suppose that Oskarshamn would have some negative experiences that would, so–to–speak, speak against peoples’ trust in that specific community for this solutions. Do they have only positive experiences which frame their state of mind here? In the first case, to what extent do you think one could ”export” this to nuclear localities which have negative experiences?

A: I think they have the negative experience of old-fashioned decision making, and they feel themselves also responsible there, so this is not only a criticism of industry or central politicians. In the past, we have taken decisions in closed rooms, and then we announced them to the public. In Oskarshamn, we brought in and interviewed the old politicians that once took the decision on accepting nuclear reactors to the municipality. They said they were told that basically nuclear power only contained positive effects. Reactors were absolutely safe and the waste was just "a couple of buckets". So they have of course this experience of the old beautiful world that was painted to them, that turned out not really to be fully true. So they are more cautious also that what the industry says is the industry's opinion and the industry is only one party of this discussion.

Q: In the multi-barrier concept, when you referred to the best site, did you have any debate in your community about what the impact of the other components of the barrier concept were? Was this sort of a secondary safety effect, or was it that you wanted to have the best site, and the best engineering?

A: I do not think I can refer to any particular discussions with the public, where they have analysed a multi-barrier approach, but I think there is a lot of interest in the encapsulation laboratory. I think the general opinion is that before you can really pick a site you must prove that you can manufacture those things that will be going down there.

Q: Has comparative data played a role in your discussions in the community? You just mentioned "a few buckets of waste". This is synonymous to a comparably low amount of waste if you take a comparison to a coal fired plant for example. Did you address the huge hazards associated with the nuclear waste, did you put that into perspective in your discussions? Perspective with other facilities that generate waste, that produce for example electricity, and is there any kind of perspective given in these terms?

A: Yes and no. With the decision in Sweden on phasing out nuclear reactors, Oskarshamn is also a municipality that faces possibly a phase-out of three reactors, so that debate is going on. But I would say that debate is separate from the nuclear waste debate and that is purposely separate. When the decision to accept a feasibility study was taken in the council, two of the political parties were against and five were in favour. Once the decision was taken, by a majority decision, the other two parties said OK, now the decision is taken, we will join in on the work, and now we work to get the best basis for our next possible decision. So, because of that, I think they keep purposely the energy discussion out of the nuclear waste discussion, because that is another critical discussion also for them.

Q: I did not mean the substitution of nuclear power with other generation systems in the future. My point was more if we are overdoing the things in terms of nuclear power and do we address hazard associated with nuclear power adequately? If you compare nuclear risk to other risks then you put the things more into perspective and if you see what you are doing in other areas, you maybe see that you are overreacting.

A: There has been individuals at some of these meetings in Oskarshamn, who felt threatened by "this is very well taken care of, this is safe, but there are other things that are much worse that you should really be concerned about and let me do my job". That is causing the absolute opposite reaction. It is a very dangerous point to bring up in a public meeting, because if it is brought up by the industry, it is clearly felt by the public that the industry is trying to escape responsibility. I have seen that reaction a couple of times.

Q: It should be clearly stated that Oskarshamn is a unique example in Sweden. All municipalities do not act like Oskarshamn. One could of course ask why is that the case, especially since we also have one other nuclear municipality with a ongoing feasibility study. What is your opinion in Oskarshamn of the reasons why your involvement is so much bigger and deeper. Is the existence of the interim storage CLAB in Oskarshamn the only reason or are there also other explanations?

A: CLAB is one reason I think, and the fact that the encapsulation plant was proposed in 1992 has also given a lot of time for the municipality to build up its own strategy. Another aspect is that, in the municipality council, they seem to be convinced that they — within a couple of years — will get the question if they like to participate in a site investigation, so for them it is a preparation, a sincere preparation for that decision.

Chair: You say there is a minor interest on retrievability. Once disposal starts it will be completed. Is that basically due to the fact that retrievability is already built into the programme? That after a ten year period, even though you are not sure what you are going to know in ten years, the citizens are convinced that, if there is a problem, the waste will be removed. Do they actually trust not only their elected authorities but also SKB and SKI and SSI to live up to the responsibilities to retrieve it if there is a problem? Is that why it is easier to address retrievability, because they have that trust?

A: I think the focus is more on putting pressure on especially the regulators, to do a thorough review and use all their expertise to decide if the safety case is there or not. Then, once disposal starts, they are expected to monitor this closely. Why should you allow 400 canisters to be deposited, if something goes wrong with the first or second or third one. Then you would stop disposal, of course? That is sort of a wonder they have, why this specific number, why these eight years? They want to be sure that SKI will be there, watching every canister that goes down, so there is no problem with that, and if there is a problem it should be stopped immediately.

RETRIEVABILITY — A MATTER OF PUBLIC ACCEPTANCE? REFLECTIONS ON THE PUBLIC REVIEW OF THE PROPOSED NUCLEAR FUEL WASTE DISPOSAL CONCEPT IN CANADA

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Abstract

Environmental assessment has been used as a planning tool in Canada for almost three decades. Public participation, one of its fundamental principles, is at the heart of environmental assessment in our country. To date, approximately 12 large projects related to nuclear energy have been the subject of public reviews by independent panels of experts appointed by the Government of Canada. These include: the development of uranium mines in Northern Saskatchewan; the construction and operation of two CANDU reactors in New–Brunswick, the second of which was never constructed; proposed uranium hexafluoride refineries in Ontario and Saskatchewan; expansion of a dry storage facility for nuclear spent fuel in Québec; and decommissioning of uranium mine tailings areas in Ontario. All of the assessments mentioned above were conducted under the environmental assessment regimes of 1975 and 1984 that preceded the *Canadian Environmental Assessment Act* (1995). One of the public reviews of particular interest to this workshop is that of the proposed concept for deep geological disposal of nuclear fuel waste in Canada. This paper focuses exclusively on the public review of the Nuclear Fuel Waste Disposal Concept developed by Atomic Energy of Canada Limited (AECL), particularly as it relates to public acceptance of retrievability. The paper first describes the historical context in which AECL's concept was developed prior to the public review. It then briefly outlines the changes in the societal context that occurred between the time when decisions were made to proceed with the development of the concept in 1978 and the time when public hearings were held in 1996–1997 and the panel report was presented to the government in 1998. It also provides a short description of the concept itself. The paper then presents a discussion of the arguments used by the public in the panel review, arguments, which demonstrate a decrease in confidence in a concept lacking effective post-closure retrievability.

1. INTRODUCTION

Environmental assessment has been used as a planning tool in Canada for almost three decades. Public participation, one of its fundamental principles, is at the heart of environmental assessment in our country.

To date, approximately 12 large projects related to nuclear energy have been the subject of public reviews by independent panels of experts appointed by the Government of Canada. These include: the development of uranium mines in Northern Saskatchewan; the construction and operation of two CANDU reactors in New Brunswick, the second of which was never constructed; proposed uranium hexafluoride refineries in Ontario and Saskatchewan; expansion of a dry storage facility for nuclear spent fuel in Québec; and decommissioning of uranium mine tailings areas in Ontario (Fig. 1). All of the assessments mentioned above were conducted under the environmental assessment regimes of 1975 and 1984 that preceded the *Canadian Environmental Assessment Act* (1995). One of the public reviews of particular interest to this workshop is that of the proposed concept for deep geological disposal of nuclear fuel waste in Canada.

This paper focuses exclusively on the public review of the Nuclear Fuel Waste Disposal Concept developed by Atomic Energy of Canada Limited (AECL), particularly as it relates to public acceptance of retrievability.

The paper first describes the historical context in which AECL's concept was developed prior to the public review. It then briefly outlines the changes in the societal context that occurred between the time when decisions were made to proceed with the development of the concept in 1978 and the time when public hearings were held in 1996–97 and the panel report was presented to the government in 1998. It also provides a short description of the concept itself. The paper then presents a discussion of the arguments used by the public in the panel review, arguments, which demonstrate a decrease in confidence in a concept lacking effective post-closure retrievability.

2. CONTEXT

2.1. Historical Context

Over the past 25 years a number of groups and governments have studied different approaches to managing nuclear fuel waste in Canada. These groups included a Royal Commission, Parliamentary Committees, Interdepartmental Committees, Technical Advisory Committees and most recently the Environmental Assessment Panel appointed under Canadian environmental assessment legislation.

In 1977, the Government of Canada, through the Minister of Energy, Mines and Resources, engaged a group of experts headed by Dr. Kenneth Hare of the University of Toronto to study the problem of nuclear fuel waste management and to assist in developing a long term policy for managing these wastes. The various options considered by the group included: reprocessing, immobilisation, surface storage and disposal in ice sheets, in space, on or beneath the sea floor or in various types of underground rocks. In their report, the authors concluded that deep geological burial offered the best potential for Canada. It suggested that primary effort be concentrated on plutonic rock, while salt and shale might be retained as second and third choices, respectively. It also urged the Government of Canada to keep a close watch on other rock types as well as on research conducted in other countries.

FIG. 1. Completed panel reviews of nuclear energy related projects across Canada since 1974.

In 1978, the province of Ontario's Royal Commission on Electric Power Planning also endorsed disposal in plutonic rock. It concluded that there was clearly an urgent need to develop ultimate disposal facilities to ensure that these wastes became isolated from the world's ecosystems [1].

Following these endorsements the governments of Canada and Ontario jointly announced in 1978 that Canada would embark on a research and development program aimed at verifying that permanent disposal in an underground repository in deep geological formations would be a safe, secure and desirable method of disposing of radioactive waste. This announcement identified Atomic Energy of Canada Limited, a federal crown corporation responsible for the development and sale of CANDU reactors, as the agency responsible for work on the immobilisation and disposal of waste from nuclear power reactors, including geological field and laboratory studies. Ontario Hydro, a provincial crown corporation responsible for the production of electricity in the province of Ontario and the owner of the largest quantity of nuclear fuel waste in Canada, would support the work of AECL through continued studies on interim storage and transportation of nuclear fuel waste.

Initial opposition to the siting of laboratory facilities brought the governments of Canada and Ontario to jointly announce in 1981 that no disposal site selection would be undertaken until a full public review including public hearings had been held on the merits of the proposed disposal concept. Therefore the public review of the disposal concept was completely dissociated from site evaluation.

The Atomic Energy Control Board (AECB) regulates the Canadian nuclear industry. Regulatory Policy Statement R–71, one of four AECB regulations applying to the proposed concept for disposal of nuclear fuel waste, was issued in 1985. It further endorsed deep rock disposal as the preferred approach for the long term management of radioactive wastes. The regulation requires retrievability at the pre-closure phase and specifies that the effectiveness of a disposal system must not be compromised by any provision that may be made for post-closure retrieval [2]. Regulatory Policy Statement R–104, issued in 1987, also endorses disposal as the favoured option and completes the requirements for post-closure by specifying among other items that the disposal option, to the extent reasonably achievable, should not rely on long term institutional control [3].

These endorsements set the stage for AECL's research to focus on a disposal facility that would be closed once any desired extended monitoring stage had been completed and closure approval was obtained [4]. AECL stated that the facility should include only retrieval capability that did not compromise long term passive safety, in accordance with R–71 and R–104, and should not include features that would prevent post-closure retrieval [5]. One of the main rationales for this approach was that those who receive the benefits from nuclear energy and produce its wastes are responsible for finding a waste management solution that would relieve future generations of the burden of caring for the wastes.

In 1989 an environmental assessment panel was appointed by the federal Minister of the Environment to conduct a public review of AECL's concept. The panel's mandate was to review the safety and acceptability of the proposed concept along with a broad range of nuclear fuel waste issues, including the examination of the criteria by which safety and acceptability of a concept for long term management and disposal should be evaluated. It was also asked to advise government on: whether the AECL's concept for geological disposal was safe and acceptable or should be modified; and on the future steps to be taken in the management of nuclear fuel waste in Canada. The mandate, however, excluded discussion of the energy policies of Canada and the provinces and the military applications of nuclear technology.

The review lasted eight years during which the panel consulted the public at three different stages: the identification of issues and preparation of Environmental Impact Statement guidelines, 1990–1992; the verification of the proponent's Environmental Impact Statement (EIS) and its conformity with the panel's guidelines, 1994–1995 and; public hearings held in three phases, 1996–1997. Fig. 2 provides a chronology of events during the panel review. In its 1998 report to the Government of Canada the panel concluded that there was not sufficient public support to proceed with the proposed concept at this time, although it had judged the concept to be, on balance, safe from a technical perspective at this stage of development. It 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.

In December 1998, the government of Canada responded to the panel report, endorsing most of the recommendations. In its response the Government stated its commitment to three fundamental policy objectives for long term management of nuclear fuel waste in Canada:

- the establishment of a dedicated fund for nuclear fuel waste by the owners and producers; the necessity for the waste management organization to report regularly to the federal government on the progress of waste management activities; and
- the establishment of a federal review and approval mechanism to provide federal government oversight and access to the funds [6].

Options on these policy objectives are expected to be presented for decision by the government before the end of the year or shortly thereafter.

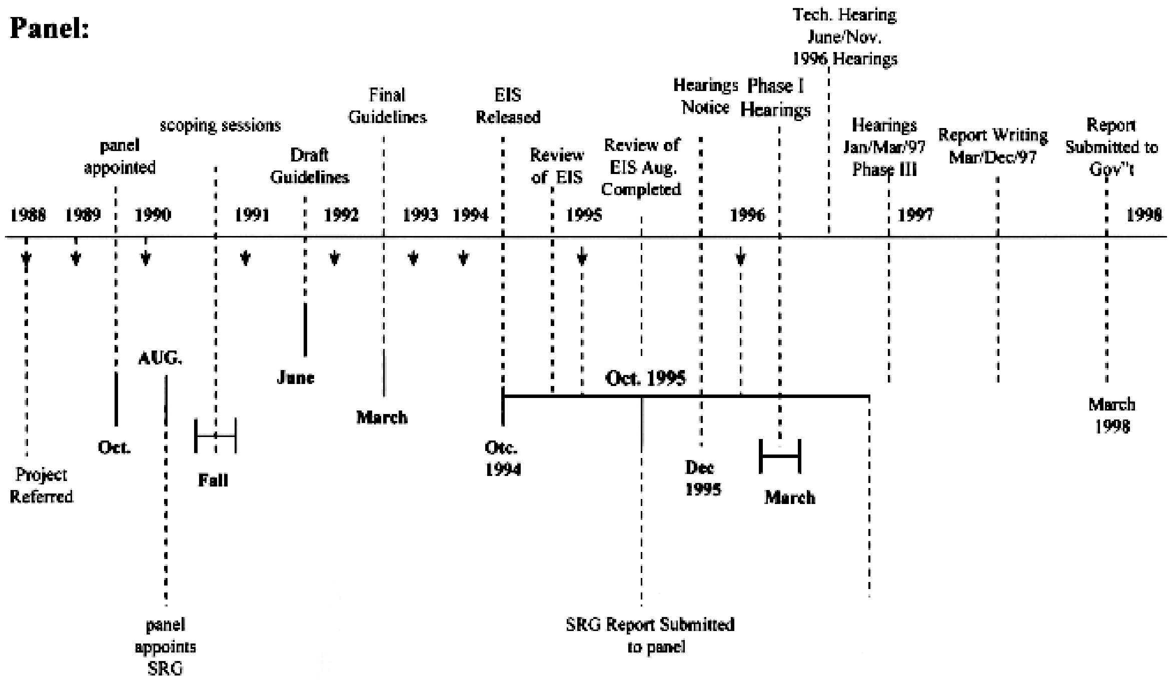

FIG. 2. Chronology of panel review.

2.2. Societal Context

During the 1970s, when decisions to proceed with disposal were made, affluence in the western world was evident and society was more inclined towards consumerism rather than conservation. Remembered as the decade of big government and big spending, expansion was the driving force behind the economy. It was also the decade that produced the oil crisis, created by the formation of the Organization of Petroleum Exporting Countries (OPEC) cartel, which led nations outside the cartel to turn to other sources of energy such as nuclear, wind, solar, and others. Energy needs were such that developing mega-projects, such as offshore oil developments and nuclear reactors, in order to become energy self-sufficient, became the norm. Hence, in 1977, when the advice to proceed with disposal was provided to the Government of Canada it was mainly formulated on the basis of technical and economic considerations.

During that same period, environmental impact assessment processes were receiving increasing attention in Canada. Concerns about the way decisions were made on large development projects led to the formation of citizens' groups that enhanced public awareness of the environmental and related social impacts of these developments. It was particularly notable with nuclear power issues, where citizens' groups assisted in raising public awareness on how waste disposal related to environmental and ethical aspects of nuclear power [7].

In the 1980s, large deficits led to important increases in national debt as governments attempted to fulfil the mega-dreams of the previous decade. During that period, however, the Brundtland Commission, with its report *Our Common Future*, signaled a major shift in societal values, with emphasis being placed on sustainable development. Many references to this new philosophy were made during the Canadian panel hearings, indicating an increasing acceptance of the idea. Many intervenors stressed among other things: the obligations of current generations to future generations and the well being of the planet; the need to reduce consumption and waste generation; the importance of re-using and recycling; and the trend away from disposal as a waste management method.

In 1996, almost twenty years after recommending deep geological disposal to government, Dr. Hare reminded the panel that, despite his advice that government make his recommendations the subject of wide public discussion before writing them into policy, such public discussion had not taken place [8]. Given that the panel review was perhaps the first opportunity for the public to air their opinions on a broad range of nuclear fuel waste management issues, many participants called for a comparative risk and benefit analysis of all available nuclear waste management options. Repeatedly raised was the possibility that long term storage, with the ability to monitor and retrieve wastes, and to develop and integrate new technologies, might be a better solution than geological disposal. This signaled a decrease in the public confidence in disposal, with its inherently more difficult waste retrieval and reliance on passive safety, as a solution for nuclear fuel waste.

3. THE AECL CONCEPT

The AECL proposal consists of a multiple barrier containment system to dispose of nuclear fuel waste at depths of 500 to 1000 meters in plutonic rock of the Canadian Shield. The barriers, both engineered and natural, are: the waste form, the container, the buffer, the backfill and other vault seals, and the geosphere. Fig. 3 illustrates the AECL concept.

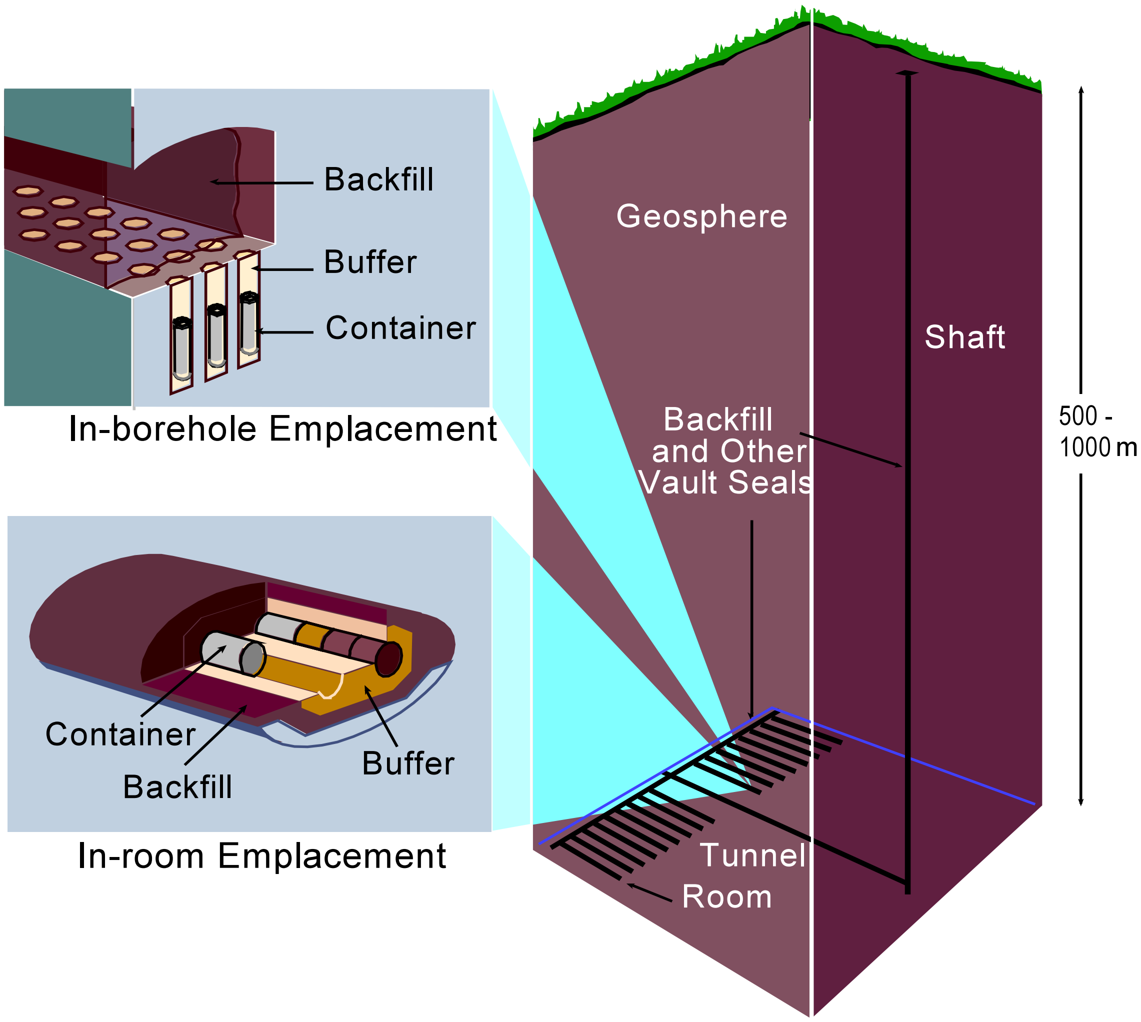

FIG. 3. AECL's concept.

A vault consisting of a network of horizontal tunnels and disposal rooms would be excavated deep in the rock, with shafts extending from the surface to the tunnels. The waste, spent Canada Deuterium Uranium (CANDU) reactor fuel, would be placed in containers made of titanium or copper and designed to last 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 buffer material likely containing clay. Each disposal room would be backfilled and sealed with clay or cement materials. 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.

AECL stated that it would take approximately 60 to 100 years to build and fill the vault, 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 in its EIS that after decommissioning, retrieval would be more complex and expensive [9]. A study completed after AECL released its EIS supports the Corporation's claim that it would be possible to retrieve the wastes from a decommissioned facility, although it is estimated that the process would take approximately 5 to 15 years depending on the nature of the intervention required [10]. On that basis AECL asserted its concept to be a retrievable concept. This view of retrievability was not shared by the Panel and some other participants who viewed the proposed disposal concept as a permanent solution to managing nuclear fuel waste.

4. RETRIEVABILITY — A MATTER OF PUBLIC ACCEPTANCE

By concluding that the AECL's concept did not have the level of support to be chosen as Canada's approach for managing nuclear waste, did the panel mean that the Canadian public does not have confidence in a non-retrievable system? Using some of the panel criteria for determining acceptability, and its recommendation on the need to modify AECL's concept, this paper will attempt to demonstrate that retrievability has greater public appeal at this time. However, the views expressed to the panel by review participants represented only a proportion of the Canadian public at large, although an influential one due to its continuous commitment to the issue.

One of the tasks given the panel was the examination of the criteria by which safety and acceptability of a nuclear fuel waste management concept should be evaluated. The application of these criteria would assist the panel to determine the level of acceptability for the AECL's proposal. It would also assist it to develop recommendations to government on how to proceed to obtain acceptability. The panel therefore 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 perspective;
- have been developed within a sound ethical and social assessment 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 [11].

The remainder of this paper presents a discussion of some of those criteria, that relate explicitly or implicitly to public acceptance of retrievability.

4.1. Broad public support

On risk-related issues, the public is demanding more openness, scrutiny and debate, and shared decision-making. The public is no longer willing to leave technical decisions to scientists, nor socio-political problems to politicians. There are expectations that any decision-making process will be transparent and will accommodate public input and that decision-makers will be accountable for their decisions.

The panel viewed broad public support from an informed Canadian public as a prerequisite to making a determination on the acceptability of a proposal and hence making decisions on long term management of nuclear fuel waste. In order for a proponent or decision-maker to obtain broad public support, it must rely on a public that is well-informed on the technical and social implications of the proposal and has been engaged in the debate through a sustained participation and consultation program.

This is particularly important as fear and mistrust of the nuclear technology exists and is deeply entrenched in some segments of our society. This “dread factor” as it is referred to in the panel report is real and palpable. It is not only associated with the imperceptibility, mobility and longevity of radiation hazards and its disturbing potential effects on health, but also with the link that technology in general has had with past disasters, nuclear and others, involving human errors and engineering failures [12]. Furthermore, it must be understood that although science provides tools to analyse the soundness of various technologies; the social values and ethical principles guiding human behaviour are just as important as scientific analysis in determining the acceptability and safety of a technology.

The public therefore must be involved in the design of a consultation and participation program in order for it to be confident that appropriate information integrating social values and ethical principles to scientific analysis is available. Public involvement is also required for members of the public to be fully aware of the key stages in the process that will lead to the determination of acceptability, including the complete decision-making process, such as: when are decisions likely to be made; by whom will they be made; and what are the dispute resolution mechanisms.

These are essential elements of a process that could lead to broader public support.

Consultation processes conducted in the last 20 years by the regulator, the proponent and the panel satisfied some of these requirements, but they were not sufficient to determine whether there was broad public support for any approach to the long term management of nuclear fuel waste.

The consultation to date was conducted under processes established by institutions and designed without public input. For instance, a participant pointed out that only a handful of public comments had been provided in the development of the Atomic Energy Control Board regulatory policy R–104, most of which had come from government and industry, hence little attempt was made to reflect the values of the Canadian public [13]. As most of the consultation processes were principally aimed at providing information, they failed to empower participants to modify the decisions regarding permanent disposal that were made in the 1970s with little or no consultation.

After eight years, participants in the public review were still expressing their lack of trust in decision-makers, the nuclear industry and scientists. Although suspicious of the outcome of the review, they recognized the efforts that had been made to provide them with an opportunity to debate publicly, perhaps for the first time, many issues relevant to them regarding nuclear waste management.

Participants in the panel review process were, however, lacking important information, such as which organization would be responsible for implementing the proposal, leaving them with no guarantee that their input would be taken into account. No comparison of options was available to them. The review process, including the limited panel mandate of focusing on a disposal concept, did not provide a forum where the broad public support required, could be assessed. Participants, therefore, expected that the panel review would be the first step towards a more consultative approach in finding a solution to the nuclear fuel waste problem in the future.

The panel observed in its report that there was insufficient data that would assist it to determine how widespread was the public understanding of the issues related to nuclear fuel waste management, let alone what kind of support there was for the proposal of permanent disposal. The panel further observed that it was difficult to determine whether participants in the hearings, both those opposed and those supportive of the proposal, were representative of the public at large.

Furthermore, the level of support for AECL's concept was difficult to gauge in the absence of a real site or design, since there was no directly affected public involved in this review.

The panel was, however, able to conclude that there were a sufficient number of participants opposed to the AECL proposal to warn against proceeding without getting broader public support [14]. Failure to obtain this broader support would lead to confrontation.

Therefore, it appears from the discussion on this criterion, that there is a requirement to conduct further consultation through a more elaborate and open process to determine whether there is sufficient support to proceed with any approach, retrievable or not, to long term management of nuclear waste.

4.2. Safety

Discussions on the issue of safety of the proposed concept were marked by a deep divergence of opinion on the ultimate limits of science and the ability of society to adequately protect its members and future generations for periods lasting thousands of years into the future. The panel concluded that safety was a key part, but only one part of acceptability and that safety must be viewed from two complementary perspectives, technical and social [15]. Both perspectives are reflected not only within the panel and among review participants but also within Canadian society.

Those who tend to regard safety from a technical perspective rely on factual information obtained from the application of science and scientific models that can be used to construct analytical linear arguments to prove safety. Those who tend to regard safety from a social perspective will rely on historical experiences, examples of similar projects and social values. These two different approaches to safety have created considerable frustration among the two sides particularly on the issue of nuclear fuel waste. Their differences revolve around how safe is safe.

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 not surprising that there are disparate views of what is safe and acceptable. The panel observed that conceptions of safety, risk and acceptability are coloured by each individual's or community's perspectives [16].

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 they believe would remove from unstable societies the responsibilities of managing this hazard. Some participants among this school of thought, however, believed, as we shall see later, that access to the vault 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 identified from a technical and engineering perspective. Design as you go is an acceptable approach.

For other participants, who do not have such confidence in the ability of science and engineering to resolve problems of this nature, an important characteristic of nuclear wastes 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 by-products resulting from its lifestyles in order to intervene in the future, implement solutions it deems acceptable to the problem 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 [17]. 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 vault or close to it, should be incorporated in the disposal concept. Such a system would provide forewarning and trigger appropriate action, including retrievability if deemed necessary, in the event that a series of unexpected events were to thwart passive safety [18]. 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 [19].

Many participants in the review believed that the longevity of the radioactivity of nuclear fuel waste and the inability to easily retrieve or monitor at the post-closure stage, represent a risk to safety that they are not prepared to accept. It might be that the regulatory requirement for passive safety might have to be re-examined in the context of changes in societal values if it appears that science does not have the ability to provide an acceptable compromise between passive safety, monitoring and retrievability. Such need for modification to the concept or the regulation may be assessed periodically through an ethical and social assessment framework, a tool recommended by the panel to gauge and achieve sustained public support.

4.3. Equitable choice for future generations

One of the major aspects of the panel's mandate was the examination of future steps to be taken with respect to the long term management of nuclear fuel waste in Canada. The panel was asked to take into account the degree to which we, as a society, should relieve future generations of the burden of looking after the wastes.

All participants in the review, whether they favoured retrievability or not, recognized the responsibility of this generation to relieve future generations of the burden of looking after the wastes. They disagreed, however, on what constituted a burden and what did not.

All agreed that those benefiting from a technology must assume the cost of solving problems created by it. Current generations have a responsibility to future generations, not only to themselves, with regard to protection against harm. Current generations cannot impose a risk on others that they would not be prepared to assume themselves.

The responsibilities of the current generations towards future generations can be viewed from two ethical perspectives. On the one hand, it is considered inappropriate to pass on to future generations the burden of looking after the wastes we have created by leaving them with the responsibility to look after their security, monitoring and maintenance. On the other hand, it is considered unethical to prevent future generations from looking after the wastes if they choose to do so and hence we, as a society, should not do anything to prevent them from taking control of the decision. These two views were a major point of contention between participants when discussing the merits of retrievability in fulfilling the responsibilities of this generation.

Those who share the first viewpoint tended to judge disposal as a means of protecting future generations. They argued it was unlikely that existing institutional and social frameworks would survive as far into the future as the geological formations contemplated for disposal. Hence it is more important to rely on what we, as a society, know and are capable of doing today. Retrievability they considered an issue of less importance, as they shared AECL's view that it would always be possible to retrieve the wastes at a greater or lesser cost depending on whether retrieval took place before or after the disposal facility had been closed and decommissioned. They believed that the pre-closure period would leave future generations plenty of time to assess the safety and performance of the facility and to decide whether to extend monitoring or to close the facility. For them, delaying a decision to proceed with the proposal was equivalent to absolving the current generation, which is responsible for producing the wastes, of the responsibility to finance and implement a solution to a problem it created.

Those who share the second viewpoint tended to support both long term retrievability and continued monitoring, concepts they considered almost inseparable. These would provide future generations with better control over their destiny. They argued that the proposal consisted of a technology that remains unproven, knowing that the wastes will remain hazardous for unimaginable periods of time. They had confidence in the safety of present storage practices, if improved. They believed that options should be kept open for future generations, and hence that we should proceed with caution on a step by step approach to find a permanent solution to the wastes. Moreover, they felt it would be unethical to remove from future generations the control over decisions concerning their health and their future. Sixty or a hundred years is a very short period of time to make a permanent decision when we consider that these wastes could remain a hazard for thousands of years.

For those supporting retrievability, bearing the cost of finding a solution also meant setting aside sufficient funds today for the long term management of these wastes. The funds should be a proportion of the rate paid by those who consume energy produced from nuclear technology. These funds would be used exclusively in finding and implementing a safe and acceptable permanent solution to the waste problem. The availability of funds paid by the generation that uses the energy would fulfil its responsibility towards future generations, leaving them with the ability to conduct adequate research and the freedom to choose the best technology possible to solve the problem. For these participants, this responsibility had clearly not been assumed by the previous generation that decided to proceed with nuclear power without giving any consideration to a solution for the wastes it would produce. They believed that looking after the wastes is less of a burden under appropriate conditions than having no control over uncertain future events. Instead, they believed that delaying a hasty decision represents an opportunity for future generations to make appropriate and responsible choices and to keep some measure of control over decisions affecting their lives [20].

In general, many participants in the public review felt that waste monitoring and timely long term retrievability were less of a burden to future generations than a solution lacking them. Providing resources were available for research, it would leave them with more flexibility in making decisions with regard to an acceptable solution. The elaboration of an ethical and social assessment framework would assist in capturing changing societal values over a long period of time. It would allow present and future generations to re-evaluate periodically the acceptability of the proposed approach in light of the values and priorities of the day and to make choices as decisions are made.

4.4. Options for comparison

All participants in the review, whether in favour of retrievability or not, were preoccupied with the choice of the best technology to meet the intended objective: safe long term management of nuclear fuel waste. The proponent's justification for its proposal did not enjoy unanimous acceptance as it was assessed on the basis of different value systems. The panel, recognizing that acceptability is a subjective matter that raises such questions as "acceptable to whom" included in its own acceptability criteria the requirement that a selection be done after comparisons were made with the risks, costs and benefits of other options.

Both the study group headed by Dr. Kenneth Hare and the Atomic Energy Control Board recommended that Canada should pursue deep geological disposal in plutonic rock while keeping abreast of research taking place abroad. The governments of Canada and Ontario adopted this recommendation and directed AECL accordingly. AECL followed these instructions and developed the proposed concept for disposal with its inherently complex and expensive capability to retrieve the waste at the post-closure stage. In its 1992 guidelines for the preparation of an EIS and in its request for additional information after the EIS was reviewed, the Panel explicitly asked AECL to discuss possible alternatives to its concept. Yet very little comparative information was presented in the EIS and during the hearings.

Certain participants that supported storage and retrievability were not convinced that it was necessary and advantageous to opt for permanent disposal now unless the objective was to remove the last barrier to further expansion of the nuclear industry in Canada. In their opinion, opting for permanent disposal now would ensure the continued production of nuclear fuel waste and the continued storage above ground of the most hazardous of these wastes. This would run contrary to the argument that permanent disposal would eliminate the threat posed by these wastes.

In response to questions from panel members and participants, AECL and the electrical utility companies stated that current above ground storage practices are safe, widely accepted and provide sufficient capacity for many years into the future. This was sufficient for the participants supporting a monitored/retrievable system to argue that it would be better to use the time available to improve the existing storage technology and the proposed disposal technology while keeping an eye on the development of new technologies. Focus should be kept on technologies that would improve health and environmental protection or that could eliminate these wastes forever. Some even argued that with the speed at which technology is progressing, society may soon be provided with the means to destroy these wastes as opposed to sealing them away. A serious comparison of options has not been done for twenty years and without such a comparison it is impossible to make the best choice.

Certain participants felt that 15 years of research and 575 million Canadian dollars spent on developing an option recommended twenty years ago were sufficient to proceed. They argued that, since financial resources are limited and society is challenged by many other priorities, it is time to commit to the implementation of a permanent solution for nuclear fuel waste. Other participants, using the same argument, felt that failure to achieve stronger scientific consensus and greater public confidence after all these years and money spent on developing this proposal led to the conclusion that a mistake had been made in pursuing disposal. Hence they were of the opinion that this initiative should be abandoned in favour of other alternatives.

In the absence of comparisons with other options, supporters of a retrievable concept were reluctant to endorse a technology that still remains unproven, as no project of a similar nature exists anywhere in the world. It is their view that people generally are more likely to judge a risk acceptable if they can compare the risks caused by all other alternatives and conclude these to be more risky [21]. Thus an evaluation of the risk of AECL's concept could not be done as no comparative information was presented on alternatives. Acceptability is difficult to assess in the absence of comparison.

In light of repeated assurance by the utilities and AECL that storage above ground was safe, it appeared to some that there is no urgency to move to permanent disposal. As a result, one participant suggested that it might be preferable to choose storage with its inherent retrievability as the least bad option, while improving the proposed concept and searching for a better alternative technology [22].

It appears from the panel review that the Canadian public no longer finds it acceptable to be asked to make a decision based on one option only. "A choice of one is not a choice", stated the panel in its report [23]. On the basis of the information received, the panel stated that the concept of deep geological disposal could be accepted only if it compared favourably with other alternatives. As there did not appear to be any urgency to move to disposal, the panel suggested that better technologies for safe post-closure monitoring and retrieval must be developed and incorporated into the concept. Such modifications to the disposal concept could provide the level of security required to earn public confidence and would also satisfy the need to strike a balance between minimizing the responsibility placed on future generations and maximizing their choices [24].

4.5. Future use of spent fuel

Some participants were concerned about locking away a potential future source of energy in a facility from which it would be difficult to retrieve. Most of these participants, who generally supported AECL's concept, argued that spent fuel is not a waste, but a source of energy that could be re-used. It is well known that some of the countries that generate nuclear energy reprocess their spent fuel for re-use in reactors. During the panel hearings, government officials stated that Canada has currently no plans to reprocess nuclear fuel waste [25]. Canada has a plentiful source of natural uranium that makes reprocessing an uneconomical proposal at this time.

These participants also suggested that this potential source of energy might have a substantial economic value in the future. Although these participants are likely to support disposal as a permanent solution to the nuclear fuel waste problem on the basis of safety and current generation's responsibility, they suggested that AECL's proposed concept should be more flexible. They felt that, although considerable emphasis is placed on the responsibility not to burden future generations with finding the solution for the waste being generated today, flexibility was necessary in order to allow for changing approaches to the disposal problem [26]. Recuperation of the wastes should remain easily accessible for as long as society may wish to recycle them.

5. IS AN ACCEPTABLE SOLUTION TO LONG TERM MANAGEMENT OF NUCLEAR FUEL WASTE ACHIEVABLE?

After eight years of consultation, many people might have expected the panel to make a more categorical recommendation for or against the proposal. Based on the information received during its review, the panel could have elected to proceed on several courses of action. One might have been to recommend that the government reject the proposal, as there was a sufficient number of participants who were opposed to the AECL proposal. Another might have been to recommend that the proposal be allowed to proceed to site selection, as there was a need to get site-specific information to confirm safety and acceptability. Neither of these recommendations would have left the government with a workable solution. Rejecting the proposal outright would have eliminated the opportunity to continue progress in the search for an acceptable solution, while proceeding to siting would likely have led to confrontation.

Instead the panel suggested pursuing the public consultation process it had begun. The panel believed it essential that broad public support be obtained for the chosen technology, whatever that technology might be. In addition, the consent of communities directly affected by whatever facility might be built in the future would also be essential.

The panel was aware that its recommendation might be perceived as irresponsible in certain circles. Opposition to nuclear fuel waste management technologies in Canada and abroad was sufficient demonstration to convince it of the need to pursue the exercise of participatory democracy until broader support is reached on an acceptable solution.

The panel therefore recommended an approach focused on public participation for which the objective is to establish a greater level of trust among the parties. Such an approach will permit the demonstration of safety of technologies by integrating technical and scientific factors with social values. The panel review had its primary focus on permanent disposal, while the approach recommended is that safety and acceptability can only be demonstrated on the basis of a comparison of alternative solutions.

The step by step approach recommended by the panel include: the creation of an implementing organization at arms length from AECL and the utilities; the development of a comprehensive process of public participation, including a parallel process for Aboriginal people; the development of an ethical and social framework; and the development and comparison of reasonable options.

The public review revealed that there was no pressing urgency to move to disposal. A number of participants indicated that we should use the time available to improve current technologies and search for better alternatives to disposal. This situation and the approach suggested by the panel provide government with a possible means to achieve broader support on an acceptable approach to nuclear waste management.

Although limited retrievability, as described in AECL's concept, does not appear to have the confidence of the public at this stage, the panel suggested that it could be re-evaluated through an ethical and social assessment framework, given the length of time it will take to decide upon and implement a solution. Therefore the question is not whether confidence in retrievability or irretrievability can be achieved, but rather whether we can identify a solution to safely manage nuclear fuel waste that will leave future generations with options that are acceptable to them. One generation has passed since the original decisions were made to proceed with permanent disposal and already a change in societal context requires that adjustments need to be adopted to continue the course. The approach suggested by the panel provides for that opportunity without requiring that the current generation abdicate its responsibility. It may require, however, that the regulator re-examine its requirement for passive safety in light of the ability of technological developments to accommodate a balance between continuous monitoring and passive safety.

6. CONCLUSION

Public discussion on the acceptability of a technology in the absence of a comparison of options and without any site-specific information proved to be a very difficult exercise. Much technical information on the concept itself was made available by the proponent, allowing the scientific community and some members of the public to debate the technical merits of the disposal concept in detail and to allow the panel to conclude that certain elements of the concept could be acceptable. It also provided an opportunity for the scientific community to identify a number of shortcomings in the proposal that would create enough doubts in the public's mind for it to question the wisdom of proceeding now with permanent disposal. As Dr. Hare stated at the hearings, it appeared the mood of the Canadian public had changed since he had made his recommendations. He said that in the early 90s, twenty years after his report, public opinion, where the public had an opinion, had moved towards long term, monitored and managed storage of the fuel in most cases because there were doubts as to the wisdom of sealing the chambers until there was assurance that the performance was as predicted [27].

Much discussion, however, was focused on issues of an ethical and social nature for which the information base was limited because of the absence of site-specific information and the lack of participation of social scientists in the development of the proposal.

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 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 minimizing the responsibility placed on future generations and maximizing their choices [28].

The government of Canada supported the recommendations made by the panel regarding acceptability and the need for the public to make their opinion known on the basis of a comparison of options that would include a modified AECL concept. It specified that the development of such options for long term management should allow for a balance to be maintained between passive safety and the ability to retain institutional control as required by regulation [29].

By elaborating criteria for safety and acceptability, the panel offered a set of principles that will guide the future steps in the process. It has also recommended that public consultation be pursued in an attempt to identify, among feasible options, a long term nuclear fuel waste management approach that would receive broad public support and could be implemented with the consent of a larger segment of the population.

The government has by and large responded positively to the panel's recommendations. The level of public involvement achieved in implementing a long term nuclear fuel waste management approach will determine whether an acceptable solution to the waste problem can be found. Decisions must be made on the basis of sound science, but the best science in the world will be of little avail where nuclear questions are involved, if the message is not accepted by the ultimate decision-maker: society at large.

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QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: What did your environmental impact assessment cover?

A: It covered the technology that AECL developed at the Underground Research Laboratory (URL) and the potential impact of such technology on the environment, which was very difficult to define.

Q: Do you mean the actual safety, the long term safety implications and what they were going to do to the environment, like rivers etc.?

A: It dealt with the safety of the concept itself, the technology. There was no specific environment to deal with, as it was a generic assessment.

Q: You said you had been involved in twelve other assessments? Does that include five uranium mines?

A: Yes.

Q: Please tell us how big these assessments were compared to this assessment of a theoretical project. Can you tell us how long they took and how much effort?

A: The five uranium mines started in 1989 and they were complete in 1995/96. In terms of cost they were not as expensive as this one. However, they were very extensive public reviews nevertheless.

Q: This is a national process. You have been through all concerned regions and held hearings. From our experience, it is very difficult to get people out and engage them unless you have a very particular proposal that concerns them. I wonder who were coming to these type of hearings and how representative they were for the public at large? Another question: I guess that the environment is fairly demanding for AECL, that these hearings will give a lot of challenge, but for those who are opponents or who have independent expertise bringing in other opinions, how do you generate the demanding atmosphere also for those viewpoints?

A: We visited about fifteen cities. Lots of the environmental groups were there. Some of them beat the drums around their communities and got in other people. Before the Panel would show in cities we had a consultant that called radio stations, newspapers para-public organisations, trying to get them to motivate people in those communities to show up. The Panel staff conducted two series of open houses in 25 cities using different venues such as public libraries, shopping centres and a subway station in Montreal. We used everything we could to try to reach out to some people. We were not as successful as we would have liked to be but we reached a certain level of success. In the first round of hearings, we invited guest speakers to address certain topics such as safety, ethics, risk, implementation organisation, etc. These speakers were people who were not necessarily associated with the nuclear industry or the nuclear business but were knowledgeable academics on such topics. That is how we tried to attract the public. We did not necessarily reach the public at large, but the groups that participated were representatives of different sectors of society. In reply to your last question: about a million dollars was provided to participants who qualified, for them to be able to get some expertise in reviewing the documentation, preparing briefs and communicate with other groups in order to organise themselves. It was a participant funding program.

Q: We are discussing in Oskarshamn how to generate an atmosphere in these public meetings where we can not only challenge SKB and SKI but also those who have other opinions. We would like to have a dialogue where everybody can present their case and be equally challenged, so you get a sort of a balance in the debate. Did you attempt to do that, did you attempt to challenge also those alternative opinions on safety facts or whatever in the process?

A: Yes, the Panel did, like I said, in the first phase of hearings which were dealing with societal issues. We invited some guest speakers trying to promote some discussions on issues which were broader than just dealing with the concept itself. The Panel attempted to do that in the two other sessions, the technical phase of hearings and the final phase which attracted mainly those who were committed to nuclear issues.

Q: Being enlightened with the EIA during the last two years, and knowing that the social impacts are mainly the only impacts that this kind of project actually causes, and being heavily involved with the Canadian EIA, I am astonished that when forming the guidelines, many years before the EIA, why did not anybody suggest that an impressive part like social impact assessment should have been attached to the AECL's work. The work was basically a safety case, without any bearing to societal issues, and of course, if we want to get public support or public acceptance, we have to talk about social impacts. So now I realise, a couple of years later, that the Canadian EIA never had a chance to pass the first kind of kamikaze suicide attempt and now we also see the result. So should we blame those people who defined the guidelines? I have seen very tedious work with the EIA and how AECL has dealt with the guidelines etc. Very impressing, but still?

A: Are you referring to the Panel's guidelines or are you talking about the original decision to go to disposal after they had had a look at different options for disposal in the Hare report in 1977?

Q: I am talking about the guidelines according to which AECL drafted the documentation.

A: The Panel did include a fair amount of requests on socio-economic impact, knowing that the mandate, that was given to AECL, did not cover that part. AECL had received a mandate in 1978, and in 1981 to do a safety assessment of a disposal concept, and socio-economic impact was not part of the mandate. The Panel's mandate was broader and included a number of waste management issues, which they integrated in their guidelines. AECL could have voluntarily fulfilled these guidelines and included information on this topic in its EIS. They chose not to do so, and I do not know why. They, however, lived up to the mandate they were provided by government in submitting the EIS that they submitted.

Q: My first point is that apparently they had the option, because of years of additional storage capacity to make this decision. But was there any indication that the decision would have been different if they had run out of storage capacity? Secondly, with respect to wanting them to look at retrievability post closure, did they give any sort of period of interest for how long retrievability might be proposed?

A: I do not know if I can answer that question. The Panel was repeatedly told during the hearings that there was sufficient storage capacity at the reactors sites. According to a study submitted to the Panel, three scenarios were explored. I do not know for how long after closure retrievability might have been contemplated in the study. Suggestions are that it would take five to fifteen years to get back in the vault, retrieve the waste and reseal it. But I have not seen any figures in terms of whether it is immediately after or 300 years after closure.

Q: Those municipalities that are now sitting with the temporary storage facilities, what is their reaction to the fact that there is no real strategy for the nation's waste?

A: They are not too happy. One of them, hosting the Bruce NPP, is proceeding with court action on an environmental assessment that was done for expansion of the storage facility at the plant. There was a commitment at some point, that these wastes would be moved to a permanent facility.

Q: The first two presentations from the session examined waste disposal from both a generic level and at a site specific level. Does this observation give new input to our opinion with regard to the evaluation of the Canadian programme?

A: I will quote from my complete paper and that may respond to your question.
"After eight years of consultation, many people might have expected the Panel to make a more categorical recommendation for or against the proposal. Based on the information received during its review, the Panel could have elected to proceed on several courses of action. One might have been to recommend that the government reject the proposal, as there was a sufficient number of participants who were opposed to the AECL proposal. Another might have been to recommend that the proposal be allowed to proceed to site selection, as there was a need to get site specific information to confirm safety and acceptability. So those are your two dilemma. Neither of these recommendations were felt by the Panel to have left the government with a workable solution. Rejecting the proposal outright would have eliminated the opportunity to continue progress in search of an acceptable solution, while proceeding to siting would likely have led to confrontation".
Our case was clear, only one course would allow progress.

Q: There was also another thing that the Panel could have done, namely trying to get this accommodation process within a framework of siting, for example, giving guidelines on how to proceed with siting which would then include the things that were missed out in the earlier guidelines. By making the kind of announcement it made from outside the system, it seems — despite the careful wording of the report — that the Panel brought the concept as such of geologic disposal into somewhat of disrepute which make it harder to go down that line. Did the Panel not consider recommending a further stage in siting with some more specific guidance built in?

A: The Panel provided the steps in the process, step by step, how to go through a siting process. But it said you cannot move to a siting process until you get broader public support. The support was not there to move, and if one had attempted siting at that point, it would have likely faced confrontation. That was a conclusion that the Panel reached. One just had to recall the difficulties and civil disobedience encountered in Germany with the return of a shipment of reprocessed wastes from the UK.

Q: Do you think there will ever be broad enough public support to proceed?

A: Through the guiding principles that are in the report, the Panel has tried to establish a means by which consultation could take place. Participants could assist in determining the process they want to participate in, be involved in the development of options and then provide enlightened input in a decision in terms of which way to go. The Panel described such a process with timelines associated to it, e.g. three years to reach a decision on an option. Two years have already elapsed, governments are looking at how they are going to have over-sight. The producers are looking at how they are going to create the implementation organisations. I strongly believe that if they do get these processes in place, there is a possibility of success. But I do not think that the next board to make the recommendation on the option to pursue should be a Panel as the one I have been talking about here. I think it is up to the politicians to get down on the street and meet the people and make that decision on the option. They should receive the input directly and make the decision, not leave the public consultation to another board of ex-public servants and dedicated Canadians.

HAS WELLENBERG SHOWN THE WAY, OR IS IT MERELY POSTPONING THE INEVITABLE?

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Abstract

In Switzerland, the current law stipulates that the repositories should provide the required level of safety without requiring active institutional control. Hence, even for short-lived low- and intermediate-level wastes, an underground repository must be provided. The site of Wellenberg in Canton Nidwalden was selected for such a repository in 1994. The people of the siting community of Wolfenschiessen agreed on two occasions in 1994 to host the repository by 63% and 70% affirmative votes. However, the decisive cantonal vote on 25 June, 1995 was negative by about 52%. In order to understand the voting motives, an opinion poll was organised after the vote, the results of which provided directions for future action. According to the poll, the people of Nidwalden rejected granting a combined concession for an exploratory drift and the subsequent construction of the repository — a step-wise approach (i.e., a concession for the exploratory drift only in the first step) would have been accepted by 66% of the voters. Another argument was that the waste was assumed not to be retrievable after being emplaced in the repository cavern. 61 % would have accepted a repository project optimized to make the waste retrievable. Since the voters apparently did not reject the Wellenberg site as such, but only the content of the concession application (drift and construction at once and the suspected lack of retrievability), GNW decided to modify the project and opt for another vote. This paper briefly describes the selected site of Wellenberg, as well as the procedure applied to enhance project acceptance. It analyses the reasons for the negative cantonal vote and describes the technical and political measures taken to cope with the new situation.

1. THE SELECTED SITE OF WELLENBERG

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

The site evaluation procedure for an underground LLW/ILW repository began as long ago as 1978. The initial 100 siting options were gradually narrowed down to give a total of four potential sites in three different host rocks which were included in the final evaluation. The results of this evaluation were presented in a series of reports [1–4].Based on the results of these investigation programmes, Wellenberg in the community of Wolfenschiessen (Canton Nidwalden) was selected for recommendation to the Government. In a direct comparison with the other potential sites, Wellenberg offered distinct advantages, both in terms of the feasibility of providing a convincing demonstration of long term safety (influenced by geology) and from the point of view of environmental impact.

The objectivity of the evaluation procedure leading to the choice of Wellenberg was attested to by a political commission including representatives of all four siting Cantons. The site selection process has been reviewed and accepted by the Swiss Federal Safety Authorities. The Swiss Federal Government formally took note of the findings of its experts on 23 February, 1994. Also an independent Expert Group, established by the Government of Canton Nidwalden, regarded the site selection as “transparent and acceptable”.

The main advantage of Wellenberg lies in its large volume of compact, low-permeability marl host rock, which promises a large degree of flexibility when designing the optimum layout of the disposal caverns. Enclosures of very old (i.e., fossil) water and an extended under-pressure zone in the host rock, originating from the decompression of the rock after the last glaciation, demostrate the extremely low permeability of the host rock. The suitability of the site from the point of view of geological safety is uncontested — the Swiss Federal Safety Authorities confirmed that “according to the present knowledge it can be expected that a final repository on the site of Wellenberg can be implemented securing the necessary protection of mankind and environment” and recommended to continue the exploration by the construction of a drift.

2. LICENSING PROCEDURE

2.1. Federal licences

In Switzerland, a final repository must pass an extended federal and cantonal licensing procedure. The first step consists of submitting an application for a general licence to the Swiss Federal Government. The application was submitted in June 1994 and consisted of a comprehensive technical report [5] presenting the necessary details on the geological and geographical situation of the site, outlining the construction of the facility, specifying the waste categories foreseen for the repository and summarising the safety and environmental impact reports. Special reports were devoted to long term safety and to ecological considerations, such as the Preliminary Safety Assessment Report [6] and the Report on the Environmental Impact Assessment [7]. After thorough examination, the Safety Authorities in May 1996 recommended the general licence to be granted [8].

The Government will decide on the application for the general licence considering the recommendations of its experts, but only after extensive, two-phase hearings involving the siting community and Canton as well as various experts and institutions. The final decision of the Federal Government must still be ratified by the Federal Parliament.

At present, the general licensing procedure is interrupted for several years, due to the unsolved political situation.

2.2. Cantonal and community licences

Parallel to the federal licensing procedure, cantonal and community licences for the underground investigation (drift), for the construction and later for the operation of the repository need to be applied for. Although these licences lie within the administrative sphere and do not require to be submitted to popular vote, they can be brought before the Supreme Court of Switzerland by any opponent and this can be highly time–consuming.

An even greater obstacle is that in Nidwalden, in addition to the federal licences, a special mining licence (concession) must be applied for to the Canton, since the repository is considered as a facility which may interfere with hypothetical future mining projects and, in Switzerland, mining issues are covered by cantonal law. This concession was applied for in September 1994 and was granted by the Cantonal Government in January 1995, but later rejected by the cantonal voters.

Since the repository entrance will be constructed outside zones foreseen for industrial purposes, the zone planning of the community must be adapted accordingly. In Switzerland, this requires a vote by the community assembly. Hence the people of the siting community Wolfenschiessen also had the opportunity to directly express their position with regard to the repository. In a first vote in June 1994, the people of Wolfenschiessen had agreed to host the company responsible for constructing and operating the repository (i.e., Nuclear Waste Management Cooperative Wellenberg — GNW) by a 63% affirmative vote. The vote concerning the repository zone planning in December 1994 turned out to be affirmative by slightly more than 70%.

3. COMPENSATION FOR SERVICES RENDERED IN THE PUBLIC INTEREST

Public acceptance of a nuclear repository project is influenced — among other factors — by two main components:

- the general "nuclear fear" (i.e., safety aspects), and
- the siting aspect, expressed by the simple question: Even if the repository is safe — why must it be located *here* ? (i.e., NIMBY syndrome).

It is very important to realise that the safety issues must be discussed and solved first, before any discussion of financial incentives may begin. Starting financial discussions at a stage when the population may question the safety of the facility would indeed be counter–productive — the financial compensation would be regarded as a "risk premium" and obviously lack of safety cannot be paid for. However, compensating the siting region with financial incentives for services rendered in the public interest by accepting the disposal facility for the whole nation is a legitimate way to overcome the NIMBY problem. In Switzerland, such compensation is common in the case of site–specific facilities which benefit society as a whole. For example, mountain communities that make their water rights available for the production of electricity receive compensation.

In this sense, GNW expressed its willingness to compensate the siting community and the Canton, in particular for the inconvenience expected during the construction phase of the repository, for the increased time and effort of the local administration involved in the licensing procedure and, of course, for the cantonal mining concession fees. The compensation to the siting community was foreseen to take the form of monetary payments; compensation to the Canton should have mainly taken the form of free electricity for the cantonal electricity supply utility. The total amount of these future compensations was planned to be equivalent to about 1 US$ per resident of Switzerland per year (i.e., a total of about 6 million US$ per year — one third to the siting community, two thirds to the Canton). The amount was foreseen to be paid for a fixed period of 40 years, beginning with the start of construction work, considered as the "operational period" of the repository. In addition a fund has been established which will ease the transition for future residents of the siting community when direct payments cease in 40 years' time. These direct compensatory payments aside, the construction and operation of the repository, with an estimated investment of more than 400 million US$, should have a positive impact on the economy of the region.

At present, due to the negative cantonal vote in 1995, the compensation agreement with the Canton has not become valid.

4. THE CANTONAL VOTE OF 25 JUNE, 1995

4.1 Rejection of the concession

As mentioned before, the outcome of the decisive cantonal vote on the mining concession was negative by about 52%. Nidwalden is one of the smaller Swiss Cantons, having only 11 communities and a population of some 35 000 residents. The siting community as well as four other communities were positive, the margin was narrow — about 500 negative votes decided the outcome of a waste management project with nation-wide importance.

During the voting campaign some 25 public orientation events were organised, by means of which about 15% of the voters were directly approached and informed. The information of the proponents was mainly factual–technical, about the construction project, the safety issues, the results of the geological investigations, the waste categories to be disposed of, etc. The opponents concentrated mainly on emotional fear issues, claiming that the repository would not be safe and evoking scenarios of a highly contaminated, hostile environment. The proponents acted on a cantonal base, while the opposition was heavily supported by national anti-nuclear groups which demanded first the phasing-out of nuclear energy, before tackling the waste issue.

4.2. Voting motives

Immediately after the vote, an opinion poll was organised which yielded interesting results on the voting motives. The acceptance was much higher in the male population (52% yes) than with women (41% yes). Younger people rejected the project more frequently than those aged 35 and over. The main motive for rejection was a feeling of lack of safety and general fear, the single main motive for accepting the issue was a strong feeling of responsibility (the repository must be sited somewhere!). These motives were to be expected — more interesting was the fact that only 30% of the voters interpreted the negative outcome as an indication that Wellenberg should be abandoned as a site — more than 55% expected a second vote on an improved project.

In 1995, GNW asked simultaneously for a combined mining concession, for a) an exploratory drift and b) the subsequent construction of the repository, if the drift exploration results were positive. However, the voters were not prepared to believe GNW and the Cantonal Government, who would have to judge whether the results were positive or negative — the people of Nidwalden wanted to be presented with the exploration results before they decided on the concession for repository construction: 66% would grant a concession restricted to the exploratory drift in a second vote.

Another strong argument against the concession was the assumption that the waste will not be retrievable after being emplaced in the repository cavern. In order to decide whether this was a real concern of the population, the voters were asked “In a second vote, would you grant a concession if the repository project were amended in order to make the waste retrievable?” Here 61% answered in the affirmative.

Among other arguments it showed up that the foreseen compensation payments to the Canton should have been divided between the communities — and not have remained in the general “treasury” of the Canton.

The opinion poll indicated that the voters apparently did not reject the Wellenberg site as such, but only said NO to the content of the concession application (drift and construction at once) and also to the lack of provisions for retrievability of the wastes. This result influenced the actions taken after the cantonal vote.

5. ACTIONS TAKEN AFTER THE CANTONAL VOTE

5.1. Politically difficult situation

The negative vote of the Canton created a politically difficult situation and presented the Federal Government with a dilemma: Wellenberg is geologically suitable but politically blocked — should a site be abandoned for purely political reasons? Can and should the Federation override a Canton using federal law? Could a repository be constructed against the will of the local population even if this were legally possible? Or should the project be adapted and submitted to another Cantonal vote? If yes, how should the project be adapted in order to improve its chances in the coming vote?

Since the Repository Company GNW is a technical organisation it is not able to take political decisions. These are the prerogative of political authorities, especially of the Federal Government. Therefore, GNW completed the ongoing explorations at the Wellenberg site at the beginning of 1996 and subsequently provided the safety authorities with further results which once again confirmed the site qualities [9]. In addition, GNW asked the Federal Government to decide upon the political steps to be taken.

5.2. Steps taken by the GNW

In order to facilitate the political decisions, GNW has taken several procedural and technical steps. In particular, GNW signalled willingness

- to restrict its concession application to an exploratory drift; and
- to present a project where the retrievability issue was taken into account (cf. the following chapter).

These changes have been regarded as necessary in the light of the voting motives. They were also a condition asked for by the Government of the Canton Nidwalden.

5.3. Modifications to the disposal concept

As mentioned above, the current Swiss law stipulates that repositories should provide the required level of safety without any further human post-closure actions. Provisions for retrievability can be foreseen only if they do not compromise long term safety. GNW was, nevertheless, planning additional possibilities for control of the facility even in the original project: the backfilled caverns can be monitored as long as the access tunnel remains open and the surface environment above the repository can be supervised with no time restrictions. However, these measures are not in any way intended to compensate for a concept which fails to provide the required passive safety measures. They have no active safety function and simply provide tangible evidence for future generations that disposal of the waste has been carried out correctly. Retrieval of the waste is possible in principle but, in the interest of long term safety, no specific provisions were made to simplify the procedure or minimise the retrieval costs.

It turned out that this message had not been successfully communicated to the general population and the politicians. In fact, it cannot even be communicated to laymen — the mere fact that the waste will be emplaced in the caverns and the empty space backfilled more or less immediately after emplacement evokes a feeling of irreversibility and "loss of control" over the waste. On the other hand, there must not be any compromise with regard to the long term safety of the repository, which must not depend upon questionable, non-guaranteed future supervision and control.

A solution in principle to this dilemma was found — to postpone the decision on backfilling of the caverns by 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 general idea has been thoroughly investigated during the years 1996–1997. There are technical aspects and those of long term safety which must be considered. From the engineering point of view for instance, the stability of large caverns must be guaranteed for the long times envisaged. In addition, since the caverns will remain open and accessible, they cannot be filled up totally (the upper part over the crane remains empty). Hence, the geometry of the caverns must be adapted in order to save the expensive underground space. Also the details of the waste emplacement and the postponed back-filling, etc., must be reviewed.

Even more important was to assure that the long term safety is not adversely influenced by the delayed closure of the repository. Open caverns and access tunnels constitute a place with zero hydraulic potential — will this change the hydraulic situation of the site? What is the influence on re-saturation? Does the delayed closure of the (ventilated!) caverns negatively influence the geochemistry and the sorption properties of the near-field? etc. etc.

These investigations have been carried out by the Swiss National Cooperative for the Disposal of Radioactive Waste — Nagra — under the assumption that the caverns remain open for about 100 years. The results were encouraging — the new repository concept proved to be realisable from the construction point of view, the long term safety remaining excellent, and the additional implementation costs being acceptable.

The results were published in 1998 [10] and presented to the Swiss safety authorities, Federal and Cantonal Governments and other involved parties. The echo was positive; it can be expected that the combination of high societal decision flexibility and uncompromised passive long term safety will facilitate the necessary political steps toward the implementation of the repository.

5.4. Steps taken by the Federal Government

Parallel to the technical modifications of the projects several steps were taken on the political front. After the negative vote, the government of the siting Canton had no reason to act — from their point of view the issue was definitely decided. Hence, the ball was with the Federal Government who must ask the Canton to co-operate in solving a problem of nation wide importance.

The Federal Government established several expert groups to get advice on how to proceed. Two groups consisting of federal and cantonal experts have been asked to review the technical and the economic aspects of the project, respectively. The groups worked during 1997–98, the results were published in summer 1998 [11, 12]. The conclusions of the groups were positive. The site selection was accepted, the safety situation regarded as favorable, the repository concept as appropriate, the impact on the regional economy excellent (investment volume leading to regional value added of 1 billion CHF, compensation payments). The groups recommended the implementation of the next step (exploratory drift) and some technical and financial adjustments (e.g., to divide the compensation payments among the communities of the Canton).

In addition, the Federal Government asked a group consisting of NPP operators, ecologic organisations and State safety authorities to review the disposal concepts. This group worked in 1998, but no consensus has been reached. The ecologists insisted on "monitored retrievable storage" (even for LLW), the operators and authorities favoured the current concept of geological disposal. The Chairman of the group proposed the technical concretisation of the concept of monitored storage and the in-depth comparison of it with the (existing) concept of final repositories. Irrespective of this comparison, he recommended proceeding with the exploratory drift at Wellenberg [13].

In further so-called "consensus meetings" between the Federal Government, the Canton, NPP operators and ecological organisations at the beginning of 1999, no consensus was found. In addition, the Canton Nidwalden required the concept comparison to be performed *before* any voting on the Wellenberg project — if the Wellenberg concept should prove to be wrong there would be no sense in building an exploratory drift!

Finally, on 7 June, 1999, the Federal Government asked a third group of experts to compare the disposal concepts and to submit its report by the end of 1999. At present, this group is working. Since the facts are clear and, in addition, GNW has presented a repository concept with postponed closure which complies with both the monitoring and the safety requirements, it can be expected that the Wellenberg project will get the green light at the beginning of the next millenium.

6. CONCLUSIONS, FUTURE ACTIVITIES

This "green light" will, of course, not yet mean that GNW can start building the exploratory drift. It will merely end the present phase of waiting, the next step being a second cantonal vote on the drift consession, probably at the end of the year 2000. If the vote is in the affirmative, the drift construction will start in 2003.

The organizers of the KASAM symposium proposed a slightly provocative title for this paper “Has Wellenberg shown the way, or is it merely postponing the inevitable?” The answer is YES — to both questions. Due to the directly democratic political system in Switzerland the construction of the final repository — which indeed is inevitable — has been postponed by several years. On the other hand, GNW strongly feels that the implementation of a disposal facility must be accepted by the involved population. The decisions must be supported by the people in all phases, i.e., during the exploration, construction, operation, as well as for the final closure and conversion of the facility to a passively safe artefact.

Past experience has proved that this acceptance can be achieved — the siting community agreed to the project with high majorities of 60 to 70%. The loss of the cantonal vote by 2% resulted in years of wasted time (and money) but indicated that the original procedure was wrong: too fast, too comprehensive and too technocratic. The next time, GNW is prepared to take more time for the necessary communication work and to adapt the project to societal wishes — without compromising the ultimate maxim of passive long term safety.

Wellenberg has shown the way.

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QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: I would like to ask a “what if” question. If you would get a 55 to 45 percent vote, do you think that that would be enough or would the minority be strong enough to make a problem?

A: Well, we have now lost by two percent, and maybe 0.1 percent would be enough to lose it. I feel that we can get a majority between 55 and 65 percent, but I would not be happy to have less than 55 percent. I must say that, either we will achieve sufficient majority, say something like 56, 57, 58 percent, or there will be no repository for low level waste for the next ten, twenty years in Switzerland. Then we have the situation that Ernst Warnecke described in the opening session, that we have not a retrievable storage but we have a wait-and-see or actually a wait-and-don’t-see strategy. We are trying to avoid it, but we cannot, and I agree with everybody here, with people who have been speaking before, that you cannot build a repository against the will of the community and of the region. You must have their acceptance, even if it would take five years more of discussion, of persuasion and of changing the projects.

Q: You spoke about giving the public the choice. Suppose that you have filled your repository, it is monitored, and you can leave the decision whether to keep the option open by having the repository open or closing it. Does this mean that you indicate that the decision to close a repository is also one for Cantonal vote or something like that? Wouldn’t such a decision that be limited to the authorities?

A: Sure, I think it is necessary to realise that a closing of the repository needs two components. One component is a technical, safety component, so you present your case to the safety authorities and ask for their opinion about now closing the repository, or at least closing several caverns or so. I am sure that, under the prevailing conditions, there will be a Cantonal vote about it. We feel that within one hundred years, the people will decide either to close it or not to close it. After one hundred years, the activity of this short-lived waste will have decayed by a factor of one hundred. We feel though that at least we can say to the people: look, we cannot predict what will happen after one hundred years but we are not going to close it by technocratic means. There will be a democratic process.

Q: Just a very hypothetical question. What if the scientific community says that this is our best solution and you say that you need a large majority, not less than 55 or 60 percent, until then you will do nothing. How would you frame this problem? How do you think people would react to such a thing? Earlier today, we have heard about the experts, who are trying to save the community and the society from itself and about other people opposed to these initiatives. What if the experts do not take the initiatives, just state what they want? How do you think people would react?

A: Well, we are the experts who are proposing something, and we have, in Switzerland HSK, which is a Nuclear Safety Inspectorate, and we have several commissions. In the beginning, if we would say well we leave it open for some time, then people might claim that it would be dangerous to leave it open. So we have really put a heavy work into assessing if it is less safe in the long term or not. We have changed the profile, we have decided to put all the waste in concrete containers in heavy overpack to be able to get it out again. There are no drums which are put in without overpack. We have assessed the cost, the cost is about five percent more than before, especially since we are not thinking in using this part, the upper part of the caverns for waste, so we have lower loading factor of waste etc.

First, there was a large persuasion work done by these experts. They said come on, come on folks, after all this is low-level waste, so you need not to make all this trouble. Actually we are not sure from the technical point of view that we should do it, but if the society is wanting us to do it, we are giving this to society. But if the society would say make this part, but in highly-permeable but stable - from the point of view of engineering — rock, which we could not guarantee for long term safety, I think we would then have to say no. This is something which we are not going to do. And so far we have got support from the technical community. But we have been fighting for it.

Q: I would also like to ask you a "what if" question. You have here the situation that you are dealing with low and intermediate level waste. The seminar is focusing on high level waste which has heat generation. In your case you moved relatively easily, I mean according to your presentation, from a closing system to a monitored system of waste disposal. Would you have done such a step as easy if you had high level waste with the additional problem of heat generation and the thermo-mechanical effects that are due to the heat-generating waste?

A: Definitely not, but this question should be answered by Marcus Fritschi here and not by GNW. I am working with low level waste only.
Contd. answer by Fritschi: I think it depends to a large extent on the type of waste you dispose and also on the type of host rock. In the Swiss concept, as you know, we have this concept of in-tunnel emplacement of waste and continuous back-filling with bentonite. But you can still leave the repository as such open like the test tunnels and you also could in this field of parallel emplacement tunnels drill monitoring tunnels to make the surveillance and the monitoring of the repository. We now have prepared a project for the disposal of high level waste in Switzerland and in this context we studied the retrievability from such a facility. The conclusion is that it can be handled with this back-filled emplacement tunnels. It can be handled as an industrial process with similar efforts as when putting the waste in. I think, in the perception of the public, this will probably be enough to demonstrate retrievability at that

stage in the process. I think, what is more difficult is the concern of the public regarding monitoring. I think retrievability is an industrial process in our case and it could be done, but the question is what we will monitor and for how long we will monitor.

Q: In Sweden, after the stop/go nuclear debate in the seventies, we were faced with the question by society that we were not doing enough in this area. We were told that you must stop looking at this primary repository and you must take care of the questions. Today I have a feeling that sometimes some communities say that you are pushing us a little too far and too hard. We want to wait and see, we have not yet had time to think about these things. And I understood the question a while ago, that if you have a belief in this area, then just imagine that the society would take the lead instead and require us to do this. Thereby you would be in another position. I do not know whether this is a feasible description of the Swiss situation, but I think it would have some meaning in Sweden.

A: I have been discussing this further, during the coffee break, with Britt–Marie Drottz Sjöberg, she is a sociologist. I have told her that I understand too little about this to answer her question, but I know the name of Paul Slovic. He is a well known American psychologist, and he has told the very nice anecdote of the loving mother who makes a gift to her son: two shirts, one blue and one red. So the son loves the shirts and takes one, puts it on and says: look at me! And the mother says, very sadly: "and the other one you do not like"? So you can do whatever you like, it is always the wrong way. We have started with the blue and now we are forcing the red shirt and very probably we will be forcing the blue shirt again, and so on. I think it is, from time to time, necessary to work like this and to be sure to have some inner ethics. We will not compromise on the long term safety. But we also have the problem with scientific organisations which must keep their know-how, and it costs a little, every year of delay. But we have been waiting and we feel this democratic way of making decisions is very necessary. This is the only possibility of — excuse my wordings — "educating public" by doing something. By discussing this and by taking care of their fears and demands.

C : You could also turn that around and say that now is the time when the public has come to realise that it has to educate the scientific society and the experts. The public is trying to get its points of view across to the technical society. Everybody is waiting for each other to get some kind of acceptance and understanding. It is just as much an issue for the technological society to understand that it takes a long time to get these social values across to the very highly technological society.

A: You are absolutely right and I hope that I have been able to demonstrate that we are learning, that we are changing our attitudes. We are no real technocrats. But this is a process of giving and taking. It is coming from both sides. I could underline everything you said.

ETHICAL ASPECTS

(Session 3)

RETRIEVABILITY IN AN ETHICAL PERSPECTIVE

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Abstract

At the outset, a short summary is given of how the ethical discussion developed historically, all from the so-called double KASAM principle of 1987 — safety in operation, combined with reparability, with controls not necessary, but not impossible — until the phase of focusing on retrievability as a result of a deepened ethical discussion. The ethical development is seen schematically according to two phases. The concept of retrievability functions as a symbol for the shift from the first to the second phase.

- Intergenerational equity is interpreted as an obligation to maximize the safety of future generations, whilst imposing a minimum of risks, burdens and costs. The basic disposal concept is an intrinsically definitive and non-retrievable one.
- The second phase carries over from the first its principle of the total responsibility of our generation, but interprets the principle of intergenerational equity as also including equal opportunities. This leads to the following conclusion: What is at stake is a precarious act of balance, with a preserved equal weight for the two principles in each decision and every measure.

Finally, some questions for future treatment are put, and the author draws the following conclusions. 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. But at the same time we cannot guarantee future generations freedom to act without providing for them a repository which is designed to be finally closed.

Let me begin my presentation by making my theme more explicit, in quoting the philosopher Sven Ove Hanson from his contribution “Twelve Theses on Nuclear Waste and Politics” to a Swedish inter-disciplinary seminar in 1987 on “Ethical Action in the Face of Uncertainty”, arranged by KASAM and what was then called the National Board on Spent Nuclear Fuel. Hanson writes:

An ethical discussion should not only be regarded as a humanistic seasoning for a ready–made technological dish. Expressed in technical terminology, ethics must contribute to the specification of the basic requirements.

(*Etik och kärnavfall,* SKN–Report 28, 1988, p. 150).

The increased attention which the possibility of retrieving spent nuclear fuel placed in geological repositories has attracted during the latest few years could easily be interpreted as a fulfilment of the wish which this once radical statement expresses. In the extensive material which has become available in a few years time concerning retrievability, there are also quotations which give the increased impact of ethical aspects and principles credit for having placed retrievability far up on the agenda. Yet, at the same time there are signs which indicate that the focus on retrievability is due to political considerations, and functions as "the political price to pay" for obtaining public acceptance (e.g., P.J. Richardson, *Development of Retrievability Plans*, DRAFT, Swedish National Co-ordinator for Nuclear Waste Disposal, March 1999, p. 25). In such a perspective there is a risk that retrievability becomes separated from the wider scope of motives and from the complex context where it only represents *one* aspect.

Not least against this background I have found it important for my contribution to insert indications of how the ethical deliberations around nuclear waste management was developed historically. This is necessary in order to give retrievability its right proportions, and to indicate the difficult ethical dilemmas we are confronted with.

Here a preliminary general observation is important. It may be formed as a thesis in the following way: *Ethical insight is never developed in a void, but in an interplay with different areas of knowledge and competence*. Since KASAM, internationally, nowadays often is given credit to being the first instance which brought the wider ethical perspective into the discussion — where retrievability is one aspect — I may be allowed to mention that KASAM underlined this strongly already in its first report on Nuclear Waste — the Scope of Knowledge of 1986 (*Kunskapsläget på kärnavffallsområdet,* 1986).This report contained a section entitled "Final deposit — not only a technical, scientific and economic problem". We read in that report: "Against this background (i.e., that every evaluation should be related to and build upon information and knowledge from different areas) KASAM wishes to encourage an increased understanding of the importance of ethical values in this interplay" (p.10). When these values were further specified as to their concrete implications in this case at the inter-disciplinary seminar in 1987, this occurred against the background of a broad knowledge survey from different relevant areas.

In the documentation from this seminar we also find, for the first time, an *extension* of the original basic concept of management of nuclear waste (= a final and sealed repository) to imply what we term today retrievability, though without yet using the term. However, we find words like reversible or accessible repository, and also the possibility for coming generations of taking control. The motives behind this are double. First of all, respect for a possible need of reparability. Secondly, advances in knowledge may be such that coming generations will have the capacity to improve the safety of the repository and/or allow them to use the waste as a resource. We have no right to deprive future generations of these options (*Ethical Aspects of Nuclear Waste*, SKN report 29, KASAM/SKN, April 1988, p. 14 f).

On purpose, I used the word *extension*, not *substitution*. Consequently, it is also important to remind us of the double conclusion of the seminar: "A repository should be constructed in such a way that it makes controls and corrective measures unnecessary, while at the same time not making controls and corrective measures impossible. In other words, our generation should not put the entire responsibility for maintenance of repositories on coming generations — however, neither should we deny coming generations the possibility of taking control". Thus, there is a two-edged objective: Safety in operation combined with reparability, with controls not necessary but not impossible. This double conclusion must be strongly underlined, and I will return to it.

At that time, in 1986 and 1987, KASAM's conclusions were far from accepted, even though the philosophical morality ideas from which they were nurtured were available since decades. What was new, however, was that this way of thinking was applied to the question of nuclear waste, and that time was ripe for a constructive interplay between this thinking and other factors like knowledge and technology development and social processes. Today, when we can establish that the question of retrievability successively has come into focus in our discussions, we know that this is the result of a concerted process. This process is a complex one, and contains in itself an interplay between different factors, mutually corrective and interdependent. Three of these factors may be pointed out.

(a) A more deepgoing and widened ethical discussion, based on a growing awareness of the consequences, for man and the environment, of an unforeseeable future of human activity. All from KASAM's first ethical outline in 1986, the problem of inter-generational equity, i.e. our responsibility for a fair distribution of opportunities between now living and future generations, played a very important role. Not least internationally, our discussions have been inspired from e.g. the World Commission on Environment and Development Report *Our Common Future*, with sustainable development as its key notion. Owing to a number of factors, radioactive waste has been among the first, if not the very first, of environmental problems to come under wide scrutiny.

(b) A growing need has been felt for a democratically rooted basis of the necessary decisions, as far as choice of systems and places are concerned. Not least due to the pressure from affected citizens on the local level, the question of nuclear waste has turned out to be, not only — as was presupposed in the beginning — a problem of technical skill and scientific knowledge, but to an equal degree and on all levels an ethical question (cf. the quotation from 1987 I started with). Thus, also all engaged citizens have an indispensible competence to contribute. Besides, those uncertainties which are unavoidable in connection with the responsibility for long term consequences, have turned into a key question the problem of how we, with preserved credibility, may make binding decisions for coming generations.

(c) Decisive have also been the experiences of continued research and development, leading to proposals for implementation through an incremental process over several decades, or a stepwise development of a repository. The experiences of developing a defense and protection system have, in other words, confirmed the, fundamentally, self-evident prerequisites of all technical development, i.e. it happens stepwise with due time for testing, evaluation of results, accumulation of new knowledge, improvements of construction facilities, etc. They have also confirmed the gradual character of the process, typical of all decisions, in order to secure the democratic process of decision making, where all people concerned are invited to contribute their own competence.

This indicates the context where the ethical perspective stands out. Against that background I will now concentrate my attention on the first factor, i.e. the more deep going reflexion concerned with the problem of intergenerational equity. The reason for this, is that our obligation towards future generations, from the very beginning, defined our interpretation of our own generation's responsibility for the management of nuclear waste, and has then remained a superior principle. The decisive question, however, is how we understand what this obligation means. Here we may speak about *two phases of development* — where my personal judgment of the situation is that we are at present in the middle of a shift from a first to a second phase. The concept of retrievability seems to me to function as a coordinating symbol of this shift.

At the very beginning — let us call it a *first* phase — we interpreted our responsibility as an obligation to manage the radioactive waste "in such a way that will not impose undue burdens on future generations" (the IAEA principle no. 5). "The burden on future generations shall be limited by implementing, at an appropriate time, a safe disposal option which does not rely on long term institutional control or remedial actions as a necessary safety factor". Or, in still another alternative formulation: "Our generation, that has had the benefit of nuclear power, must also take the full responsibility for the radioactive waste, and not leave an undue burden to coming generations". The task of our generation was to maximize the safety of future generations, whilst imposing a minimum of future burdens.

Retrievability is, of course, not excluded, but is not a part of the basic concept of waste disposal. The latter is an intrinsically definitive and non–retrievable concept, and has as its goal to favour security/safety without surveillance. Such a goal is alone regarded as compatible with the understanding of intergenerational equity — as being, in the first place, a question of equitable intergenerational distribution of risks, burdens and costs.

This goal has been decisive for the system concepts of disposal, as well as for the principles of radioactive waste management and radiation protection. When, today, we discuss a stepwise development of the repository, where retrievability is possible under an experimental period of development, the basic motivation is to test the long term tenability and safety of the system concept. Retrievability is, more or less, a temporal prerequisite for a safe further system development, and is limited to the pre-closure period. In regard to future safety a reversible process during the construction period has a value of its own. As such it can also raise the level of confidence in the system.

A *second* phase may be characterized in the following way. It carries over from the first phase — and this must be as strongly underlined as possible — the principle of the total responsibility of our own generation. This cannot be postponed to a distant future. Every measure we take and every decision we make must include in itself — based on the present day level of knowledge — a regard for the long term effects and consequences. Yet, there is a decisive difference: the understanding of what intergenerational equity implies is widened, and the earlier concentration on equitable intergenerational distribution of risks, burdens and costs is transcended.

Of an equal dignity as that principle is the principle which KASAM was the first to clearly express in documents from 1986 and 1987: "It is of equal worth that we guarantee coming generations the same right to integrity, ethical freedom and responsibility that we ourselves enjoy" (*Ethical Aspects of Nuclear Waste*, SKN Report 29, p 13). The principle which this quotation expresses was later called *the equal opportunities principle*. It does not focus exclusively on foreseeable risks, but takes also into account resources and benefits. This assumes that considerations will be taken to future generations' options and freedom of action.

Risks and benefits cannot be completely separated. Nor can a strict time limit be drawn between generations in regard to managing the risks and benefits that make up the legacy. The latter is always a blend of risks and benefits and, in this inseparable blend, it transfers possibilities for development to future generations. In other words, the principle emphasizes an equal distribution of resources, *and* the freedom for future generations to make their own decisions with regard to utilisations of resources and their own value judgments about safety. However, the principle will hardly allow us to draw any far-reaching conclusions about retrievability. Yet, it is obvious that it puts an increasing focus upon the possibility of retrieving the waste in the future, as a necessary issue to study and to take into account.

Sometimes one has talked about the two principles, now mentioned, as opposing ethical principles. I hope to have made clear that such a contrast between them is untenable. Already the knowledge available to us today about the far-reaching consequences of our actions inform us that such is the case. Today, if we would stay passive, abstain from decisions, and thus also abstain from that total responsibility which the first principle implies, we would certainly endanger the freedom of action of coming generations. At the same time, every one of our own steps implies that we, in a certain sense, both restrict this freedom and increase it through those resources which our allocation of research and development in fact supply. This doubleness characterizes all human activity in relation to our obligation to promote intergenerational equity.

The fundamental conclusion we now can draw is the following one: What is at stake is a precarious act of balance with a preserved equal weight for both principles in each decision we make and each measure we take. On the one side, this implies long term considerations on the basis of the present day status of knowledge, as far as security is concerned, including full sustainability of the chosen solution regarding the management of high level radioactive waste. On the other side, it actualises demands of sufficient openness, in order to give future generations workable options for their own actions.

Is it, then, possible to differentiate this general fundamental conclusion in more concrete requirements? I am fully convinced that this is possible, though only under *one* condition: an interplay between different areas of knowledge and competence, similar to the concerted process which brought about that the question of retrievability once came into focus. In that process, the ethicist possesses no other merit than, possibly, being able to demonstrate and to lay bare ethical dilemmas and conflicts between competing value judgments, when we are confronted by a need to choose our way of action. That choice cannot take place in contradiction to available knowledge. At the same time, it may force us to search for new knowledge and technical alternatives of development. For this reason, I choose here, finally, to formulate a number of questions, extracted from that obligation of responsibility which the above mentioned two ethical principles seem to clearly indicate.

(a) Should we not acknowledge that there is an unavoidable lack of balance in the dispersion of nuclear power utility benefits, such as energy, and the responsibility for the management of the high level radioactive waste that is produced? The long time span perspective — and attached to that at least partial uncertainty about the long term effects — seems to imply that the responsibility aspect extends far beyond the utility aspect, as we interpret the latter today.
(b) And will not this, in turn, lead to the conclusion that we, in our own responsibility measures, must also include future generations as acting subjects? But if so, this requires a completely new set of ideas about the role of future generations as participating in the procedure of responsibility — without our own refraining from our responsibility for coming generations.
(c) But how can we, then, visualise such a participation? Are those conceptions used in today's debate, such as "rolling present", "a chain of generation" or "institutional control", fruitful as a link, or transfer, of responsibility, knowledge and resources for development between generations? If so, what is, then, the requirement of institutional structures?

(d) Is the concept of a repository system, presupposing a stepwise and reversible process, and thereby including retrievability during the operating phase, compatible with the responsibility we may take today to guarantee future generations equal opportunities? Or is there another way for us to handle the act of balance between the two principles, than to regard it as our own generation's responsibility to work for the optimal solution, i.e. a solution which also provides conditions for effective closure of the repository? At the same time, we must do this with the openness which a stepwise process demands, when measured with today's level of knowledge — yet without pretending to know for sure whether it really is that optimal solution. The price we seem to have to pay is to act under the premises of uncertainty, while not being able to use this uncertainty as an excuse for not acting at all.

My own conclusion, after having once again re-considered the matter, 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. But — and that is now my final 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? My 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 reasonable freedom to act.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: Why do you think that our generation has such a deep of concern for future generations? Has that always been the case, and can we expect that in the future as well? Does it matter to us, what we believe about the intentions of the future generations in relation to the nuclear waste or if they have good or evil intentions?

A: All generations have been concerned about future generations. But as a result of our knowledge about the long time consequences and the risk for time-bombs or catastrophes, because of our actions today, the concern has been growing, and must continue to grow. It is not just a "popular trend" but quite necessary, in order not to endanger the future of the coming generations.

As an answer to your second question I will refer to the philosopher John Rawls' concept of the "veil of ignorance". Because we cannot have any knowledge about future generations, we have to think that they will be like us. We do not have the right to assume something worse about future generations than about ourselves and we should rely on them in the same way as we rely on our own generation.

C & Q: The discussion on ethical values is very interesting, in particular because there is not only one absolute ethical approach to a system. A Christian, a Muslim or a Buddhist society have different ethical values. There are many possibilities to judge on ethical values. Even within one society, ethical values will change with time. How do we know what future generations really do want or what their ethical values are? We cannot really judge on that. And that makes it so difficult to deal with ethical values. I agree with your conclusion that we should give reasonable freedom to future generations to act on the closure of the repository.

Future generations may not be in agreement with what we today think would be good for them. They could, for instance, have the opinion that it would have been much better if the present-day generation would have closed the repository. And that ,with their technology, they would have had the opportunity to go back into the repository area, if they believe that the waste of our generation is a resource for them. I think there are two competing ethics, both are ethically valuable, both have their merits and disadvantages. Therefore it is very much a matter of a kind of democratic decision within today's generation.

You also said that we should not make binding decisions for future generations, and I think that this is a very critical point. In terms of energy generation we are doing this and we are violating your requirements all the time. If we burn oil to produce electricity, this is a binding situation for future generations. This is irreversible. Can we — if we apply your ethical plea — still continue to burn fossil fuels, or is this not the first thing we should stop?

A: You are right that there are different ethics and that there are conflicts between values. Whatever choice we make, we are bound in some way or another. But in every choice we make, we have to include an effort to estimate long term consequences. If the consequences in the far future seem to be irreversible, then we must be very careful about what to do. The difficulty is that we do it under uncertainty. Because of that, we must have the democratic discussion too. That is the reason why I mentioned these three factors, which are included in a concerted process: the ethical values, the democratic discussion which interprets ethical values and give contributions to ethical values and the development of knowledge and technology. These three must be used together. We can never be quite sure. That is why I finished my presentation with some questions and not by trying to answer.

RETRIEVABLE DISPOSAL — OPPOSING VIEWS ON ETHICS

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Abstract

In the previous decades many research programmes on the disposal of radioactive waste have been completed in the Netherlands. The experts involved have reconfirmed their view that deep underground disposal in suitable geological formations would ensure a safe and prolonged isolation of the waste from the biosphere. Both rock salt and clay formations are considered to qualify as a suitable host rock. In 1993 the government in a position paper stated that such a repository should be designed in a way that the waste can be retrieved from it, should the need arise. In an attempt to involve stakeholders in the decision-making process, a research contract was awarded to an environmental group to study the ethical aspects related to retrievable disposal of radioactive waste. In their report which was published in its final form in January 2000 the authors concluded that retrievable disposal is acceptable from an ethical point of view. However, this conclusion was reached in the understanding that this situation of retrievability would be permanent. From the concept of equity between generations, each successive generation should be offered equal opportunities to decide for itself how to dispose of the radioactive waste. Consequently, the preferred disposal option is retrievable disposal (or long term storage) in a surface facility. Although this view is not in conformity with the "official" position on radioactive waste disposal, there is a benefit of having established a dialogue between interested parties in a broad sense.

1. INTRODUCTION

The disposal of radioactive waste in the Netherlands has a long history. Already in the late seventies the suitability of salt formations in the deep underground in the northern part of the country was investigated for this purpose. Several model studies have been carried out and comparative safety assessments of different repository designs have been made. The preferred disposal option is still a mine type of repository with spatially separated compartments for low — and intermediate level waste on one hand and high level waste on the other hand. However, due to opposition of the local population and environmental groups the suitability of these salt domes could not be confirmed by site investigations. Exploratory research of the salt domes was postponed as well as any further decision on a disposal site. As a temporary solution the government decided for long term storage in an engineered facility operated by the national waste management organisation, COVRA.

In 1993 year the government published its policy on disposal methods for highly toxic wastes, including radioactive waste in a position paper [1]. It stated that non-retrievable storage and disposal methods for highly toxic wastes, including radioactive waste, are not in accordance with criteria for sustainable development and should, consequently, be rejected. Since that year in which also the suitability, in principle, of deep underground salt formations for disposal of radioactive waste was reconfirmed after discussions in Parliament, the concept of retrievability for radioactive waste and other highly toxic wastes has been the cornerstone in the Dutch waste management policy.

2. RADIOACTIVE WASTE QUANTITIES

The storage facility of COVRA is designed for a capacity of 200 000 m^3 LILW and 2000 m^3 HLW. This capacity was based on estimates made for the waste generated by the two nuclear power stations (NPS) in operation and two additional NPS of 1000 MWe which was the envisaged nuclear energy programme before the accident in Chernobyl occurred. For the high level waste the estimates have to be adjusted downwards, because the extension of the nuclear capacity never happened. The estimates of the LILW are still largely valid due to the need to safely manage new types of radioactive waste, mainly from the process industry.

Currently there is about 10 000 m^3 conditioned LILW kept in storage at the COVRA establishment. A separate building for storage of HLW is under construction.

3. RESEARCH PROGRAMMES

3.1. The OPLA research programme

Research on the permanent underground disposal of radioactive waste has been carried out under the OPLA programme. This programme focused on the examination of the possibility of long term disposal of radioactive waste in salt formations. Although it is envisaged that an underground disposal facility would accommodate both high and low/intermediate level radioactive waste, the safety studies focused on the integrity of the galleries containing high level waste. In 1989 phase 1 of the OPLA programme was completed. The feasibility of an underground disposal facility for radioactive waste in rock salt formations was demonstrated. In order to validate the approach used in phase 1 with comparable studies abroad, a Review Team consisting of experts from the NEA, EC and some specialised institutes was invited to review the programme. The Review Team was, in its report in 1989, favourably impressed with the progress made and stated that this it is a first step in an iterative process, leading to a robust safety case. The Team recommended that further studies should focus on a reduction of existing uncertainties in the models and emphasised the need for the acquisition of site-specific data to validate the assumptions made.

After completion of phase 1, phase 1a of the OPLA programme was commissioned taking into account the recommendations of the NEA Review Team, except that no approval was given for an *in situ* examination of the properties of the specific salt domes envisaged as possible hosts for the radioactive waste. This phase of the study was completed in 1993. It was concluded that from a safety point of view there are no prohibitive factors in connection to deep underground disposal of radioactive waste in salt. The more ethically-oriented question whether the underground may be used for the disposal of waste and thus withdrawing it from other possible uses is still a moot issue.

As mentioned in the introduction, in the same year the government published its position paper on the disposal of highly toxic wastes in deep underground repositories and committed itself to a policy that demands that no irreversible steps will be taken. In other words, disposal of radioactive (and other toxic wastes) should occur in repositories designed such that the waste can be retrieved if and when deemed necessary.

Consequently, many projects in the subsequent research programme focused on different aspects of retrievable disposal.

3.2. The CORA research programme

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

- To broaden the scope to other relevant host rock materials. In particular the suitability of tertiary clay which is an abundant host rock material in the Netherlands is to be taken into account.
- To further explore the impact of the principle of retrievability of radioactive waste from a repository and in particular to 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 of the repository.
  - 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 participation in international projects.

A diagram representing the main areas of research as well as the interdependencies of the different research projects is given in Fig. 1.

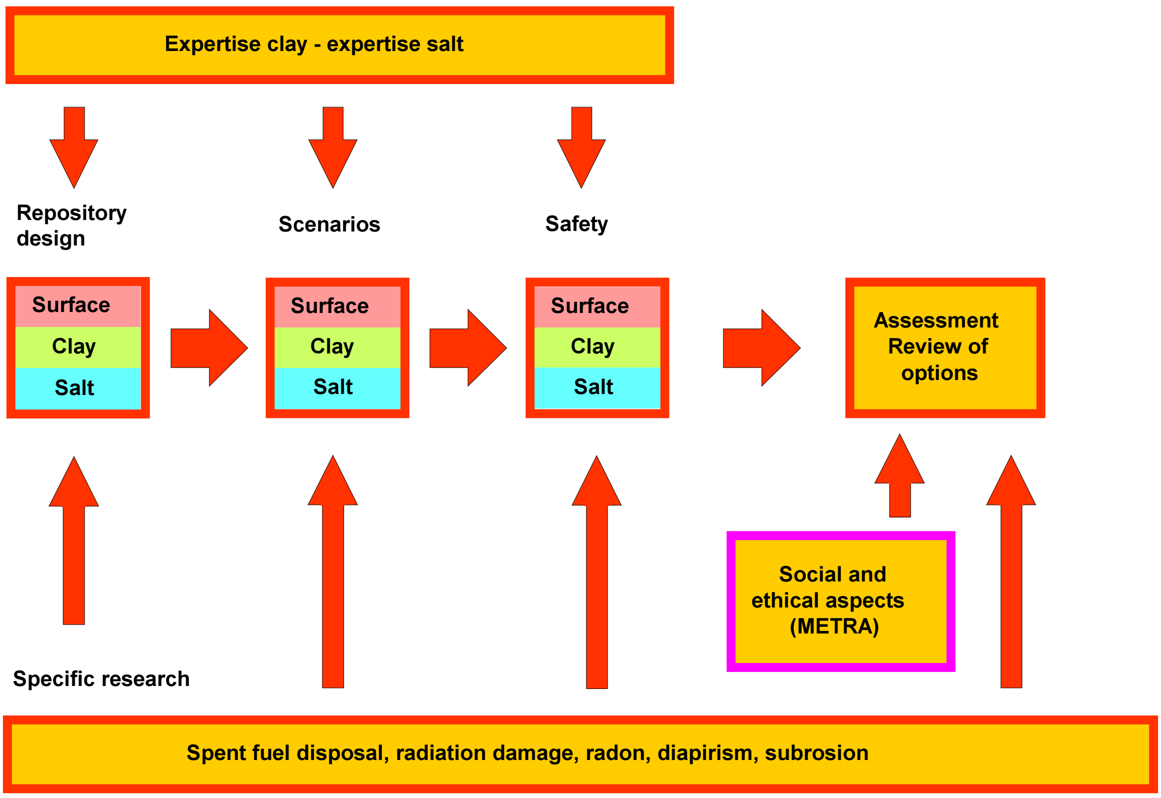

FIG. 1. The CORA research programme.

3.3. The METRA project

Although it was not envisaged from the outset, it was recognized in the course of the CORA research programme that in order to find a solution for radioactive waste at all, it is necessary to also involve in an early stage stakeholders representing groups outside the energy sector or the regulatory body. There was reason to believe that the attitudes of the local population and of environmental groups could be more responsive towards retrievable disposal than towards non-retrievable disposal. It was therefore decided to extend the programme with a social/ethical module under which the METRA study was conducted. The contract for that study was awarded to an environmental group originating from the northern part of the country which in the past had been considered for the disposal of radioactive waste due to the presence of geological stable, underground salt domes. The group had opposed vehemently against such disposal and against any on site exploratory research aimed to assess the suitability of this salt formation as a host rock for a radioactive waste disposal facility.

The METRA project had two main objectives:

- to identify the social and ethical considerations underlying retrievable disposal; and
- 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.

The METRA study was completed in May 1999 with the submission of the final report to the steering committee of CORA [2].

4. ETHICAL CONSIDERATIONS RELATED TO (RETRIEVABLE) DISPOSAL

The report of the METRA study is organised such that discussions of social and ethical aspects are conducted on the basis of a limited number of main themes as specified below:

- Can (past) production of waste be justified?
- Can disposal of waste be justified for the current generation?
- Can disposal of waste be justified for future generations?
- Are nuclear energy and radioactive waste sustainable?
- Is retrievable disposal a more ethical solution than definitive disposal?

It should be stated that the contents of the report do not necessarily represent either the view of the members of the CORA steering committee, or from the government of the Netherlands. Without prejudice to any future position of the government with regard to the conclusions arrived by the authors on each of these themes in the METRA report, these conclusions will nonetheless be represented in this paper and be compared with either national policies or with consensus statements drawn from publications of intergovernmental organisations. It is, however, believed that the discussion on radioactive waste disposal would benefit from openness and transparency of the arguments of all stakeholders and that a solution for radioactive waste which has broad support in the population can only be achieved if all arguments have been addressed and all possible options have been considered.

4.1. Can (past) production of radioactive waste be justified?

The view of the authors in the METRA study is that radioactive waste can not be considered in isolation but only as a phase in the process which generated it. This means that it is not possible to answer the question of justification of existing waste without also bringing into the discussion the justification of the practice that generated the waste. This requires that the perambulatory question whether the generation of nuclear energy is justified has to be answered first. According to the authors nuclear energy is a burden which causes harm. There are insufficient benefits (electricity generation) associated with nuclear energy to make up the detriments (possibility of serious accidents, non-sustainable resource, generation of long lived waste) and there is an unequal distribution of benefits and detriments in space and time.

Some environmental organisations interviewed even take the position that any co-operation to a solution for the radioactive waste problem is denied as long as the government has not put a ban on nuclear energy. They expressed fear that a consensus on radioactive waste disposal would clear the way for a reintroduction of nuclear energy.

The government position on waste in general, including radioactive waste, is laid down in several official documents [3,4]. The gist of this policy is sustainable development, which means satisfying the needs of the present without compromising the ability of future generations to meet their own needs [5]. This concept translates in a more practical sense into integrated life-cycle management of industrial processes. In this context waste is an undesired commodity and processes should be geared as to prevent the generation of waste. Waste which can not be prevented should, to the extent possible, be recycled or reused under the condition that such recycling or reuse can be performed in an environmentally responsible way. If recycling or reuse of waste is not possible, disposal is the preferred option, but only as a last resort. Waste disposal facilities should be designed such that the waste is isolated from the biosphere for sufficiently long periods of time.

4.2. Can disposal of waste be justified for the current generation?

In the METRA study a distinction is made between ethics of utilitarianism and ethics of justice. The former approach uses economic tools such as weighting and discounting which makes it possible that detriments are valued differently when incurred at different places or at different times and that detriment can be compensated by offering other benefits. The latter approach demands that all detriments are valued equally and that no discounting should be allowed. The METRA study assumes the ethics of justice approach as the preferred option. The consequence of this approach for present generations is that there is no justification if the persons receiving the detriment of waste disposal (the locals living in the vicinity of a waste repository) are different from the persons receiving the benefits (the users of electricity generated by the nuclear power station having generated the waste), which is usually the case. Compensation offered by the government to balance any inequalities in detriment in the population can be regarded as bribery, and should be rejected according to the approach of ethics of justice.

The position of the government in this respect, although it is not specifically stated in any national policy document, can be derived from the radioactive waste management principles 1–3, contained in the IAEA Radioactive Waste Fundamental [6] a publication endorsed by the government (Box 1).

Principle 1	**Protection of human health** Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health.	
Principle 2	**Protection of the environment** Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.	
Principle 3	**Protection beyond national borders** Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account	
		Box 1

4.3. Can disposal of waste be justified for future generations?

In trying to answer this question the METRA study again refers to the ethics of justice which demands that future generations should not be in a worse position than we are today. This requires that our generation should bear full responsibility for their actions also if these have an impact in the far future. Radioactive waste is considered to constitute a potential hazard in the future by the risk of uncontrolled release in the environment and thus exposing future generations which obviously have not had any benefit from it. The time scale for radioactive waste to be a potential hazard amounts to as much as hundreds of thousands of years which is beyond comprehension. It is unrealistic to expect that the present generation can take responsibility for such long periods. Consequently, from an ethical point of view radioactive waste is a difficult issue.

Again the government position aligns more or less with the principles 4 and 5 of the IAEA Safety Fundamental on radioactive waste (Box 2).

Principle 4	**Protection of future generations** Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact which are acceptable today.	
Principle 5	**Burdens on future generations** Radioactive waste shall be managed in such a way that will not impose undue burdens on future generations.	
		Box 2

It also is in close agreement with the concept of the "rolling present" as introduced by the NEA in its Collective Opinion on the environmental and ethical basis of disposal of radioactive waste [7]. This concept advocates a postponed decision on disposal of radioactive waste. During a period of reflection the waste is stored in a retrievable way in order to keep it accessible and available in a form that enables to process it with more advanced technologies. Not only the waste form is passed on to a next generation, but also the resources and the technical abilities to manage the waste in an environmentally responsible way.

4.4. Are nuclear energy and radioactive waste sustainable?

In the METRA study eight different criteria were defined which should be met in order to comply with requirements of sustainability (Box 3). When assessing nuclear energy and nuclear waste against each of these criteria, the authors of the METRA study concluded that none of these criteria were met. It is not clean, because waste is generated. It is not safe, because accidents with serious consequences cannot be excluded. It is not considered efficient in combating the greenhouse effect, neither is it affordable due to the high cost of safety requirements and waste management. The resources of uranium are not infinite and consequently not sustainable. Finally nuclear technology will not be provided to some undemocratic regimes. It goes without saying that the views on these criteria can be completely opposite to the conclusions arrived at in the METRA study, depending on the assumptions made.

- **clean**
- **safe**
- **efficient**
- **reliable**
- **payable**
- **available for the long term**
- **not obstructive**
- **not discriminatory**

Box 3

4.5. Is retrievable disposal a more ethical solution than definitive disposal?

According to the earlier mentioned ethics of justice embraced by the authors of the METRA study there should be no difference in detriment between the present generation and future generations. If for the present generation retrievable disposal is the preferred option, this should also be applicable to future generations. Consequently, this approach calls for permanent retrievability. Each new generation should take on the task to take care of the waste which is inherited from the previous one. An irreversible situation is thus avoided. Permanent retrievability is considered less unfavourable than final disposal. Because of the requirement of permanent retrievability rock formations such as salt and clay whose physical properties (plastic deformation) tend to fill the space between the disposed radioactive waste and the host rock, are considered to be less obvious. Therefore a permanent retrievable disposal facility at the surface is the recommended option. 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 and that deliberate or inadvertent human actions may lead to a release of radioactivity from the facility. However, no solution is offered for that.

Although the government has not taken any formal position in this matter, the main objection against a surface disposal facility for high level waste is that it offsets the main advantage of an underground repository i.e. that negligence to manage the waste properly will at least lead to an inherently safer situation.

5. CONCLUSIONS

There continues to be 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 disposal method is, manage the waste such as to keep all options open and pass on 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 that can be made is that it this study has proved that there is a beginning of a dialogue between the official bodies and persons representing environmental and social organisations and that at least a significant part of the latter groups have shown a determination to remain involved in the further discussions.

A comparison with experiences in other countries in which such discussions have been held may be useful to identify the factors which are relevant for the establishment of an atmosphere of openness and confidence which are a prerequisites for a fruitful discussion.

Given the need to work towards one or another solution for the radioactive waste which has been generated in the past, a fact which is also acknowledged by most of the environmental groups, a stepwise process towards disposal may be agreed upon as a result of a broad discussion, consisting of a series of public hearings in which all stakeholders involved should participate.

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QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Chair: One of the interesting things is the clear description of the arguments and the line of reasoning behind what has led different groups to quite different lines of action for the nuclear waste. It is important to have that picture at a meeting like this.

Q: What would your government do with respect to publishing the METRA study or taking a stance on it? You claimed that sustainability is the common theme that you both agree on. But the criteria for sustainability in the METRA study will not be satisfied by any technology ever in any universe. It should be 100% clean, 100% safe and last for ever!! Do you know if the government, which is also interested in the issue of sustainability, intends to make these things clear?

A: The METRA study is part of the CORA research programme, which is officially not yet finished. I guess that the documents will be published but I doubt if they will be immediately followed by a formal statement by the government.

Q: Do you have any idea on how the people behind the METRA study think that energy should be generated in an industrial society? All the criticism they have on nuclear energy is also applicable for the main alternative energy sources, such as fossil fuels. Those are even worse — based on these criteria.

A: Certainly they have their favourable methods of energy generation and that means that there is a focus on renewables. The other stance they take is that we should try to conserve energy much more than we do now.

C: I just wanted to point out that we did invite the authors of the METRA–study to attend this seminar and to defend their own views. Unfortunately, they felt unable to attend. So we apologize, in a sense, to Henk Selling, for actually having to answer the questions on their views.

Q: According to the presentation, the METRA-study does not give any alternative solution of its own. Is this because of the clay — salt situation or do you think they might have had different views if granite or tuff were available?

A: It is mainly because of the availability of clay and salt in our country. A quotation may illustrate their view: “Permanent retrievable storage in salt or clay formation is less obvious because of its creeping properties. Thus permanent retrievability can not be guaranteed. Therefore we conclude that above ground retrievable storage is the ethically less unfavourable choice. However, this calls into question the stability that have to control the nuclear waste and the durability of buildings and location. This remains a dilemma without any real solution”.

RETRIEVABILITY, ETHICS AND DEMOCRACY

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Abstract

Ethiticity is always a social concern, an integrated part of laws and regulations. Treatment of ethics as a separate part in the decision making process is therefore always debatable. It cannot be introduced as an extraneous component to compensate for, or to improve, a morally flawed practice, and the margin for unethical practices is strongly circumscribed by regulation in the nuclear field, internationally. However, a discussion on different stakeholders and their different ethical concerns should always be welcome. One example is the implementer's views on ethics. Even if they are in complete parity with existing legal and regulatory goals, the goals may still represent the implementer's own motives and choices. Also, stakeholders may view the laws or regulations as unfair. In making the critique, the stakeholder simply formulates a separate political standpoint. Finally, an alternative discussion is to place existing regulations into an ethical perspective — adding a new dimension to the issues. Retrievability for high level waste repositories is often in focus in ethical discussions. Unfortunately, it is used in many ways and has become an unclear term. It may cover anything from planned recuperation to the property of waste of being retrievable in years or tens of years, or in the distant time range of hundreds or thousands of years. The term retrievability is often proposed to cover mainly positive qualities such as the option of a later changes to the repository or a new disposal concept. However, as ICRP and others have pointed out, it also implies the possibility of: i) operational exposures, ii) continuing risks of accidental releases, iii) financial provisions to cover operating costs and iv) continuing reliance on institutional control, thus imposing some burdens to future generations. In a certain sense, anything can be retrieved from any repository. There is therefore a need for a clear and operable definition of retrievability requirements, including the definition of the corresponding legal consequences.

1. ETHICS AND DEMOCRACY

Nuclear waste management gives rise to a multitude of concerns and positions, including ethical ones. In this paper some scenarios are presented which all involve ethical elements, in order to stimulate their discussion. The list of scenarios is not intended to be complete, but the intention is to include examples of both probable and more speculative issues. Looking at the list, we may find some which should be given a legal or regulatory expression, as well as others with which we simply have to learn to live within a democratic society.

1.1. Ethical and legal concerns

Why "bother" with ethics in the first place? This fundamental question is not an expression of arrogance. It reflects the fact that the laws and ordinances have been decided and confirmed through a legal process. This is particularly true in a highly regulated area such as the nuclear sector. In the field of radioactive waste disposal, there is no doubt that the fundamental issues have been, and continue to be, thoroughly debated. The margin for unethical scheming seems therefore to be strongly circumscribed by regulation of observant and agile regulators.

Laws and regulations do not in any way prevent representatives from the implementer to reflect on the motives behind the different choices made in waste management, particularly in such parts of the process where there is societal participation, such as site selection. Choices have been made from a large list of possibilities and the implementer may have his own motives. It should not be forgotten, however, that (most of) the unethical options weren't open to the implementer in the first place since they would have been stopped by society's regulations. This kind of ethical debate is therefore to a large degree a question of who takes credit for a good choice. Ethiticity is always a social concern with societal choices expressed in the legislation.

1.2. Unjust laws or regulations

Many debates in society, in- or outside the political channels, certainly stems from disputing the ethics of laws and regulations. However, in the authors' experience, this type of conflict is more an exception than the rule in the public debate on the Swedish High Level Waste regulatory system. Much of the concern expressed by environmental groups, for examples, originates in the lack of formal requirements in e.g. laws and regulations regarding the consultation process.

Another line of reasoning should be mentioned, i.e., the unbalance in the societal resources allocated for protection from radiation of artificial and natural origin. It was noted in Sweden, after the Chernobyl accident, that the resources actually used on counter-measures — about hundred million US$ — saved (using ICRP's estimates) in the order of one or a few cases of fatal cancer, whereas the same amounts of resources would have saved ten in radiodiagnostics, 100 if used to reduce radon in dwellings, and 1000 cases of fatal cancers if used to advice against excessive sun-bathing. In this case, however, there is a clear commitment from society and there is no doubt that the cost of Chernobyl was in full agreement with a political wish since a large amount of the resources was allocated by a specific decision by parliament.

It should be mentioned in this context that there are no explicit requirements regarding nuclear waste retrievability in the relevant Swedish laws.

1.3. New ideas

In the process of site selection or in the regulatory review of the implementer's (Swedish Nuclear Fuel and Waste Management Co., SKB) research and development programme (RD&D; research, development and demonstration), new and unforeseen issues may rise which require legislative initiatives. The basis for such initiatives may have an ethical dimension. One example is that the current Swedish Environmental Code empowers certain environmental groups to challenge formal decisions, based on e.g. an environmental impact assessment. This led the Swedish Radiation Protection Institute, SSI, and the Swedish Nuclear Power Inspectorate, SKI, in the latest review of SKB's RD&D programme to point out that, logically, there should be support available in some way to the groups identified by the Code. The purpose should be to allow them to be adequately prepared in following and participating in the decision process, which is time-consuming and contains special technical issues.

In this connection, the authorities constitute one of several available resources to the environmental groups (as well as to other stakeholders). Members of several environmental groups, both local and national, actually often consult the authorities both directly and through various multi-stakeholder channels such as meetings and debates in the municipalities involved in the siting process. Fairness in this arena thus requires the authorities to be able to respond to the demands from the stakeholders.

1.4. Discussions among stakeholders

Much energy has been devoted to debate among stakeholders, for example between groups opposing a specific disposal site and the nuclear industry. The debate is heated and certainly involves ethics, but it does not reflect the global democratic view.

Such a global view must by necessity include the national and local governments and authority representatives. It involves the obvious need of a national solution balanced against the potentially less credible choice of one site from a long list, invoking the "not in my backyard" dilemma. It is also a question of what guidance is given on the local scene. In Sweden, for instance, the authorities take an active part in the work at the municipal level, but the state's presence does not match the implementer's in the municipalities involved in the present site selection process. However, this largely reflects the divisions of responsibilities expressed in the legislation, and a desire to control society's costs.

1.5. Adding a dimension

Ethical reflection does not necessarily have to harbour an urge to change. The reflection may add a dimension to what has already been discussed, and put a process into a new perspective. The fact that such reflections may have no immediate consequences does not imply that they are meaningless. By broadening the scope they may have strong influence, guiding in future choices in the process where arguments, not operational today, may have decisive force.

2. ETHICS AND RETRIEVAL

2.1. What does it imply to require retrievability?

Retrievability is often used as a broad term with a minimum of information about the consequences. Two issues are in fact embedded in the term retrievability: recuperation of waste on the one hand, and the more general term reversibility of decisions and actions on the other. Although it has a life of its own, the broad consultation process in the local communities cannot be reversed, obviously. The term reversibility refers to technical steps in the implementation of SKB's programme.

Reversibility is closely connected to the strategy of stepwise decisions, allowing every decision to be discussed and related to the specifics of the prevailing technical and political situation. This process' natural evolution can be used to formulate a general principle:

> "Do not foreclose an option until sufficient widespread confidence exists on the outcome of such action".

A concrete example of reversibility is SKB's suggestion of having a 10–year period for evaluating a demonstration phase of the spent fuel disposal.

Regarding **recuperation** of waste, SSI and SKI have to consider various time scales:

- **Minutes, hours and days —** operational retrieval, related to the transport for example of a damaged canister back to the surface while the main stream of canisters is downwards into the repository;
- **Years or tens of years** — near in time after emplacement, including the, possibly extended, period before closure; and
- **Hundreds or thousands of years —** after closure.

In discussing retrievability, there are several questions to consider. One, very obvious, is that SKB's main suggestion, KBS–3, can be reconciled with retrievability throughout all the above time scales (although the implementation still has to be presented in detail to the authorities). When a requirement for retrievability is presented (such as by the Swedish National Council for Nuclear Waste, KASAM), it is to some extent to ask for something already at hand. It could make SKB's option of geological disposal in the hundreds of meter range a necessary requirement, i.e. a new idea transformed into new legislation. It could also have a flavour of 1.5 above, i.e. adding a dimension to what is already proposed.

Although there is presently no application from SKB to build a repository and therefore no document available describing the repository in all its details, the authorities have taken some stand on SKB's method. The authorities distinguish between the following levels in describing the industry's method:

- **General strategy —** of a geological repository, such as SKB proposes;
- **The concrete method proposed —** KBS–3, and;
- **Variants and sub-variants within KBS–3** — such as different canister deposition arrangements, vertical/horizontal, short or long tunnels etc.

The authorities SSI and SKI:

- **Fully support** the general strategy — as opposed to transmutation or a wait and see attitude;
- **Support KBS–3** to the extent SKB's reporting is available, and;
- **Do not at present take a stand** regarding details.

Thus, there is a message to the concerned municipalities to support the view that that SKB can continue their work along the lines of KBS–3.

2.2. The Government's view

According to the Act on Nuclear Activities, SKB must every third year present a RD&D-programme to the Government, which may set conditions for SKB's future work. The review is managed by SKI with SSI's separate review as one of the more important components in the review process.

When reviewing the SKB's RD&D programme 1992, SSI took the opportunity to discuss some unregulated issues, in a separate letter to the Government (1 February, 1993). One issue was retrievability in connection with safeguards. SSI commented that there was a possible conflict between safety and a projected version of safeguards. If the Government would prefer safeguards to apply not only to spread over distance but also over time, i.e. if the issue of non-retrievability was equal to or perhaps even more important than safety issues, then deep boreholes would emerge as a major alternative.

At that time, deep boreholes and KBS–3 came to symbolise the two different options, making the waste difficult or easy to retrieve. The Government has not taken any decisions to intervene, and it must be assumed, until another decision is taken, that there is no political objection to SKB's main alternative. This implies that the SKB's work will be followed and judged according to laws and regulations in their existing formulation.

At the end of the day, therefore, radiation protection, and the required safety to achieve that goal, is the only rationale for SKB's activity. The need for safety stems from protection objectives. Safeguards in connection with repositories is an area under development at present, and it may be carried out by satellite surveillance and/or other means, but it is not in contradiction to geological repositories.

The door is still open for the Government to make requirements regarding retrievability, so as to discard the value of deep boreholes as an alternative to KBS–3, for instance. In a document appointing Olof Söderberg as advisor to the Government (6 May, 1999), the Government states that the optimum solution needs to be an "open solution that leaves room for decisions for generations" (the author's translation). If, for political reasons — which may or may not be ethical, themselves — retrievability would become the Government's preferred solution, it may still be relevant to present an overview of all existing alternatives, including deep boreholes.

2.3. What is the purpose of a repository?

In general, the purpose of a repository should be linked not only to safety but also to security and to protection from accidental and malicious intervention.

If follows from the previous section that, in Sweden, a repository is mainly intended for protection against the repository's content of radiotoxic substances. The repository's barriers also hinder malicious intervention in connection with such purposes, such as those controlled by non-proliferation activities. However, since the ultimate repository design may be different for radiation protection and non-proliferation, the implementer must have guidance regarding intrusion. SSI has regulated that the protective capacity comes first and that any step taken to prevent intrusion, or facilitate access, must be assessed and reported.

3. DISCUSSION

Some examples of ethical aspects in the present Swedish process of HLW management have been mentioned, and are summarised below.

Type of ethical consideration	Examples — Scenarios
1. Independent reflection	The implementer's own motives — hopefully in parity with existing legal and regulatory goals, but not necessarily expressed the same way.
2. Ethics in contradiction to regulation	Unfair laws or regulations — defining a new political standpoint.
3. Opening up new alternatives	Speculation about new, unregulated issues.
4. Reflection on subsystems in the process	Questioning information given by one stakeholder.
5. Adding a perspective	Putting existing regulations into ethical perspective — adding a new dimension rather than suggesting immediate change.

3.1. Identify conflicts which needs to be resolved by legal means

It follows from the table and reasoning above that some conflicting ethical positions, for example between environmental groups and the nuclear industry, may not be resolved, and cannot be expected to be resolved. It does not follow, however, that common grounds could not be found in details. (Nor is it ruled out in principle that all parties could agree on every aspect). However, we may isolate some issues, which should not be unresolved for a longer period of time. Disputes over well-defined waste management options fall in this category. If such disputes cannot be resolved by consulting the existing legal framework, efforts should be made to put them to trial in the proper forum, i.e. parliament, national or local government or authorities, depending on the problem.

3.2. The status of an alternative solution

If a formal requirement for retrievability was introduced, it would look innocent at first sight since KBS–3 already fulfils this requirement. However, such a requirement would have repercussions for the existing legal system, because the Swedish Environmental Code requires that alternatives be presented. The deep borehole's status as an alternative would be *problematic* (?) under a retrievability requirement.

The efforts put into exploring alternative solutions will change during the technical and societal decision process. The range of alternatives will, and should, narrow throughout the decision process. Some alternatives such as launching waste containers into space has a place in a general description in most national waste programmes, but will typically be mentioned as an example of the discussion in the early days of the programmes. If on the other hand a credible and potentially safe alternative exists, it is reasonable that resources are spent throughout the programme. In SSI's and SKI's view, this is the case for deep boreholes in the Swedish nuclear industry's research.

At present, SKB actually spends considerable resources in exploring this alternative. SKB's research regarding deep boreholes is in line with the authorities' request, that SKB must present an overall system analysis, which includes analyses of the alternatives. In the authorities view deep boreholes is the most reasonable alternative to KBS–3 and it may be assumed that in connection with a final application, SKB will be able to present a comprehensive system analysis for deep boreholes. This would not be required for a speculative alternative such as launching waste into space.

The method of separation followed by transmutation is studied by SKB today using the same order of magnitude of resources as deep boreholes. In reviewing SKB RD&D programme 1998, SSI and SKI pointed out that this alternative cannot be viewed on the same level as other alternatives (i.e., KBS–3 and deep bore holes). If, for formal reasons, deep boreholes were ruled out, this should be pointed out the same way in the review process. The level of research activity directed to the deep bore holes concept justifies both a serious assessment and an authoritative position from society. Clear positions serve to direct research efforts and they contain valuable information to the public and decision-makers.

If a political decision ruled out deep boreholes, the present level of activity would certainly be disputable, and perhaps also ethically questionable.

If, finally, it is advocated that SKB should be directed to carry out research into deep boreholes with the goal of finding a retrievable version of that alternative, then the advocate would ask for a new concept, which would need to be stated clearly.

3.3. Intergenerational ethics in an open repository

Another well-known ethical aspect of retrievability is the question of a repository, held open for future generations to make the final decision about closure. The reasoning contains a logical problem by the requirement that generation No. N cannot decide about closure since they must leave the question open to No. N+1. Such a — hypothetical — repository would never be closed.

Many valid arguments can be formulated to support a predetermined period of consultation after waste emplacement, but the length of the period has obvious consequences in terms of society's resources. A ten-year consultation period already exists within SKB's suggested programme, but a fund with earmarked resources kept over hundreds or thousands of years have very little credibility. In addition, continued storage involves both operational personnel exposures, releases to the environment and potential accidents.

3.4. The questions and the answer

It can be seen from the arguments presented above, that it is of particular value that all stakeholders clearly present their view regarding retrievability so that the legislation can be clarified, if necessary, and that concrete requirements may be set for the implementer in a transparent way. A serious position necessitates a clear and operable definition of the concept, and a full understanding of the consequences.

Most concerns in relation to retrievability relate to the fear that the implementer may be moving too fast towards a point of no return. The answer to most such questions has to do with the reversibility that can be found in stepwise decision-making, such as the process going on in Sweden today.

ACKNOWLEDGEMENT

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QUESTIONS (Q), COMMENTS (C) & ANSWERS AFTER THE PRESENTATION

Chair: It is important to highlight the definition of the term "retrievability", because it is also a question of the *degree* of retrievability. It could be a danger if we have discussions without realizing that we do not have a common reference when it comes to what is retrievable and what is not retrievable. I think we all agree that as long as we keep spent fuel in a wet storage or in a dry storage, it is certainly retrievable, and that it would be irretrievable if we dispose of it in outer space. To reprocess is a way to retrieve, but the spent fuel as such is no longer there, so that is also irretrievable. Then we have all different grades of retrievability in between. Most concepts of deep geological disposal are in principle retrievable concepts, as long as we have a fair canister and you do not go too deep. Some people might argue that deep sea-bed disposal is irretrievable and some that Man might also be able to go down in the deep sea and recover such canisters, but that would be a very large effort. We have to keep the following aspects in mind: 1) Retrievable in principle or not, 2) retrievable with what means and with what effort, 3) with what skills? If we do not do that, everybody in the public will make up his own mind about what is retrievable.

Q: Does the ICRP-statement about storage of waste say anything about the time frame in relation to surveillance and maintenance of the storage facility?

A: No, I think they are referring to storage in general first, and then they add that if storage is used in a meaning different from final storage, i.e., a storage that you need to monitor, they seem to mean a temporary storage or prolonged storage. This is more like a reminder that you need to go down and check. For this reason we have operation exposure. There is always a risk of accidental releases when you have easy access. Since they mean a prolonged storage you can infer that they were thinking of 30 generations rather than 30 years. The ICRP-check list is not giving us very much help. They refused to address the issue of high level waste storage so long, that now, when they are finally doing it, they are too late. We already have our regulations in place. We can check if they differ from us. But in most places they are the same. And if they differ from us — we think they are wrong!

C: The final point of the ICRP statement is rather interesting. They are saying there, that similar considerations regarding the continued reliance etc., apply, if the retrievability is added to the disposal concept. Here we come back to the problem of definition. But this was also very obvious, when I listened to Henk Selling's presentation of the situation in the Netherlands. For instance, there were indicated a number of reasons for retrievability or what would be the objectives of retrievability. Postponement of the decision until sufficient confidence has been reached was mentioned. I would like to use this as an argument for KASAM to look very carefully on the definitions in this document. There is a difference between retrievability in waste management and about disposal retrievability. What definitions are the correct ones? I know that among implementers, the disposal with retrievability often means the disposal *without the intention* to take it up but *with the* *possibility* to retrieve. You cannot say that retrievability will give you a chance to postpone a decision, because then you have said that some retrievability options require future actions by the future generations. That might be OK, but generally people do not mean that when they say that they have a retrievability connected to the disposal. There might be a lot of misunderstandings if these definitions are not very clear.

A: At a seminar in Sweden almost a year ago, Phil Richardson mentioned the Swedish word "återtagbarhet" and compared that to "retrievability" and noted some difference in the meaning. Perhaps there is a little more of intention in the English word than in the Swedish word, which would mean "the property of being in principle retrievable".

C: When talking about retrievability we probably need to make a distinction between two forms of retrievability: 1) Retrievability according to the SKB concept, as described yesterday, when you close the repository but are still capable of removing the backfill and the buffer and recover the waste, and 2) retrievability where you leave the repository open, which is a totally different thing. I believe that the ICRP statement only applies to retrievability of an open repository. Because, if the repository is closed, you may not have all these liabilities.

A second comment refers to my impression of what you said that inaccessibility and safety are potentially contradictory aspects of a disposal solution. This is not necessarily the case. If we choose, for instance, the deep borehole concept, it is not at all sure that the safety will be lower. We will have to perform the safety assessments, and only thereafter we will be able to see if the safety is lower or higher. It may very well be that inaccessibility is a positive factor and contributes to safety. Certainly it will decrease the importance of the human intrusion scenarios.

A: I agree. But what we have said is that if the inaccessibility is mandatory, then we must look to deep boreholes. Some other reviewers have also mentioned this, for example, in relation to the review of SKB's RD&D Programme 92. So, if the inaccessibility is the most important, then we would expect more emphasis on deep boreholes. But I agree with you, that it may be that such a solution can also be made in a safe way. Presently, honestly, it does not look like this. As I understand, you will have to put one pin at a time down in a small borehole, and it is the feasibility of the concept that is mostly in question. One can make a safe repository if one puts the waste 6000 kilometres deep — at the centre of the earth — but it is not very feasible, it is not easy to see how that could be achieved.

SUMMARISING DISCUSSION ON SESSION 3

H. Åhagen

On Anne-Marie Thunberg's paper: we discussed yesterday the feasibility of monitoring in relation to long term safety. I am looking at your paragraph stating that "the basic motivation is to test the long term tenability and safety of the long term concept". I also brought up, in my paper, that there are questions on what you really can monitor in this eight years period, that is scheduled in the Swedish programme. How do you relate this first step — or first phase — to the feasibility of any monitoring. And how if the monitoring is not possible? Would that change this decision making process from an ethical consideration point of view? You say that "retrievability is, more or less, a temporal prerequisite for a safe further system development". I read that as based on monitoring results. And it is limited to the pre-closure period. What would it mean if monitoring of any results would not be possible? Would that affect your decision making conclusions?

A.-M. Thunberg

I mean that long term safety has priority, according to the first principle, which I mean is quite relevant. We will reach a stage when we must choose between safety and to close some options for future generations. But I cannot today tell when we can come into such a situation.

S. Wingefors

If retrieval is going to happen, it will not be due to anything found in the repository. The odds are very much that it will be knowledge accumulated outside the repository, in laboratories around the world, that will cause us to question the safety of the repository. It is not so much a question about the monitoring going on within the repository, as about the continued ongoing R&D within the waste management community. We must not forget that development and technical/scientific progress is going on all the time, as the repository is operating.

C. Thegerström (chair)

I agree to that, as an implementer. Of course some monitoring can be done down there, not giving direct signs about the long term safety, but at least giving some information on the actual initial state of some safety related parameters. You can get that over a period of some decades. But of course you will not get any monitoring that will tell you what will be the state of matters in thousands of years from now. Then, a lot of the research work could provide additional information.

E. Kowalski

As a physicist I have always problems with very abstract ethical considerations. So let me put it in a very practical form. I am trying to give my children and grandchildren some sort of sustainable education, so they get at least the same starting chances I have had. They get plenty of freedom. But there is one point where I am restricting this freedom. They are not allowed to make anything which I know that it would cause harm to them as, for instance, to lean out from the window, etc. I have always thought that this is a rather ethical way of educating children. But during this discussion I have got some doubts. Is it correct that I am trying to prevent danger for future generations?

T. Äikäs

I am a bit puzzled by the post closure retrieval decision-making, and have tried to find out the ways how the initiative for this kind of decision-making would have been made. We have just heard that monitoring of the safety is not possible. So what are the grounds for this kind of decision making and why and who takes the initiative? This puts a tremendous pressure on the regulators, because they should show why it should be retrieved. When we in Finland start making preparations for final disposal and make the first step towards the repository, the initiation is made by the implementer. And the whole society will participate in the decision making and the highest decision is made by the Parliament, whether we will go forward or not. What similar kind of procedure is required to retrieve the waste after closure?

C. Thegerström (chair)

What I could foresee in spent fuel disposal is that we do this repository stepwise and we close it. We cannot know how the coming generations, say 200 years into the future, would view that material. Would they consider it in the same way as we do? Would they consider it as much more of a resource that they want to use etc.? If they have come to the conclusion that this is a resource, we cannot regulate how they would make a decision to retrieve it. If they will be like us, there would be some kind of a licensing procedure from somebody who would like to retrieve it, checked by the authority, and then a decision, probably by the government, and then a big undertaking of the same kind as we did when we put it down. My point is that, as we do not know if we can provide the same level of protection, it is a positive value that it is retrievable technically, compared to another solution giving the same level of protection where it would not be retrievable. To me that is one of the points, justifying to look into the issue of retrievability.

D. Bullen

Don't you think that the true answer to Timo Äikäs' question about how you decide on retrievability for future generations, is going to be a cost-benefit analysis, estimating how much it would cost to go down and retrieve the material versus the cost of using enrichment of natural uranium that is already available from somewhere else in the world? If retrievability is not cost effective, then you will get the resources from somewhere else. So by putting it in a deep geological repository you may have set the threshold for cost too high.

C. Thegerström (chair)

I can see three main parameters. It represents a potential danger, that is why we want to make isolation in different ways. It may represent a potential resource and the judgement on the balance between these two can vary from generation to generation. And then there is the term of cost to explore the resource or to protect you from the danger. That is the kind of equation we are trying to solve and to give our answer to.

L. Thunberg

Two additional remarks. To a great extent, our discussion on retrievability is a kind of preliminary discussion. There are other aspects which are not as preliminary. But some of them are preliminary and we must ask ourselves if it is helpful or worthwhile to have this more or less abstract and "in principle" discussion about the retrievability, even though it may be that the consequences of the discussion have to be taken far ahead, much later.

The other point is that if we talk about cost-benefit, we must also consider — in view of future generations — that the whole scheme of cost-benefit may be very different from ours today. When we discuss cost-benefit today, we do it in our own context. There may be — in the very distant future — a situation where they say that the benefits of retrieval are very high in comparison to the cost.

C. McCombie

Just to broaden the discussion on cost-benefit a bit. We talk about inter-generational equity, but we have not talked very much about equity within the current generation. What is fair across current generations? It was pointed out that this generation seems to be more concerned about the future than other ones. But it is not just this generation, it is this industry, this business that we have to be concerned with. With firm cost-benefit thoughts, we try to "square circles" and try to solve conflicting things. Let us make it totally unretrievable for safety reasons! Let us make it totally retrievable at the same time! That costs money! It seems to me that, in the first paper of today, there was a quote that, owing to a number of factors, radwaste is one of the first areas of doing this. It does not say what the number of factors are. I wonder why, for this particular area, we are doing so much. Is it because radwaste is such a huge problem, the biggest problem that is around? Or is it for some other reason, among these factors, for instance that you have got the resources to do it? We should actually be using cost-benefit analysis as much as we can, even for deciding to implement the measures that are now being proposed all around the world. We have discussed engineering solutions to try to satisfy at least partly contradictory ethical considerations, without anybody saying: how much does it cost to satisfy these things? I think there is an initial fairness across activities, fairness across generations inside this generation, fairness across generations and fairness across different people.

T. Äikäs

I was afraid that somebody would raise the question of cost as a decision making issue. This has its difficulties because the next requirement would then be that you will have to provide funds for retrieval — forever.

C. Thegerström (chair)

Sometimes we consider cost as some kind of parameter that does not at all relate to ethical values. But it does, of course. If we in one area push too far and spend too much resources, material as well as intellectual ones, resources will be subtracted from other areas of society's priorities. We need to keep in mind that they are interrelated.

E. Warnecke

The final conclusion in the METRA paper was to have the waste either in a permanently open repository or permanently retrievable in a surface facility. I had the pleasure some time ago to listen to a professor of ethics, who was just dealing with the question of access to the waste in a time frame of a few hundred years. His point was that access to the waste required permanent maintenance of the facility. The professor then referred to the situation in the past. Over the last 100–300 years there was no stable state, no stable government and no stable society. His conclusion was that it is not possible to guarantee stability in the future. As there is no guarantee for permanent maintenance it was concluded that, from an ethical point of view, this was not a solution. Did such considerations play a role in the METRA study, and what were the arguments against the standpoint as it was expressed from an ethical point of view?

H. Selling

This issue was not addressed in the METRA study. In direct response to your question, I quote again from the study: “The authors conclude that above ground retrievable storage is the ethically less unfavourable choice. However, this calls into question the stability of institutions that have to control the nuclear waste end the durability of buildings and locations”.

This addresses the point of stability of institutions and, one step further, it calls into question the stability of the whole society. But they conclude that this remains a dilemma without any real solution. So they recognize the problem, but they do not offer a solution to it.

E. Kowalski

In Switzerland, in a very similar discussion, this problem has been accepted as being the solution to the problem. So, if the waste remains dangerous, and visibly dangerous, people will take care of it. If the waste will be disposed of safely, it is out of sight and out of the minds and nobody will take care of it!

B.-M. Drottz Sjöberg

I heard that, in the Dutch government, there seems to be a redefinition of waste. It was defined as an undesired commodity. That is very interesting, because, as I understand it, as soon as you talk about commodities, you go outside the legal frame of the current rules for waste. The word commodity is used in trade, and by redefining the word waste, we might be drawn into a discussion about trading of the waste (under a different legislation). Is that redefinition intentional or not?

H. Selling

This question is basically addressing a semantic problem. I used the word commodity, and I did not mean to redefine waste. I used that word, because I thought it would reflect the concept of waste, but I could use another word. The only point I wanted to make is that waste is not considered to be a desired product of industrial processes. That is the basis for the policy to try to prevent the waste from arising and, if it does, to try to recycle it or reuse it. In the end, it is recognized that there is still some waste and that you have to manage it properly. That is the line of thought that is not only the policy of the Netherlands, but which has also been internationally agreed on.

B.-M. Drottz Sjöberg

Maybe it is just a matter of words, but this also makes it very clear that the words are extremely important. According to people within the field of legislation we treat radioactive waste in this way because it is defined as radioactive waste. If it is defined as a commodity, it may fall into other categories of legislation.

P. Richardson

The debate, in the IAEA or between the states, about the setting up of a convention on nuclear waste, has shown that it seems to be a great problem in some countries, refusing to accept spent fuels as a waste. Some countries regard the spent fuel as a resource, not as a waste. It may be that, in 25 years time, a country that today would define spent fuel as a resource, has a major change of heart and refers to it as waste.

C. Thegerström (chair)

When I came as a young engineer to the Swedish programme in the mid 70s, spent fuel was considered mainly as a resource. In 1976, there was a state committee proposing that we should build our own reprocessing plant. That gives me a reminder that the way society views these matters suddenly changes, and may change also in the future. But that must not prevent us from going forward, and implementing what we see as the most reasonable way today, in our judgement.

Of course, there is a lot more to discuss. But it is normal, in ethical discussions, that one does not come to a final and definite conclusion. It is part of the game that it is the discussion itself that is the important thing.

LONG TERM MONITORING AND COST CONSIDERATIONS

(Session 4)

ACOUSTIC REMOTE MONITORING OF ROCK AND CONCRETE STRUCTURES FOR NUCLEAR WASTE REPOSITORIES

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Abstract

Excavation and thermally induced damage is of significance for many types of engineering structures but no more so than in the case of nuclear waste repository design. My research and that of my group, formally at Queen's University Canada and Keele University UK and now at the University of Liverpool UK, has focused on the development of acoustic techniques for the *in situ* detection and quantification of induced damage and fracturing. The application of earthquake seismology to this problem has provided the opportunity to study the micro mechanics of damage mechanisms in situ and provide validation data for predictive geomechanical models used for engineering design. Since 1987 I have been a principal investigator at Atomic Energy of Canada's Underground Research Laboratory (URL), responsible for the development of acoustic emission techniques (AE). In the last twelve years, the application of acoustic techniques to rock damage assessment has been pioneered by my group at the URL and successfully applied in several other major international projects including the ZEDEX, Retrieval and Prototype repository experiments at the Aspo Hard Rock Laboratory (HRL) of SKB Sweden. In this paper I describe what information is available by remote acoustic monitoring of rock and concrete structures and demonstrate this with reference to two international scientific experiments carried out at the URL Canada and the HRL Sweden.

1. INTRODUCTION

The principles employed in the acoustic detection of damage in rock and concrete are closely related to those employed by seismologists to study earthquake mechanics and the internal structure of the Earth. At the scales generally associated with civil engineering projects, acoustic methods can be broadly split into two categories, depending on the frequencies of the sound waves considered. Microseismic (MS) systems monitor energy in the 0.1–10 kHz band and are suitable for monitoring large volumes of rock ($\leq 1 \times 10^7$ m^3), around a mine or tunnel complex. Acoustic emission (AE) systems record higher frequencies (30–250 kHz or greater) and are used for high resolution monitoring of smaller volumes of rock or specific concrete structures (volumes between 1m^3 and 1×10^4 m^3).

Acoustic methods are particularly suited to the monitoring of rock and concrete associated with civil engineering structures, as they are relatively non-invasive and, once installed, can monitor for extended time periods with little or no user intervention. In most cases a volume can be monitored by an array of sensors inserted in a few narrow boreholes, attached to the surface of the structure, or, in the case of concrete, embedded in the structure when it is cast. Once installed the same instrumentation can be used for both passive monitoring (listening for acoustic emissions) and active monitoring (measuring the rock properties using ultrasonic pulses or artificial shots). Data from these sensor systems are recorded as waveforms from which a wealth of information can be derived. Ultrasonic monitoring has been shown to be an effective tool for observing induced fracturing and the response of a medium to applied stresses. Falls and Young (1998) give a review of acoustic emission and ultrasonic velocity results from a number of excavation experiments conducted in different underground environments.

2. WHAT INFORMATION CAN AE STUDIES PROVIDE?

Acoustic monitoring can tell us much about the behaviour of a volume of rock or concrete over time. In particular, these methods are ideal for the delineation and characterisation of damage. Such damage may occur as the result of, for example, stress field changes or material degradation. In many early investigations, AE studies were used in laboratory rock mechanical experiments, and the number of AE 'events' was used as a simple measure of damage within the sample. More recently these techniques have become more sophisticated and considerable information can now be obtained in both laboratory and in situ studies. Acoustic methods can be used to:

- ***Say where damage is taking place.*** Using the arrival times of the seismic phases, the AE/MS events can be located within the rock with great accuracy.
- ***Assess the extent of the damage.*** The location of events and the event rate can be used to assess the areas within a material where the most damage is occurring. The velocity of seismic waves within the material (derived from passive seismic tomography) can also be used to assess areas of damage as, in general, regions of high damage will show lower velocities when compared to those from intact material.
- ***Determine information on the damage mechanism.*** The shape of the waveforms recorded at each sensor is a function of the source mechanism and the path effects experienced by the acoustic energy as it travels from the source to the receiver. From these data it is therefore possible to derive information about the orientation and mechanism (e.g. shear, isotropic) of the failure.
- *Derive information relating to the stress field.* Studies have indicated a relationship between zones with high velocity anomalies and regions of higher stress and, therefore, increased damage potential. These may be identified by passive tomographic imaging and used in conjunction with stress models derived from numerical modelling and/or in situ measurements. In addition, the orientation of the principal stresses acting at the source of the acoustic activity can be interpreted from waveform processing of the AE/MS activity.
- ***Determine material properties of the volume.*** As energy travels through rock, concrete or other materials the frequency and amplitude are affected by the material properties. Measurements of seismic velocity, anisotropy and attenuation are therefore sensitive to changes in these material properties.
- ***Assess the time-dependent behaviour of the material in response to engineering activities.*** The response of the material may vary with time in response to excavation or other engineering activities. The ability of acoustic methods to monitor in a continuous and passive manner is one of their greatest assets.

3. APPLICATION OF ACOUSTIC TECHNIQUES FOR MONITORING ENGINEERING STRUCTURES

The techniques described above offer a powerful tool for non-destructive evaluation in an engineering environment. The methodology for these techniques has been verified in a number of important experiments. Several of these are associated with developing technology suitable for the long term storage of nuclear waste in sub-surface repositories. As part of such studies a number of underground research facilities have been built, in which experiments to study their behaviour are on going. At these facilities delineating zones of damage associated with tunnel excavation (i.e. the Excavation Disturbed Zone) is very important for determining the hydrogeological properties of the rock. This technology has been very important in developing an understanding of the relationship between the in situ stresses, the excavation method and the long term behaviour of the rock mass. AE technology has also been used to investigate the long term behaviour of a rock mass undergoing loading due to thermal stresses.

Case study 1: The Tunnel Sealing Experiment at the Underground Research Laboratory (URL) of Atomic Energy of Canada: The URL is situated within essentially homogeneous Lac du Bonnet granite, which is initially unfractured (below 240 m depth) before the excavation of tunnels. The results described here are taken from the Tunnel Sealing Experiment (TSX) located at a depth of 420 m in the URL. The objective of the TSX is to study the problems associated with the construction, sealing and pressurisation of a tunnel to pore pressure (see Young and Collins, 1999). The TSX tunnel is elliptical in shape (4.4 m × 3.5 m) and is oriented in the direction of the principal stress. The maximum stress concentrations from elastic modelling are 105 MPa in the roof and floor, with −0.5 MPa in the sidewalls. Induced seismicity and AE associated with excavation damage has been used to investigate the mechanics of microcracking around the TSX. Fig. 1 shows a 3D view of the TSX tunnel, seals and AE monitoring boreholes. 10 triaxial accelerometers, operating in the 10 Hz to 10 kHz range, are used to monitor the largest induced seismicity at the URL (−1 moment magnitude). 24 ultrasonic transducers were positioned in boreholes around the clay seal volume and monitor very small-induced AE activity in the 50–250 kHz band. AE transducers were also placed within the concrete bulkhead.

The events are overlaid on the tunnel geometry and keys and the mean location error is 0.54 m, calculated by a calibration survey. Fig. 2a shows the events clustering around the new excavation rounds which occurred in Period 1 and also activity in the roof and floor of the region excavated. The events clearly cluster within an approximate 0–2 m shell around each new excavation round, including the region ahead of each blast round. The concentration of activity in the roof and floor are the regions where stress modelling shows the greatest predicted stress concentration and delineates the areas of breakout potential.

During Period 2, approximately 500 events are recorded over the length of the tunnel mainly in the roof and floor regions (Fig. 2b). This seismic response indicates that slight stress changes are occurring along the tunnel over this approximately 2.5–month period, even though excavation is not taking place in the immediate vicinity. These stress changes and the resulting microseismicity may be resulting from activities such as time-dependant deformation and/or triggered seismicity from adjacent experimental excavations. Fig. 2c shows a significant MS response during the excavation of the rectangular clay key slot. Part of the concrete key slot in the floor is also excavated during this Period and a number of events are recorded in this region. During Period 4, MS events mainly cluster around the newly excavated concrete key, but also a significant response occurs around the clay key and a couple of meters to the SE of the clay key where the steel restraint slot is being cut (Fig. 1 and 2d).

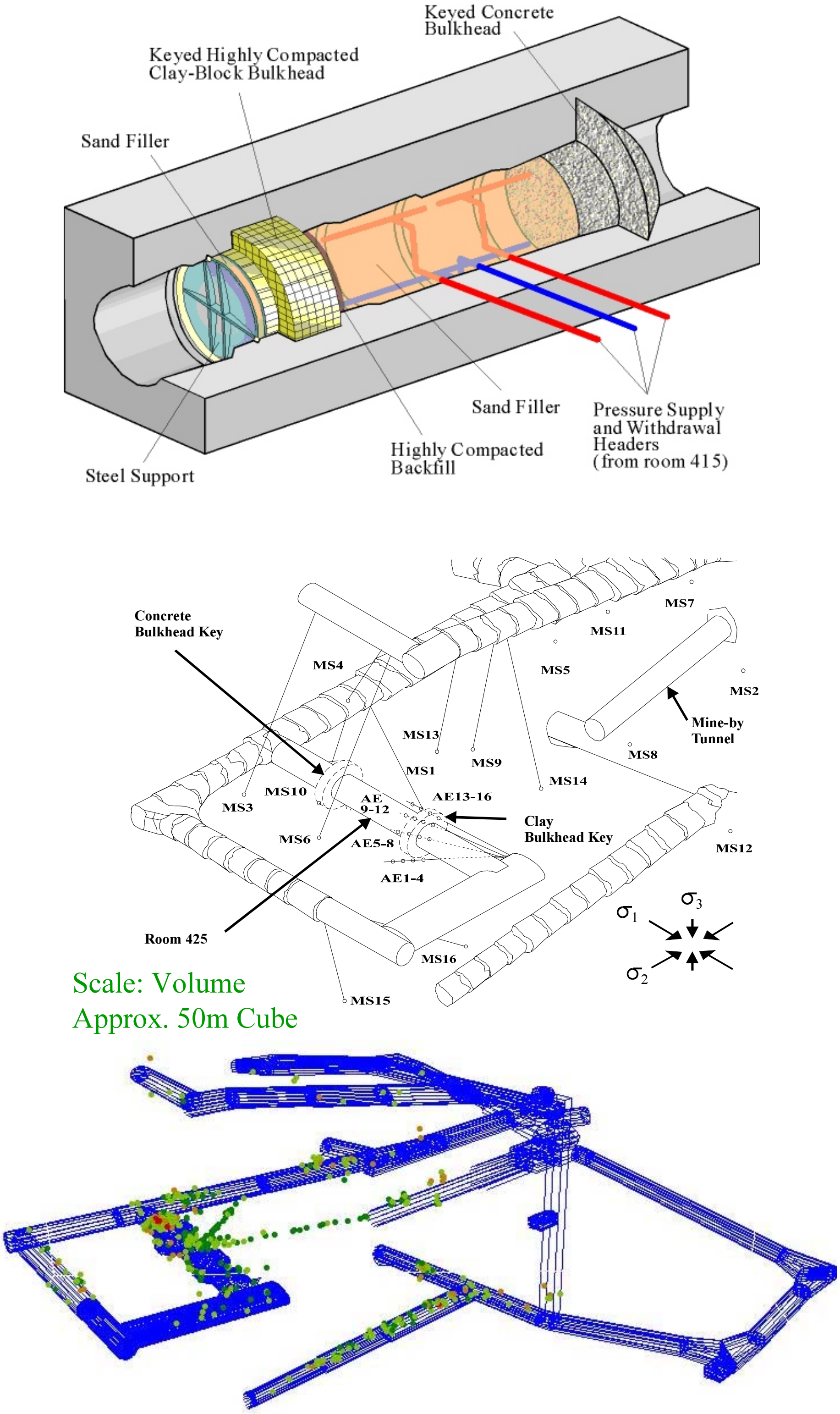
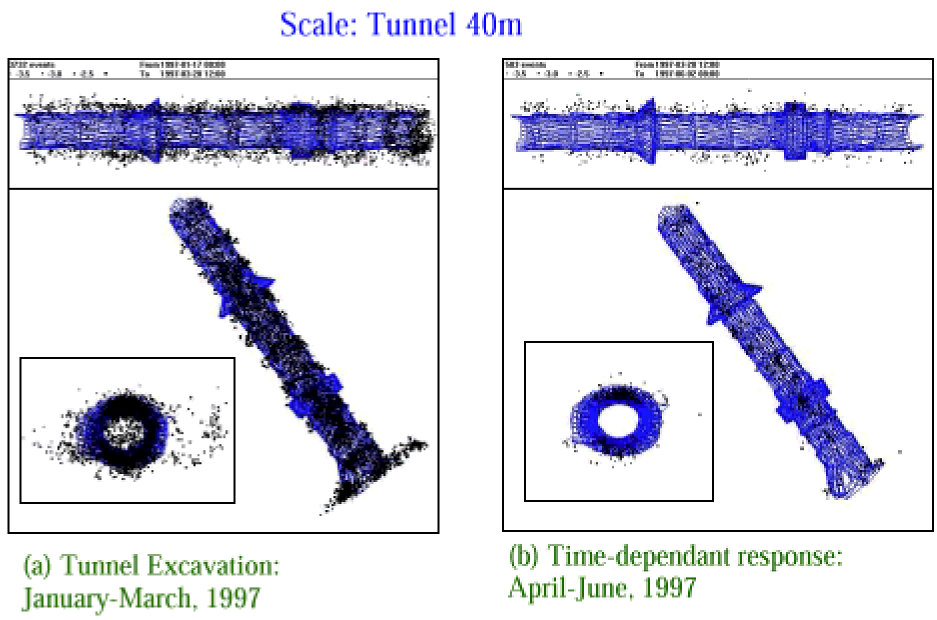
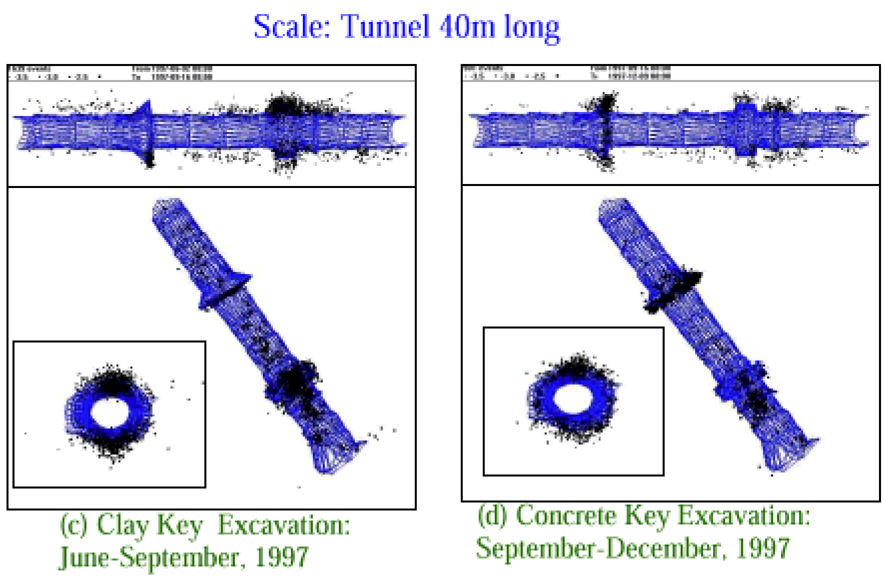


FIG. 1. The upper diagrams show the TSX tunnel, the two seal technologies, filler material and pressurisation boreholes. Also shown are the location of triaxial accelerometer boreholes around the TSX volume and the AE sensors in four boreholes surrounding the clay key. AE sensors were also placed within the concrete bulkhead to monitor long term curing of the concrete and rock/concrete seal integrity. The lower diagram shows some microseismicity aligned along pressurisation boreholes which highlights the resolution and sensitivity of the technique.

Figures 2a–d display the 6775 microseismicity (MS) events that occur in the vicinity of the TSX during the 4 periods of excavation activity (Table I).



FIGs 2a and 2b. Excavation induced microseismicity mapping the excavation-damaged zone around the TSX tunnel.



FIGs 2c and 2d. Excavation induced microseismicity mapping the excavation-damaged zone around the TSX tunnel.

TABLE I. ACTIVITIES DURING 4 PERIODS OF MS MONITORING

Date	Activity
Period 1: Jan 17 - Mar 20	Blast excavation of TSX tunnel (rounds 1-13)
Period 2: Mar 20 - Jun 2	No excavation in TSX tunnel
Period 3: Jun 2 - Sep 16	Part of concrete key excavated in floor. Complete clay key excavation.
Period 4: Sep 16 - Dec 9	Concrete key excavation. Excavate steel restraint slot.

Figure 3 shows the AE activity in the floor and walls of the TSX clay key, which was excavated for a bentonite bulkhead in August, 1997. The AE is only shown for the lower half of the tunnel where detailed monitoring was carried out. The calibrated mean location error of the AE events is 3.3 cm. The activity is concentrated in the modelled high stress regions in the floor of the tunnel and around the newly excavated key and along the boundary between the tunnel damaged zone and intact rock. The gap between the AE activity and the tunnel perimeter is because the induced AE from the key excavation is now activating the boundary between previously damaged rock from the tunnel excavation and intact rock. The time dependant response to the key excavation can be seen between August to December, 1997. In order to monitor the changes in elastic properties of the rock, the same AE sensors were used to pulse ultrasonic waves through the damaged zone, delineated by the excavation-induced AE.

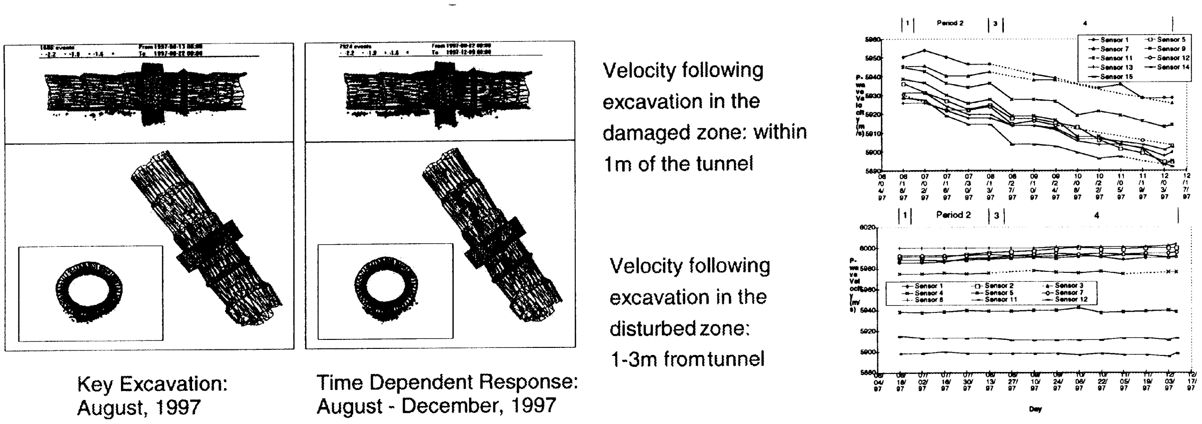


FIG. 3. AE activity and velocity change in the vicinity of the TSX clay seal.

Figure 3 also shows the change in P–wave velocity from June to December, 1997 in the seismically active zone within 1m of the tunnel perimeter and through the stress disturbed zone 1–3 m from the tunnel. By using cross-correlation/interferometry techniques, velocity change can be determined to an accuracy of between 1-3 m/s depending upon ray-path length. These data can therefore be used to monitor small excavation and stress induced changes in the rock volume. The graphs show ray paths, which pass in different orientations through the rock mass but each show consistent trends following excavation. In the damaged zone for the 5 months after excavation of the key the velocity reduces by 19–44 m/s dependant on ray path as the induced seismicity and damage continued. In the disturbed zone slight increases in P–

wave velocity are thought to be associated with preferential closure of microcracks in response to stress redistribution from the excavation. S–wave velocity measurements have been performed, with the results showing similar changes to P–wave data. This confirms that the velocity changes associated with the AE activity are primarily the result of microcracking rather than desaturation. The in situ AE and velocity data shows evidence for some time-dependant deformation in granite. This is consistent with a stress corrosion model proposed by Potyondy and Cundall (1998) using PFC for the modelling of notch development in the Mineby tunnel at the URL.

This technology has recently been applied to the study of the operational behaviour of the TSX concrete bulkhead. The methods have been successfully used to study:

- The curing process and its relationship to the material parameters of the concrete.
- The development of damage and the growth of macroscopic fractures. Using ultrasonic and AE methods the amount, location and orientation of fractures within a concrete bulkhead have been resolved.

Figure 4 shows an example of using ultrasonic methods to delineate and map the growth of a fracture in a concrete bulkhead. The acoustic emissions detected by an array of sensors embedded within the concrete are shown in 3 time intervals on 24 September, 1998. This allows us to identify the point of origin of the fracture and observe its development with time. The formation of this crack corresponded with a significant drop in pressure behind the bulkhead AE locations delineate a growing macroscopic fracture within the TSX concrete bulkhead. The P–wave velocity and amplitude variation for the ray path between pulser 4 and receiver 9 show initial increases during curing followed by rapid loss as the fracture grows. This ray path passes through the region of AE that occurred on 24 September, 1998, resulting in the large drop in AP, and no subsequent VP measurements. Subsequently the fracture was grouted and the AE and interferometer data used to determine if the fracture had been sealed. The data shows continuous VP measurements following grouting, and the AP value to have significantly increased, suggesting that the injected concrete grout has successfully filled in the connected microcracks along the ray path.

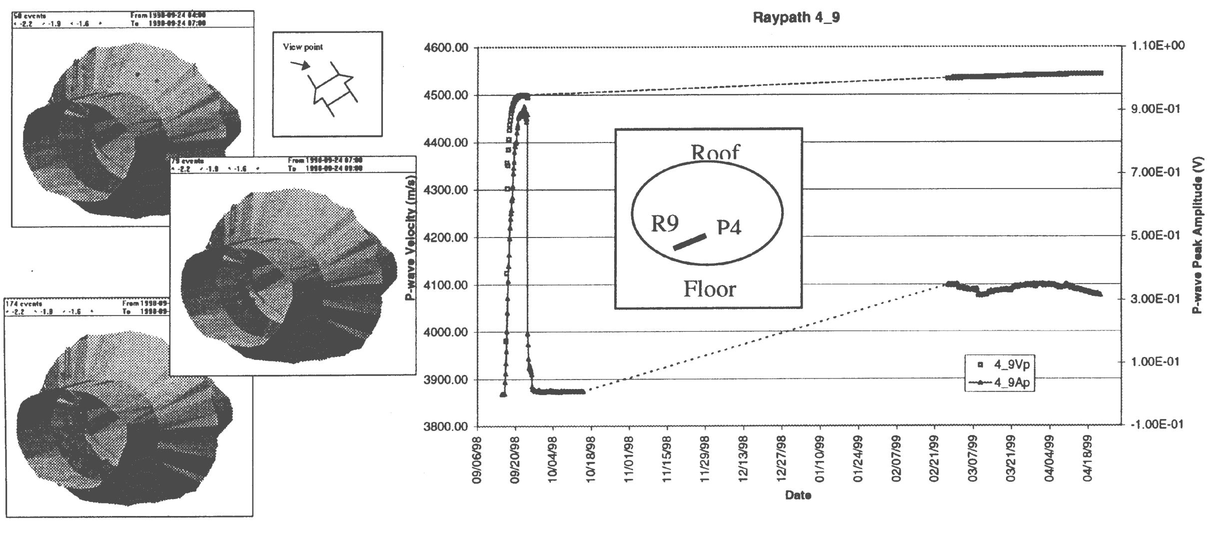


FIG. 4. AE data showing the delineation of a fracture during the curing of the concrete bulkhead. The velocity and amplitude interferometry data shows significant increases during curing. This is followed by signal loss during fracturing and the later data shows that the subsequent remedial grouting had filled the fracture and velocity and amplitude values recovered.

Case Study 2: Canister Retrieval Test (CRT) at the Aspo Laboratory, Sweden: The aim of the CRT is to illustrate that waste canisters can be safely retrieved from a repository underground environment. It is located at the 420 m level in SKB's Hard Rock Laboratory (HRL), Sweden (Fig. 5).

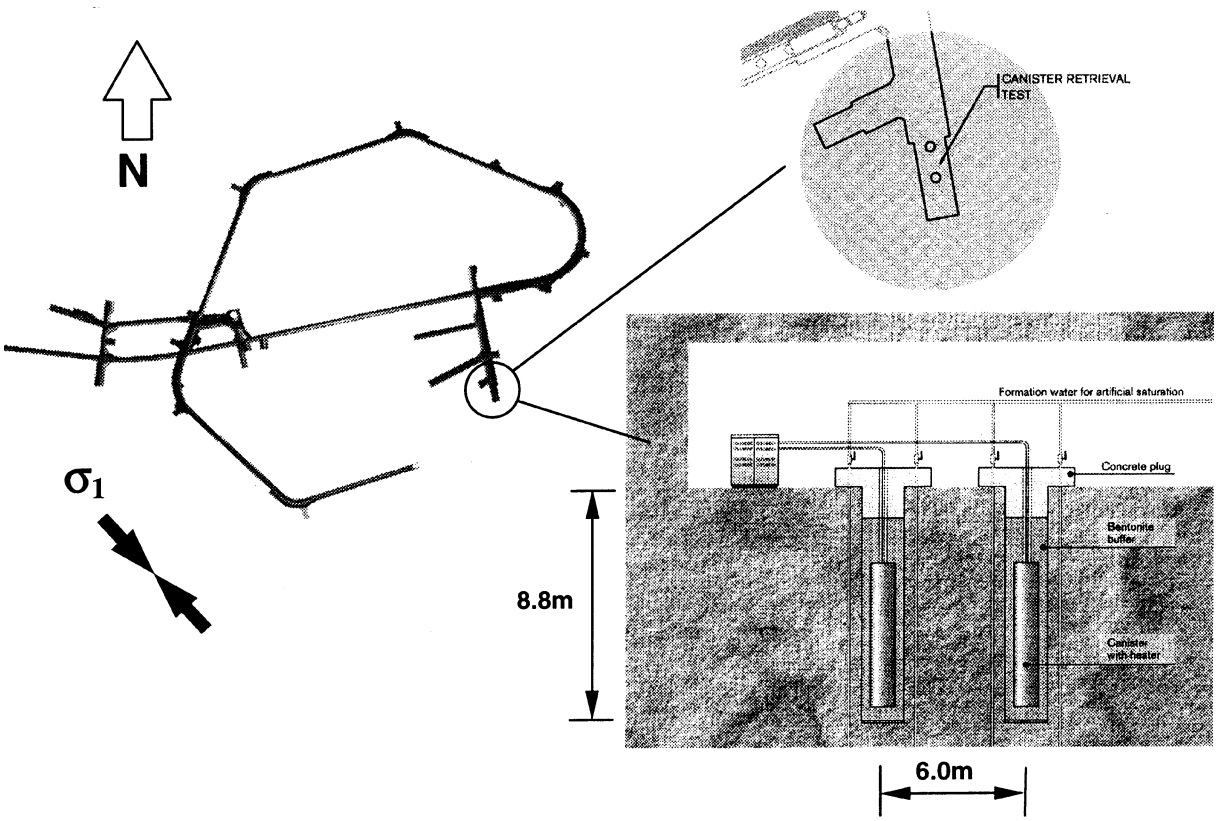


FIG. 5. Plan view of the experimental tunnels at the Äspö HRL and the location of the CRT. A schematic illustration of the final CRT experimental set up is shown with canisters and bentonite clay installed in the two 1.75 m diameter deposition holes (courtesy of SKB).

Two experimental deposition holes have been excavated in the Äspö granite as part of the CRT at the HRL, Sweden using a large diameter boring machine. The holes are 1.75 m in diameter and 8.8 m in length and were excavated in eleven 0.8 m rounds. An ultrasonic array was installed around each deposition hole to investigate the response of the rock mass to the excavation. Acoustic emission (AE) monitoring has been used to delineate zones of stress-related fracturing around the deposition hole perimeter. Changes in ultrasonic velocities, measured every hour, have been used to investigate the response of the rock mass over a broader time and volume than the AE scale, and to quantitatively measure the accumulation of fracturing in the damaged zone.

The AE results show regions of microfracturing located in clusters down the deposition hole wall (Fig. 6). These regions are orientated orthogonal to the maximum principal stress at the 420 m level. The damaged zone is restricted to approximately 20 cm from the deposition hole wall and activity decays rapidly within the first few hours after excavation. The clusters are probably a result of the interaction of induced stresses with excavation through pre-existing features. A linear macroscopic fracture is also imaged. AEs are strongly time-dependent with fracturing being reinitiated around previous rounds when excavation of the deposition hole continues. AEs occur at a much-reduced rate after completion of excavation. These effects are believed to be associated with stress redistribution in the pre-weakened regions.

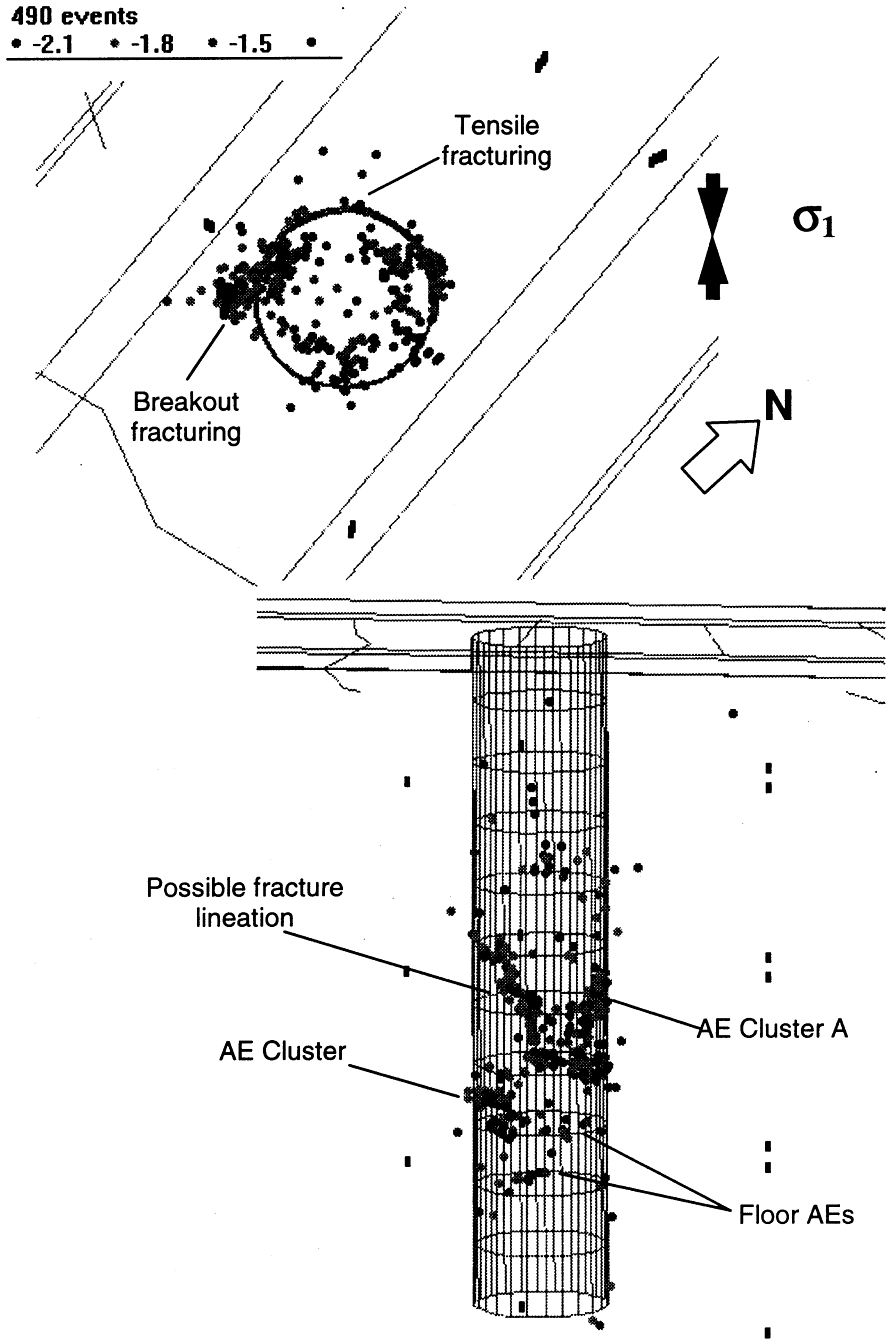


FIG. 6. AE locations from monitoring an experimental deposition hole. Events shown within the hole volume are those AE recorded ahead of the bottom of the hole at the time of excavation. The marker colour indicates the relative ultrasonic magnitude and black markers show transducer locations.

Ultrasonic surveys give velocities for the pre-disturbed rock mass as approximately 5900 m•s^{-1} for P–waves and 3350 m•s^{-1} for S–waves. A 3% anisotropy has been imaged. Surveys generally describe a drop in velocity during excavation. Observed changes vary from 4 m•s^{-1} for ray paths at distance from the deposition hole to sharp drops of 20–30 m•s^{-1} for ray paths skimming the deposition hole wall. These variations can be explained using a disturbed and a damaged zone model. As ray paths travel through the disturbed zone, in which induced stresses have preferentially opened or closed pre-existing microcracks, then the ray experiences small increases or decreases in velocity. This results in, for example, a 4 $m \cdot s^{-1}$ change observed at distance from the deposition hole. However, ray paths skimming the deposition hole perimeter at 2–3 cm distance pass through a region of accumulated damage close to the wall. These then experience a much sharper change in velocity of the order — 15 $m \cdot s^{-1}$ measured over the entire ray path. This corresponds to a 15% decrease in Young's modulus for the damaged zone. Fig. 7 shows the effect of excavation on velocity change in the EDZ.

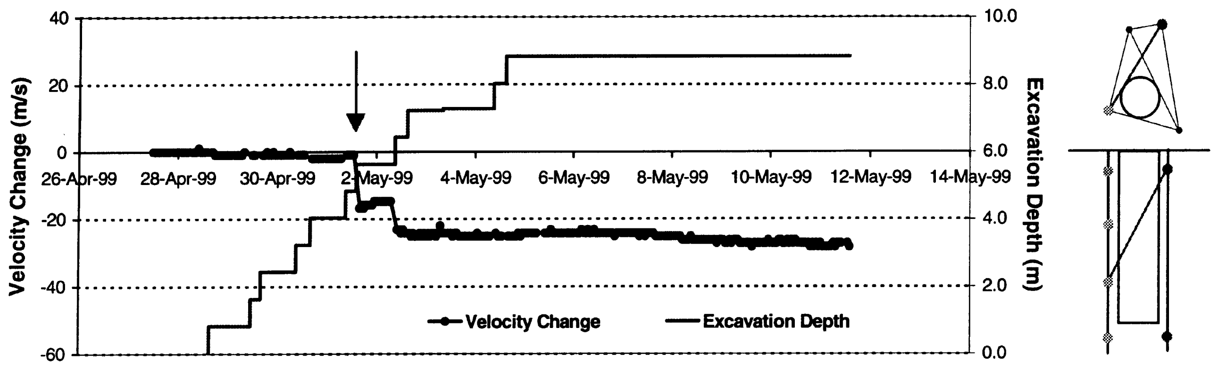


FIG. 7. Velocity change measured on the ray path illustrated in the right-hand margin. The red arrow shows the time at which excavation passed the ray path.

4. CONCLUSIONS

Acoustic Emission and ultrasonic techniques provide a remote, non-destructive method of monitoring the response of rock mass or concrete structure over a wide range of volumes. The relatively non-invasive nature of the technique, coupled with its ability to monitor both passively and actively over a long time period makes it ideal for civil engineering scenarios, particularly where the early identification of damage or damage potential is critical to the safe operation of the facility.

ACKNOWLEDGEMENTS

I thank the TSX international project team, AECL, ANDRA/EDF, PNC and WIPP for their scientific and financial support and permission to use some of the URL data. I also thank the Aspo Hard Rock Laboratory (HRL) team and SKB for their permission to use some of the HRL data. I also thank the staff of the URL and HRL for their continued support and enthusiasm for my work, especially Neil Chandler and Jason Martino of AECL and Dr Olle Olsson of SKB. I am especially grateful to members of my research group past and present especially Drs Calum Baker, Dave Collins, Jim Hazzard, Will Pettitt and Roger Bowes (ESG) who have contributed to different aspects of this work. I am also grateful to the staff of Applied Seismology Consultants (ASC) who were involved in the HRL case study.

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QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: What is the design life of the sensors? Would you need to be routinely replacing them if you wanted to save fifty years of retrievability?

A: Probably most of these sensors would last at least twenty years; probably they may even last fifty years. Some sensors that we use at the underground lab were installed in 1987 and they are still working today. This gives an idea.

Q: I think that if you conceive using them, for example, for safeguards application, it might be open-ended, because as long as there is a safeguard requirement you will have to listen to what happens and to any activity in the repository. But then, changing the sensors is not a problem because you are remotely located from the facility. Do you have any experience about efficiency of the method in different kind of rocks, for example, in clays?

A: I did not talk about this, because I kept it specifically to these two laboratories, but we have done work in Mon Terri and in Tournemire, both in Opalinus clay and also in the claystone materials that ANDRA is interested in. The softer rocks, of course, do not behave anywhere near as nice in terms of creating acoustic noise as granite will. They do create acoustic noise, but it depends on the speed at which the rock is deformed. If you, for example, deform rock salt very slowly, you might not get very much acoustic activity, but if you create a hole in it, the immediate response can create acoustic activity and it is the same in the claystone. So it is not as widely applicable for softer rocks. It depends on how fast the process takes place.

Q: Therefore safeguards application would work also in soft rocks I think.

A: Yes certainly if somebody would be drilling.

Q: Over what distances would you be able to use this? Would you be able to use it from the surface in a post-closure phase?

A: Well, that sort of question is like: how long is a piece of string? It depends to a certain extent on what level of threshold you want to go down to. If you want to detect a pencil lead break then you are not going to be able to do that from the surface. You need to be close. If you want to detect the equivalent energy releases of hammer blows, then you can do that from quite a considerable distance away from the repository. Likewise, you could detect really major activity from a long distance away from the repository. But to improve this whole monitoring process, the best way is not to do it from the surface, but to do it from just the sub-surface, because the first few metres of the upper surface of the rock are very weathered and they attenuate and dampen the sound waves. So if you get below that zone, you can improve the efficiency significantly without actually going into what might be considered the repository volume.

Q: What would be the resolution? You mentioned a couple of centimetres if you were close to the object. But say from 200–300 metres distance, what kind of precision in your geometric determination would you get?

A: Well, in the equivalent of the hammer blows, this was being done in a 50 × 50 × 50 metre volume. Hundreds of metres away you might get to accuracies of a metre resolution, which would tell you whether you were near to the repository or not, whether this activity was lining up in terms of some drilling or whatever.

Q: Do you think these techniques are really going to be of use in safeguards areas? We heard several people say: what are you going to be able to monitor in the short term to know whether you have to retrieve or not? Do you think these measurements are only going to be concentrated on safeguards?

A: I believe that they will be used probably predominantly for model validation, because, at the final repository stage, there is going to be some concern about drilling lots of boreholes in the actual volume itself, because of all the sealing problems that would follow. So I think the whole idea of developing this technology is that because it is remote and we will always have models to try and determine the processes that are going on. In order to make sure that these models are doing what we believe they should be doing, you have to have some way, some measurement, to actually validate them. I think these processes, these techniques are very valuable for that, and I think that probably will be a prime use of these techniques in the future.

Q: You mentioned, I think it was in the framework of the Canadian programme, the detection of micro-cracks or micro-whatever, in the concrete sealings. Do you know if — within the frame of that programme — anyone looked at what to do with the results of those measurements, like when is your sealing not good enough?

A: To be fair here I am giving you some results from an ongoing programme, so you can see that, at the moment, they are just starting to pressurise this particular tunnel, so the experiment is only half-way through. But some of these issues are going to be studied during the course of this experiment. I am giving you results from the early phases, if you like, the excavation phase and also the start of the pressurisation phase. The important thing here was that these instruments were in place before anybody went into this volume of rock, so you had the instruments sitting by and you could study as the first excavation took place and monitor any micro-cracks, and then see how those micro-cracks respond to any subsequent loading that might take place. And the loading can be when they simulate heat, which they hope to do in this experiment. This particular volume of water in that test tunnel will be heated to 80^{o}C, so you can, if you like, map out damage and disturbance that is happening around this tunnel and then see what aggravation the increased thermal load would have. And in fact they have developed models to try and predict the amount of extra stress that will occur on these micro-cracks. But what you do not have is an easy way of validating that, so this is where those techniques come in.

Q: I just wonder about the significance and definition of one metre damage zone and that one to three metre disturbed zone, respectively, in Canada in the URL. Can you say something about these zones at the conditions we have in crystalline rock here in Sweden? Also, do you plan to use this AE technique to study the concrete plugs in the tests at Äspö?

A: With regards to the first question, part of the problem is to try and relate this micro-cracking to permeability change. At the URL, this particular seal geometry was designed to try and cut off the excavation disturbed zone. So modelling had shown, that by creating a sealed plug of a certain shape and size, it was possible to cut off that tunnel excavation damage, and therefore reduce the axial permeability down the borehole. Studies are continuing to relate the mapped out zone to physical changes in permeability, and this work is ongoing. With regards to sealing experiments at SKB, at the present time, we are working on the retrievability test and I am not certain as to what other tests we may be involved in at Äspö at this point. But we are going to be monitoring in the prototype repository as well.

ALLOCATION OF RESPONSIBILITIES FOR MONITORING AND RETRIEVAL ACTIVITIES

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Abstract

Geologic disposal is considered by many to offer a way to achieve the long term isolation required for radioactive wastes. The extremely long timescales, however, have drawn attention to the need for society to plan far ahead into the future. Perhaps for the first time, much thought and debate is being explicitly devoted to the burdens and the benefits which a technology will bring to many generations in the future. The questions to be answered concern not only **what** the benefits and burdens are, but also **who** bears the responsibility for defining courses of action affecting future generations and for implementing any measures required to protect society beyond the lifetimes of those initiating activities with far future impacts. In the present paper, the intention is to review the actions which may have to be taken during and after the operation of a disposal facility, to consider who shares responsibility for such actions and to look rationally at how responsibilities can best be allocated to ensure that they will be fulfilled in a way which protects future generations from harm, be it physical or financial. The paper defines the phases in the lifetime of a geologic repository, and postulates that responsibilities are to be shared between governments, regulators, repository implementers, waste producers and potentially also supra-national bodies. The specific responsibilities ranging from conceptual planning through to financial provisions for actions are then listed. The allocation of these responsibilities is then discussed. The broad conclusions are that waste producers are responsible for all financing and for most of the specific actions to be taken. At very far future times, however, responsibility for a closed and sealed national repository must revert to the government of a State.

1. INTRODUCTION

The fact that radioactive wastes do decay with time (as opposed to some other toxins like heavy metals) opens avenues for protecting humans and the environment for all times. If one can isolate the wastes for sufficient time for decay to reduce the toxicity to levels which are harmless (given the natural dispersion of residual materials in the geosphere over very long times), then permanent protection is assured. Geologic disposal is considered by many to offer a way to achieve such isolation. The extremely long timescales, however, have drawn attention to the need for society to plan far ahead into the future. Perhaps for the first time, much thought and debate is being explicitly devoted to the burdens and the benefits which a technology will bring to many generations in the future. The benefits (or burdens) need not be direct; they can also be indirect results of actions taken by current generations which alter the future environment, preserve or exhaust raw materials, provide future freedom of choice etc Similar deliberations are certainly spreading to other activities such as disposal of chemotoxic wastes, exhaustion of raw materials etc.

The questions to be answered concern not only **what** the benefits and burdens are, but also **who** bears the responsibility for defining courses of action affecting future generations and for implementing any measures required to protect society beyond the lifetimes of those initiating activities with far future impacts. Does this generation have a responsibility to solve problems in a manner which **we** judge to be permanent and acceptable, without being certain of future attitudes? Conversely, is it more ethical to leave future generations to implement solutions which **they** judge adequate, even if this implies passing on direct burdens? Can we "square the circle" by implementing solutions which can either be left permanently in place or be reversed at any future time? The concepts being developed in the field of radioactive waste disposal may have wider societal repercussions.

In the present paper, the intention is to review the actions which may have to be taken during and after the operation of a disposal facility, to consider who shares responsibility for such actions and to look rationally at how responsibilities can best be allocated to ensure that they will be fulfilled in a way which protects future generations from harm, be it physical or financial.

Some of the issues involved concern legalistic points of title to wastes, contracts at different national and international levels etc. However, this paper does not attempt a legalistic analysis but concentrates rather on matters of principle (e.g. intergenerational equity) and practicality (e.g. which organisation is most fitted for any specific task).

2. PHASES IN THE LIFE OF A REPOSITORY

A waste repository goes through a series of phases during its long development history. The considerations in the current paper focus on deep geological repositories since all contentious issues connected with monitoring and retrieval are highlighted by this choice which maximises the timescales to be considered. The phases in this case cover times into the very far future since the long lived wastes foreseen for geologic disposal remain potentially hazardous for tens or hundreds of thousands of years.

The phases considered here are:

1. Planning and design — Already at this stage decisions with far reaching implications are taken.
2. Construction through to closure — This is the period of most intense activity at and around the site and also the phase of highest risk to local populations.
3. Active and institutional control — Here specific measures are taken on a continuing basis to minimise the probability of repository disruption and to maximise the probability of detecting any malfunction.
4. All later times — In this phase, although at most passive information archiving activities remain, consideration must still be given to responsibilities for unplanned developments (e.g. remedial actions or decisions to retrieve for other reasons).

In more detailed studies of responsibilities for monitoring and retrieval throughout repository lifetimes, such as that currently in progress under the auspices of the EU, the above operational Phase 2 is broken into finer activity periods. However, these are of more relevance for defining the specific activities to be undertaken than they are for broad considerations of allocation of responsibilities.

3. BODIES AND ORGANISATIONS SHARING RESPONSIBILITIES

At the highest national level, responsibility for societal actions with widespread, long lasting implications lies with **governments** and decision makers whose task is to represent the public. This is true in all countries, although the mechanisms to ensure that the government represents the people vary from nation to nation (elections, referenda, public opinion etc.). Evidently, at times in the future, beyond which the continuing existence of specific individuals and organisations is no longer assured, responsibilities for any relicts from the past — including repositories — must revert to government. At earlier times, however, responsibilities of different kinds are borne by the government, by the **regulators**, by the **implementers** or operators of a disposal facility and by the users, i.e. by the original **waste producers**.

Responsibilities in today's world can also be allocated above government levels, i.e. with international or **supra-national organisations**. Examples here are the United Nations, the European Union and so forth. For the particular case of radioactive materials, the IAEA already has supranational responsibilities in the safeguards and transport areas. It is not impossible that the IAEA could assume responsibilities or even ownership of materials in a closed repository, especially of wastes containing fissile materials which must be controlled for the sake of all mankind.

4. LEGAL LIABILITIES, OWNERSHIP OF WASTES

As indicated above, there are complex legal issues connected with ownership of radioactive wastes from their time of production to their final disposal. These differ from country to country. In some cases, the situation is clear, at least in principle. For example in the USA, it is foreseen that the Government will take title to spent fuel from utilities and with this title goes all future responsibilities. This works where the Government is also the repository implementer. The situation is more complex when a third party — for example a dedicated waste management organisation outside the Government — is the implementer. The possibilities then are that the original waste owners retain joint responsibility for future events or that a private body takes over the wastes and also the responsibilities. In either case, the Government must be involved in some way because of the ultimate responsibility which it will bear. Even more complex is the case where wastes are transferred from one country to another. The issues of transfer of title and of long term responsibilities then almost certainly become the subject of supra-national arrangements governed by intergovernmental treaties and agreements.

5. PRESENT AND FUTURE RESPONSIBILITIES RELATED TO MONITORING AND RETRIEVAL

Moving now from general responsibilities to the specific subjects of monitoring and retrieval, it is useful first to consider which activities must be carried out in these areas throughout the repository lifetime. A list of relevant actions is as follows:

1. definition of monitoring programmes for all phases (including definition of action levels and corresponding actions);
2. design of the repository to make feasible any monitoring or retrieval measures judged necessary;

3. execution of monitoring programmes from pre-construction through to post-closure phases;
4. construction, operation and closure of the facility;
5. decision to retrieve at any time (for safety or resource recovery reasons);
6. retrieval actions, if judged necessary;
7. financing of all monitoring activities; and
8. financing of any retrieval deemed necessary for safety reasons.

For actions 1 and 2, prime responsibility clearly lies with the repository implementer. However, he will possibly be constrained by conditions set by the regulator in order to reflect government policy. Regulations in the USA, for example, are relatively explicit on the monitoring programme and also on the need for retrievability for a given period of time. In Switzerland, the regulatory guidance is less easy to apply — post-closure monitoring and retrievability are not required (but are also not forbidden). Any measures taken to facilitate retrieval may not negatively impact on long term safety.

The execution of monitoring programmes throughout the first three phases in repository life is largely an implementer responsibility, although the regulator will certainly maintain independent oversight. In the far future, post active control period, it is reasonable to assume that monitoring around a repository location would be subsumed into some national environmental monitoring programme.

The actions during construction and operation of the facility which are obligatory with respect to potential retrieval concern the keeping of good records. All repository design features which could affect retrieval must be well documented, inventories and positions of waste packages must be maintained and all documents properly archived. This is clearly an implementer responsibility with regulator oversight. A more controversial construction issue concerns the inclusion of design features aimed at easing retrievability. Apart from the previously mentioned question of whether long term safety is then compromised, there is a philosophical choice between ease of recovery in case this is a chosen future course and difficulty of recovery to hinder misuse of fissile materials. The choice of philosophy in the design phase is societal or governmental, but the implementation of chosen measures is also an implementer responsibility with regulator oversight

Potential action 5, a decision to retrieve wastes, is a more problematic issue, primarily because there are potentially different reasons for retrieval. In the unlikely event that retrieval is needed because a malfunction gives rise to unacceptable risks, the decision will be enforced by the regulator if the implementer does not himself immediately react. Other reasons which have been suggested as potentially leading to retrieval are recovery of useful materials (fissile materials or isotopes) or a wish to implement a better technology. A decision to retrieve for either of these reasons would clearly have to be made at governmental levels. Where fissile materials are concerned, then supra-national consent to retrieve should also be a pre-requisite.

The justification for retrieval also would affect the responsibilities for performing the task. If inadequate safety is the reason, then clearly the implementer would be expected to perform directly or indirectly the work of recovery, reconditioning (if needed) and arranging an alternative disposition for the wastes. If the implementer no longer exists, or if the government should decide to retrieve for other reasons then all responsibility for further actions must transfer to the government.

Financing of all monitoring activities is also a clear implementer responsibility. In this case, however, the responsibility can be fulfilled for all future times even beyond the lifetime of the implementer organisation. Relative to the substantial costs of any repository project, the funding needed on a continuing basis for monitoring activities is small. The implementer can be compelled to establish at closure a dedicated fund which is large enough to generate sufficient interest for an effectively indefinite monitoring programme. The governments of future generations can then at any time take a political decision to terminate the monitoring and use the funds for other purposes, if they so wish. Public acceptance at the outset of disposal operations, however, may well be enhanced if dedicated funds were protected by legislation from being diverted for some (long) specified time period.

The final issue on the list, financing of retrieval, is perhaps the most problematic. Retrieval costs can be high — comparable to repository construction costs. Moreover, if retrieval is not to allow re-use of the materials, further actions (new siting, new waste treatments) can also be very expensive. The probability of retrieval being necessary for safety reasons, on the other hand, must be agreed by all to be very small before geologic disposal is allowed to take place. Nevertheless, the small remaining risk lasts for an extremely long time. How does one factor these considerations into a concept for allocating future financial responsibilities?

In principle, one could establish a dedicated fund also for retrieval. The resources needed depend strongly on the agreed time before retrieval becomes credible. If this is long, say hundreds of years, modest funding suffices. This option may well be justifiable because a robust designs for a repository can give high confidence that early failure is extremely unlikely. If sufficient funding to allow retrieval is, nevertheless, to be available at any time from day one following closure, then the cost of disposal rises considerably. Setting aside so much funding to cover such an unlikely event may not be the best use of society's resources. The chances of such a sum being left untouched by a long succession of future governments can also be debated!

An intermediate option, assuming that the utilities or governments which have generated the wastes will have a longer lifetime than an implementing body which has just closed and sealed its repository, is that responsibility reverts to the original owners of the wastes. The government would have to enact appropriate legislation for this variant, which may, in any case, be of minor importance since the difference in life expectations may be negligible on the scales being discussed here. No countries have yet explicitly legislated the far future responsibilities. However, discussions, for example in Switzerland where a new nuclear law is in preparation, have included this option for relieving the national government of some of its burden of responsibility for a longer time.

Ultimately, at some future time, all responsibility for buried wastes will revert to a national government, or to a supra-national organisation. The ethical debate which has been running for some time is whether this burden is less than the burden imposed by any other waste management strategy. In the judgement of the present author, the burden imposed by a properly sited and constructed repository is extremely small and there is no obvious alternative which places a lesser burden on future generations. Since there are currently no viable alternatives to geologic disposal, then — at a minimum — we should pass on accepted repository concepts, the required technological know-how, acceptable sites and adequate funding for future implementation of geologic disposal.

A final remark concerns the complication resulting from potential disposal of wastes in an international repository. Does the ultimate responsibility which unavoidably falls on a national government then extend for the host government to all of the wastes which have been imported? Rather than accept such a situation, it is conceivable that the host government might insist on State Treaties which continue to share responsibilities for the unlikely event of retrieval out into the indefinite future. It is equally conceivable that the customer country governments would be quite prepared to accept this shared responsibility. Given that no respectable country would allow its wastes to be exported to location judged to be less safe than that of a national disposal project, shared responsibility for a common international facility may well be more attractive than full responsibility for a national repository. This sharing could be under bilateral or multilateral agreements, but the probability that supra-national organisations would be directly involved is high.

6. SUMMARY OF RESPONSIBILITIES

In Table I below a visual impression of the shift in responsibilities with time is given, This is achieved by allocating responsibilities for the above numbered monitoring and retrieval tasks at each Phase in the repository life. For the body bearing the main responsibility in each case, the corresponding number is underlined and bold. Obviously, there could be much debate about the entries.

Nevertheless, the table shows that:

- joint responsibility and consensus is to be aimed at in the conceptual planning phase;
- through the operational life, the implementer carries the largest burden, controlled at all times by the regulator;
- in the active monitoring phase, the implementer may no longer exist but the original waste owners will do and the financial burdens can be borne by these; and
- at long times responsibility must revert to the government.

TABLE I. MONITORING AND RETRIEVABILITY RESPONSIBILITIES (LEAD ROLES UNDERLINED)

	Government (+ supra-national)	National regulator	Repository implementer	Waste producers or owners
Planning and design phase	1,2	1,2	1,2	-
Construction and operation phase	-	3,4,**<u>5</u>**	**<u>3,4</u>**,5,6,7,**8**	8
Institutional control phase	5	**<u>5</u>**	implementer may no longer exist	**<u>6,7,8</u>**
Long term post closure phase	**<u>5,6,8</u>**	-	implementer may no longer exist	producers may no longer exist

7. CONCLUSIONS

Concerning the allocation of responsibilities for monitoring and retrieval of wastes from radioactive waste repositories, the following broad conclusions can be drawn:

- 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 influences.
- 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 straightforward 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.

ACKNOWLEDGEMENT

The text of this paper benefited from thoughtful review by Gregg Butler, Neil Chapman, Malcolm Johnson and Jim Voss.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Chair: In your paper, you also included cost and financial responsibilities. Since we have a separate paper on that later in this session, I suggest that we postpone such questions until after next paper.

Q: You said that it would be likely that the waste producers would be lasting for longer times than the implementors. It might be true, but I think it could also be the other way round. A lot of things are happening in the field of utilities, so there could be big changes on that side too. I think one would have to think of that also. In the long term, the “waste producers” would not be the same, as when the waste was produced.

A: Maybe it might be a better terminology to say waste owners. The implementor has got to become the owner somewhere along the process. You cannot allow people to go out of business without having transferred their responsibilities properly.

Q: We have many examples of waste producers, who have vanished. Superfund has been looking for responsible parties and almost never they have found any, because they have disappeared, gone bankrupt. So eventually, the responsibility, in such a case, would go back to the government.

A: That is right, but we have got a better starting position here, because certainly — if you look at commercial nuclear power — we know who are the owners now. So you should not get into that situation. Any time an organisation does want to disappear, then it should not be allowed to do that unless it has formally transferred responsibility to another organisation further down the line.

Q: I have a comment or a question relating to your preamble actually, not about the main paper. You made a point that if you put retrievability high on your priority list, this may lead to postponement of geological disposal. I understood yesterday — from the NAGRA presentation — that they were putting it high on the list for the Wellenberg site. They are at least hoping to get underground earlier than they would do if they had not put it on. Maybe not geological disposal in the traditional sense, but by putting it high up they may get underground earlier. Do you have any comment on that?

A: NAGRA wishes to emplace the waste reversibly underground in a place where it will be also OK for disposal. If the requirements were to have only containers which you can inspect for cracks, for example, or retain the option to look at other host rocks, then you would not be able to go along that path. The basic bottom line of my argument is just that the most retrievable system of all is probably the one that is on the surface, that is, the most accessible. The NAGRA system is useful because it has some inherent advantages with horizontal entry and you can go in pretty easy. But if I want to look at another kind of deep facility for example, then it is more complicated to make it easily inspectable and totally retrievable at all times. Like Mikael Jensen said, if you want to take it out and if you want to have retrievability instantly, at any time, in a short period of time, then it drives you away from the disposal concept.

Q: I feel very unhappy. We have been discussing the ethical part of the business and now we are discussing the practical part. We are thinking in terms of passing money over 200, 300 years, of making a large fund and putting in a little money now and then. It will grow and grow, by interest and interest and we are acting under the assumption that the money would grow. But in the future after 200 years, somebody would have to do the work and I do not know if I would be able to do the work now if somebody 200 years before has decided and put some money aside. There is no automatics in this — that is my first point.

Secondly, we are discussing who will disappear first, implementors, regulators, owners, producers etc. I think this shows that — beside of the general ethics — there should be some kind of practical ethics, taking into account what really could and should happen. If we would start thinking in these terms of practical ethics, we should try to solve the problem as soon as possible. Very probably, we are able to forecast the future of the producers of electrical power for the next ten, twenty, thirty years; very probably for the implementors too, but I would not dare to forecast the future for us and our children in fifty or one hundred years. I just want to say that it is very difficult to pass funds to future generations and it is very difficult to pass know-how to future generations. It is probably even very difficult to pass information about where the "switch" is, to switch off the repository. The point is that we should not de-couple the benefits of the technology and the evils of the technology. We are now just discussing about the ways and in terms that this is evil and we are thinking that — somewhere in the next 5, 10 or 20 years — the benefits will stop and we are supposing that we are free to de-couple the waste problem from the benefit problem. I think this is the largest problem, the largest ethical problem, which we should discuss. Now we have incentive to solve the problem, but in 50 years we will have no incentive to solve the problem.

A: I hope nothing that I said was picked up as meaning we should not be trying to solve the problem now. About the difficulties in not solving the problem now, I agree with you. Then you would really have to pass on active know-how for decades on the surface and have the continuing present. I can envisage passing on funding more easily than I can envisage a continuing present where I pass on the whole capability into the future, solely for the purpose of maybe having to do something.

Q: One more very short comment. We have the demographic problem, that we are getting older and older, and we are putting some money aside in order that we shall have some remuneration when we are very old. But this is "dead money". If there will be no new generation working for us, this would be totally lost, and the same is true with the waste. We are not able to pass on money. Money is a convention, you have to do something for it.

A: I do not agree! Money is a way of passing things on, at least in the short time-scale. Money reflects the work which people have put in now to generate that money. I do not think it is a good idea to do it, but you cannot be blind to the fact that you can pass on some things by financial means. As you say, the money is only a convention for doing it, but the money translates, the money is there now because other people have done work now and you have got no other good way to pass it on. But I would rather pass on a sealed and safe repository.

C: Presently, times are very calm in the industrialised world, but we are not so sure that they are so calm in future, and therefore I can only underline what has already been said. Make the solution as soon as possible!

Q: I am just surprised about the comment about the inability to pass knowledge. Look at all the technology we have around. If aboriginals themselves pass traditional knowledge from at least seven generations, we should not be worried about not being able to pass knowledge with the technology we have.

A: Well, I understood it differently, it is not that you cannot pass the knowledge, it is just that it is not a good use of society's resources. Suppose that we finish with nuclear energy, and we end up passing on the knowledge to do the job that we could do now, just because we do not want to do the job now. That is where I see a problem. Do the job when the knowledge is here! That is a better over-all optimisation.

Q: I was just thinking about a situation, where you come out to a municipality and give this presentation of how responsibility would be transferred. First it would be with the implementors and the regulators and then it would be with the government and then it will go to some super organisation several levels over their heads. The politicians would feel more and more out of control, I think, even if it is not reflecting the 1000 year or 100 000 year time span, the local legislators and public like to feel that they are in control, that they have some insights on what is going on, what the results of monitoring are and how this possible decision of retrievability is being developed.

A: When I use regulator and government I do not mean national regulator and national government alone. The government and the regulator has a kind of local component as well.

Q: I believe that you are right, that when a facility is closed, the responsibility is away from the implementor and it goes over to society or to government. The situation, I believe, needs some more clarification in the case that the operator can show that any institutional control or so would not be needed from a safety point of view, but that society would demand such a institutional control for a certain period of time or forever, because they want to be convinced that what the operators say is correct. It is difficult to argue that the operator for such a programme of monitoring has responsibility for such a demand and I think you cannot ask an operator to be available for a few hundred years only for this purpose. If safety needs institutional control, then it is different and it is a planned activity, which the operator must do. But if it is safe without institutional control, I think the operator cannot be charged with responsibility any more and this must then be the responsibility of those who requested. The originator for this request is then the society and its government. What do you think about that?

A: Yes, I think in principle I agree with these coupled questions. As soon as the state agrees that you do not need any more monitoring, you move into my last phase, where the implementor is no longer responsible, anyway. If you are in the phase where you do not have *consensus* about the need for monitoring, then the responsibility stays with the implementor. It has to do with the confidence you have got in everything being all right, and somewhere down the line you have to have enough confidence to back off and the waste becomes a societal responsibility.

Q: You are talking very well about responsibilities. You thought about some future possibilities too, with international repositories and what that would require. I think that this question may be much closer to us than thinking ahead on international repositories. We have, I think in all our countries, decided that the waste should be taken care of within our countries, that is the general agreement within the European Union, in most countries. But at the same time, we start buying electricity from other countries. Some countries have phased out their nuclear energy. Sweden is about to do so, and then we will buy electrical power from Preussen Elektra, Électricité de France or whoever wants to sell to us. Should we have a moral responsibility to take care of the proportion of the waste that our consumption has introduced in these countries?

A: That is a really difficult question. I am not even sure if I want to get into a big discussion here, because I do not think it affects the other issues we were talking about up to the national level. My international part was an add-on, and you have picked up a very important part of it. What responsibility do we have for cadmium wastes because we import batteries from somewhere? But maybe we should talk about this outside the meeting. That is another dimension that will get too complicated for the meeting here.

Q: I just want to add another complication which is actually discussed in communities and that is that governments are not stable either. The other point is that the waste owners may also change and sometimes very quickly.

A: I agree, and my last word here would be I think these are all really important things and my only wish is that we do not discuss it just for nuclear waste disposal. I grew up in Scotland and I feel much more bitter by the fact that my ex-Scottish government has used up the whole of the North Sea oil which maybe could have made my grandchildren into Arab sheikhs in the future, to finance bad household keeping now.

COST-RELATED IMPLICATIONS OF RETRIEVAL: WHO SHOULD PAY? WHO SHOULD ASSESS THE COST/BENEFIT?

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Abstract

This paper contains an analysis of three different cases *when* a retrieval operation could take place. For each of the cases, the analysis covers three conceivable *reasons* for the retrieval. This means a total of nine scenarios to be analysed. One requirement for the analysis should be observed. That requirement is that there is, in a country, a system where assets are set aside today to cover such costs in the future which are caused by the current production of nuclear power. Within this framework, the analysis focuses on the financial implications of costs in connection with retrieva. (Consequences on the total national economy of such a financing system and of a retrieval operation are not discussed.) A financing system along these lines is consistent with two generally acknowledged principles: the *polluter pays* principle and the principle of *not imposing undue burdens on future generations*. But how are these principles applicable if, in the future, spent nuclear fuel were to be retrieved? Different time-horizons for a retrieval operation might produce different answers. And these answers might also differ depending on the reasons for retrieval. The three chosen approximate times for retrieval are retrieval after a 10 year demonstration period *(case 1)*, retrieval after the repository has ended its operating period but before final sealing has been carried out *(case 2)* and retrieval after about 50 years from sealing *(case 3).* The three reasons, which could be relevant in all three cases, can briefly be summarised as "the solution is not safe enough", "the solution is safe enough but a better method than the chosen one has been developed and should be applied" and "what was considered as nuclear waste when disposed of now represents an economic asset which should be used by Man".

1. THE PROBLEM

In many countries there is a system where assets are set aside today to cover such costs in the future which are caused by the current production of nuclear power. A financing system along these lines is consistent with two generally acknowledged principles, the *polluter pays principle* and the *principle of not imposing undue burdens on future generations*. But how are these principles applicable if, in the future, spent nuclear fuel should be retrieved? Different time-horizons for a retrieval operation might produce different answers. And these answers might also differ depending on the reasons for retrieval.

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* The author is also Chairman of the Board of the Swedish Nuclear Waste Fund. The paper is the result of a close co-operation with Olle Stångberg, Consultant and a former Director of the Asset Management Department, the Legal, Financial and Administrative Services Agency (Swedish: 'Kammarkollegiet').

2. PRINCIPLES FOR CARRYING COSTS FOR DISPOSAL

One of the internationally agreed fundamental principles of radioactive waste management is, that the waste "shall be managed in a way that will not impose undue burdens on future generations"[1]. One possible way for a country to comply with this principle is to establish a system whereby assets are set aside during the period when nuclear power is produced. In that case money will be available in the future when costs for final management and ultimate disposal of nuclear waste have to be covered. If such assets are to be provided by those who produce the nuclear energy, the system is also consistent with the 'polluter pays' principle.

One example of a country applying both these principles is Sweden. The current Swedish system for financing future expenses for management and disposal of high level nuclear waste/spent nuclear fuel comprises a fee that nuclear power producers have to pay to the government. The fee is a certain amount per produced kWh of nuclear electricity. These fees are collected in an interest-bearing government controlled fund, called the Nuclear Waste Fund. The fund is intended to ensure that the nuclear power producers are able to carry the costs for the future disposal of spent nuclear fuel, for other measures in connection with the final management of spent nuclear fuel, and for the decommissioning of the nuclear power plants. Certain legislation ensures that the Government cannot use the assets in this fund for any other purpose. The fee constitutes a production cost for the nuclear power producers and is reflected in the present-day consumer's price for the electricity. The fee-system is supplemented by a system of financial guarantees from the nuclear utilities, available to the government in the event that the size of the fund should prove to be inadequate.

The intended effect of this financing system is to ensure that the 'generation' of people which benefits from the use of nuclear power also will pay for the future costs for taking care of the waste, caused by the production. Today's generation should carry the entire financial burden, not pass it on to coming generations.

One of the prerequisites behind this financing system is the assumption that it is possible to determine, with a reasonable degree of certainty, the estimated costs of the whole future operation. Such cost estimates have to be presented annually by the producers of nuclear energy, who are the owners of the Swedish Nuclear Fuel and Waste Management Co (SKB). SKB's estimates are reviewed by a government authority, the Swedish Nuclear Inspectorate (SKI).

For calculating the fee per kWh, it is also vital to have a clear picture of **when**, in the future, certain measures will be taken, that is when costs will occur. The importance of this time factor is due to the fact that all assets in the fund create interest up to the moment they are spent. Another two assumptions also have to be made. One is, that it is possible to project, on a long term basis, the rate of return of the fund (the rate of return of the capital which is accumulated during the lifetime of the reactors). The other assumption concerns the lifetime of the reactors and how many kWh of electricity they will produce.

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[1] IAEA Safety Fundamentals: "The Principles of Radioactive Waste Management" (1995), see Principle 5. Cf. Joint Convention (1997) on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, Preamble XIV.

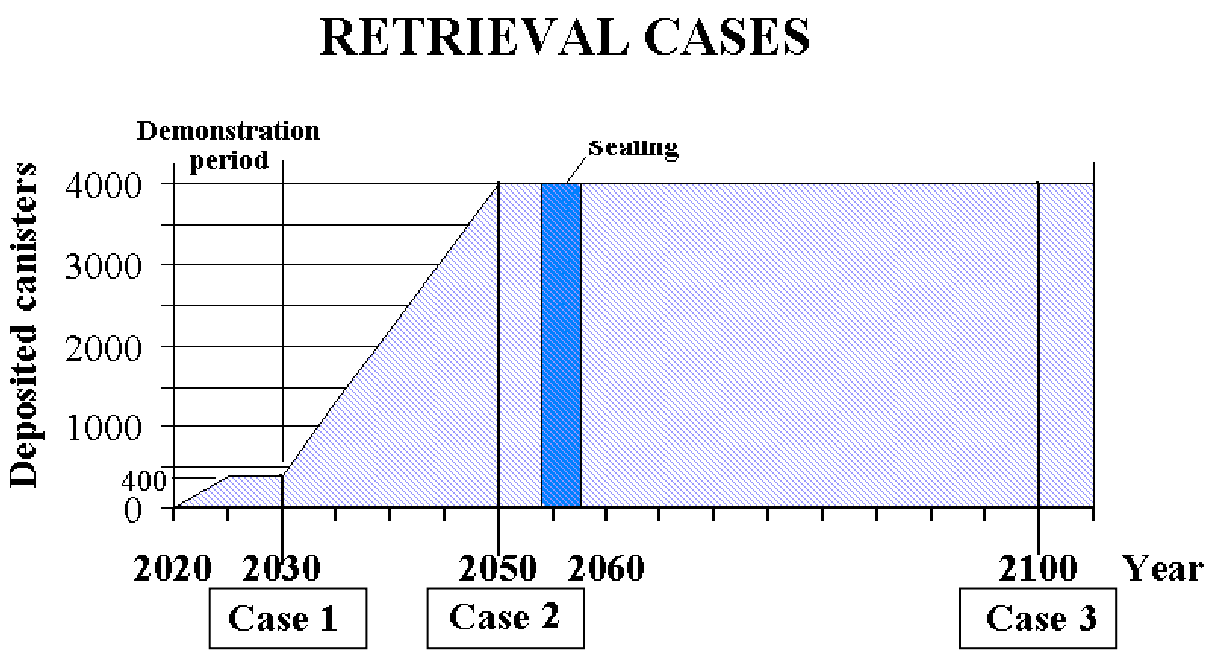
Inevitably, all three assumptions are exposed to a certain degree of uncertainty. However, the Swedish financing system for future expenses for spent nuclear fuel is intended to take into account such uncertainties up to what is generally considered as a reasonable level. The final judge of what is 'reasonable' is the Government, based on advice from the responsible regulatory authority, the SKI.

3. SOME MAJOR FEATURES OF THE TIME-TABLE FOR A SWEDISH DEEP DISPOSAL FACILITY

The following account is mainly based upon plans presented by the SKB in "RD&D–Programme 98". A response by the Swedish Government to these plans is likely to appear before the end of 1999.

Based on data from ongoing feasibility studies in six municipalities and from other material, SKB plans to select at least two sites during 2001 for more thorough investigations. These site investigations may take 4–8 years to complete. The results will be used for selecting one site for detailed characterisation and construction of an operational disposal facility of limited size. Such a facility could be ready to start operations after another 6–10 years. During an initial operational phase covering another 5–10 years ('demonstration phase'), about 5–10% of the encapsulated spent nuclear fuel would be placed in the repository followed by a thorough evaluation of the experiences of the operations. Based on the results from these evaluations, a decision would be taken on whether to continue to enlarge the disposal facility to allow for the rest of the spent fuel to be placed there and to carry out further such operations. Such a 'regular operation phase' is expected to last 20–30 years. A decision would then have to be made with regard to 'final sealing'. Two main alternatives seem to exist. One is to continue supervision and monitoring for some time without 'finally' sealing the repository. The second alternative is to 'finally seal', with or without a long term monitoring period.

These sequences can be illustrated as in Fig. 1[2]



[2] The figure on this page is partly based on a figure from SKB's RD&D Programme 98 p.12.

From SKB's projected timetable it can be concluded that initial operations of a disposal facility somewhere in Sweden might start within the 5–year period of 2015–2020. For the following analysis of cost implications of possible retrieval, year 2020 is chosen as the starting year for the initial operations of the disposal facility.

4. THREE POSSIBLE APPROXIMATE TIMES AND THREE POSSIBLE MAIN REASONS FOR RETRIEVAL

For this analysis three alternative approximate times for a retrieval operation have been chosen. In each of these three cases it is conceivable that a decision to retrieve depends on three alternative reasons.

The three chosen approximate times are retrieval after a 10 year demonstration period *(case 1*), retrieval after the repository has ended its operating period but before final sealing has been carried out *(case 2)* and retrieval after about 50 years from sealing *(case 3).*

The three reasons, which could be relevant in all three cases, can briefly be summarised as "the solution is not safe enough", "the solution is safe enough but a better method than the chosen one has been developed and should be applied" and "what was considered as nuclear waste when disposed of, in a new situation represents an economic asset which should be used by Man".

Cases and reasons are illustrated in the following figure. Nine different scenarios could be analysed and compared with each other.

CASE	**REASON FOR RETRIEVAL**		
	Not safe enough	Safe enough but a better solution is preferred	Former 'waste' is regarded as an economic asset
"10 years" ***Case 1***	***Scenario 1.1***	***Scenario 1.2***	***Scenario 1.3***
"Before sealing" ***Case 2***	***Scenario 2.1***	***Scenario 2.2***	***Scenario 2.3***
"After 50 years" ***Case 3***	***Scenario 3.1***	***Scenario 3.2***	***Scenario 3.3***

If this approach is applied on current plans in Sweden, the three cases above would occur at the following approximate points of time:

Case 1: Around year 2030 (10 years after initial operations of a disposal facility has started).

Case 2: Around year 2050–2060.

Case 3: Around year 2100.

As an attempt to make the following analysis of different scenarios (sections 5–7) as tangible as possible, it is based on a 'Swedish' approach[3]. But the principal lines of argument should apply to several other countries.

5. RETRIEVAL AROUND YEAR 2030 (CASE 1, AFTER A 10 YEAR DEMONSTRATION PHASE)

In case 1, about 5–10% of the total volume of spent nuclear fuel has been encapsulated and placed in a deep repository. This 'demonstration phase' of about 10 years results around 2030 in a decision to retrieve all encapsulated spent nuclear fuel from the repository. Who is the probable decision-maker in such a case? What cost considerations should be applied? Who should pay for the operation? Which are the approximate extra costs? Will the answers to these question be dependent on the underlying main reasons for the decision to retrieve?

Scenario 1.1. *Main reason: The chosen site and/or method is not considered safe enough.*

Description

Based on experience during the 10–year 'demonstration period' the implementer concludes that the selected site or the chosen method is not safe enough. As a consequence, a retrieval operation is considered necessary to allow for disposal using a different method and/or another site with more suitable conditions. A decision to retrieve might also be caused by an intervention by the regulatory authorities and the Government.

Cost implications

It seems obvious that both the 'polluter pays' principle and the principle of 'today's generation' carrying the costs should be applied. The rationale for having a 'demonstration period' is to allow for mistakes, misjudgements, evaluations, and prolonged considerations. If the demonstration period results in a conclusion that the chosen method and/or site is not safe enough, it seems clear that the producers have to carry the costs for a better alternative (and use money they have collected from those generations which have benefited from the use of nuclear power).

To some extent the Swedish financing system has been designed to be able to cope with such a situation. Possible additional costs in a situation of this kind are meant to be covered through the system of guarantees.

Approximately how much additional cost could Scenario 1.1 cause? As a part of SKB's 1998 cost estimates, a similar scenario has been presented. That scenario includes the actual retrieval operation, a new detailed characterisation and construction of a repository at an alternative site, investments in a facility for temporary storage of the retrieved encapsulated spent fuel, general delay of the disposal programme for 25 years, etc. The costs are estimated at SEK 10 700 million.

[3] It should be noted that current Swedish energy policy is based on the assumption that nuclear power production will cease at some given time in the future, although the year 2010 is no longer mentioned in policy documents.

This amount could be compared with today's estimation of future costs for the whole operation of management and disposal of all spent fuel from the Swedish power reactors and for the decommissioning of these reactors, around SEK 48 000 million. A comparison could also be made with the total projected spending for the whole operation (including parts of the decommissioning work) during the period 2010–2029. For this period, SKB in its 1998 estimates has calculated the total costs to be covered by the financing system to be SEK 20 250 million (SKI Rapport 98:34 enclosure 2 page 17; in Swedish).

As mentioned above, the system of guarantees is meant to cover, to some extent, the economic consequences of such a situation. When estimates are made concerning the suitable size of such guarantees, the probability of a certain event is also taken into consideration. Based on the advice of SKI, the Government has decided that the guarantees for covering extra costs for a number of possible, but less probable, events (one of which is the described retrieval situation) should gradually be built up to around SEK 7700 million.

At the same time it should be noted that if a retrieval operation starts relatively early (after the demonstration period in this scenario), a considerable part of the assets in the Nuclear Waste Fund will still be left in the Fund and create more income to the Fund in the form of interest. Such income could contribute towards covering the extra costs for an early retrieval operation, given that the rate of interest exceeds the rate of inflation (real interest is positive).

Scenario 1.2. Main reason: Although the method is considered to be safe enough, a better method has been developed and should be applied

Description

When the 10–year 'demonstration period' comes to an end, both the regulatory authorities and the implementer agree that the chosen method and site still meet safety requirements. But scientists have developed an alternative method which seems to meet safety requirements with a considerably better margin. That alternative method has been developed to a stage where it would be possible to apply it without any delay. Based on advice by the regulatory authorities, the Government orders the implementer to retrieve the contents of the repository and to apply this alternative method.

Cost implications

Both the 'polluter pays' principle and the principle of 'today's generation carrying the costs' should be applied. The fact that a viable, more safe, solution has been developed during this comparatively short period of time is a strong argument for adhering to the basic principles for cost-responsibility.

Although it is not possible today to make any reliable calculations of the extra costs in Scenario 1.2 (cost calculations can hardly be presented for a method that is still waiting to be developed!), it is assumed in this analysis that extra costs might be in the same order as in Scenario 1.1. The consequences for the financing system are probably the same as in Scenario 1.1.

Scenario 1.3. Main reason: Direct disposal of spent nuclear fuel is no longer considered a good solution because in a new situation what was regarded as nuclear waste when disposed of, now represents an economic asset which should be used by Man.

Description

When the 10–year 'demonstration phase' comes to its end, both the regulatory authorities and the implementer agree that the chosen method and site still meet safety requirements. But new technology, and/or changed attitudes in public general opinion, leads to re-thinking about the concept of 'nuclear waste'. Such re-thinking could mean that spent nuclear fuel should not be regarded as waste to be disposed of. Instead, spent nuclear fuel represents an economic asset from which more energy and/or valuable raw materials can be extracted in an economic way.

Cost implications

Even if Scenario 1.3 is very unlikely to happen, given the short period of time between the start and the end of the 'demonstration phase' (10 years), some arguments of a more principal nature can be discussed.

Scenario 1.3 means that the owners of what was regarded as 'waste' to be disposed of at a certain cost are suddenly in possession of a valuable asset which can be exploited for profits. So there is no longer a need to use money that has been collected within the nuclear waste management financing system to cover costs for waste disposal.

It could also be argued that in such a situation a surplus in the financing system should be reimbursed to the nuclear industry, as the money is no longer needed for the intended purpose. The legislation regulating the Swedish financing system contains provisions which could be applied in a situation like Scenario 1.3.

Furthermore, it could be argued that in Scenario 1.3 the owners of the spent nuclear fuel, that is the nuclear power companies, are entitled to the profits from an exploitation of the material. But the issue is complex and needs to be discussed taking into account all factors that have led to Scenario 1.3. This paper is not the place for such a discussion.

6. RETRIEVAL BEFORE SEALING (CASE 2, AFTER A REPOSITORY HAS ENDED ITS OPERATING PERIOD BUT BEFORE FINAL SEALING IS CARRIED OUT)

When all spent fuel has been disposed of in a repository, a decision has to be made whether to finally seal the repository or not. A decision not to seal the repository might be combined with a decision to await the results from a period (limited or open-ended) of monitoring. Such a decision might also be combined with a decision to immediately retrieve all nuclear material which has been disposed of in the repository.

Case 2 in this analysis represents the last mentioned situation. Given current plans in Sweden, such a situation could arise around year 2050–2060. Who would be the probable decision-maker in such a case? What cost considerations should be applied? Who should pay for the operation? Which are the approximate extra costs? Will the answers to these questions be dependent on the underlying main reasons for the decision to retrieve?

Scenario 2.1. Main reason: The chosen site and/or method is no longer considered safe enough

Description

Based on experience during later parts of the operational phase of the repository, the regulatory authorities conclude that the selected site or the chosen method is not safe enough. As a consequence, a retrieval operation is considered necessary to allow for disposal using a different method and/or another site with more suitable conditions.

Cost implications

A retrieval decision at this time would obviously lead to significant economic consequences. Therefore, the issue of who should pay for such an operation would probably be controversial. Given the significant costs for the operation, it seems more probable that such a decision would be initiated by the regulatory authorities and the Government than by the implementer.

The principle of 'today's generation' carrying the costs can hardly be applied. The Swedish financing system has not been designed to carry costs of this magnitude[4]. But the 'polluter pays' principle is still valid. It is worth noting that spent nuclear fuel, according to the current Swedish legislation, is not regarded as owned by the state. It is owned by the utilities who have to bear their own responsibility. The current legislation contains no provisions saying exactly when this responsibility ends, but it is generally assumed that the Swedish state, at some time in the future, has to declare that the owners have fulfilled their responsibility concerning the management of nuclear waste and are relieved of that responsibility. Such a declaration would probably also mean that they should no longer be regarded as the owners of the contents of the repository. It seems reasonable to assume that such a declaration will be made in connection with a decision to allow sealing of the repository. This issue has not been discussed in depth so far in Sweden. These comments should therefore be regarded as very preliminary.

So even if the Swedish financing system (the Nuclear Waste Fund combined with guarantees) cannot provide the necessary means, the owners of the waste still have a legal obligation to bear the costs for retrieval in Scenario 2.1.

Scenario 2.2. Main reason: Although the method is considered to be safe enough, a better method has been developed and should be applied

Description

Experiences and observations during the operational phase of the repository have not resulted in any revised judgement concerning the long term safety of the repository. But scientists have developed an alternative method which seems to meet safety requirements with a considerably better margin. That alternative method has been developed to a stage where it would be possible to apply it without delay. Based on advice by the regulatory authorities, the

[4] It might, however, be theoretically possible to raise the fees to a level that would allow also for this situation. But does the principle of 'today's generation carrying the costs' necessarily include also costs that will occur only in a very unlikely future situation?

Government orders the implementer to retrieve the contents of the repository and to apply this alternative method.

Cost implications

A retrieval decision under these circumstances would have the same economic consequences as in Scenario 2.1, but would probably be considerably more controversial. It is hard to imagine a Scenario 2.2 unless the Government, based on advice by the regulatory authorities, have forced the implementer to carry out the retrieval operations.

Using the same arguments as in Scenario 2.1, the conclusion is that the owners of the waste (the implementer) still have a legal obligation to carry the costs for retrieval in Scenario 2.2. But such a conclusion is probable to be called into question by the implementer.

Scenario 2.3. Main reason: Direct disposal of spent nuclear fuel is no longer considered a good solution because in a new situation what was regarded as nuclear waste when disposed of, now represents an economic asset which should be used by Man.

Description

Experience and observations during the operational phase of the repository have not resulted in any revised judgement concerning the long term safety of the repository. But new technology, and/or changed attitudes in the public general opinion, leads to re-thinking about the concept of 'nuclear waste'. Such re-thinking could mean that spent nuclear fuel should not be regarded as waste to be disposed of. Instead, spent nuclear fuel represents an economic asset from which more energy and/or valuable metals can be extracted in an economic way.

Cost implications

The arguments presented under Scenario 1.3 might be more relevant in Scenario 2.3. Both scenarios mean that the owners of what was regarded as 'waste' to be disposed of at a certain cost are suddenly in possession of a valuable asset which can be exploited for profit.

However, there is one considerable difference between the two scenarios 1.3 and 2.3. In the latter case, the disposal operation is completed and the costs for the operation have been paid, using money from the financing system. So there no longer exists any surplus in the financing system to be reimbursed to the nuclear industry.

As in Scenario 1.3 it could be argued that the owners of the spent nuclear fuel, that is the nuclear power companies, are entitled to the profits from an exploitation of the material. But the issue is even more complex in Scenario 2.3 as this scenario is more distant.

7. RETRIEVAL AFTER ABOUT 50 YEARS FROM SEALING (CASE 3)

The prerequisite for Case 3 is that the 'final repository' for spent nuclear fuel has been sealed after the operational phase. All parties concerned — the implementer, as well as the regulatory authorities and the Government — made such a decision because they felt convinced that sealing was the best alternative, also taking into account long term perspectives. The state has declared that the former nuclear power companies have met their responsibilities as defined in the legislation. As a consequence, the responsibility for the contents of the repository has passed to the state (which seems to be in accordance with Preamble (vi) of the 1997 Joint Convention on the Safety of Spent Nuclear Fuel Management and on the Safety of Radioactive Waste Management).

But approximately 50 years later the situation has changed completely and the Government decides that the contents of the repository should be retrieved. Case 3 in this analysis represents such a situation. Given current plans in Sweden, such a situation could arise around year 2100. Who would be the probable decision-maker in such a case? What cost considerations should be applied? Who should pay for the operation? Which are the approximate extra costs? Will the answers to these questions be dependent on the underlying main reasons for the decision to retrieve?

Scenario 3.1. Main reason: The chosen site and/or method is no longer considered safe enough

Description

Based on experiences after the sealing was carried out, the Government, advised by the regulatory authorities concludes that the repository is not safe enough. As a consequence, a retrieval operation is considered necessary to allow for disposal using a different method and/or another site with more suitable conditions.

Cost implications

A retrieval decision at this time would obviously lead to significant economic consequences. Given this fact, it can be assumed that Scenario 3.1 will only appear if the safety reasons are considered to be obvious. The costs for the operation will no doubt be weighed carefully against the risks of not retrieving.

As the earlier financing system has served its purpose and the former owners of the contents of the repository have been relieved of their responsibilities, there is only one actor left to carry the costs. That actor is the state and future generations of taxpayers.

Scenario 3.2. Main reason: Although the method is considered to be safe enough, a better method has been developed and should be applied

Description

Experience and observations during the operational phase of the repository have not resulted in any revised judgement concerning the long term safety of the repository. But scientists have developed an alternative method which seems to meet safety requirements with a considerably better margin. That alternative method has been developed to a stage where it would be possible to apply it without delay. As a consequence, a retrieval operation is considered necessary to allow for disposal using a different method and/or another site with more suitable conditions.

Cost implications

With reference to what is said under Scenario 3.1, such a scenario seems highly improbable. However, the same arguments would apply.

Scenario 3.3. Main reason: Direct disposal of spent nuclear fuel is no longer considered a good solution because in a new situation what was regarded as nuclear waste when disposed of, now represents an economic asset which should be used by Man.

Description

Experience and observations during the operational phase of the repository have not resulted in any revised judgement concerning the long term safety of the repository. But new technology, and/or changed attitudes in public general opinion, leads to a re-thinking about the concept of ‘nuclear waste’. Such re-thinking could mean that spent nuclear fuel should not be regarded as waste to be disposed of. Instead, spent nuclear fuel represents an economic asset from which more energy and/or valuable metals can be extracted in an economic way.

Cost Implications

As in Scenario 2.3 the issue of costs in no longer relevant. However, Scenario 3.3 means that there is a profit in the operation. As the responsibility for the contents of the repository in this scenario is presumed to rest with the state, it seems reasonable that a surplus from the operation goes to the state and the taxpayers of that generation. However, the validity of such a conclusion might also be dependent on future provisions in mining regulations.

8. CONCLUSIONS

A retrieval operation carried out in any of the nine scenarios defined in Section 4 might have the following cost-related implications, from a Swedish perspective.

If a retrieval is carried out after a 10 year demonstration period (Case 1), it is clear that both the ‘polluter pays’ principle and the principle of ‘today’s generation carrying the costs’ can be applied. The government controlled financing system seems to be sound enough to handle both Scenario 1.1 and Scenario 1.2. In Scenario 1.3, the financing system would create a surplus, which might be reimbursed to the nuclear power companies. It could also be argued that, in this scenario, the owners of the contents of the repository — the nuclear power companies — are entitled to the profits of a possible exploitation of the contents.

In Case 2 (retrieval after the repository has ended its operating period but before final sealing has been carried out), the ‘polluters pay’ principle would still be applicable. But the government controlled financing system is not constructed to take care of such a case and the application of the ‘polluters pay’ principle would probably be controversial both in Scenario 2.1 and, even more, in Scenario 2.2. Scenario 2.3 could lead to similar conclusions as Scenario 1.3 with regard to profits from a possible exploitation of the contents of a repository.

Case 3, retrieval about 50 years after sealing, presents a markedly different situation. This is caused by the fact that the government, in connection with a sealing permit, is presumed to have declared that the former nuclear utilities have met their responsibilities as defined by legislation. Such a declaration would probably mean that the responsibility for the contents of a repository has shifted from the nuclear companies to the state, although future provisions in mining legislation have to be taken into account. It would not be possible, in any of the Scenarios 3.1, 3.2 and 3.3, to apply the two basic principles that we use today. A retrieval operation in any of these scenarios would have to be paid for by the generations living around 2100. They have to judge whether the arguments for a retrieval operation is 'worth' the costs. We cannot make that choice for them.

Is today's generation acting in a morally defendable manner in view of the Case 3 scenarios? I believe the answer is yes. The line has to be drawn somewhere. It would simply not be reasonable for our generation to provide financing for situations that, based on thorough considerations, are regarded as very unlikely to occur.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: Your scenarios 1 and 2.2 seem to be the most problematic ones, when it comes to economics. Would it be unreasonable to think of some ideas — perhaps the creation of a fund — that could be used at the time of sealing, for other things than nuclear? It is still perhaps unfair to the nuclear industry to impose fees that might never be used and that might in the future be put to other uses for other clean-ups, but is this a possible way to go? I know it is difficult for reactor owners in Sweden to do this, but is it something that could be considered in Sweden?

A: As I said in my concluding remarks, I think the line has to be drawn somewhere. One has to ask the question, who should make that decision. The level of guarantees that we have presently in our system is ultimately decided by the Government, because it is a matter of opinion how much guarantee you should ask the owners to put up, and it is a matter of judging the probability of an event and the costs. As that system now works, it is up to the owners to propose something, the SKI will endorse that or say something else and then this issue goes to the government. I do not see any other way of solving this judgement problem.

Q: Does that mean that the government has to power to over-rule SKI and SKB with regard to the level of guarantees?

A: Yes of course they are free to do that. The reason why this is a government decision and not just a decision by SKI is simply that it is considered to be not only a question of mathematics. Also other factors should be applied to such a decision (the size of the fee and the size of the guarantees).

Q: In the phase one scenario, the future costs depend on the hypothesis that there will be a second repository. What is the probability that there will be a second repository if the first is abandoned for safety reasons?

A: I do not remember exactly what the probability for this is in SKB's calculations. I suppose SKB has the answer to that question.

C: Given our current level of opposition, I do not believe that society would go through a similar experience again, if a repository was seen to fail for safety reasons.

A: I suppose that one of the costs that SKB is taking into account is that the programme will be delayed for at least twenty-five years.

C: I cannot give a very good answer to that — speaking for SKB — but if this first repository is not regarded as safe enough, there are of course special reasons. One possible reason could be that we have some new understanding and that some new knowledge has been developed.

That does not have a connection with any direct malfunction. It might even be that the criteria for safety have been changed, or something like that. And then of course the issue is whether this change or new knowledge could be compensated for by new actions or something.

C: I would like make to make a general comment — also from the industry's side — about this interesting exercise in terms of thinking about every possible scenario. At the same time, I would like to inject a different perspective, because I feel a little uneasy, when I hear this discussion. Suppose that we would have such a discussion in the feasibility study municipalities, what would we then communicate? I think we have to reflect about that, and I would like to start by saying that my feeling is that we maybe already have gone too far from the industry side. It is obvious that we should accept to make some extra funding, for example, to allow some extra time for the first phase and allow us to go back from that. But now there is a discussion about additional extra funding. We should remember that we build full-scale underground laboratories, we build full-scale encapsulation plants. Even before making any repositories, we are spending billions of SEK to get a very solid basis for the case. So there is a solid basis for starting siting and starting the development and implementation programme. To me, we have now reached the limit for how far we should go with setting aside resources in case of very, very, very improbable scenarios. To go further than that, I feel, would be to push too far in this particular area and according to my own judgement that would not be a very good use of societal resources, material resources and resources for expertise. I think that if we go too far even in the discussion of these things, we communicate a message implying that we do believe that our solution is not safe enough.

SUMMARISING DISCUSSION ON SESSION 4

N. Rydell (chair)

I would like to bring up the aspect of retrievability and reparability, about possibilities for future generations to take their decisions. I think we should discuss this here, because Anne–Marie Thunberg was the one who pioneered. I particularly like a sentence she wrote on page 4 of her paper. “Retrievability is more a less a temporal prerequisite for a safe further system development and is limited to the pre-closure period. In regard to future safety, a reversible process during the construction period has a value of its own and as such it can raise the level of confidence in the system.”

We have spoken of retrievability as kind of persuading the local population at the site that in case something comes out wrong, we can retrieve waste, we can move it somewhere else. But I do not think that assurance is only for the local public at the selected site. It can go just as much for myself, since we are doing the first of a new kind of installation. The requirements on the repositories are unusual. We are making them for a service period of thousands, ten thousands of years. So it may be an uphill work, it may be difficult, as was said here. The first site may show deficiencies. It is possible that we will have to move from one site to another. There may be oversights in the design of the canister or the engineered barriers. But let us look on what will be behind a decision on closure.

According to the SKB programme — and I think it will be similar in other countries — there will be more than 40 years from the establishment of a repository prototype, like the one SKB will build at Äspö. There will have been perhaps 35–40 years of experience, monitoring of the first demonstration sized repository. We can have sensors close to the canisters and in the buffer etc. because we should anyhow demonstrate retrievability and it will be retrievable. And when, some time 40–50 years later, we may wish to make a decision to close, we can do that based on long experience of canisters, engineered barriers and the host rock from actual experience.

Olof Söderberg points also at three reasons why we might want retrieval. “Not safe enough”, “Safe enough but a better solution is preferred” and “Former waste is regarded as an economic asset”. These questions will naturally be brought up when the government should take a decision on closure or not. So in that situation, it is up to the authorities to say that they are satisfied, that the safety of the repository as built, is in accordance with the safety assessment and the performance assessment. The government can overlook the consequences for at least the nearest few hundred years. And, of course, then the government also in a way says that it accepts the solution, and is not looking for something better.

If the fuel subsequently, a hundred years later or so, would be regarded as an economic issue, it is not a problem that you have closed the repository, because, as someone pointed out, it is not a particularly difficult mining exercise to retrieve this waste if one would like to do so. What I want to say is, that you are fully justified to talk about retrievability in connection with the establishment of the repository up to the time of closure. I think we should cease talking about retrievability after the closure. Because what could really happen? We have still some heating of the rock, obviously. The host rock system is still under development, as is also the disposal system, but it is not very much left. We can have non-invasive monitoring to locate and listen for creep in the rock, which can happen due to the heating, we can take water samples of the groundwater, we can do that from downstream of the repository and upstream of the repository and make sure that these are in accordance with the performance assessment. The action to undertake, if something happens, is not to retrieve, it is to repair. Up to the closure, the work is combined with retrievability, after the closure we talk about reparability and in that case Olof Söderberg has pointed out that it is very unlikely that we would have these costs post-closure. But, it would be interesting to hear your opinions about this. I suggest that one conclusion from this seminar should be that we cease to talk about retrievability post-closure. Retrievability up to closure, reparability after closure!

C. McCombie

I do not think we can choose to use these words. We are not the only people in the world. We cannot make the choice, not to talk about retrievability after closure, because other people will talk about it anyway. It would be nice, it might be a really nice world, but that is not how the world is. People are entitled to ask questions about recoverability or retrievability or whatever word you want to use also after closure, so I do not think this seminar can decide anything else.

N. Rydell (chair)

My answer to that is that the ultimate in reparability would be to recover all the fuel. That is not excluded, but that would be at the extreme end of reparability, the basic thing is reparability. Consider one thing, in that future situation there is much more of experience and familiarity with the thing than we have today.

T. Papp

I would like to support Charles McCombie in this, because retrievability is very much internationally used as the possibility — in principle — to retrieve, i.e. not actual retrieval, but the *possibility in principle* to retrieve, and this is not an issue that depends on what we want to do. This is a physical characteristic of the system. From that point of view, it is important — from the definition point of view — to take away the intentional part of this word, so it is clearly indicated that retrievability is a *characteristic* of the system. Otherwise, there is risk that, when we will talk with others, everyone is using the word retrievability but mean completely different things.

N. Rydell (chair)

The problem I think of, when maintaining the concept of retrievability for a repository, is that it will give the impression that whatever we do, and even after closure, we are very uncertain.

E. Kowalski

This is exactly the point. We started — at the point of departure — by talking about final repository or final disposal, with no intention of retrieval, but with retrievability being in principle possible. Then somebody came and said that you have to demonstrate that. Now we are doing like if we would have changed our intention. We are thinking about the cost, and about who should be responsible, and I think this is the point which came out. We are at the point of departure. We are at the very nice old responsibility for the waste, with no intention of retrieval, but we are going to demonstrate that retrievability is possible for this or any other reason.

C. McCombie

I agree with Emil Kowalski on this. If we concluded anything, it would be the conclusion that Tönis Papp gave and also Peter de Preter, that retrievability is in principle always possible. I think what we are trying to do is to make retrievability easier and easier. We are engineering it in and we are starting on big programmes to do that. If we believe that the retrievability is such a low probability event, we should not do big engineering measures for it. If there was a basic acceptance that retrievability is in principle always possible, then you have got much more chance of moving on to fresh ground.

P. Harrington

I would rather not introduce new terms. We have had retrievability, we have had reversibility, today I have heard reparability and recoverability. All we are doing is confusing the issue. My vote would be to use retrievability and simply define what that means at what point in a repository's life, rather than having a number of different terms.

B.-M. Drottz Sjöberg

We seem to come back to this moral issue, what should we do? I think the moral obligation is to take care of it as well as we can at this moment and also open possibilities for future generations. If they are so good in using this waste, they will also find a way to do it in a proper way. So we should limit our discussion to what we are supposed to do with this issue. That would also limit the use of this terminology.

P. Richardson

If we continue to use the word retrieval, and if we then discuss the pre-sealing and post-sealing periods, are we then saying that a good way forward would be to do nothing that makes it difficult to retrieve in the pre-sealing, and conversely we do nothing to make it easy after we have sealed it. That is a kind of combination of the two approaches, and it maybe gets over to concerned members of the public, that it can be put right before we seal. If we have made the decision to seal, we have already decided that it is probably not necessary to put anything right anyway. Is that a fair reflection of what people are saying?

E. Kowalski

A small comment on this. We should do nothing which compromises the retrievability before closure and we should do nothing which compromises the long term safety after closure. I think it is small difference.

J. Swahn

Yes, and also after closure, one could think about the safeguard issues and maybe think about how to make it a little less accessible than just closing it in a simple way. One could perhaps even increase irretrievability.

C. Thegerström

With reference to what Emil Kowalski proposed, I am not sure about making nothing to compromise retrievability during operational phase. If we look at the KBS–concept, we put the canisters in deposition holes in the floor of deposition tunnels. Of course these canisters would be technically more easily retrievable during the operational phases, if we did not backfill the deposition tunnels. But that would not be technically very feasible, so we are very careful to describe this to people, that we will backfill the deposition tunnels as an integral part of the operation of a repository and that we have to face that this will make retrieval a little bit more difficult, but of course not at all impossible. So we are always trying to find the right compromise between how we have to do technically and the grade of retrievability.

C. McCombie

I think that is right. What you are doing now is employing subjective weighting to the two things. We do it over and over again, we bring up two objectives as though they could not contradict one another. Mostly they do in some instances contradict one another. When they do, you have to have a set of "ethical beliefs" or intentions, which allows you to set priorities. I feel quite proud of the industry, that the ethical beliefs we have had so far, are the ones that Claes Thegerström has mentioned. The long term safety takes precedent over other things, because with short-term measures we can handle the other things as well. It does not mean they do not contradict, it means you have to recognise when they contradict, accept that they do and set priorities according to some overriding ethical framework.

P. Harrington

Along with the definition of retrievability we also need to have a better definition of what closure is. The U.S. programme is probably the only one that has a single point in time that at which the repository is closed. For the others, it is not clear when we talk about retrievability after closure, is that installation of a working plug, a final shield plug, backfill locally, backfill for a section or backfill of the whole thing?

N. Rydell (chair)

Life is always more complicated than just two simple words. But it is a good proposal, that we should think about this quite thoroughly, because we need to know what we are talking about, and do that properly. It would be different in different countries perhaps, but the dilemma is there I think.

B.-M. Drottz Sjöberg

How stable are these funds over time?

O. Söderberg

I think it is fair to say that that is dependent on the stability of society. We are talking about guarantees in a very general way, but the only guarantee we have for this money is the stability of the economics in our part of the world. Even if, at present, the Swedish taxpayers have guaranteed a certain amount of interest, of course it can be discussed if they really can do this. Government bonds are usually regarded as safe papers, but we all know that also government bonds can lose their value. That has happened in other countries.

E. Warnecke

I agree to your response, but I would also say there is a responsibility of the government and a need for an ethical behaviour of the government regarding such funds. There are always situations where governments are looking for sources of money. There may be a big temptation to use up waste management funds for other purposes. Such behaviour of a government, although unethical, is a real threat to such funds.

O. Söderberg

I totally agree and for me personally this is a very strong reason not to accept the "wait and see" attitude, but do something while we have money available.

N. Rydell (chair)

Intrusion in the fund is very much more probable than intrusion in the repository!

F. Gera

I think that future governments would be totally free to set their own priorities and might find them in such a situation where the nuclear waste becomes a very low priority compared to their much more urgent matters. So they might even be totally justified to spend this money for other things.

C. McCombie

Given the time of day, I allow myself a facetious suggestion to finish the afternoon with. I think we should scrap the copper containers in the Swedish programme and substitute them with solid gold containers, so you get the resources in the place you want them!!!

SAFETY AND SAFEGUARDS ASPECTS

(Session 5)

SAFEGUARDS FOR GEOLOGICAL REPOSITORIES

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Abstract

Direct disposal of spent nuclear fuel in geological repositories is a recognised option for closing nuclear fuel cycles. Geological repositories are at present in stages of development in a number of countries and are expected to be built and operated early next century. 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. In conjunction with this, 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 safeguards agreements a State concedes verification of nuclear material for safeguards purposes to the IAEA. The Agency can thus provide assurance to the international community that such nuclear material has been used for peaceful purposes only as declared by the State. It must be emphasised that all three criteria mentioned 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. Based on comprehensive safeguards agreements signed and ratified by the State, safeguards can 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. As 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 nuclear material in the repository has not been diverted for an unknown purpose. The nuclear material disposed in a geological repository may eventually have a higher and long term proliferation risk because the inventory is substantially large. Change in social, economic, environmental and other scenarios might demand recovery of nuclear and other material from the repository sometime in the future. To this end, the Department of Safeguards has developed a policy paper to guide the planner, designer and operator to incorporate safeguards related features, as appropriate. In parallel, a programme for the Development of Safeguards for Final Disposal of Spent Fuel in Geological Repositories (SAGOR) was launched to foster technological 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, optimise IAEA resources, and make best use of existing technologies while still meeting the requirements for safety and environmental protection.

1. INTRODUCTION

Direct disposal of spent nuclear fuel in geological repositories is a recognised option for closing nuclear fuel cycles. Geological repositories are at present in stages of development in a number of countries and are expected to be built and operated early next century. Geological formation for direct disposal may include clay, crystalline rock, salt or tuff. The operational life of a repository is expected to be 20–70 years before it is finally closed, completely back-filled and sealed. The spent fuel in a filled repository is expected to contain 2000–200 000 tons of uranium and 20–2000 tons of plutonium. A repository would thus contain nuclear material of strategic interest creating a long term proliferation risk. Safeguards has to play a role in order to continually assure society of ‘no diversion’ under any circumstances.

Geological repositories for the disposal of spent fuel are being designed to ensure their isolation from the human environment for an extremely long period of time. This is being achieved by using engineered and natural barriers in order to prevent or reduce the migration of radio-nuclides stored in the repository. An adequately designed, constructed and located repository with such passive features is considered by safety experts to provide sufficient safety awareness during the hazardous lifetime of spent fuel. Nevertheless, there are arguments in favour of certain activities related to the repository post-closure phase. These activities are aimed at, for example, preventing or decreasing the likelihood of intrusion into the repository and providing additional assurance to the public.

To ensure a safe and reliable repository performance, spent fuel in repositories may remain retrievable for some time prior to back-filling and closure. A State may require that the spent fuel in a repository remains retrievable for several decades to provide ample time to evaluate not only the overall safety performance, but also future requirements of the fissile material contained therein.

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. In conjunction with this, 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 safeguards agreements a State concedes verification of nuclear material for safeguards purposes to the IAEA. The Agency can thus provide assurance to the international community that such nuclear material has been used for peaceful purposes only as declared by the State.

It must be understood that all three criteria mentioned 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. Therefore, the design of a spent fuel disposal site which is largely dictated by environmental and physical protection requirements will also have to incorporate safeguards measures, not only during operation, but also after closure.

2. SAFEGUARDS OBJECTIVE

The objective of safeguards is the “the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection.” By applying a set of measures the Agency should be able to draw a conclusion on the non-diversion of nuclear material from declared activities and on the absence of undeclared nuclear material and activities, thereby providing the international community with credible assurance.

To this end, the effective application of safeguards for spent fuel in a geological repository, throughout the repository operation period and beyond, must assure continuity–of–

knowledge that the nuclear material in the repository has not been diverted for an unknown purpose.

3. CASE AND CONDITIONS FOR TERMINATION

The safety community has yet to fully estimate the wisdom of implications of non-proliferation undertaking of nuclear commitments and hence has tried to argue for termination of safeguards for all nuclear material including spent fuel disposed in geological repositories.

INFCIRC/153 (Corr.), the basic model safeguards agreement for States party to the Non-proliferation Treaty, provides three circumstances under which nuclear material safeguards may be terminated. The versions given here paraphrase the actual text.

- Article 11 provides for termination upon a determination by the Agency that nuclear material subject to safeguards has been consumed or diluted in such a way that it can no longer be utilised for any relevant nuclear activity, or has become "practicably irrecoverable".
- Article 12 provides for termination when nuclear material has been transferred out of the State and the recipient State has assumed responsibility.
- Article 13 provides for termination, by mutual agreement, when nuclear material is used for non-nuclear purposes such as alloys or ceramics.

Article 35 of INFCIRC/153 (Corr.) also deserves attention to note 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 Agency and the State shall consult on the appropriate safeguards measures to be applied." The Agency's Legal Division interprets that Article 35 does not permit the Agency to terminate safeguards where the conditions of Article 11 are not met.

Based on these requirements, safeguards can be terminated only when the Agency determines that 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. In the event that safeguarded nuclear material cannot be considered to be practicably irrecoverable, the State and the Agency may apply appropriate safeguards measures.

At this point, one may ask for an accommodation to define technical criterion based on the "consumed", "diluted" or "practicably irrecoverable" attributes which could qualify spent fuel to be withdrawn from the nuclear fuel cycle. Spent fuel in storage facilities either at the reactor site or away–from–the–reactors which is used for interim storing, cooling and conditioning until suitable repositories are available does not meet the requirement of being "practicably irrecoverable". Spent fuel placed in any form of interim and retrievable storage facilities remains accessible and nuclear material therein can be recoverable. Spent fuel stored for a long time after discharge becomes more easily recoverable as radioactivity decreases considerably after several decades and plutonium extraction becomes more feasible.

Geological repositories would be the source of large quantities of plutonium and other potentially valuable elements. Changes in institutional system and social needs may provide incentives for recovery of spent fuel for energy generation or as sources of other minerals. The possibility to recover nuclear material exists even following closure of a permanent geological repository and any country which emplaces spent fuel could at any given time retrieve it. The same technology, skill and effort are required for emplacement as well as retrieval and advancement in mining technology will even make it easier. Should a State be intent on diverting material contained in fuel elements and deposited permanently in a geological repository, there is no conceivable way of making the material irrecoverable.

We are, therefore, confronted with a very fundamental question, i.e. to what extent should safeguards on spent fuel be continued? However, before deciding the fundamentals of a safeguards policy, the safety issues may be examined more carefully.

4. SAFETY ISSUES AND SAFEGUARDS IMPLICATIONS

Experts have argued that a number of basic safety considerations should be fulfilled for safe operation of geological repositories. The safety issues and their interpretation may be revisited or expanded in the light of safeguards issues for advancing an integrated approach.

Safety of future generations

Radioactive waste shall be managed in a way that predicted impacts on the health of future generations do not exceed levels that are acceptable today. This principle is derived from an ethical concern for the health of future generations. In order to ensure the protection of human beings in the future, radioactive waste should be isolated from the human environment over extended periods of time and, while it is not possible to ensure total containment indefinitely, the intent is that there will be no significant impacts when radionuclides enter the environment. In deep geological repositories, isolation will be achieved by a system of barriers surrounding the spent fuel — some engineered (the waste canister and the back-fill material) and some natural (the geosphere and the biosphere). The concept of barrier is also applicable for assurance of non-diversion of the material content. While the safeguards consideration involves control down to a few kilograms, safety concerns demand attention to the microgram level.

Burdens on future generations

Radioactive waste shall be managed in a way that limits burdens on future generations. The ethical basis for this principle is the premise that the generation that produces waste should bear the responsibility for managing it and assure safety for future generations. Considerations of importance to safety or a burden on safety are primarily of an economic and social nature. Non-proliferation is a veritable concern and hence a burden that would eventually be inherited by future generations. It cannot be eliminated but can be controlled by a sound safeguards approach.

Responsibilities of the present generation

Nevertheless, safety experts have identified responsibilities of the present generation including (i) development of the technology, (ii) construction and operation of the facility, and (iii) provision of funds for adequate control and plans for management of radioactive waste. These developments would help to ensure an effective safeguards regime.

Institutional control

Safety prescribes that the management of radioactive waste should, to the extent possible, not rely on long term institutional arrangements or actions as a necessary safety feature, although future generations may decide to utilise such arrangements, for example, to monitor radioactive waste repositories or retrieve radioactive waste after closure has been effected. The identity, location and inventory of a radioactive waste disposal facility should be appropriately recorded and the records maintained.

Long term in safety interpretation is extremely long, some thousands or millions of years ahead, making it beyond any prediction or interpretation of nature or concept of institutional control. It is expected that near-term experience with safety (and safeguards) practice along with technological advancement will dictate the nature of institutional control to be adopted. A number of near-term safety measures would be able to provide assurance of non-diversion of nuclear material. Uncertainties related to institutional and technical development probably will require that safeguards for geological repositories, once established, be re-evaluated from time to time.

Integrated approach

It is important that once a repository has been closed and sealed that it is not disturbed in a way which could impair its safety barriers. For repositories containing spent nuclear fuel (and possibly also for those containing high level wastes) safeguards are to be continued in order to prevent possible diversion of nuclear materials for use in weapons production. A possible issue concerns the nature of the safeguards needed for repositories and, in particular, whether that would disturb the passive safety features of a repository. It is expected that safeguards measures take into account safety considerations. Safeguards requirements are also mutually beneficial for waste management safety, e.g. the proposed long term surveillance of closed repositories, would place a burden on future generations, but on the other hand would benefit safety assurances. Various consultations with international experts on both disciplines have recommended that in order to ensure that safeguards requirements are developed which are compatible with plans for long term isolation of radioactive waste, safeguards and waste disposal safety experts should work in close co-operation.

5. DEFINING A SAFEGUARDS POLICY FOR SPENT FUEL

In view of various technical, social and political concerns, the IAEA has taken the initiative to develop an international consensus on the future policy of safeguards for spent fuel placed in permanent geological repositories. An Advisory Group Meeting on *Safeguards Related to Final Disposal of Nuclear Material in Waste and Spent Fuel*, held at IAEA Headquarters in September 1988, was attended by 43 representatives from 17 Member States and Euratom. Discussed at length was the basic issue of whether mere placement of spent fuel in a geological repository — or perhaps whether some added characteristic of the repository or degree and method of conditioning — would make the spent fuel practicably irrecoverable. It was 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 to fully elaborate on this basic recommendation contributing to the development of an IAEA policy for spent fuel disposal in geological repositories. It is expected that this will provide sufficient 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, to ensure that these requirements are integrated into the repository design and to permit adherence to these requirements during the construction and operation of the repository in order to establish an effective and efficient safeguards system.

6. HIGHLIGHTS OF THE POLICY

Spent fuel disposed in geological repositories is subject to safeguards in accordance with the applicable safeguards agreements. Safeguards for such material are to be maintained after the repository has been back-filled and sealed and for as long as the safeguards agreement remains in force. The safeguards applied should provide credible assurance of non-diversion and absence of any undeclared activities.

The safeguards systems must meet rigorous system specifications and standards in order to function for a very long time period with minimum or no service, perhaps in a rugged environment and preferably in an unattended mode. Since emplaced spent fuel cannot be re-verified, sufficient redundancy, diversity and robustness should be incorporated into the safeguards system and adequate maintenance measures applied to avoid system failure and ensure continuity–of–knowledge. The safeguards systems for a repository will be based on an integrated safeguards verification system (ISVS) and design information verification (DIV) to confirm that no nuclear material is removed by any declared or undeclared access routes; and 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, as applicable. An ISVS should have the capability of functioning, as far as is practicable, in automated, remote control and remote data transmission modes. An ISVS should have high system reliability and capability to detect component failures and to notify the IAEA in a timely manner of such failures, preferably by remote transmission.

DIV constitutes an important safeguards measure during the pre-operational and operational phases. DIV should confirm the design of the geological repository and detect any undeclared modifications and activities, both in the repository and in its vicinity. The IAEA should verify that the excavation areas are as declared and that there are no undeclared excavations. As the repository design will change during excavation, for example to adapt to geological findings, the application of DIV must be a flexible, ongoing process. During the operational phase, the IAEA should also provide assurance of the absence of undeclared underground reprocessing and assurance of no undeclared operational capability underground which could mask the substitution between containers.

Once the repository is closed and sealed, safeguards should consist of suitable surface monitoring measures to provide assurance of ‘no access’ to nuclear material, e.g. visual observation through photographic techniques or video-recording, remote surveillance including optical, satellite, geophysical and environmental techniques. These measures should be adapted to site specific requirements. Upon request by the IAEA, the State should provide access to any building or to any location at the geological repository site or to any location outside a geological repository site which the IAEA considers might be functionally related to the geological repository. Arrangements should be made with the State for advance notification to the IAEA of any: a) intention to access the sealed geological repository after final closure; b) intention to retrieve the spent fuel from the geological repository; c) intention to retrieve any other material from the geological repository; and d) tunnelling, mining or blasting activities in the vicinity of the repository.

7. TECHNOLOGICAL DEVELOPMENTS INITIATIVE

In parallel, a programme for the Development of Safeguards for Final Disposal of Spent Fuel in Geological Repositories (SAGOR) was launched to foster technological 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, optimise IAEA resources, and make best use of existing technologies while still meeting the requirements for safety and environmental protection.

In September 1991, following the recommendations of a Consultants' Meeting, the Director General announced the SAGOR task with participation of Member State Safeguards Support Programmes (MSSPs). Eight Member States (Belgium, Canada, Finland, France, Hungary, Sweden, UK and USA) participated in this task which began in 1994 and culminated in 1998 with the publication of a five volume report. A model safeguards approach has been developed for the different operations associated with spent fuel disposal, assessing diversion paths, addressing verification techniques and identifying R&D needs. The technical work was conducted by MSSPs; task management was provided by the IAEA. Important areas for future development work include a variety of geological techniques, e.g. satellite, seismic, radar, electromagnetic, acoustic and thermal. Use of environmental monitoring along with information analysis would detect any undeclared activities. Remote transmission of data would be able to reduce costs and provide early detection of diversion. However, these would require further development work in order to perform effectively in various geological environments.

8. CONCLUSIONS

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 nuclear material in the repository has not been diverted for an unknown purpose. The nuclear material disposed in a geological repository may eventually have a higher and long term proliferation risk because the inventory is substantially large. However, the safeguards measures must be flexible enough to respond to changing technological developments and to changing needs of current as well as future generations. Change in social, economic, environmental and other scenarios might demand recovery of nuclear and other material from the repository sometime in the future.

There are some generic features applicable to geological repositories, but detailed threat analysis, diversion strategies and safeguards approaches will need to be examined separately for each specific repository. The primary assumption on which the threats and diversion strategies for geological repositories are based is that spent fuel will be disposed only as verified nuclear material on which continuity–of–knowledge has been maintained.

Current development effort will have to be tuned with other factors such as:

- variation in geological formation — with consequent differences in excavation difficulties and scope for use of geophysical techniques;
- the technical concepts (e.g. repository layout, depth, potential for retrievability, time period for which the repository will be kept open);
- potential technological advancement in safeguards, safety and mining;
- socio-political factors (e.g. regarding the other institutional controls, the importance of safeguards in the distant future is not known);
- compliance with the principle of radioactive waste management; and
- climatic developments (e.g. periodic glaciations may make safeguards irrelevant).

Close co-operation between the IAEA and international community is the key to effective and efficient safeguards for such a complicated facility. In addition, participation of experts as well as advancement in other disciplines, namely safety, waste management, environmental protection, whose understanding of safeguards needs are indispensable, will have a significant role in geological repository affairs. Possible retrievability should be the guiding consideration in defining safe and proliferation resistant methods in geological repositories.

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QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: You mentioned that some sorts of high level waste could remain under safeguards in the repository. What kind of high level waste do you mean?

A: Well, it would depend on the concentration level. According to the safeguards agreements it could be terminated only if it could be proved that it had been consumed or become practically irrecoverable. Suppose, for example, that you have an accident and you have an amount of material that has been leaked and now classified as waste. That would not be terminable because of the material concerned. The material has the potential to recover, if terminated, and diverted for non-peaceful purposes. Accordingly, the Agency, as I have explained, devised a set of criteria taking the concentration level into consideration. If HLW does not fulfil these criteria, safeguards has to be continued even after disposal in geological repositories.

THE SAGOR PROJECT AND ITS OUTCOME

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Abstract

The Programme for Development of Safeguards for the Final Disposal of Spent Fuel in Geological Repositories (SAGOR) was carried out at the request of the International Atomic Energy Agency (IAEA). The final reports of the SAGOR project, published in September 1998 by the IAEA (STR–312), include model safeguards approaches for all three phases of the final disposal process. They include spent fuel conditioning facilities, operating repositories and closed repositories. For each facility type, also the diversion paths and detection points are included in addition to description of the needed research and development efforts.

1. SAGOR PROGRAMME

The SAGOR Programme was initiated in 1994 and completed in 1998. The multinational Member State Support Programme (MSSP) had participation from eight States: Belgium, Canada, Finland, France, Hungary, Sweden, United Kingdom and United States. Representatives from these countries and the IAEA composed the SAGOR Technical Coordination Committee (TCC). Germany and Euratom took part as observers.

The immediate objectives of the Programme were to identify (i) the safeguards requirements which have to be taken into account during the initial design of the facilities, and (ii) research and development work required for effective implementation of safeguards for final disposal of spent fuel. Retrievability of nuclear material was not considered as an option in developing the generic safeguards approaches.

2. CONDITIONING FACILITY SAFEGUARDS

A generic conditioning facility design includes shipping and receiving area for casks, a hot cell for repacking of fuel assemblies and cans of pins, and a hot cell for consolidation of spent fuel pins. The diversion concerns include removal of full cask, canisters, cans of pins, assemblies, and pins from the storage areas and conditioning process areas.

Conditioning facility will offer the last possibility for verification of fuel data. However, the facility itself allows the use of conventional safeguards measures because spent fuel in the conditioning facility is available for verification prior to becoming difficult, in practice impossible, to access.

Identified safeguards measures, based on the classical safeguards, include design information verification (DIV), nuclear material accountancy (NMA) and containment and surveillance (C/S). The model safeguards approach includes:

- Verification of the identification of casks received and shipped, assemblies and cans of pins.
- Application of C/S measures in storage areas and around hot cell.

- Verification of spent fuel contents at gross or partial defect level[1].
- Verification by radiation monitoring the presence or absence of nuclear material in all containers removed from process hot cells.
- Application of dual C/S measures to full canisters and casks in storage awaiting transfer to the repository and during transport.

3. OPERATING REPOSITORY SAFEGUARDS

An operating geological repository includes large number of excavated disposal rooms, access tunnels to the rooms, shafts for surface access and ventilation. Disposal rooms will be excavated also during disposal operations.

The safeguards measures need to assure that no diversion or undeclared reprocessing of nuclear material takes place during the repository is open. Spent fuel arriving at the repository has been verified in the conditioning facility. The verified knowledge of the nuclear material contents will be maintained using C/S measures and item counting. In addition to reliable C/S measures, continuity of knowledge (C–o–K) will be assured by applying item counting and monitoring of the cask flow. For the repository area, the primary safeguards measure is design information verification using, among other things, geophysical techniques.

The reliability of C/S measures in the repository is of crucial importance. Multiple redundancy is required. The C/S system includes motion and radiation detectors, optical surveillance and seals. Unmanned operation and remote monitoring of the safeguards system will be applied.

DIV would be periodically implemented (possibly even 3–6 times per year) to give assurance of the correctness and completeness of the declared activities and design of the repository.

4. CLOSED REPOSITORY SAFEGUARDS

The generic repository will be operated over a period of 40–50 years before closing. The closing phase will last several years. It includes backfilling of all drifts, tunnels and shafts to the repository. Boreholes, surface installations and monitoring equipment will remain until the public and regulatory authorities consider they are no longer necessary. The surface site of the closed repository will be restored to allow unrestricted public access.

Diversion of nuclear material from the closed repository requires excavation. Possible diversion paths were identified to include excavations of the original or new shafts and tunnels, excavations from other mines, tunnels or caves. To detect excavation activities, the surface area including original shafts needs to be monitored in addition to the area around the repository. Monitoring needs to cover also the adjacent mines, tunnels and caves. Both on-site inspections and remote monitoring may be considered.

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[1] Gross defect = assembly replaced or missing, partial defect = more than 50% of irradiated nuclear material replaced or missing.

The model safeguards approach includes:

- Unannounced random visual inspections possibly by applying also 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 doesn't 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.

5. R&D NEEDS

Research and development of new or improved safeguards measures need to be carried out to satisfy the safeguards needs.

The specified R&D needs for the conditioning facility include:

- Non-destructive assay (NDA) methods for gross and partial defects verification of shielded casks or overpacks, unshielded canisters, spent fuel assemblies and cans of consolidated spent fuel pins.
- Cask weld integrity monitor for cask lid and cask bodies.
- Authentication of radiation/environmental monitors to detect indicators of pellet diversions or reprocessing in a conditioning facility.
- Dual C/S system for casks or overpacks during transport.
- Integration of safeguards components into a unified system.

The R&D requirements related to safeguarding of the operating repository include integrating of individual components into an integrated safeguards verification system. Such a system would collect, store and process the information and, if required, transmit it to the IAEA.

The specified R&D needs for operating repository include:

- Safeguards application of seismic techniques.
- Ground penetrating radar technology for verifying the repository environment.
- Automated data review and interpretation for geophysical methods.
- Unique identifiers for canisters and casks.
- Environmental sampling to detect undeclared underground processing activity.

Safeguarding of a closed repository is not only a technical challenge to the safeguards community. The classical safeguards were based on quantitative and mechanistic application of methods and techniques in verifying non-diversion of nuclear material. The current or modern safeguards include also qualitative elements used in a non-mechanistic way to gain a credible assurance of the absence of undeclared nuclear operations or facilities.

The evolution of the strengthened safeguards system (SSS) in addition to the synergies expected with other arms control and verification systems is expected to make the planned safeguards approach more effective and efficient.

Specified R&D needs for safeguarding a closed repository are related to geophysical monitoring systems and satellite surveillance. The general technological development is expected to help solving the future monitoring needs.

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Volume 4: Overview of Model Safeguards Approach for Closed Geological Repositories
Volume 5: Reference Volume

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: You made a statement that retrievability complicates safeguards. I would like to know if you think anything actually fundamentally changes, or if it just complicates things in another way?

A: I think it complicates, from safeguards point of view, because if you consider a conditioning facility, you verify declared nuclear material data and if the material is retrieved, you somehow confirm that the data are correct. Then you come back to the verification question again. We verified above the ground, but when it go underground, we somehow make a control that nothing goes up again. But now if something is intended to be brought up again, it is all again in our hands.

Q: My initial question was: taking retrievability into a design, does that fundamentally change anything? Retrievability does not encompass the intention to retrieve.

A: May be not the way that you put it, because if you only plan to retrieve it, I think it is still the same situation.

C: If the repository is not closed, but stays open, then of course it is much more demanding.

Chair: And we may also have an additional comment that there is not somewhere a room adjacent where fuel is taken out of casks and reprocessed and the empty casks are then placed somewhere.

Q: I am a little bit confused. What is the difference between an open repository and an operating repository as regards to safeguards?

A: I think it is very much the same.

C: I think the difference is the following. In the operational phase you have to distinguish between the emplacement phase and the phase where you will decommission the remaining voids, including the shafts. Not until all has been shut down and the shafts have been closed, you will have the post-operational phase of the repository, that means the post-closure phase.

Q: No, the question was about the difference — with respect to safeguards — between an operational phase of the repository and a repository after operation but which is still open.

Chair: This is very difficult, retrievability was not discussed in this project, so we did not take a position here.

C: When a repository is operating, there are three phases. In one part, we are making preparations for emplacement. Another part is already operating, that means you are putting the fuel there, and when this is filled, you are backfilling. And if the repository is to be in operation for 70 years, there will be many parts where there is backfilling, maybe 10, 20, 30 years before the end of that period. That makes it a bit complicated for application of safeguards, because all the machinery and all the things one needed to stay working will still be there. Therefore, we are giving more importance on what we call the *design verification information* to confirm that there is no undeclared route to take, to confirm that the backfilled repository has not been opened, to confirm that there is no other route on the site of another mine from where the material can be diverted. That is — as Matti Tarvainen tried to explain — why this is the most complicated part to handle. But once everything has been backfilled and completely closed, then it might be easier, because there might be easier ways for verifications, like satellite monitoring, or other types of inspection.

Q: I am wondering about these eight member states. Are these the only states working with you? Do they have a special mission?

A: I did not have time to explain that in more detail, even though I had a plan. The eight member states were those volunteering, countries who offered funds to consider this task for the agency. It is a joint effort of these eight countries.

Q: Can you discuss a little more the NDA proposals? As I read this, it almost would imply that if I have a utility ship, an intact fuel assembly, if I received that intact, then I put it intact into a waste canister, that I would also be doing NDAs on them. Is that the intent?

A: Well, to stay on a general level, what the Agency needs to know is the correctness and completeness of the declared data. Of course, you can verify the fuel with the NDA measurement either before shipping or upon arrival, but the Agency tends to support the verification as late as possible, because the transfer is always the difficulty from a safeguards point of view. So it depends on what level of verification has been gained before shipping the assemblies. Based on how well you know this, how well the continuity is guaranteed, you will verify either on gross defect level or on partial defect level.

C: The point is that there are many kinds of carts that will be going in. It will arrive in one kind of cart, and then the empty cart will go back. So diversion may take place. Material may go back instead of being unloaded. At another point, an empty final disposal cart comes in and a filled one will go out, and the same is true when you are transporting the material in a transporter cart inside the repository. Because the filled one will go in and empty one will come out and be the used cart, there is some sort of containment and a NDA measurement capability would likely be developed.

C: I have to make a remark concerning the strength and safeguard system of the Agency. Open resources are only available in democratic countries, so-called western countries, through the media, but I fear it will not happen in closed societies as, let me say, North Korea, Iraq and such countries.

Q: A question related to the R&D needs for operating repositories. You mentioned environmental sampling. Could you expand on that a bit?

A: Environmental sampling is a tool that the Agency is looking at very carefully nowadays. Everybody seems to like that you just take a sample anywhere, and it is a magic sample, which tells you all about your history and background. The serious part of it is that the environmental sampling is included in the measures to reveal the diversion of pellets or rods etc. at this level, any leakage or emissions. It is discussed in more detail in the reports because they are long stories, it is difficult to give a short answer unfortunately.

Q: Presumably, retrievability and the potential impact of that will be on the agenda for your new experts group at IAEA?

A: Yes, retrievability will be on the agenda of the experts group in the future.

C: I think we cannot know the answer to the question of retrievability, when we design safeguards. Depending on when the retrievability will occur, all the safeguard activities have to be resumed. Depending on that, intrusion may be too much.

A: So it will be proposed by the Agency.

Q: The new group you mentioned, that met at STUK, is that a just a continuation of the old group, the same eight countries, or a different group?

A: At the start of the four years period of co-operation, the group was not very easy to handle, with members coming from very different countries and conditions. After four years of co-operation, we started to communicate and that means that we have started to share understanding. So communication in the way that you share opinion was a good basis. We then made faster progress because we had already established the rules for the group. That is why it was proposed that it would be a pity if we lose this group with this expertise and background, and so it was proposed by the Agency to continue this discussion on safeguards that is rather new, including the back end of the fuel cycle.

Q: You said the first part of the SAGOR group was financed by the eight countries, is this continuing group also budgeted that way?

A: Yes, because of the fact that we only get funds through the support programmes. So the support programmes makes a framework for us to be able to get funds for this work.

PRACTICABLY IRRECOVERABLE AND RETRIEVABLE AT THE SAME TIME? FINDING A BALANCE BETWEEN SAFEGUARD CONCERNS AND OTHER UNCERTAINTIES ABOUT THE FUTURE

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Abstract

There is an increasing interest in making the possibility of retrieving nuclear waste from mined geologic repositories an inherent feature of the repository. Compelling arguments for retrievability can be made but making retrievability a feature for a repository for spent nuclear fuel forces the debated issue of whether there is a need for long term surveillance of mined geological repositories for spent nuclear fuel. I will in the following presentation summarise the basic issues, describe how my own thinking on final disposition of spent nuclear fuel has shifted in the last decades and present my own view on how to proceed forward.

1. THE BASIC ISSUES

Let us first summarise the basic issues. These are taken in the historical order in which they have been raised.

Firstly, in *ethical considerations* of the management of long lived nuclear waste, two points have been focused upon:

- The need for long term surveillance should be avoided in order not to impose undue burdens on future generations.
- Retrievability of the waste is a positive aspect as it allows future generations the possibility to take control of the management of the waste.

The development of basic thinking along these lines was complete by the end of the 1980s.

Secondly, in *safeguard considerations* as a result of the existence of the plutonium in spent nuclear fuel in mined geologic repositories two points have been focused upon:

- The need for long term surveillance for spent fuel in mined geologic repositories is necessary as long as a safeguard regime is in place in the world and this could be seen as imposing long term burdens on future generations.
- Retrievability of the waste is a negative aspect as it makes it easier to mine the repository for nuclear weapons material.

According to present safeguard terminology the spent fuel should be considered "practicably irrecoverable" in order to remove safeguards and surveillance, thus the title to this presentation. Suggestions have been made to change this largely undefined term to allow spent fuel in a closed repository to be removed from safeguards. Such suggestions do, however, build their reasoning on that premise that the fissile material in a mined geologic repository is made as inaccessible as possible and that retrievability is therefore minimised.

The basic thinking on the safeguard issues of nuclear waste management has developed from the late 1980s through the 1990s. Due to the inherent conflict between the ethical considerations of the 1980s and the safeguard considerations of the 1990s there has been some controversy and disagreement about whether safeguard considerations are important for mined geologic repositories of spent nuclear fuel or not. I will not dwell on this issue here.

Thirdly, in an effort to find public and political acceptance for the siting of mined geologic repositories *acceptance considerations* have focused on one main point:

- Retrievability of the waste is a positive aspect as it allows decisions in the face of uncertainty while still leaving an opening if the decisions were considered erroneous by future generations.

Retrievability as an important factor in order to find public and political acceptance for the choice of method and for the siting of repositories has come into focus in the past few years and appears to be growing in importance. It is important to realise that safeguard considerations raises a second point when this factor is introduced:

- A mined geologic repository built to allow retrievability needs to be under long term surveillance.

  The first point in the ethical considerations is thus not achieved when retrievability is a major goal. It remains to be seen what impact this change in perspective may have on the acceptability of mined geologic repositories as a waste disposition option for spent nuclear fuel.

Finally, as a result of the increasing interest in retrievability the following *environmental security consideration* is being raised:

- Enhancing the retrievability of nuclear waste from mined geologic repositories should not compromise long term environmental security of the repositories.

Despite the ethical advantages of retrievability that were pointed out in the 1980s the main line of thought within the nuclear waste community, at least in Sweden, has since been that the waste should never be retrieved. The introduction of the safeguard issue in the early 1990s made a focus on non-retrievability even more important. Much of the design and development work on mined geologic repositories have thus been made on the basis that retrievability is not important and ongoing changes in order to allow retrievability must not compromise long term environmental security features of the planned repositories.

2. TWO DECADES OF CHANGING PERSPECTIVES ON FINAL DISPOSITION OF SPENT NUCLEAR FUEL

I have spent almost two decades studying, evaluating and attempting to give creative input on the issue of final disposition of nuclear waste. My efforts have led me to look both backwards and forwards, as well as trying to understand the present. I believe that nuclear waste management policy is one of the most complex issues that mankind has faced. But, we have learnt much already and we will learn much more as we head into the next millennium.

If I look back I find that my first interest was not in how to manage civil nuclear waste but rather what could be done in order to dispose of excess fissile material from nuclear weapons disarmament. This was in the early 1980s, before any disarmament appeared likely, but it gave me the opportunity to understand military nuclear technology. In the early 1990s I took this knowledge and used it to try and understand the long term military implications of putting spent nuclear fuel containing plutonium in mined geological repositories. My conclusions at that time was that there was a long term ethical conflict due to the apparent necessity for long term surveillance of spent fuel in mined geological repositories. At this time I tried to make the point that an extra effort should be taken to try and make the spent fuel as inaccessible as possible, to try and find solutions that made the plutonium "practically irrecoverable". After evaluation a number of alternatives to mined geologic repositories I suggested that more efforts should be put to examining if the use of very deep bore-holes could provide a preferable solution.

As the years passed into the mid 1990s, I came to realise that it was very difficult to influence the choice of method for spent fuel disposal and I began to advocate the idea that the goal should be make retrievability of the spent fuel from a mined geologic repository as difficult as possible in order to minimise long term needs for surveillance. This could be done with different techniques during the closure stage of repository operation and by choice of the site. So far these ideas have not been adopted when planning for a Swedish repository.

I must admit that the recent growing interest in retrievability of the spent fuel has initially troubled me, as it appeared to close the possibility of minimising long term safeguard needs. I have now realised that the only difference with the new situation is that the repositories should be made retrievable during the operational phase but that the repositories could still be prepared for a difficult–to–retrieve state after closure. The decision to close the repository can be made after the uncertainties have been acceptably resolved or could be made as a result of an unforeseen scenario. This would transfer the repository into a less-retrievable state where long term surveillance would be necessary but requiring less resources than if retrievability after closure was still high.

3. WHERE COULD WE GO FROM HERE?

I think that general consensus can be built for the idea that mined geological repositories should allow for a high level of retrievability during operation or in a demonstration phase, i.e. before closure. This will allow uncertainties about the method and the site to be resolved with a possibility to change method and/or site.

I believe that we will find that as the focus is put on retrievability, the long term surveillance issue will also come to public attention and the ethical implications of this will once again be discussed openly. As retrievability is intended to lower hesitance about making decisions in the face of uncertainty, the uncertainties about safeguard futures as well as uncertainties about energy futures will be further examined. There will very likely be demands for further studies of alternatives to mined geologic repositories.

The case should, however, still be argued that mined geologic repositories should be built if public acceptance for the method chosen and for the siting can be gained. This should be considered a precautionary measure in case alternative disposition methods that do not require long term surveillance are not developed in the future. Such repositories should be designed and built for retrievability of the spent fuel and it should be explicitly stated that such repositories will need to be under a safeguard regime for an extended time and thus under long term surveillance. As discussed above the level of long term surveillance efforts can, however, be lowered if the repository is prepared for a closure that minimises retrievability.

The decision to close the repository or to retrieve the material can be referred to the second half of the next century when uncertainties about alternative methods, about the future global energy mix and about the future role of nuclear weapons in the global security system will have a high likelihood of having been resolved.

I think that the case can and will be made that alternative solutions to mined geological repositories will not be available in the near-term. There may be better alternatives for disposition in the future, alternatives that avoid long term surveillance, but as a precautionary measure if none are found, I would rather that we proceed with a method that may not be perfect but may be ultimately the best that we will get. However, strong efforts and substantial funding should still be put into finding alternative methods for spent fuel disposition that do not require long term surveillance. Such alternatives could be integrated into future nuclear fuel cycles using transmutation, but it is quite uncertain whether nuclear energy will find a place in a long term global energy mix. Non-nuclear alternatives, i.e. very deep burial in bore-holes, transmutation methods independent of a nuclear energy future, or even solar disposal should thus also be further evaluated.

To summarise, we could regard a highly-retrievable mined geologic repository at least as a mid-term storage solution for the next 50–100 years. By that time we will know much more about the future global energy mix and the future role of nuclear weapons in the global security system as well as and other factors influencing whether the repository should be finally closed or not. The closure decision can then be made in a situation when many of the uncertainties that exist today will have been resolved.

As a last point it should be noted that there is a possibility that mined geologic repositories will only be a temporary disposition method and the economic implications of this should be evaluated, taking into account that there are uncertainties involved. Possible measures range from disregarding possible extra costs to future generations, to increasing the present waste disposition fees levied on nuclear electricity generation.

I find it very exiting that this seminar has been arranged. I have been studying, evaluating and attempting to do some creative thinking on these issues for almost 20 years. It appears as though the time has come for an open and unprejudiced discussion and analysis of the best way to proceed forward. I am grateful for the opportunity to play a part at this meeting, which I truly believe may be pivotal in how we come to view nuclear waste management policy in the future.

I have in this paper tried to be short-worded, to-the-point and constructive. Below you will find a list of further reading that elaborates further on some of the points made in the presentation.

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QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

C: One of the questions that the safeguards community has not considered very well is the cost. If we extend the period of active safeguarding, and that time gets longer and longer, even small costs per year will amount in a huge amount of money. This is also a new challenge for the safeguards people, because the conventional safeguards has been considering time periods that are easier to handle and for which it is easier to estimate the costs and find somebody willing to pay.

A: My thinking on this is that I find the long term costs less troubling, because they will be integrated into a global safeguard system and, of course, there will be surveillance of different kinds of activities all the way round the world. Are these the long term costs that you are worried about? Maybe that you are considering other costs?

C: You want to be actively aware what is in the repository, and you have always difficulties — if you are using the conventional safeguards approach — if the system fails. If the system fails, then you cannot recover. So that is why we need an optimum system, that will not fail, somehow fail-proof. It is not the extension of the conventional safeguards that will solve that problem. So, I still think there are major cost factors there.

A: You can probably transfer that cost to a worry about having to take care of it for a long time, which is my concern. I think that the question of long term surveillance of this issue is not a question of cost. It is more a question of responsibility to future generations.

C: I was a bit confused by the statement in your paper that, after closure, retrievability would be easier. We have not heard anybody say that they have made any plans for making retrieval after closure easier. In fact, all of the plans for closure seem to be the same as they were before we started talking about retrievability. Also, there is a belief among the mining profession that, after closure, it would actually be easier and safer to construct new access ways rather than to re-excavate old access ways.

A: That is possible. That would depend on how you have closed your repository. I am trying to raise the issue that something could be put into that. Concerning the question whether one considers post-closure retrievability interesting, I think there is no difference from before. It is retrievable, and that is why we have to have safeguards for it.

Q: I have a historic question, since you have been working for so long in this field. I am actually very curious about when these ideas about retrieval surfaced for the first time and if you have an idea about the history of this idea of retrievability.

A: The present interest goes back three, four, five years approximately. I noticed it about three years ago — at conferences — that there seemed to be a realisation that if retrievability became an issue it might be more easy to get public acceptance. On the other hand, the question of being able to retrieve material from a repository has been discussed in the ethical discussion in Sweden, for example, already in the eighties.

Q: I would like to raise a question to all three speakers. We have discussed safeguards here in general for high level waste. I would like to state briefly that we have, in terms of high level waste, either spent fuel or re-processed high level waste. The re-processed high level waste does have about 0.2% of the original fissile material included, it is in a boron-silicate glass , which contains a neutron-poison. It is difficult to recover it if disposed in a geological formation. Is that practically irrecoverable? Can that give a chance for safeguards to be terminated?

C: I can answer from an IAEA perspective. The IAEA tries to define what practically irrecoverable means, because that is the only way that the safeguards can be terminated, according to article 11 of the comprehensive safeguard agreement. There have been no definitions of what practically irrecoverable means. So we try to put a concentration level, below which it is considered by the experts, as practically irrecoverable. I do not remember exactly what that is, but in-house we have developed a policy paper to follow to withdraw safeguards from material. I would like to remind you again, according to the Euratom Treaty, there is no clause whatsoever, for termination of safeguards.

Q: In the United States, the WIPP plant is in operation now. Is WIPP safeguarded or not?

A: You are asking a very sensitive question because, as you know, safeguards has been discriminatory in a sense. It is applied in nuclear power nations in different ways. In case of the United States, it is a voluntary access to a facility and an agency can decide whether they want to continue safeguarding that particular facility or not. As far as I know, WIPP is not under safeguard.

Q: So, normal high level waste should not be under safeguard?

A: I do not have a mandate to answer that question.

Chair: In terms of safeguards, the IAEA has a mandate to go into member states to inspect and control the activities of the member states. In the area of waste safety, the IAEA does not have this mandate. There is often confusion about this. In waste management safety issues, the Agency can go into member states only if it has been requested by the member states to do so.

SAFETY AND SAFEGUARDS ASPECTS ON RETRIEVABILITY: A GERMAN STUDY

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Abstract

The article refers shortly to the definition of the term ‘retrievability’ and shows two different possibilities of retrieval scenarios, their advantages and detriments. The second part lists the Safeguards aspects of retrievability, gives a short outlook on the present German Safeguards Reference Concept in the post-closure phase of a repository in a salt dome and about the results of German studies concerning some proposed Safeguards methods. Furthermore, planned investigations on Safeguards in the post-closure phase of a repository are mentioned. The third and main part finally describes the results of the German Retrievability Study,which was elaborated in the middle of the nineties by DBE on behalf of the German Federal Ministry of Education, Science, Research and Technology, BMBF, under an R&D–contract.

1. INTRODUCTION

Since the middle of the sixties, safety investigations on the final disposal of radioactive wastes in geological repositories have been initiated in Germany. Between 1966 and 1978, the unretrieved emplacement of LLW and MLW had been investigated in the Asse salt mine. For more than twenty years Germany has investigated safety and Safeguards aspects of the direct final disposal of spent nuclear fuel in a salt dome repository, too. In 1988, Germany installed the joint task ‘Safeguards for the Final Disposal of Nuclear Material in Repositories’ with the IAEA within its Support Programme. Under this programme works have been carried out to investigate the possibility of retrievability of emplaced spent nuclear fuel from a repository in a salt dome [1, 2].

2. SAFETY ASPECTS ON RETRIEVABILITY

According to the IAEA Radioactive Waste Management Glossary, retrievability is defined as

the ability to remove waste from where it has been emplaced [3, 4].

In the post-operational phase of a spent fuel repository, there are two possibilities to retrieve the emplaced nuclear material:

1. The repository has been kept open after the last waste package has been emplaced, i.e. it is furthermore accessible after the completion of emplacement actions. That means: The repository is in the phase of post-operation, but not in the phase of post-closure. Access would be possible via the open access roads (shafts, tunnels and drifts) from the surface.
2. The repository has been closed, i.e. all underground voids or openings have been backfilled and the shafts and/or ramps as well as the mine have been sealed from the above ground environment. Then the repository is in the post-closure phase. Direct access would not be possible. Access roads must be created by sinking shafts from the surface or by driving ramps from an existing mine in the vicinity of the repository or by reexcavating the old, backfilled and sealed access ways of the former repository.

Some safety aspects have to be considered:

In *case one* the possibility of

(a) break-in of brines, ground-water and even water from the surface via the shafts and ramps;
(b) human intrusion; and
(c) diverting nuclear material

is a relatively likely scenario.

These are the detriments. A great advantage of this case — from the economical point of view — would be the possibility to easy retrieval of the emplaced material or parts of it following declaration to the IAEA.

In *case two* the material which has been disposed of is 'nearly irrecoverable'. That means:

(a) break-in of brines is not possible, groundwater and surface water cannot get into the repository;
(b) human intrusion is extremely improbable; and
(c) an attempt to divert the emplaced nuclear material is extremely difficult and can, if Safeguards is applied, practically be excluded.

As a detriment from the point of view of economy, the following has to be named: the nuclear material and fission products or their stable daughter-products can only be recovered with enormous effort. This effort will be described later.

In 1995, the principle 5 of the IAEA Safety Fundamentals stated, that

"those who generate the waste should take responsibility, and provide resources, for the management of these materials in a way which will not impose undue burdens on future generations"[5-8].

With other words: to avoid imposing the burden of ongoing surveillance and management, and of ultimate disposal, on future generations, the producers of waste also should take care for their management and/or removal.

This view is also adopted in the NEA document "The Environmental and Ethical Basis of Geological Disposal of Long lived Radioactive Wastes" and in the "Joint Convention on the Safety of Spent Nuclear Fuel Management" [5-8].

In the last time, question marks have been put to this present position by a part of the radioactive waste management community. There is a reconsideration of the merits of a strategy of ongoing monitoring and of the advantage of controlled wastes, for which one is free to choose a disposal or even a further application option in the future.

3. SAFEGUARDS ASPECTS ON RETRIEVABILITY

In the case of the open post-operational repository, a lot of Safeguards measures are necessary and could be performed: monitoring procedures for the emplaced material, measurements of the nuclear material content in the packages from time to time — with the disadvantage of additional radiation exposure of the personnel (staff and inspectors!), C/S–measures as seals, video, etc. Keeping open the emplacement voids would influence safety negatively. This all would mean a lot of effort (for instance maintenance of Safeguards and other monitoring and surveillance equipment, works to keep the underground voids open in case of convergence, employment of personnel, radiation exposure of the personnel), and expenditure (high costs). Most of these measures would lead to a high detection probability in case of diversion [9-13].

In the second case, the repository in the post-closure phase, the presently pursued German Safeguards Reference Concept [14-16] foresees that Safeguards measures could be restricted to simple methods: Satellite imagery and perhaps occasional reconnaissance plane image-taking (in case of bad weather) as well as occasional inspections of the above ground area of the former repository to exclude undeclared mining activities. This would save a lot of funds in comparison with the above mentioned first case.

Additionally until now proposed geophysical monitoring would not lead in the case of a repository in a salt dome to a plus in Safeguards in our opinion, because these methods are unpromising [17-18].

The geological characteristics of the Gorleben site presently unter scrutiny by the German authorities would not allow good results. The reasons are:

(a) Layer borders within the salt dome (different strata) as well as inclusions (gas, brines, clay and anhydrite shreds within the foreseen emplacement layer, the older rock salt).
(b) Creeping behaviour of the salt owing to the rock pressure of overlying strata ("convergence").
(c) Several groundwater horizons as well as clay strata and small lignite deposits in the main material sand of the overburden.

These are the geological reasons. Additionally, it has to be mentioned that

(d) the present German emplacement concept foresees the direct successive backfilling of open remaining voids which are not further needed after emplacement of the waste and spent fuel packages during the operational phase; and
(e) anthropogenical and environmental influences (tides, wind) have also to be considered.

Based on studies, BfS has initiated up until now [19-21], it can be concluded that geophysical monitoring would not contribute much to Safeguards objectives with salt as host rock.

Many methods will fail by attenuation caused by water. Other methods will need additional open remaining boreholes for maintenance and repair purposes which could create paths for break-in of brines, groundwater etc.

Next year it is intended to begin experiments in salt mines to investigate seismo–acoustic methods within the German IAEA Support Programme with the objective to differentiate between excavation noise and other noise produced in a salt mine. These investigations aim mainly at the operational phase but they could also become interesting for post-closure Safeguards to monitor retrieval works, if the results of the experiments will be satisfying.

With the change of the German nuclear policy by the new Federal Government the suitability of salt as a preferable host rock has been called into question. For this purpose, new site suitability criteria as well as site selection criteria in different host rocks are being elaborated as part of a national waste management plan. If the decision is made to investigate other host rocks besides salt in Germany, the effects to the presently pursued Safeguards Reference Concept have to be evaluated for those other host rocks.

4. RESULTS OF THE GERMAN RETRIEVABILITY STUDY

In the middle of the nineties the German Federal Ministry of Education, Science, Research and Technology (BMBF) sponsored work under contract no. 02 E 8371 to study the possibility of retrievability of spent nuclear fuel from a closed geological repository in rock salt. This work led to a report also published within the IAEA/BMBF Joint Programme [22].

The summary and summarizing evaluation of this report were:

There are two conceivable diversion paths after the mine has been closed as a repository:

(a) access by the specific sinking of boreholes or shafts directly into the emplacement fields, or
(b) indirect access by excavating a new mine.

Retrieval is only possible at a time and a place where the temperature limit of 100°C is not exceeded in the repository area. According to temperature field calculations, about 40 years after the start of emplacement (or 70 years after discharge from reactor), i.e. still during the operating phase, the surface temperature of the first two POLLUX casks situated at the outer exposed end of a marginal drift will have already dropped below 100°C.The retrievability of all 19 casks of a drift strongly depends primarily on the surface temperatures of the respective casks.

Thermomechanical calculations for a small emplacement field point to low compressive stresses. Tensile stresses which could endanger the stability of a drift do not arise. In driving a drift, maximum convergence rates of 5–7 cm per month are to be expected initially and will be rapidly reduced at later dates.

Salt is today successfully mined at a depth of 1500 m and at rock temperatures of more than 60°C so that mining engineering is available for high rock temperatures. Remote–controlled machines with special cooling equipment, machines with climatic protection cabs, protective suits for the workforce, particularly efficient mine air coolers and drift insulations have been developed for this field of application. High convergence rates and crack formation close to the drift can be handled by reaming or by a combined roof bolt and wire netting structure. The upper limit on rock temperature which can currently be dealt with by mining engineering is in the region of 100°C.

The analysis of a possible retrieval cycle from excavation of the emplacement drift up to transport of the POLLUX cask indicates that the time currently required is about 2.5 days. If the drift is excavated simultaneously from both ends then all the POLLUX casks in a drift can be retrieved in less than one month. With the drift being open for such a short time, retrieval will not be severely impaired by drift convergence and rock fall.

The presently pursued repository concept for the potential Gorleben repository assumes disposal of 2540 POLLUX casks with spent LWR fuel elements, which have a burn-up of 45 Wd/tHM and cooling times of 30 years after discharge from reactor and which are subject to Safeguards, in 11 drift emplacement fields at a depth of 870 m in the north-eastern wing of the salt dome. Based on the current state–of–the–art, it was investigated whether it is technically feasible to retrieve these fuel elements during the post-operational phase and, if so, what expenditure of time and labour is required. Indications can be derived from this analysis of whether Safeguards monitoring is also necessary during the post-operational phase of a repository.

The basis for the study was an analysis of the situation in the salt dome after emplacing the radioactive material. It was examined whether the temperature and stress conditions in the salt dome are so unfavourably changed by the emplacement of heat-generating, radioactive mate-rial that a retrieval is made significantly more difficult or prevented. With the current state–of–the–art of mining, maximum rock temperatures of approximately 100°C can be controlled.

By means of temperature field calculations, the development of the maximum temperatures, the temperature propagation as well as the temperature gradients after starting radioactive material disposal were investigated and possible points of access and times for a retrieval were identified. As already mentioned above, it became apparent that the first two POLLUX casks (of 2540 POLLUX casks at all) have already cooled to below 100°C forty years after the start of emplacement, i.e. during the operational phase. Ten years later (50 years after start of emplacement) the number of POLLUX casks cooled to below the temperature limit has already increased to 60, i.e. about 2.4%, with the lowest temperatures occurring at the projecting corners of small emplacement fields in edge or isolated positions which were filled first. One hundred and fifty years after beginning of emplacement, approx. 500 POLLUX casks (nearly 20%) have already cooled to below 100°C in the repository. After 1000 years, the temperatures no longer exceed 100°C anywhere in the emplacement area.

Thermomechanical calculations for a small emplacement field 50 and 150 years after the beginning of emplacement have indicated that the temperatures in the vicinity of the emplaced material remain below the temperature limit of 100°C required for mining operations and that neither the rock stresses nor the drift convergence rates exceed the stability of the rock salt.

An analysis has revealed that direct access provides some slight advantages in time (17.5 months) and effort (specific labour expenditure is more favourable up to a retrieval quantity of 20 POLLUX casks) for the retrieval in comparison to indirect access. However, safety risks arise from sinking shafts directly into the hot emplacement regions of the less stable, heated older halite. There, high convergence rates and possible cracking owing to thermomechanical stresses can be expected and thus the technical feasibility of this diversion path is doubtful. In contrast, the technical feasibility of indirect retrieval can be regarded as given. Furthermore, in the case of direct access the ventilation and operation conditions are much less favourable and the number of retrievable casks is severely limited. Because of the large shaft drilling and hoisting equipment required, the probability of detection is very high for both methods. Only retrieval with the aid of a new mine is therefore meaningful for a potential diverter. Using this diversion method, the time required to retrieve the first POLLUX cask would be approximately 19 months at least.

In order to analyse retrieval in detail, the underground workings for a hypothetical retrieval mine were planned. Since most of the retrieval mine will be excavated in an unheated or only slightly heated section of the salt dome, use can be made here of conventional mining engineering. Ventilation technologies have been developed for mines at great depths with high ambient temperatures, enabling temperatures of up to 100°C to be controlled in the hot retrieval areas. Maximum air temperatures of 50 or 70°C are permitted in the cross-cuts and retrieval drifts in order to limit loads on the rock in the drift walls. These temperatures can be handled without difficulty by using appropriate cooling machines as well as protective suits and air-conditioned operator cabins.

Selective cut heading machines and front-end loaders designed for air temperatures of 70°C are already in use today for drift advance. It is technically possible to design them for even higher ambient temperatures. The heading machines achieve high extraction rates permitting rapid drift advance, important in hot retrieval areas to keep the times short during which the drifts are open. All the machines can be remote–controlled for use in unsafe or particularly hot regions.

In the case of high convergence rates, the drifts can be reamed by roof milling tools. If excessive rock fall occurs, a drift can be secured by installing a combined roof bolt and wire netting structure. The corresponding roof bolter and setting devices can be directly mounted on the heading machine.

A possible retrieval cycle for a POLLUX cask was investigated from the operational and time aspect.

The cycle starts with excavation of the retrieval drift up to the first cask by a narrow selective cut heading machine. The barren rock is transported by a frontend loader to a belt conveyor in the cross-cut, in an operation which is largely simultaneous. The heading machine subsequently drives around the POLLUX cask on all sides leaving a salt jacket around the cask. Removal of this salt jacket, uncovering the lifting trunnions, and cleaning of the drift floor can be performed by remote–controlled manipulator systems equipped with an impact rammer and a bucket. If necessary, the drift can be protected against rock fall by a combined roof bolt and wire netting structure. Subsequently, a mobile gantry crane loads the cask onto a transport vehicle which conveys the cask to the shaft. The length of the ventilation air ducts and dust extraction system can be adapted in parallel to drift advance.

All the work required for a retrieval can be performed, for ergonomic and radiological reasons, with remote–controlled machines.

The time required for the retrieval cycle (of one cask) will be approx. 2.5 days. All 19 casks of a drift can be retrieved in approx. 1.5 months by working in four shifts. This operating time can be reduced by half if the emplacement drift is simultaneously excavated from two sides.

If the retrieval drifts are kept open for such short times, even high convergence rates or any possible rock fall down to a few centimeters do not impede retrieval.

5. UPSHOT

The investigations performed show that it is possible to retrieve POLLUX casks with current technology if the temperature limit of 100°C is not exceeded. Such temperatures can currently be dealt with by mining engineering measures. The first casks below this temperature are found 40 years after the start of disposal, i.e. still during the operating phase. Since retrieval in the post-closure phase is only possible with the aid of a new mine, the time required is very high and amounts to approx. 19 months for the first cask. The technical and financial expenditure for a retrieval is probably in the same order of magnitude as for establishing the repository. The large-scale shaft drilling equipment required as well as the above ground infrastructure necessary during the operating phase of the retrieval mine, comprising two shaft winding towers, machine house, energy and water supply, workshops, stores, connection to the traffic system etc. make an undetected retrieval of disposed of fuel elements impossible. The transportation and storage of large quantities of salt are also easy to detect by above ground surveillance.

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QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: What could be the maximum temperature within the repository at any time of these first hundreds of years?

A: At the unloading of the fuel elements and putting them into a POLLUX cask, the maximum temperatures could be over 400°C, but in a repository the temperature is limited to 200°C, when they are emplaced, at the border between wall and cask.

Q: You say that, in case 2, that the material has been disposed of practically irrecoverable. You are using the IAEA "safeguards removal terminology". Also, in the paper you are talking about safeguards, so maybe you should consider whether you should be changing this word.

A: There is a quarrel about these items. I mean "practically not recoverable without detection".

Q: The question is, again, whether it is practically irrecoverable or not. How do you define practically irrecoverable, when there are thousands of tons of uranium and hundreds of tons of plutonium in a closed repository. The materials that have been stored there, have much more better quality than material in a mine, which we all know it is "recoverable".

A: I said in my speech that it will be recoverable, but that the effort and expenditure is so high that it cannot be a hidden activity. I know there is some constraint and some difference to that what the Agency defines as practically irrecoverable.

Chair: May I ask you a question where I saw a kind of discrepancy in your paper. On the one side you say you can retrieve, for that you must keep temperatures up to a maximum of 100°C. Then, in another paragraph, you say that you need at least a thousand years to cool down the salt/canister interface to 100°C, so there is a gap in time where you cannot recover. Is that the right conclusion or can you elaborate on that?

A: Part of the casks can be retrieved very shortly, but where they are concentrated, the temperature is too high and will only decrease with time. So you cannot retrieve all at once or in the nearest future. The amount is increasing with the time and after 1000 years you can retrieve it all.

Chair: With this temperature?

A: Yes.

Chair: So there is no full retrievability?

A: Now, and in the next 150 years there is no full retrievability. After 150 years, there are 500 casks retrievable and after 1000 years they are all retrievable.

C: I would like to go back to the important distinction about the prolonged pre-closure stage, or prolonged waiting period until you take the next step of pre-sealing or something like that. I think you indicated, and I agree with you very much, that a prolonged step can have risks and those risks must be taken into account. What I would like to also point out is that very often when you take the decision not to go on to the next step by refilling the tunnels, there is a judgement, that the change of retrievability at that time, or rather the cost of retrieval, will perhaps be unacceptable and therefore you wait a further period until you have built up your confidence that this is a good step. If you know that this is a good step you do it perhaps at once in order to avoid this problem between closure stages. That, I think, is very important. There is a distinction between the issue of retrievability and the balance between each of the steps, what requirements, what safety arguments you must have in order to take the steps. Prolonged operation is very often an answer to uncertainty in performance. Perhaps we should not mix them too much, we should keep them very much apart, the prolonged operation is a consequence of an earlier uncertainty, but not a question of retrievability as such, retrievability in principle only.

A: I mean operational phase from the point of safeguards. The operational time of a repository is the time of emplacement and the time of dismantling, of decommissioning. Both together are the operational period of a repository from the point of view of safeguards. We have to distinguish between the operational phase of a repository, and the closed phase of a repository, the post-closure phase. They are two different things, because in a post-closure phase the repository is closed and retrievability would be much more difficult than before.

Q: You mentioned higher radiation exposure to the inspectorate and the operator. I wonder if you were talking about handling inside the geological repository where everything will be in a POLLUX cask. We have been told that these casks are heavily shielded, that you can even touch it by hand. So, from where does this radiation come? You also mentioned the expenditure for safeguards. Can you give an estimate of what percentage of money, of your total money, is planned for safeguards?

A: I cannot answer the last question, it is too early. You cannot minimise the radiation exposure to zero, that will never be, I agree with you. But you know the discussions we have in Germany with the public. This will be an issue in Germany, maybe not in other countries. To the first question: the neutron radiation cannot fully be kept back.

THE IMPACT OF RETRIEVABILITY ON DISPOSAL OF RADIOACTIVE WASTE

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Abstract

There are discussions in various countries about whether and to what degree the ability to retrieve wastes might be built into geological repositories for long lived radioactive waste. It is generally accepted that repositories should be designed so that retrieval will never be necessary on safety grounds. Nevertheless, reasons for retrieval have been put forward. The ways in which retrievability might be built into geological repositories and various expected impacts of such actions are briefly discussed in this paper. A preliminary comparison of some notional geological disposal strategies with varying degrees of retrievability is proposed. The comparison is qualitative because at present there are few detailed designs for geological repositories with retrievability and few assessments of the safety and other aspects of such repositories. The comparison has the aims of highlighting those factors that differ most from one strategy to another and identifying which of these factors require further assessment in order to make more complete and quantitative comparisons. The framework used for the preliminary comparison is that of a multi-attribute analysis, such as might be employed in an environmental impact assessment (EIA). This type of framework is chosen because it would be used in many countries to aid decisions between disposal options or strategies. The framework encompasses radiological and nuclear safety factors but goes well beyond these and includes a number of factors that are not quantifiable in the technical sense. However, consideration of such factors is considered important because they can have a significant impact on decision-making. The groups of factors are: radiological, nuclear safety and financial (quantifiable factors); non-radiological environmental impacts (partially quantifiable factors); non-quantifiable attributes (such as ethical and societal factors).

1. INTRODUCTION

There are discussions in various countries about whether and to what degree the ability to retrieve wastes might be built into radioactive waste repositories located in stable geological environments at various depths below the surface. It is generally accepted that repositories should be designed so that retrieval will never be necessary on safety grounds. Nevertheless, various reasons have been put forward as to why there could be advantages in building in retrievability.

The ways in which retrievability might be built into deep geological repositories for long lived wastes, and in other repositories in rock cavities located some tens of meters below the surface, and various expected impacts of such actions are briefly discussed in this paper. A preliminary comparison of some notional disposal strategies with varying degrees of retrievability is proposed. The comparison was carried out for two purposes: to clarify thinking on this topic and to assist IAEA to identify areas where further work is needed. Throughout the comparison, it is assumed that only retrievability provisions that do not compromise the long term, or short term, safety of a repository, should be contemplated.

In some concepts for repositories with retrievability it is envisaged that there will be a period when waste emplacement has been completed but repository closure is postponed. Some of the issues which arise in comparing these concepts to the traditional one of repository closure immediately after the end of waste emplacement are similar to the issues in the storage versus disposal debate. The paper therefore begins with a brief discussion of storage and disposal.

In a number of countries, a debate is going on over whether indefinite storage or disposal in suitable geological environments should be the preferred option for the management of long lived radioactive waste. In the IAEA terminology, the principal difference between storage and disposal is one of intent:

- *storage* is emplacement above or below ground with the intention of retrieving the waste at sometime in the future, in order to implement another, yet to be defined, management option; and

- *disposal* is emplacement with no intention of retrieving the waste, although retrieval is usually 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 [1].

Both disposal and storage can involve surveillance and monitoring. However, it is a traditionally accepted requirement of geological disposal that the safety of a repository after it has been closed must not rely on continued surveillance and monitoring. In contrast, the continued safety of storage does rely on surveillance and monitoring and on maintenance of facilities and their equipment.

For the majority of the scientific and technical community, and for parts of the public, the difference in intention between storage and disposal is enough to enable them to make a choice. On ethical grounds and owing to a lack of confidence in the longevity of human institutions, these people favour a measure that is intended to be permanent over one that is intended to be temporary.

For other groups and individuals the decision between storage and disposal is not so clear cut. They see storage as a means of preserving flexibility for future generations to search for a better permanent solution to the waste management problem than is available now.

Arguments related to sustainability and the principle of not imposing undue burdens on future generations are used on both sides. Those who favour disposal point out that once a repository is sealed and institutional controls are withdrawn there is no requirement for future generations to do anything, and hence no burden on them. For these people disposal is the only "sustainable" option in the long term [2]. Some of those who favour indefinite storage feel that performing a permanent and final step, such as closing a repository, commits future generations to the solution chosen by the present one, and this will be a burden if better solutions are subsequently found. In their view it is reasonable to impose the burdens associated with storage (continued surveillance, monitoring and maintenance) if these are necessary in order to provide freedom of choice [1, 2].

A radical view is that geological disposal, as presently conceived, is at best unproven and at worst flawed. Those who hold this view claim that only indefinite storage is "sustainable". Probably the most extreme view is held by those who wish waste to remain where it can be seen because they feel that this is essential to ensure that its dangers are never forgotten [3].

It can be seen from the above that the main issues in the storage versus disposal debate are not technical in nature. Rather they are philosophical, social and political. This is inevitable given the principal difference between the two options, *i.e.* one is intended to be temporary and the other permanent. The difference also means that it is not possible to carry out a full scientific and technical comparison between the two options. The most that could be achieved would be a partial comparison, for example covering the health, safety, environmental and financial aspects of disposal and storage. For these reasons this paper does not attempt to compare disposal with storage, but limits itself to a preliminary discussion of the aspects requiring consideration in order to assess the implications of different degrees of *retrievability in disposal options.*

2. COMPARISONS OF DISPOSAL STRATEGIES

In this section a preliminary comparison of disposal strategies with varying degrees of retrievability is carried out. The comparison is qualitative because at present there are few detailed designs for long lived waste repositories with retrievability and few assessments of the safety and other aspects of such repositories [4]. The comparison has the aims of highlighting those factors that differ most from one strategy to another and identifying which of these factors require further assessment in order to make more complete and quantitative comparisons.

2.1. Comparison framework

The framework used for the preliminary comparison is that of a multi-attribute analysis, such as might be employed in an environmental impact assessment (EIA). This type of framework is chosen because it would be used in many countries in Europe and North America to aid decisions between disposal options or strategies. The framework encompasses radiological and nuclear safety factors but goes well beyond these and includes a number of factors that are not quantifiable in the technical sense [5]. It is important to consider such factors because they can dominate decision-making.

The groups of factors are:

- radiological, nuclear safety and financial (quantifiable factors);
- non-radiological environmental impact (partially quantifiable factors); and
- non-quantifiable attributes.

Each of the groups of factors is considered for the period up to including repository closure (here called the pre-closure and closure period) and then for the post-closure period.

The strategies compared span a spectrum of disposal concepts. At one end of the spectrum is the traditional geological disposal concept, in which most repository engineered barriers (EBs) are emplaced during its operation, the remaining EBs are emplaced at closure, and no provisions are made for waste retrieval prior to or after closure. At the other end of the spectrum is a strategy in which all activities related to closure of the repository are postponed. In this case no repository EBs (e.g. backfill) are emplaced during repository operation, so that the waste packages remain readily retrievable until the decision is taken to close the repository. In addition, the repository has provisions to make waste retrieval after closure easier than in the traditional concept. For the purposes of the comparison it is assumed that the repository is designed so that closure could occur up to many decades after the end of waste emplacement. Between these two extremes are three strategies with more retrievability than the traditional concept but less than that of the postponed closure concept with post-closure retrieval provisions. It is important to recognise that not all the strategies will be technically feasible in all types of host rock.

All the strategies are assumed to meet current standards for pre- and post-closure radiological and nuclear safety, and other requirements for human safety and limitation of environmental impacts. The strategies are ranked relative to each other on the basis of each factor, using a scale of 1 (lowest rank, i.e. worst) to 5 (highest rank, i.e. best). It is emphasised that for some factors the absolute difference between the lowest and highest ranked strategies, while still to be determined by quantitative assessments, can be anticipated to be small.

It is assumed throughout the comparison that waste retrieval does not actually occur, i.e. that the repository and its contents behave as intended, and that no other developments occur that would make retrieval desirable. Consideration of the health, safety and other aspects of retrieval in a comparison is discussed in Section 2.5.

2.2. Comparison based on quantifiable factors

2.2.1. Pre-closure and closure period

The main radiological factors considered are occupational exposure, public exposure and radiological impacts on organisms other than man (flora and fauna). For occupational exposure both routine and accidental situations are included, because both of these types of exposure may differ from one strategy to another. For public exposure only accidental situations need to be considered because the routine exposures of the public will be mostly those arising from waste transport to the repository, and these are low and common to all strategies. Similarly, there could only be significant exposures of organisms other than humans as a result of accidents prior to and during closure. *For all three factors, it is the length of time before emplacement of EBs that discriminates between strategies.*

Also included under radiological factors are monitoring requirements and the length of time for which institutional controls would be needed at the repository site. The monitoring requirements are greatest for the postponed closure case, because here it is part of the concept to monitor throughout the time before closure, both to gather additional data and to check that retrieval is not required. Similarly, the institutional control period will be longest for the postponed closure strategy.

The one nuclear safety factor included is safeguards requirements. These depend on both the disposal strategy and the type of waste to be placed in the repository [6]. The safeguards requirements will be greater for spent fuel than for vitrified reprocessing waste. The most stringent safeguards requirements will be longest for the postponed closure strategies.

The two financial factors considered are total undiscounted cost, and the period of time over which funding needs to be guaranteed. Both are likely to be lowest for the traditional, early closure strategy and highest for postponed closure. Discounted costs are not considered because, with the discount rates currently used by most governments, they do not discriminate between strategies.

Table I summarises the comparison of strategies based on radiological, nuclear safety and financial factors for the pre-closure and closure period. It can be seen from the table that there are qualitative differences between the strategies. This is an interesting result but is of limited value for decisions between strategies. For choosing a strategy, quantitative assessments of the various factors would be required, so that judgements could be made as to whether the differences between strategies are significant.

2.2.2 Post-closure period

All repositories will be designed so that their radiological impact post-closure meets the appropriate standards, and so that there are no institutional control or monitoring requirements post-closure, and no costs. Differences in post-closure impacts may occur as a result of delays in emplacement of EBs, the postponement of closure and the nature of EBs. However, at the present time, there are not enough assessments of the various strategies to enable statements to be made as to whether these differences in impacts could be significant. Similarly, post-closure safeguards requirements have not been worked out in enough detail to assess quantitatively their potential impacts on the different strategies.

2.3. Non-radiological environmental impacts

2.3.1 Pre-closure and closure period

The non-radiological factors that would typically be included in an EIA and which are relevant to the comparison of disposal strategies during repository pre-closure and closure periods are:

- local employment near the repository site (jobs created or maintained);
- conventional safety of workers (*e.g.* likelihood of accidents underground during repository construction and operation);
- effects of routine and accidental releases of non-radioactive materials (toxic chemicals) on public health;

TABLE I. COMPARISON OF WASTE DISPOSAL STRATEGIES BASED ON RADIOLOGICAL, NUCLEAR SAFETY AND FINANCIAL FACTORS IN THE PRE-CLOSURE AND CLOSURE PERIOD

Strategy	Occupational exposure		Public exposure (accidents)	Exposure of flora and fauna (accidents)	Institutional control period	Monitoring requirements	Safeguards requirements	Total financial cost	Period over which funding required
	routine	accidents							
Postponed closure, no emplacement of repository EBs before closure, provisions for post-closure retrieval	1	1	1	1	1	1	1	1	1
Postponed closure, no emplacement of repository EBs before closure, no provisions for post-closure retrieval	1	1	1	1	1	1	1	1	1
Incomplete/reversible emplacement of repository EBs prior to closure, provisions for post-closure retrieval	3	3	3	3	3	3	3	3	3
EBs all emplaced prior to closure, with post-closure retrieval provisions	5	5	5	5	5	5	5	5	5
EBs all emplaced prior to closure, without retrieval provisions (traditional concept)	5	5	5	5	5	5	5	5	5

Note: The strategies are ranked relative to each other on the basis of each factor, using a scale of 1 (lowest rank, i.e. worst) to 5 (highest rank, i.e. best). It is emphasised that for many of these factors the absolute difference between the lowest and highest ranked strategies is likely to be very small.

- effects of routine and accidental releases of non-radioactive materials (toxic chemicals) on flora and fauna;
- use of resources (e.g. to make EBs);
- land-take (surface area that cannot be used for other purposes due to the presence of the repository);
- traffic pollution (local and global effects); and
- visual impact.

Of these only employment, conventional worker safety and land-take are likely to discriminate between strategies. The way in which they might do so is shown in Table II. It is assumed in the table that employment and worker safety depend on the length of time for which the repository is open. It is also assumed that land-take is greater for postponed closure strategies because the repository "footprint" is larger (e.g. the spacing between waste packages is greater, to facilitate retrieval), and access to the entire footprint area is restricted pre-closure.

As in Table I, there are qualitative differences between strategies and quantification would help to determine whether these differences are significant. It seems likely, however, that differences in employment, worker safety and land-take would be less important in decisions between strategies than differences in other, quantifiable and non-quantifiable, factors.

TABLE II. COMPARISON OF STRATEGIES BASED ON PRE-CLOSURE NON-RADIOLOGICAL ENVIRONMENTAL IMPACTS

Strategy	Employment	Worker safety (conventional)	Land-take
Postponed closure, no emplacement of repository EBs before closure, provisions for post-closure retrieval	5	1	1
Postponed closure, no emplacement of repository EBs before closure, no provisions for post-closure retrieval	5	1	1
Incomplete/reversible emplacement of repository EBs prior to closure, provisions for post-closure retrieval	3	3	3
EBs all emplaced prior to closure, with post-closure retrieval provisions	1	5	4
EBs all emplaced prior to closure, without retrieval provisions (traditional concept)	1	5	5

Note: The strategies are ranked relative to each other on the basis of each factor, using a scale of 1 (lowest rank, i.e. worst) to 5 (highest rank, i.e. best). It is emphasised that for some factors the absolute difference between the lowest and highest ranked strategies will be very small.

2.3.2. *Post-closure period*

The two factors identified here that are relevant to the post-closure period are the effects of releases of non-radioactive materials on human health and the effects of these releases on flora and fauna. As is the case with post-closure radiological impacts (see Section 2.2.2), any repository will be designed so that such releases are within accepted standards, and at the present stage of assessment it is not possible to discriminate between strategies on the basis of the possible magnitude of releases and their potential effects.

2.4. Non-quantifiable attributes

Some of the factors in the "non-quantifiable" category are essentially those that led to the emphasis currently being placed on retrievability in a number of countries. Other factors are concerned with the perceived disadvantages of retrievability. For the pre-closure period the factors are:

- freedom of choice for future generations;
- degree of control over emplaced wastes;
- stability to societal breakdown;
- need to transfer knowledge to future generations;
- burden of length of time for future R&D; and
- social and political burden of decision-making.

After closure only the second of these factors applies to an extent that would allow discrimination to be made between strategies. The strategies with provisions for post-closure retrieval can be said to have a greater degree of post-closure control because it is easier to intervene and retrieve the waste. A preliminary comparison of strategies on the basis of non-quantifiable factors might thus be as shown in Table III.

The comparison indicates that if equal weight were to be placed on each of the factors then the differences between strategies might not be very substantial. On the other hand a high weight for a factor such as freedom of choice would favour the postponed closure strategies, while a high weight for stability to societal breakdown would favour early closure.

2.5. Retrieval

The ease with which retrieval may be accomplished will vary from one strategy to another, and hence so will the exposures of the workers who do the retrieval and the financial cost of the retrieval operation. A distinction also needs to be made between retrieval prior to repository closure and retrieval post-closure. These factors are relevant to a comparison of strategies and are, in principle, quantifiable, although few studies have yet attempted this quantification. Furthermore, to include them in a comparison it is necessary to give some consideration to how likely it is that retrieval will occur.

Various reasons can be conceived that might lead to a decision to retrieve the waste from a repository, either before or after closure. Opinions will differ on the probability of retrieval. It is doubtful whether these differences of opinion can be resolved but they could be represented in a comparison by assigning a range of probabilities to retrieval before and after repository closure, or by placing a range of weights on the occupational exposure and costs of retrieval.

2.6. Aggregating factors and involving stakeholders

The comparison outlined above is very preliminary and qualitative and is appropriate only as a basis for further discussion. To carry out more comprehensive comparisons it is necessary to make systematic assessments of the quantifiable factors and to find means of assessing the non-quantifiable factors. In the latter case, and for aggregation of quantifiable and non-quantifiable factors, the involvement of a wide range of "stakeholders" should be considered [1]. This might be achieved by including representatives from various sections of society in the team carrying out the comparison, or by presenting the comparison to such representatives for review and comment.

TABLE III. COMPARISON OF STRATEGIES BASED ON NON-QUANTIFIABLE FACTORS

Strategy	Freedom of choice pre-closure	Degree of control pre-closure	Stability to societal breakdown pre-closure	Burden of transfer of knowledge pre-closure	Decision-making burden pre-closure	Time for more R&D pre-closure	Degree of control post-closure
Postponed closure, no emplacement of repository EBs before closure, provisions for post-closure retrieval	5	5	1	1	1	5	5
Postponed closure, no emplacement of repository EBs before closure, no provisions for post-closure retrieval	5	5	1	1	1	5	1
Incomplete/reversible emplacement of repository EBs prior to closure, provisions for post-closure retrieval	3	3	3	3	3	3	5
EBs all emplaced prior to closure, with post-closure retrieval provisions	1	1	5	5	5	1	5
EBs all emplaced prior to closure, without retrieval provisions (traditional concept)	1	1	5	5	5	1	1

Note: The strategies are ranked relative to each other on the basis of each factor, using a scale of 1 (lowest rank, i.e. worst) to 5 (highest rank, i.e. best).It is emphasised that for some factors the absolute difference between the lowest and highest ranked strategies may be very small.

3. CONCLUSIONS

The previous discussion suggests that there are a number of areas in which further work is required before the implications of building various degrees of retrievability into geological or rock cavity repositories for radioactive wastes could be assessed fully. These areas are as follows.

i) Technical studies are needed to determine, in detail, for several types of host rock, the pre-closure and post-closure retrieval provisions that could be incorporated in repositories without compromising long term or operational safety.
ii) Assessments are required of the pre-closure and post-closure radiological impacts of a number of repository concepts with differing degrees of retrievability built in. Particular attention should be paid to assessing the impacts on the public and the environment, prior to repository closure, of accidental scenarios initiated by a variety of disruptive events and failures of societal control, and the impacts on workers of routine and accident situations. It would also be useful to assess the potential exposures to workers in the event that retrieval were carried out before or after repository closure.
iii) Further work is needed to define safeguards requirements for repositories for various types of long lived waste containing fissile materials, for both the pre-closure and post-closure periods.
iv) Information is required on the relative costs of repositories with differing provisions for retrieval before and after closure. Again the information would be needed for repositories in various types of host rock. It would also be useful to assess the costs of retrieval operations.
v) It is important to investigate methods for assessing the non-quantifiable aspects of retrievability and for comparing repository concepts on the basis of both quantifiable and non-quantifiable factors. Means to include a wide range of "stakeholders" in the comparison process need also to be addressed.

In the absence of the work outlined above it is difficult to reach informed decisions, accepted by many sections of society, about whether retrievability can and should be built into geological repositories of various types in various host rocks, and, if so, about the precise retrievability provisions to be made.

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QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

C: I agree very much about what you are saying, but I am also observing — in any way in our case in Sweden - that we see that our purpose is to dispose with *no intention to* retrieve it, but with the *possibility for retrieval*, if needed. For us, the actual retrieval has a low probability. This is important from the point of view how you optimise your system, because a lot of what you are talking about here is how to create a good balance between the various options. The issue is that if you are optimising your system on a low probability event it is not sure that you get an optimised system for the other (high) probability event, which is leaving it in the repository. I think it is important to have this basis, that retrieval is naturally only a low probability event, and that you should not optimise your system on the basis of retrievability.

A: I think what you say is a very useful and important consideration and we will have to find a way to factor it in, in some way. I do not know which impact it will give, but certainly we cannot forget that it is a low probability event.

C: Presentations on the first day of this seminar said that if you develop a disposal system and you only look at safety elements and you only look at feasibility elements you automatically come to a system which has intrinsic retrievability elements. I do not see the use of theoretical simplifications which are not meant to be seen in reality.

A: The schematics I showed should be considered as examples to illustrate the proposed method. There was discussion if it made any sense to have five options if three options would have been sufficient for this purpose, or we could even think about a lot more options. So you can play with these different strategies, with different levels of detail, but I think that as far as illustrating the proposed approach, this is clearly not particularly important because then you can actually choose the strategy that is best suitable for your particular case. If you, for example, are dealing with a clay formation such as in the Belgian programme, and you are considering a number of alternatives, then of course you replace the generic options with your options, and apply the methods to the alternatives that you are considering in your case.

C: I would like to come back to what was just said in the latest comment. I think this is a very important point. What I have gathered from the last two days of this seminar is, that there is a lot of work going in the direction of trying to de-dramatizise this whole discussion about retrievability, not only by using very extreme or simplistic examples in terms of strategy. But I cannot quite see how you get to the ranking on some of the points.

A: We are saying that you have to quantify and, when you are discussing options, you must be able to tell the audience exactly what are the impacts of these alternative choices, what do they mean in terms of risk, what do they mean in terms of cost. So we have to put some numbers in this table before we can come up with rational decisions, this is the main point we are trying to make.

C: I think the whole value of such tables is to show up some trends and I was very unhappy with numbers 5, 3 and 1. For instance, if you say that you have a prolonged pre-closure period, there will be a positive impact on the employment of the population. This is true, there will be somebody employed a bit longer than before. But that is a small effect with regards to the whole problem and therefore it should only be used to show *in what direction* some indicators are going. The incremental values are normally very small with regard to the absolute value.

A: It is obvious that some of these factors will have some weight and others will be pretty irrelevant. As far as the cost is concerned, for example, and if we have good estimates, there will be a significant factor. The risk might also show significant differences, but many of the others, we imagine, will be very minor and probably the difference between options will be rather insignificant.

C: In the Wellenberg business, we are thinking in terms of 5% higher costs for getting acceptance for one hundred percent of the project. This 5% might be very high in absolute figures, but corresponds to small money — totally irrelevant — if you are thinking in terms of a detailed decision to build and to implement or not to implement.

Q: Do you think that, in the long run, you envision some decision making tool coming from this, or is it just a thing for guidance? You spoke about alternatives, comparing one alternative to another. In public fora now there is a big move to be able to compare alternatives and agencies are being encouraged or even mandated to provide alternatives.

A: This is basically a suggestion that if you want to put the discussion on rational grounds you have to come up with some quantitative estimates of what the impacts are. I would not like to push this much further at this time. The Agency is not going to be in a decision at making role in this. This will be a national decision so the member states will have to decide on their own. They will have to assess if this methodology can be of any help in making decisions, but if the Agency can be of help in promoting a discussion and developing a consensus in this, then of course that would be a useful role.

Q: You do not see it ever getting to the point of becoming guidelines?

A: I do not think that I would like to guess at this time. If it happens, it is very far in the future.

Chair: A document like this cannot, I believe, be a guideline. That would have to be a document of a different type. The guidelines are recommendations with “should”–statements and they should be tied into higher ranking documents which provide the requirements in firm “shall”–statements. This document is more of a technical kind and, as such, it should not be taken as a “quantitative” document but rather as a “qualitative” document. It contains some — if I may use the words of Anna Hiett’s paper — “gut-feelings” also about retrievability and common-sense. It could give some perspective but it is by no means quantitative. Quantitative examinations can only be done on a given case. You need a site, you need an engineering concept, or alternatives for concepts so that you can compare the costs of the various alternatives.

SAFETY AND ETHICAL ASPECTS ON RETRIEVABILITY: A SWEDISH NUCLEAR REGULATOR'S VIEW

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Abstract

An important contribution to the discussion on retrieval in Sweden has been the ethical principle of the Swedish National Council for Nuclear Waste (KASAM). "The KASAM Principle" means that the present generation, which has reaped the benefits of nuclear energy, must also take care of the waste and not transfer the responsibility to future generations; a repository should be designed and constructed so that monitoring and remedial actions are not necessary in the future. However, future generations, probably with better knowledge and other values, must still have the freedom to make their own decisions; we should therefore not make monitoring and remedial action unnecessarily difficult. SKI generally supports the KASAM principle but its application in the individual case should be based on solid evidence that both aspects have been covered in a suggested repository design. 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. SKI supports that the repository shall not be designed so that it unnecessarily impairs future attempts to retrieve the waste, monitor or "repair" the repository. However, measures to facilitate any kind of access to the repository must not reduce the long term safety of the repository. SKI concludes that: Future generations may wish to retrieve the spent fuel from a sealed repository. Disposal method 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 functions of the repository. It must be shown that the safety aspects have been adequately considered. Retrievability must always be discussed with caution, so that it will not give the impression of doubts concerning the safety of the repository.

1. INTRODUCTION

Retrievability has recently attrached considerable interest from regulators, implementers as well as other stakeholders in the siting of repositories for spent nuclear fuel.

Already in 1993 when the Swedish Nuclear Power Inspectorate (SKI) reviewed the Swedish Nuclear Fuel and Waste Management Co's (SKB) RD&D Programme 92 (presented to SKI every third year) retrievability was discussed. SKB then introduced a step-wise approach to disposal of spent nuclear fuel. In that context SKI commented that it is vital that the necessary preparations should be made to facilitate retrieval of the emplaced fuel canisters after the first demonstrational phase. This is still SKI's opinion concerning the first phase of a step-wise disposal of spent fuel.

1.1. Ethical principles – arguments in the public debate

An important contribution to the discussion on retrieval in Sweden has been the ethical principle of the Swedish National Council for Nuclear Waste (KASAM), "the KASAM Principle". This principle means that the present generation, which has reaped the benefits of nuclear energy, must also take care of the waste and not transfer the responsibility to future generations; a repository should be designed and constructed so that monitoring and remedial actions are not necessary in the future. However, future generations, probably with better knowledge and other values, must still have the freedom to make their own decisions; we should therefore not make monitoring and remedial action unnecessarily difficult. (In this context the remedial actions include retrieval).

SKI generally supports this principle but its application in the individual case should be based on solid evidence that both aspects have been covered in a suggested repository design. The credibility in designing repositories that are at the same time safe, include features for prevention of human intrusion, and with a possibility for retrieval, has been contested by environmental groups. In their comments to SKB's RD&D Programme 98 they claimed that the requirement for isolation, i.e. prevention of human intrusion, contradicts a requirement for retrievability. Thus, they consider that this double message destroys the credibility of the KBS–3 method (see below).

However, SKI does not agree on the argument that the requirement for isolation necessarily must contradict a demand on retrievability. It should be possible to develop a disposal method and repository design that balances between these two aspects. The KBS–3, or similar, disposal concepts provide for retrievability over extended periods of time without compromising neither operational nor long term safety of the repository.

For obvious reasons a balance may be difficult to achieve for some disposal methods, notably the very deep bore holes (cf discussion in the paper by M. Jensen, SSI).

1.2. "Disposal" as opposed to "deep storage"

The observant reader of SKB's RD&D programme and regulatory reviews cannot have failed to notice that SKB and the authorities use different terms for the planned deep geological repository. SKB consistently uses the term "deep storage" for what the authorities call "(final) disposal". (The ambiguity is not apparent in English — in Swedish these terms are rather much alike: "djupförvar" *vs* "slutförvar"). In doing so, SKB wishes to emphasize that the deposition of spent nuclear fuel in deep rock formations, at least for the time being, is not to be regarded as an ultimate and final disposal. SKB wishes to emphasize that retrieval is possible. Such an approach may be defensible if it is acknowledged that future generations should have the right to make their own decisions concerning final disposal.

As a regulatory authority, SKI has not agreed to adopt the term "deep storage". There are two main reasons for the regulator to use the term "(final) disposal":

- SKI is adamant that the repository must be designed to fulfil the criteria of a "true" repository, i.e. with no intent to retrieve the waste. In SKI's opinion the terminology should reflect this principle. Retrieval must not be a necessity, even if we realise that the possibility for retrieval may be provided.

- SKI does not wish to promote a terminology that may indicate that a repository is an unsafe and temporary solution.

Furthermore, the Swedish Act on Nuclear Activities explicitly stipulates that plans should be made for “safe final disposal”.

As long as this difference in terminology does not cause too much confusion, we consider it to be acceptable. However, we acknowledge that it presents some difficulties when communicating with the general public. Regardless of which term is used, it is possible to discuss different degrees of retrievability.

2. REASONS FOR RETRIEVAL — AND THEN WHAT?

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.

For example, it is possible that the repository will not perform as intended during the time that it is in operation. Another scenario of technical nature is where a new assessment of the long term safety differs from those made during licensing of the repository.

A decision on retrieval might also be taken for purely political reasons, e.g. in order to satisfy public opinion.

However, retrieval for any of these reasons should preferably only be carried out if the continued safe management of the spent nuclear fuel is ensured. This aspect of retrievability has so far not been discussed as much as other aspects, e.g. reversibility of emplacement.

Furthermore, it is possible that future generations may wish to use the fuel for nuclear energy production, which can be combined with the burn out of some long lived radioactivity (transmutation). In such a scenario the further safe management of the spent fuels will have to be inherent in the proposed nuclear system.

3. REPOSITORY DESIGN

SKB’s main alternative, the KBS–3 method, implies vertical emplacement of individual copper canisters surrounded by bentonite and backfilled drifts at 500m depth in crystalline rock. If this concept is compared to other disposal concepts e.g. very deep holes or very long to medium long holes (horizontal emplacement) it is most likely that it will be easier and less expensive to retrieve spent fuel canisters from a KBS–3 repository compared to the other options.

SKI supports that the repository shall not be designed so that it unnecessarily impairs future attempts to retrieve the waste, monitor or “repair” the repository. However, measures to facilitate any kind of access to the repository must not reduce the long term safety of the repository.

3.1. Stepwise repository development

SKB intends to build the repository in at least two stages where the first stage is a demonstration phase (deposition of 10% of the spent fuel). After an evaluation period of the demonstration phase for about 10 years, including a SKI review of a safety assessment, the licensing for a full-scale repository is planned. SKI endorses SKB's plan in this respect. Furthermore, the step-wise approach to siting and implementation provide possibilities to repeatedly evaluate, and if necessary, redirect or reverse the disposal programme.

The now accepted step–by–step construction of a repository for spent nuclear fuel and the issue of safeguards for a repository over an indefinite period of time have helped to bring the issue of retrieval and monitoring to the fore.

3.2. The operational phase

It is SKB's intention to backfill deposition tunnels as soon as all canisters are emplaced in the tunnel. The deposition tunnel will then be sealed with a thick concrete plug. As an alternative the backfilling might be postponed facilitating retrieval. However, an open deposition tunnel may contradict requirements dictated by safeguard needs. In addition, at least for the demonstration phase, tests are planned for the resaturation of the backfill and the bentonite buffer. In order to further enhance retrieval special actions could be taken for stabilising rock in tunnels and shafts.

3.3. Retrievability of wastes will always be possible — time periods

SKB considers that the KBS–3 method will provide possibility for retrieval, which can be carried out in a number of different stages: from the Central Interim Storage for Spent Nuclear Fuel (CLAB), during encapsulation of the spent fuel, during deposition of canisters, after sealing of the deposition holes, after backfilling of the drifts and after closure of the repository. SKI agrees with SKB that it is possible to retrieve the canisters during the above mentioned phases. Furthermore, for each further step in the disposal sequence retrieval will undoubtedly be more technically difficult and more costly, but it will never be impossible. Taking into account the long term requirements of the canister, it is probable that retrieval of undamaged canisters will be possible, even after thousands of years. After still longer times retrieval will be more and more like mining. However, the difficulties will increase with time — the rock may become damaged, resulting in the partial collapse of existing holes during excavation.

To be credible, it is important that methods for retrieval are developed and tested on a full scale before a decision is made to start a detailed site investigation for a repository. Therefore, SKB has, for a number of years, conducted R&D in this area and are now planning for a retrieval experiment at the Äspö Hard Rock Laboratory (HRL) for the benefit of members of the public and experts.

4. SOME CONCLUDING REMARKS

- It can not 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 a sealed repository. Disposal method 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 functions of the repository. It may have to be shown that both these aspects have been adequately considered.
- Retrievability must always be discussed with caution, so that it will not give the impression of doubts concerning the safety of the repository.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: Is there any political discussion in Sweden of this issue?

A: No political decision has been taken because we are now working with the regulations. At an early stage, we discussed to include retrievability in this work and we have now decided not to do that. I would like to pass this question to Mr. Wingefors, who is responsible for writing the regulations on this matter.

A: It is correct that there is not political decision. And it would probably be difficult for us to demand from the industry that they should include a retrievability concept. We can certainly tell SKB to consider this and recommend that it should be considered in the design of the repository.

Q: Who eventually will decide that a disposal facility for radioactive waste should be carried out in a retrievable form?

A: I think we pass that question to SKB.

C: Well, I do not know if I can give an answer from SKB, because the question of decision is very unclear here. We believe that when we eventually will get this suggested repository it will be retrievable and the question is, if the retrievability level is acceptable or do we want to change? The decisions must then be balanced in order not to jeopardise the safety of the repository. But you can say that every action you take might affect the long term safety, sometimes in a beneficial way, sometimes in the other way, depending on which scenario you are considering. So perhaps the good formulation would be that it should not impair the capacity of the repository to comply with safety criteria. That is indicating that the critical issue is whether you can go over the threshold of acceptance. If you are well below, or if you are at a much safer state than the threshold of acceptance or compliance with safety criteria, then it will be a question of balances, how we regard it.

Q: I was a bit concerned when you showed the double KASAM principle, where you use the word ”repair”. The question of repair would come, because there is a safety breach, this is what I understand. But in the absence of any active control or active safety monitoring system, it would be too late to go up to that repair and find that it is really affecting the future generation. I would like to have your comments about that.

C: I do not know if I am the right person to comment on it because I have not attended the previous sessions of this seminar. First of all, the KASAM principle has not been formulated by the SKI, but this is a principle that we at SKI agree with. But the exact meaning of the word repair could be discussed. As I see it, the alternative is probably not to repair the repository. If there are some serious problems with the engineered barrier system, you have to take a step back and maybe consider also other disposal options. Actual repairing of canisters or barriers etc. I do not find that very probable.

Q: I meant that the question of repair is coming, because there is a safety breach, otherwise that question will not come. In absence of any active monitoring system, how we will know that a repair is necessary? It will be too late to know that a repair is indeed necessary and it will affect the future generation, that is my concern. I think there is a question of repair because of the breach.

A: I would think that repair can mean repair before closure as well as after closure. After closure, it is perhaps not very realistic to speak about repairing the system, but before closure, there has been backfilling etc. and it could be possible to take some actions to remediate the situation.

Chair: To take counter measures if there were any unforeseen, unexpected release, that is the first thing you would do before you would decide to retrieve.

Q: Yes, this is my concern and this is probably a question of whether there should be an active monitoring or passive monitoring. All the safety work is done on the basis of modelling but, from the general knowledge on this, I understand that for the modelling we are using imperfect data for the prediction of safety for 10 000 years. I see a conflict in that and I understand that there is a gap of communication between safety safeguards and public relations who really do not appreciate or do not understand it properly.

A: We have not discussed monitoring at all in our paper and the reason why we excluded that is because there are so many other papers discussing that. But of course you have to monitor the repository, and that will give you some information about the necessary actions to take.

Chair: There is quite a lot of information on the isolation capability of a given site, of a given rock formation. If you can demonstrate, for example, that for millions of years there was no interaction between water and the host rock, then you have a pretty good information that this will continue in the future, if you do not damage it by drilling too many holes in it. This is a good argument against your concern that geologists cannot predict sufficiently precisely what the future of a repository will be.

C: I have two comments. The first one is about your reasons for retrieval in part two. You do not mention a retrieval reason which could be that alternatives are found in the future. That might be mentioned. There might be other alternatives that might be considered better and then you would retrieve it. Secondly, you also said that the decision might be taken for purely political reasons. You say that it is to satisfy public opinion. I am surprised about that. But if this reflects what you perceive, then you are of course free to make such a statement.

In the last point of you last slide, you say that retrievability must always be discussed with caution so that it will not give the impression of doubts concerning the safety of the repository. I think this is quite an interesting aspect. I think you could also say — instead — that retrievability must be taken seriously, in order to actually penetrate all the issues that are involved. So it is, I understand, your point that you have to discuss it openly rather than with caution, in order to be able to actually get the public opinion that you would want for a repository.

A: I would say that is a matter of wording.

C: The possible reason for retrieval — that an alternative way to deal with the waste has been discovered — has now been mentioned several times, and you raise it again. I really do not think that this is a very realistic option. We have practically no example through history of decisions that are still believed to be acceptable being undone at very high cost simply because there is another way to deal with that particular problem now available. You will use the new better system to deal with the new waste that is produced, but I doubt very much that you will go back and retrieve from a closed repository. That would really not make any sense. Anyway, such a decision would always demand a cost benefit analysis and would be justified by very strong argument which I do not believe would be realistic.

TECHNICAL FEASIBILITY OF RETRIEVAL WITHIN THE UK REPOSITORY CONCEPT FOR ILW/LLW

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Abstract

Nirex is developing a staged, reversible concept for the disposal of ILW and certain LLW in the UK. Within that concept, the retrievability strategy includes the option of keeping open the repository, for an extended period, after all waste has been emplaced. In examining the feasibility of such an approach, a number of key technical issues have been identified and options for addressing these issues have been established. This paper will describe the issues identified and the development of practical solutions for incorporating retrievability within the Nirex concept.

Nirex believes that the safest way to isolate long lived, solid radioactive waste is to place it in a repository deep underground. To ensure that options are left open, that whole process should be carried out in a staged, reversible way. This means that wastes should be capable of being easily monitored and retrieved.

In essence the concept is that of an underground store giving future generations options on final closure, whilst taking positive steps towards a long term solution. This means that the facility will have to meet the stringent criteria for a permanent repository with continued monitoring to give society the extra assurance that the waste is secure and stable.

Overall, at each stage of development, time would be available to build sufficient confidce before moving to the next stage, whilst retaining the ability to retrieve waste and pursue an alternative option if that were available and preferred.

Nirex has examined the feasibility of incorporating an extended period of relatively easy retrievability within its concept for an underground repository for ILW and certain LLW. A chematic illustration of the Nirex concept is shown in Fig. 1. During a period of interim underground storage the repository would remain open to provide access for 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.

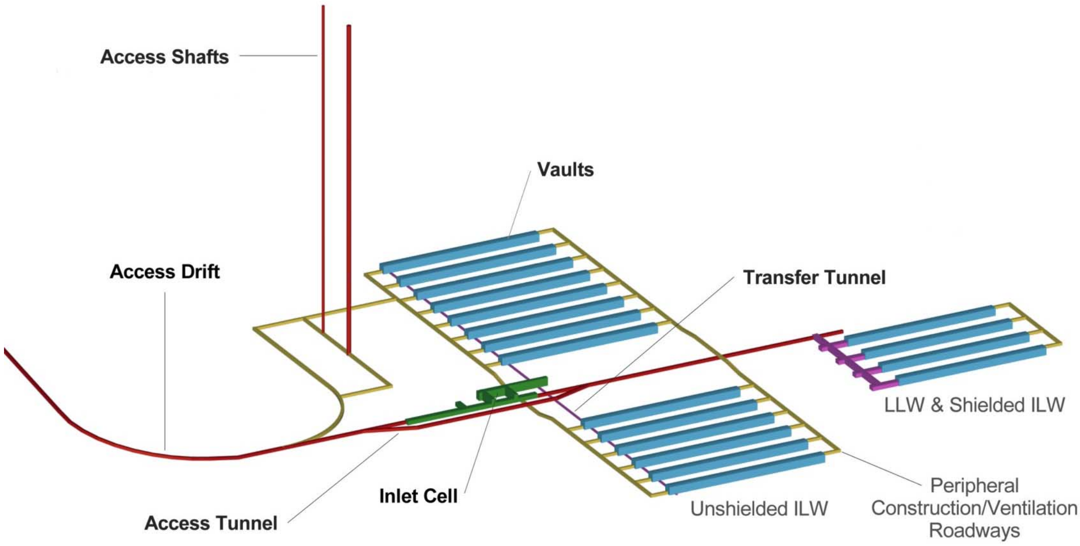

FIG. 1. Nirex concept.

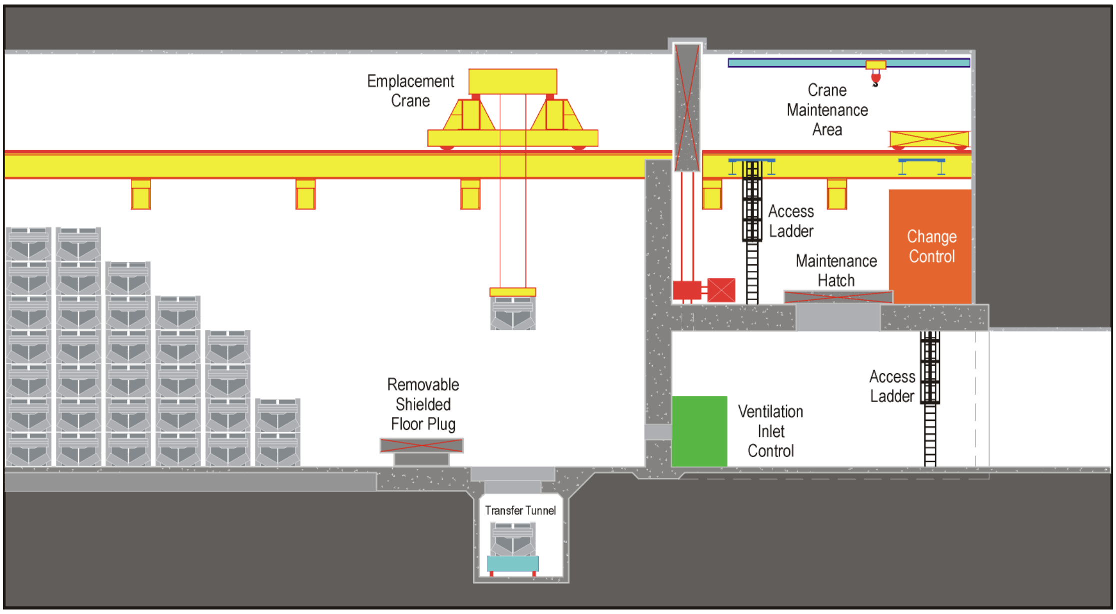

FIG. 2. ILW Vault emplacement/retrieval systems.

- All areas of the repository are accessible by people for maintenance and refurbishment apart from the vaults: here, radiation levels from the exposed waste packages would prevent access by people and all operations would be carried out remotely. The majority of emplacement equipment can be removed from vaults for maintenance, as illustrated in Fig. 2.
- The vault environment would be controlled to maintain the sound condition of the waste packages by controlling the temperature, humidity and chloride levels. This would involve the filtration of the incoming air and the management of any water to minimise contact with the waste stacks. 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 about 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 systems that would be required. For a period of greater than about 100 years it would be necessary to gain access for maintenance of rock support systems. Alternatively, it might be possible to select the host geology and size of opening so that the vaults were self-supporting.

Should a period of prolonged underground interim storage be the preferred option, the following factors would 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 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 would be designed so that it could be removed from the vault for maintenance, the only exceptions being rock support, groundwater management systems and fixed in-vault equipment such as crane rails. A number of options are available to maintain these items:
  - Removal of waste from a vault to allow access to that vault for maintenance of rock support, groundwater management systems and in-vault equipment. An additional vault could be excavated so that a ‘rolling’ programme of vault maintenance could be undertaken.
  - Design and construction of vaults so that rock support, groundwater management systems and in-vault equipment would be shielded from the radioactive waste to allow access to them for maintenance.
  - Development of robotic systems for carrying out remote inspection and maintenance of rock support, groundwater management systems and in-vault equipment.
- 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 this 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 backfilling but with increased difficulty.

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: How much nearer are we to actually having a site in England and what sort of time scales do they have?

A: One point that NIREX has been discussing is that we do not want to do what we did last time, i.e. run into a closed door. What we have said is that we want to start talking about the process of how site selection would be done, what sort of criteria would be used to judge whether a site was safe and whether or not throughout those discussions we could get some idea of how many sites people think we should be looking at. One of the criticisms of us last time is that we presented the preferred site but the process by which we arrived at that site was not open and transparent. From our technical point of view, what we have been looking at is operational and post-closure safety and, to a certain degree, transport safety. We have been trying to work out what drivers to the safety case would be relevant in any site selection process. So what we are trying to do is identify the things that we think are important in a repository concept in terms of what is affecting our safety cases.

Q: Listening to you presentation, I had the impression that you have already made the decision that the design of the repository is going to be fully retrievable. Is that correct?

A: The conclusion we have come to is that having retrievability in our concept is not against the other principles we have, which is having a very flexible and modular approach. Since we do not have a site, we have to maintain our flexibility. We have also been discussing with people, like the waste producers, how long the repository might be open and at what time it would actually start. We are not going to start in the next ten years, it is going to be quite a few years down the line. So issues such as what our total capacity would be and how many packages we would have to take in a year etc. are all very much issues for discussion. The ideas and the requirements for retrievability are not incompatible with the other aspects that we have to deal with and that is why we believe we can take this on board now without causing any problem to us.

Q: At this stage, in your proposed concept, eventually a decision will have to be taken and who will take this decision?

A: I think that is something that we have been debating and we have actually also talked about that this morning. One of the things NIREX has been doing is thinking about not who will take the decision as such but what decision processes and how to take on board this aspect of putting value judgements in your decisions so they are not just logical technical decisions. There is a whole area of work through our transparency and stakeholder dialogue etc. that is taking place on that, but we would not say at this moment that there is one body that would make that decision.

Q: Do you envisage that also the high level waste would be put in the same repository?

A: The first thing I would say is that NIREX at this moment does not have a remit for taking high level waste. One of the things the House of Lords Report said was that the approach to waste management was very fragmented and that other materials might need to have a final resting place. Part of our work at the moment is looking at those materials and what possible range of management options there might be. It does not mean that we are looking to increase the capacity of our repository. What we are trying to do, by listening to the criticisms made of us in the past, is to enter the discussions about an appropriate place for some of these wastes to go. We do have work underway, based on the QuantiSci report that has been done, to identify what the implications would be to our safety cases and to our R&D programme and our work in general, if we were to take high level waste. We have looked at studies on that and we are about to publish papers on it as well. But no decision has been made that it will be our remit.

C: Just one clarification from my side. Low- and intermediate-level waste is not only disposed of in near-surface facilities, these are only acceptable, at least in terms of the international understanding, for the so-called short-lived waste, that means waste with radionuclides with half-lives of up to about thirty years. The long lived waste has to be disposed of in other means, for example, in a geological repository. I understand the UK concept in such a way that they dispose of the short-lived low- and intermediate-level waste at Drigg and I assume that the underground disposal facility is, in particular, for the long lived low- and intermediate-level waste.

A: And for the waste that will not go to Drigg, because it is outside its conditions of acceptance.

C: There is no exclusion, you can also provide a geological repository for the short-lived low- and intermediate-level waste.

Q: I have a question about the design of the repository. You have now shown a design and you say that this is consistent with both retrievability and with the safety. But I think that, in order to convince a regulator and the decision makers about that, it would perhaps be necessary to show alternative designs where you only consider isolation capacity and safety issues. Have you considered to show alternative designs?

A: I am not sure what you mean. The idea of what we have got in our generic design is that if we were to look at any site, whether it be an existing site that might have been volunteered like an old mine or a new site or whatever, we would take those generic elements and we would apply them in the way that was relevant to that site-specific issue. And because we have looked at the operational, transport and post-closure safety assessments and we have them together, we would be able to understand what were the relevant drivers, the relevant things that were very key to the whole design and what we were looking for. So the approach that we have gone for, is doing a number of comparisons, because we believe at the end of the day we will not be looking at one site, we will be looking at designs for a number of sites.

C: What I mean is that in the Swedish presentation in this session we said that a design for retrievability should not result in a decrease in the safety of a repository to any significant degree. So if you have designed for retrievability you must also be able to show that this retrievability has not inflicted any difficulties with respect to safety.

A: Yes, and I think that we would still be able to say that, or demonstrate that we have met the safety criteria as set out for the operation, the transport and the post-closure phases.

Q: I have a very silly general remark about overheads. When it comes to presenting results of this kind or any other kind, to the public, some people literally look at these pictures and think “that’s it!”, when you present something very generally. Now I counted to 3 × 4 casks in this repository and some people are really surprised when they see the actual volume they draw. So

I would just like to make a general comment here: try to be as realistic as possible and give all the information that there is available of the extent or the amount etc.

A: We have typically, in the past, always done presentations of slides which mainly contain words, and one of the things that we have been trying to do lately is to make better use of pictures. The difficulty we then have is, that when you present pictures, people think that it is finished or that you are quite far down the line and you have got your ideas fixed in your head. I think there is an issue there that we have looked at and trying to get over to people that it is not the final thing but an illustration only. That is another area that we have been trying to think about.

SUMMARISING DISCUSSION ON SESSION 5

E. Warnecke (chair)

I would suggest to look at the session as a whole. We discussed safeguards yesterday and turned to safety today. Are there any questions, comments, remarks to any of the papers, to any of the speakers?

We are dealing with the safety issues and heard presentations on concepts for disposal, for incorporating safeguards into disposal and incorporating retrievability into disposal. Session 3 was dealing with ethics. What are the expectations of those who deal with ethics on the presentations of this session? Are there any proposed solutions from an ethical point of view? Can I ask for reactions on this subject in order to foster the dialogue between those who deal with ethics and those who represent the technical side? Would anybody want to volunteer?

A. Fattah

I just take this opportunity to mention that, in the context of our programme, we have now an expert group composed of different member states, and in the near future we would like to have topics about the safeguards/safety integration. Maybe in future I can expect contributions from you.

E. Warnecke (chair)

I refer to Mr. González' opening address which proposes to create a forum of experts not only from the nuclear science area but also from other areas, for example policy makers and representatives of the public. That goes along a similar route.

B.-M. Drottz Sjöberg

I think there are two ways to see it. Although I am not an ethical expert, I think ethics are sometimes about how you deal with different systems, different ideological and political interests within society, different value systems, norms and conflicts of various kinds. So it could be a discussion on "how to treat different opinions". Sometimes, ethics is discussed as if we were to come to some conclusion with respect to what we should do or what we should not do and that is, I think, a very different kind of discussion. So I would like to promote the discussion of how to handle various options and various value systems coming up in these discussions. That is much more important than saying this is right and this is wrong and I do not like the terms "consensus conference" or "consensus panel" just for that reason, because it says that you have some kind of interest in making people think the same way. I think it is much too early for that, if you ever reach that stage. That is a very strange society, where everybody thinks in the same way. So I would like to have this transparency concept much more viewed, that things should be easily understood and discussed openly and a lot of time and effort should go into explaining to those who do not understand the "how" questions which are the technical questions, and then a lot of time and effort should go into the discussion of "why" and "why not" and "who is gaining" and "who is taking risks". The discussion should also include these value systems surrounding the issue, and not only concentrate on what is right or wrong in some kind of absolute sense, because that is a discussion I do not think is appropriate.

S. Norrby

I think very much in line with Britt–Marie Drottz Sjöberg. You should not put ethical aspects on one side as something different from safety and radiation protection matters on the other side. To me, ethical aspects include practically all relevant matters. So I do not think that, in Sweden, the Nuclear Power Inspectorate and the Radiation Safety Institute have not considered ethical aspects. On the contrary, we see our important roles as regulators as being part of an ethical discussion. Also, I would like to suggest that we broaden the question to include ethical aspects on other parts of society, for example, on hazardous non-radioactive waste, and also on many other matters. Why should we restrict the discussion on ethical aspects to waste management and disposal?

E. Warnecke (chair)

That question has been addressed in the past sessions, not in great detail, but several comments have been given just in this direction. This is, I believe, an important perspective, otherwise we see radioactive waste management in isolation. I agree very much to the comments made here, and have no objections to what has been expressed. My point was just to see whether there is any reflection from those who ask for retrievability, whether the cases presented in this session are acceptable from a safety point of view. What would be the initial reaction to a dialogue between ethical and scientific aspects of radioactive waste disposal?

C. Thomas

May I make a very hesitant response to that. It has taken such a long time for dialogue to happen and now everybody is saying: yes we desperately need a dialogue. I think you need to market the idea of a dialogue. You have got to sell it in the newspapers just like bad news. You said the other day that now we really need to market it so that people find it useful, that they have some empowerment, that this is theirs to discuss.

A. McCall

I do not think that there is an issue about what is the right or the wrong approach to the issue of retrievability and safety. I see the issue of retrievability has been raised by others who do have an interest with what we are trying to do with deep disposal, as a means of getting us to be more open and get us to talk to them about what our intentions are. I think retrievability is more the mechanism that started it. The issue is more, for example, that the public, whoever the public are, would like to see how you are approaching retrievability. Next week it may be: we would like to know a bit more about safety. Next week again it might be: we want to know what you are doing with other wastes, etc. I do not see that there is a right or wrong answer to the issue of retrievability. I think it is just a vehicle that is being used to get us to the table and get us to do what we should be doing, which is talking to people about our ideas and our beliefs.

H. Selling

More or less accidentally, I have a role in a subject in which I am not an expert, so I was asked to give a presentation on ethical aspects related to retrievability. This brings the subject of retrievability really to the fore. To recall the situation, to regard the situation from the perspective of the Netherlands, I recall that the concept of retrievability was first suggested by people at the political level. It was not a scientific invention. So retrievability has been introduced, at least that is my view, as an instrument to buy some time, to build confidence with the people who are not convinced that the scientists have made a sufficiently robust safety case for the disposal of radioactive waste. So I see retrievability as a method, or as a concept to provide a period — yet to be defined — in which the safety can be demonstrated. Somehow, if you demonstrate that there are flaws in the models, you still have the possibility, technically, to get the waste out of the repository. What I think we should try to avoid is to give the concept of retrievability some kind of scientific background. It is the result of a call from the society in the sense: wait a little bit we are not quite convinced that you have a robust enough case.

S. Norrby

Just in line with that: retrievability as such could not be the ultimate goal. The ultimate goal must be something final. I mean final disposal or something else. Retrievability is a means to ease burden on decision makers maybe.

CONCLUDING REMARKS BY CHAIRMAN, RAPPORTEURS AND OTHERS

(SESSION 6)

INTERNATIONAL REVIEW AND SOME NATIONAL UPDATES ON RETRIEVABILITY
(Session 1)

Rapporteur: C. McCombie

I have tried to pick up some key messages which you are invited to comment on.

1. Retrievability is a very topical issue, a very active issue for study, in design and for experimental demonstration work:
   - The international overview included ten different countries and the EU concerted action programme;
   - We got details of the work that is being done in Sweden, Belgium, France and USA;
   - Detailed technical work and even experimental work is going on, e.g. at the Äspö hard rock laboratory. That is a big time experiment, partly centred on retrievability and demonstration of retrievability; and
   - There is even legal and regulatory attention being paid to retrievability. We heard about this from France and we heard from Sweden that they are looking to see if it could come into the regulation.
2. A key point is the ethical choice issue. Do we minimise burden on future generation and do we maximise future choices?
   - Some people said that we can effectively do both. Tönis Papp was the most explicit is stating that there does not have to be a contradiction and in the Swedish system, at least, there is not a contradiction; and
   - Peter de Preter said almost the same, but if I understood right, there are in some cases contradictions. An open repository definitively helps retrievability, but it also can have downsides for the long term safety.

     This is the big issue that comes up again and again. To what extent can you satisfy both these ethical premises. If you are faced with a choice between the two ethical premises, how do you put your specific weighting. I did not see a huge consensus here on this.
3. Easing retrievability and enhancing safety do not have to be contradictory, they can be common results of certain measures. There are certain things — a long lived container is the classic example — which are definitively good for both. This is a complicated issue that came up repeatedly during the whole seminar.
4. Retrieval is always possible. This was explicitly stated by at least participants from Sweden, France and Belgium, and also by the USA:
   - Cost and time are affected by this, when you do it, how you do it;
   - Current technology suffices. I think that was implied by everybody; and
   - Demonstration seems to be, if not required, at least useful.
5. Another potential conflict is between easing retrievability and making retrievability more difficult in order to strengthen safeguards. This came up already as part of the discussion in Session 1 and was later more fully addressed in Session 5.
6. The whole issue of nomenclature and semantics is important and not sufficiently clear. Retrievable, recoverable, reversible, postponable, practically irrecoverable, closure, reparability are examples of words that need to be more clearly defined.
7. Retrievability is not only being investigated everywhere. It seems to be a feature of many and probably of most national programmes. Retrievability is explicitly addressed and to some extent being programmed into them. That is the upside of it. The potential downside

is that the more work that is done on enhancing retrievability, the greater is the danger of reinforcing the perception that retrieval will be necessary.

I am also a collector of "quotable quotes" and I found at least three nice quotes in the first session. The first was mentioned by Hans Blix in quoting Camilla Odhnoff:

"Waste is what you have when you have no more imagination".

The second one was from Hans Blix. And this is a serious quote here, in relation to our discussion on public perception and public opinion. We look for middle ground all the time. I think this is a comment from the lawyer Hans Blix, a useful warning:

"A mediator must seek the middle ground and try to satisfy both parties —
a judge must seek the truth ... even if it does not lie in the middle"

For the mediator there is no good and bad, he is trying to make everybody happy. A judge cannot do that. A judge has to look for the truth. Sometimes in our business we can get faced by this kind of conflict. Something that people would like to hear, should not always be said, even if people do want to hear it. There are several truths and we should distinguish.

The last quote is again from Hans Blix. It shows how the world changes, if you like. From spending many years of trying to make people really accept that when this waste has been placed in the repository, it is safe and away and it will never return to the biosphere, we are now spending lots of effort trying to convince people that you can get it back at any time:

"The public now seems to want to be assured that the waste is always retrievable,
rather than assured that it will never come back"

PUBLIC ACCEPTANCE *(Session 2)*

Rapporteur: D. Bullen

From Session 2, one can make the following conclusions:

- The perceived risk is very important. Trying to convey to the general public actual risk or calculated risk, usually loses a lot in the translation. If the public perceives that the risk is there, it actually is there in their minds;
- Information is key to acceptance. We noted that, in the UK. Consensus Committee, the issue of retrievability still went with their "gut reaction" from the beginning. There was no change in the perception that retrievability was necessary for the further development of the disposal system. That was an important point, because the information available, provided by both sides, did not in the short term make any changes associated with the perception that people had when they originally arrived;
- Nuclear communities may be more easily accepting a disposal facility, either with or without retrievability. We noted that from Harald Åhagen's presentation. Oskarshamn has a long history of understanding nuclear power plant operation, the CLAB facility, the Hard Rock Laboratory and now being considered as a potential disposal site. There has been a great deal of effort in the development of avenues of communication and areas of understanding not only by people involved in the decision making process, but also by the general person on the street;

- Broad public support is required. The best example there is the Wellenberg case, where they had two local votes, both in favour. But as soon as they went to the cantonal level, in which a broader part of the countryside population was involved, they were defeated. In fact, the broad public support will be necessary for anyone to make the case. In the Canadian case, one of the prime reasons that they decided not to proceed was the lack of public support for the effort;
- Option for retrievability appears to aid in discussion. It may or may not be required for the safe disposal of nuclear waste. As Charles McCombie mentioned previously, the option could be either a benefit or a detriment. But is does appear to aid the discussion. In the UK case, retrievability must remain on the table, because it is an option or a requirement for the continuation of the discussion. In the Wellenberg case, retrievability was also an issue associated with the fact that they thought that maybe the wrong technology was selected for the disposal. Retrievability appears, at least to date, to aid in the discussion of the potential for a permanent storage facility or a deep geological disposal facility for nuclear waste;
- The use of language, specially definitions is important. The need for "plain English" was mentioned by Anne Hiett from the UK Consensus Committee. It is very imperative that the people to whom we are making a presentation about nuclear waste or about retrievability, understand what is said, how it is said, what the new answers mean etc. I myself am actually one of the more guilty parties associated with that;
- The level of transparency is very important. If you get to a level of complexity that is very difficult to understand or a way of thinking that is very difficult to follow, you can lose the general members of the public and actually you can lose public acceptance. People have to understand, not that it is a very complex model, but understand the physical performance of the system of natural barriers and engineered barriers and how these will work in conjunction. So we think the level of transparency is a key issue here;
- Conflicts may be hidden due to means employed to draw public into discussion. I was intrigued by the UK. proposal to send out a mailing to 4000 people, having 170 or so responding, and then taking 15 of them (as members of the committee). I would be sceptical that this method would work in the USA How you draw people into the public discussion can be very important. People may feel that they are not part of the discussion, because they have not been asked or they have not had the opportunity. In some cases with very small communities it may be easier to draw people into the discussion via public meetings, announcements in the newspaper, discussions in radio and television or by approaching people in the streets. When you get to a level where you have to go to higher authorities, for instance when you go from the community to the canton, it may not be as easy to draw people into the discussion, and people may not be willing to take part in the discussion, if the thing will not be in their own community. This is an area where potential conflicts can occur;
- Our final result or conclusion is that early and continuous public participation is essential. This is true not only for nuclear waste projects but in general for all contentious issues that the community has to deal with, whether it be hazardous waste, development of a new highway or any other thing that would require an Environmental Impact Statement.

E. Kowalski

I have just one comment. You say that options for retrievability appears to aid in discussion. I think that, in all the sessions here, it would be possible to say "step to step approach" or something like that. The transparency may be the same. "Step by step–ability" is even more important. What the people would like to have is "no irreversible decisions", to guide the whole process of decision by democratic means. It could be totally counterproductive if you say: “let us make a repository and close it, it is anyway retrievable”. That would be very negative message. The message is not the retrievability as such, but this postponed decisions and confidence building. We are to some extent mixing retrievability and the step by step approach.

D. Bullen

That is a very good comment. One of the things that Britt–Marie Drottz Sjöberg and I discussed, when preparing this summary, was a direct quote from you that future generations will decide if and when to close the facility. That is part of the step by step approach. We may make the decision to actually close now. You can say that we will build and close a facility. But the ultimate closure event and the decision to finalise that, will be made by future generations. All of us agree on that, because it will be 50 years from now before we actually get to that point. The step by step approach of identifying a site, characterising a site, licensing a site, operating a site and finally deciding to close a site are all very important and need to have public acceptance at each step.

ETHICAL ASPECTS *(Session 3)*

Rapporteur: O. Söderberg

I want to start by reminding you that Claes Thegerström, who was chairing Session 3, ended by stressing that — as could be expected — no clear or final conclusions can be drawn from such session. I will, nevertheless, try to draw some conclusions. I will pick up some pieces from the papers and from the discussion. It is not possible to cover all of it.

Anyhow, I think there are two very thought provoking messages here, in the two main papers of the session. I refer to the paper by Anne-Marie Thunberg that could be confronted with the message from the Dutch METRA project, as explained in Henk Selling’s paper. In both cases, the messages are claimed to be based on ethical considerations, but it seems obvious, at least to me, that only the one presented by Anne–Marie Thunberg is providing us with a way forward. The comments and the clarifications that were made in the discussions after the presentations did also point in this direction. In Anne–Marie Thunberg’s paper, we find questions, doubts, follow-up questions, new reflections and finally some conclusions. One important message is that we cannot act on such conclusions, unless we base the actions on the knowledge that is available today. Some of the conclusions may seem tentative. They have a degree of uncertainty, and this sort of uncertainty is unavoidable. I think that this was also illustrated today, in Session 5 in the paper by Gera and Hill, which included a table on comparisons of strategies based on non-quantifiable factors. The message in Anne–Marie Thunberg’s paper is quite clear: We have to take action now. A passive attitude is simply not defensible. Long term safety must be the primary concern, if such a goal would be inconsistent with other values. Some of what she wrote, is worth to be repeated here. One quotation is: “The price we seem to have to pay is to act under the premises of uncertainty, while not being able to use this uncertainty as an excuse for not acting at all”. I have also selected a second quotation: “We could hardly advance further than to manufacturing an interactive waste management system, allowing us to involve present and future generations in an open, flexible and non-preconstrained decision-making process”.

We may compare these messages with the message from the METRA study. As far as I have heard, the METRA study is the first attempt to entrust a study within this ethical area to a group with a completely different set of values, than is prevailing among “ordinary citizens”, if those exist. It is obvious, that the set of values given in that study is certainly not at all represented in what we could call the nuclear waste management community. To most of us, who are present here, I think that the main conclusions of this study are totally unacceptable. We find them not ethical at all. But it was also stressed in Henk Selling’s paper that there was one other issue, that I think we should regard as very important. I am referring to his conclusion: “This study has proved that there is a beginning of a dialogue between the official bodies and persons representing environmental and social organisations”. So my personal remark is that the METRA study has been useful, if it serves that purpose. With all due respect to those who commissioned the study, one may ask whether these official bodies do not feel a need to support a dialogue also with other concerned groups among the citizens, groups that may have a more open mind to discuss these matters.

The term retrievability was discussed by Charles McCombie in his report from Session 1. I have made a similar short list of words: Retrievability, reparability, recoverability, reversibility. I also heard expressions like unapproachability, inaccessibility. I suppose the latter ones mean the opposite of retrievability. I would like to give a small warning, from my point of view. This repeated discussions about how to use the proper words could cause more confusion than clarification. I understand perfectly well that experts need precise words with precise meanings. But the public may not see it the same way. They expect people to use simple words. Others have also said this, and this is very important at least if you are involved in confidence building with regard to relations between experts and those who want to participate in the public debate. The term retrievability, I think, has come to stay and it would be wise to accept that. But at the same time, as was pointed out by Claes Thegerström in one of his viewgraphs, there are different degrees of retrievability and that must be stressed as often as needed.

B.-M. Drottz Sjöberg

To me, expressing oneself in a simple way does not mean addressing someone who is simpleminded. You must be very clear what you are talking about. Clarity is perhaps a more central term than simplicity.

F. Gera

Sustainability also has ethical implications. Nowadays, something that is not sustainable is very doubtful from an ethical point of view. The retrievability issue has some sustainability implications, that have been mentioned a few times, but not very clearly. When you transmit to a future generation an open repository, this is a liability that is being left. There are no benefits attached to it, it is only a liability. If you are considering only two generations, it is not a problem. If you are considering a long series of generations, you can very well admit that every generation has allowed, as the previous one, to add one additional liability. Some time will come in the future, when these generations inherit a whole series of liabilities. They have no benefits, only responsibilities with costs and risks attached to that. Is that sustainable? I do not think so. We should keep this in mind when considering the issue of passing on an unsolved problem.

O. Söderberg

I have no objection to this. I just want to add one more comment to my summary. Do people at the local level, in the concerned municipalities, bother about this kind of debates? The answer is yes. We have made some experiment — and Anne-Marie Thunberg was very much involved in them — to put together people from what we call the local level and tell them that this is the problem which we would like to discuss from an ethical point of view. People were very keen on taking part in this discussion. It provoked interest. People want to act responsibly towards future generations. So this is not an academic exercise that we are making here. It has its repercussion in the reality too.

LONG TERM MONITORING AND COST CONSIDERATIONS *(Session 4)*

Rapporteur: F. Gera

Session 4 addressed two main topics.

One was the technical issue, including the geophysical methods for monitoring. I think there is almost nothing contentious about that. Basically these geophysical techniques have been known for a long time, they are very effective in hard rock, somewhat less effective 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 they may have a role in the safeguards system in the future. I think that basically the discussion was very straight forward, it was an exchange of technical information. Therefore I do not need to say anything more at this point.

The following two papers, one by Charles McCombie and one by Olof Söderberg, addressed the issues of liabilities, responsibilities, financial commitments etc. in the different options. That is a little more difficult and it is not very easy either to extract the main points. There are some legal implications also in the definitions of the responsibilities we are addressing, at certain points. When we discussed this yesterday evening, the Chairman of the session and myself, we thought, that as far as we were concerned, we could see clearly where the legal obligations of the operator — the owner of the waste — will finish.

Let us look at the slide with the nine scenarios, the table from Olof Söderberg's presentation. We thought that for scenarios 1.1 and 2.1, obviously there is a responsibility for the operator. He should do something to make it right. But then, for none of the other scenarios we felt that the operator could really be considered liable, because if you are in the X.2 scenarios (where it is safe but there is a better solution and society wishes to switch technology), it is not something the operator could be considered reliable for. It is obviously a free choice for the society to change direction and then the society should also pay for it. If the waste becomes a resource, then it is strictly an economical issue. If there is a benefit, for instance a mining company may be allowed to go into the repository and extract the material. And there is obviously no liability for the operator of the repository.

After closure, I guess his responsibility has been released, because he has been authorised at closure time by the regulatory authority, when the final safety assessment has been accepted. So we thought that the liability of the operator is clear only for two of these scenarios.

Then there was a discussion about the cost of retrieval. Charles McCombie made an interesting point about the actual cost, and these costs are obviously very high in some of the retrieval options. When would it be reasonable to commit resources for such an unlikely event? That is a very challenging question and I do not think there was a clear answer.

Then there was an interesting comment from Emil Kowalski, who expressed doubt about the practical feasibility of transferring funds over extended periods of time. The separation in time between committing the funds and the actual need for them for doing the work, creates some big questions. There is also a total decoupling between the benefits that are enjoyed by the generation that is using the energy and the liabilities associated with the waste that are to be born by future generations that enjoy no benefit whatsoever. This has also been mentioned as an ethical implication.

There were also doubts about transmitting effectively information over very long periods of time. That is also a big question. How reliable is this transmission of data about the actual position of the waste packages, about the conditions of the repository? In the meantime changes may have taken place, that were not fully foreseen in the first place. So there is also a technical aspect to this uncertainty.

There was another point raised in the discussion, about the moral responsibility of the users of energy with respect to the disposal of the waste. I think this is kind of an intriguing question. It is relevant for many situations that take place today. We know that countries that do not have nuclear energy import electricity from neighbouring countries which have nuclear reactors. Should they in some way be responsible for at least part of the cost and liabilities associated with the waste? I think, that, at this time, the answer is clearly no, because the question has not been raised. But in the future it may be a serious question, which must be considered. Presently, I believe that when you pay for the energy, you also pay a ticket to get out of this problem. The country that has the reactors will have the liability for the waste. But this may change.

O. Söderberg

Concerning your discussion of my scenarios. It is a matter of what you *think* is right and what is right. In practice, there is no doubt that both in scenarios 1.2 and 2.2, there is a legal responsibility with the operator, at least if I refer to the Swedish case. But I think that I pointed out in my presentation that it could be debated and it certainly will be debated by the owners of the power plants, if that situation would arise. So your comment is valid, but according to present legislation, the responsibility is obvious. Obviously, it is quite another thing with scenario 3.2.

F. Gera

I meant all three. There was agreement between the Chairman and me about this. I was forgetting one very important point the Chairman and I agreed to mention. The Chairman proposed that the term "retrievability" is not really the best term to use for operations after the closure of the repository. He suggested that, after closure, "reparability" would be a better term. There was some discussion about this and the idea did not get very much support , but we agreed that we should mention it again here.

C. Odhnoff (chair)

Regarding who should be responsible for the waste generated by imported electricity, I made that point, because Swedes generally have a very high moral standing, especially at conferences. I liked to ask the question, because I wonder how far this high moral will take us.

F. Gera

I am very sensitive to this issue, because, being Italian, I find myself belonging to a country that has closed down the nuclear industry, on the basis of all kinds of considerations, including ethical ones. But then it imports very large amounts of electricity from France. And that electricity is totally produced by nuclear reactors. But public does not seem to be bothered by this at all. Obviously, there are some ethical aspects of the issue they have not fully considered.

T. Papp

Just for clarification: When you talk about the legal responsibility, in case there are better options available, I assume that you mean that in the regulations issued by the Swedish Radiation Protection Institute there is now the requirements for best available technology. Still, this requirement to use best available technology is circumscribed by the fact that it should be reasonable with regard to economic evaluations. So a discussion of "the size in safety and cost" will be an important part when to decide who is responsible for carrying out such a solution.

O. Söderberg

Yes, I agree. Perhaps all these scenarios 1.2, 2.2 and 3.2 are very improbable to occur in the real world.

P. Harrington

With respect to the concern that electricity users in other countries might share the responsibility. In the USA, the utilities have to assess a fee on the users for the response. Is that common elsewhere?

O. Söderberg

Yes, the fee that is included at least in the Swedish financing system, is paid by the power companies to the state — a certain fee per produced kW·h in a reactor. It does not matter to whom they sell that kW·h. The fee is part of the production cost for the utilities. So even if the electricity would be exported, the utilities would still have to pay this particular fee to the waste fund.

P. Harrington

But do not the utilities pass that cost on to the consumer? So the users are still paying, in reality?

O. Söderberg

Yes, of course they do.

F. Gera

On the other hand the discussions during these days have shown that the price for the disposal is a big question mark. It is very difficult to estimate reliably at this stage. So this fund which is intended to cover the waste management is some kind of a fictitious structure. It may turn out to be grossly inadequate in the end. If retrievability and very long institutional control were included, it is clear that the price of the operation would go up.

C. McCombie

Before we finish the discussion on Session 4, we should also discuss when the state definitely, at some time, gets the responsibility. There is no way out of that. It is an activity which is so long lived that the government or the state or the society has got to take over the responsibility. Don't you think that is kind of an overriding conclusion?

F. Gera

When we discussed this, we thought that the responsibility of the operator was clear for scenarios 1.2 and 2.1, but for all the other scenarios there was no responsibility for the operator of the repository and, therefore, the responsibility has to go to some kind of higher authority, which is probably the government.

SAFETY AND SAFEGUARDS ASPECTS *(Session 5)*

Rapporteur: E. Warnecke

I had to draw conclusions on the subject by my own because there was no time for a consultation with the authors of papers in Session 5. Authors are welcome to comment and contribute during the discussion.

(a) General conclusions:

- Without any doubt, safety has priority;
- Safety shall not be compromised (by safeguards, retrievability or anything else); and
- Safety comprises radiological and conventional (mining) safety. In dealing with safety, it is necessary to distinguish between operational safety (including the staff as well as members of the public) and post-operational safety.

(b) Safety aspects

- "Normal" scenarios (waste emplacement, backfill of disposal rooms, closing of drifts and accesses).
  For such a normal scenario, safety has been demonstrated by various means, and there is no doubt that repositories can be built, operated and closed safely.
- Retrievability scenarios:
  Here I have identified two different situations:
  - One of them, I term it "reversibility" as it was done in the Swedish presentation, means that disposal of the waste is done in a similar or in the same way as in the "normal scenario", but provisions are made to allow retrieval at every step in the scenario. In this situation, the safety case is very similar to the normal scenario. In such a "reversibility" scenario an adjustment of the repository layout may be necessary. For example, the maximum temperature may need to be limited below 100°C or whatever limit may be justified for the respective host rock. There may also be a need for adjustment of the waste package in order to provide mechanical stability or chemical durability, if this has not already been built into the system, due to other considerations. I would like to mention that, in HLW management, some disposal concepts are based on thick-walled, corrosion resistant and leak tight canisters. Other concepts are based on unshielded waste packages — for example HLW glass blocks — which are directly disposed of in a repository. In the latter

cases, it is necessary to check whether such waste packages are adequate in order to ensure retrievability. Furthermore, there is a need for development of technologies, for example equipment for waste retrieval. There is also a need to ensure mining safety in the case of retrieval. In particular, rock stress and increase of rock stress as a function of temperature is an important aspect for conventional mining safety. Finally, if retrievability is to be implemented, radiological safety has to be ensured, that means that radionuclide releases from contaminated or leaking waste packages have to be assessed and, as necessary, additional engineered features have to be built into the concept in order to deal with retrievability.

– The other scenario, I term it "full retrievability", means that the disposal rooms are open until it is decided to close them. That is a new safety case, which is not covered, neither by the "reversibility" nor by the "normal" scenario and which needs to be assessed. In this case, all the issues mentioned under the "reversibility" scenario are more crucial and need very thorough consideration. A particular issue is the stabilisation of open rooms, which may collapse as a consequence of temperature increase and this may result in conventional accidents. Measures to stabilize open rooms for the necessary period of time under thermomechanical stress is a safety requirement of primary importance, including limitation of temperature. In terms of long term safety the generation of new pathways due to thermomechanical effects needs to be addressed. Again, radiation protection has to be ensured. As long as all the rooms are open, all waste packages contribute to radionuclide releases to the environment. This would result in higher occupational and public radiation exposure if no special consideration is given to the situation. Some experts even expressed the opinions that full retrievability is not consistent with the IAEA/ICRP principle of optimization, because exposures are not "as low as reasonably achievable".

Regarding feasibility, the opinion of the experts present at this meeting was: yes, retrievability is feasible, although (a) it is difficult to achieve, (b) it has to take into account additional measures, and (c) it is more expensive. The discussion showed that the safety case for the "full retrievability" scenario has not yet been fully assessed, neither theoretically nor practically, for example, in demonstration experiments in laboratories, pilot plants or underground research laboratories. On the other side, such work has been initiated and is under way. It is necessary to wait for the results of such investigations and see, whether they confirm the above mentioned experts' opinion.

(c) Safeguards

Work has been going on for several years targeting on integrating safeguards requirements into the spent fuel disposal concepts. The results of these efforts can be summarised as follows:

- The spent fuel conditioning plant has to undergo safeguards inspection. Open disposal rooms have also to be inspected. It would be desirable to monitor closed room prior to closure of the repository by geophone measurements or other remote control measures.
- After closure of the repository, land surveillance of the repository site, for example by satellite systems, would be a suitable measure to ensure that there is no diversion of fissile material.

The above mentioned work on safeguards concepts did specifically deal with retrievability. Therefore, it is necessary to check whether the above mentioned basic approach is sufficient or needs to be amended in the case of retrievable disposal.

Details on the implementation of the safeguards concept are being developed in a multinational activity. Some of these concepts have been presented.

(d) Retrieved waste

No conceptual approach for dealing with retrieved waste has been presented at this seminar. The question of what to do with the retrieved waste is unclear. Is it necessary to have a storage facility available, or is the retrieved waste going to another repository, or is there any other solution?

(e) Final remark

It is very important to have an integrated approach to radioactive waste management, from the generation of the waste through to its disposal, including items such as safeguards or retrievability, in order to avoid conflicting requirements. The work on safeguards shows in principle that cooperative work can lead to reasonable concepts which suit both, those who deal with safety and those who deal with safeguards.

A. McCall

I do not recall that the issues of mine stability and mine safety, operational safety and the application of the ICRP optimisation were actually discussed in the session. In particular, concerning the conclusions under point 1, that identified areas for further investigations, I would not agree that they were a conclusion of the session. We did not go into that detail.

E. Warnecke

I did intend to repeat the session. My emphasis was on putting the session into a broader context and address essentials that have not been presented but which are necessary in order to judge on the feasibility of retrievable disposal. My remarks refer also to safety relevant factors reported in other sessions, for example, the USA presentation in Session 1.

C. McCombie

I do not see any program that has ever combined conventional safety with radiological safety. I mean in terms of producing a safety case, which is putting both on the same footing or integrating them or whatever. Maybe this is a question to the EIS (Environmental Impact Statement). The Yucca Mountain must be the most recent one. How much effort was put into conventional mining safety as opposed to radiological safety estimates?

P. Harrington

I cannot really comment on that, but I would like to comment on the other aspects of safety. Certainly, when we make a case, a case that the regulatory authorities get for review, we focus very heavily on nuclear safety aspects. Part of it is also public safety or worker safety. In addition to the nuclear safety case we have made in order to support workers, we do actually make a case to support a safe occupational environment. So although occupational safety will not be a large component of the regulatory basis for the repository, we still have to make it.

D. Bullen

The only other aspect I could add with respect to the mining safety deals with the radiological exposure to the public of the radon gas that will be released during the mining. That is the only specific difference that is associated with safety in the EIS. As Paul Harrington mentioned, all of the other issues like dust generation etc. that have environmental impacts, are in there. But I do not think there is anything that specifically calls out mining worker safety as opposed to the radiological impact in the EIS, if I am not mistaken. But I am not an expert on that.

E. Warnecke

Conventional safety must be provided in a repository for radioactive waste. It is essential to avoid, for example, rock fall, which could kill humans. Temperature increase results in thermomechanical stress which will affect disposal rooms, drifts, shafts, etc. Stabilization wil be necessary in the case that rooms of a HLW repository will be open for a long period of time.

P. Harrington

Disposal rooms will be subject to a rigorous radiological safety regime. There will be no miners in there. Any actions will be made remotely.

A. McCall

I just wanted to say that, in the UK, we do cover conventional safety in our operational safety assessment. We have the Construction, Design & Management regulations — CDM regulations — which cover conventional safety. We have also covered toxic hazards, which particular regard to personnel who might be down there and any gases that might be given off. I would agree with Paul Harrington in terms of the increase to the operational safety hazards and the mining hazards. I do not think there are any additions to mining safety. I would not be concerned about that. We talked about maintenance of these things. But I think that in terms of operational safety and dose assessment, in the maintenance period, you are talking about having a dose to any workers who are down there for that period of time. But the whole philosophy is around keeping the workers away from any dosed-up areas, so I would not think that there would be any real issues regarding that, because again you have to stick to your regulations and your principles - elimination, mitigation and protection. I do not really see that the retrieval flies in the face of safety, whether it is conventional safety or radiological safety.

E. Warnecke

In the case that all disposal rooms are open all the waste packages of the waste repository will contribute to the release of airborne radionuclides. Such radionuclide releases will be higher than in the option of closing the disposal rooms immediately after filling them with waste. Releases of radionuclides may not be a major concern in the case of a thick-walled, sealed and leakproof HLW container or in the case of vitrified HLW which is a high temperature waste form. But, for example, LILW from reprocessing, will always have a leakage of tritium into the environment and this will contribute to the exposure of staff and members of the public. This has to be taken into account in the safety case. Special measures to reduce occupational and public exposures may be necessary if disposal rooms are not immediately closed, but left open as all rooms contribute to the release of volatile radionuclides. These comments were not intended to address a particular national disposal concept. They were meant to be generic and should draw the attention to the different situations in terms of radiological safety in the case of immediate closing of disposal rooms and leaving such rooms open in order to allow waste retrieval.

A. McCall

Some of those have a time factor as well.

E. Warnecke

Yes. There is a build-up of radionuclide releases during waste emplacement and, at the same time, a radionuclide decrease by decay.

T. Papp

I would like to comment a little on the wordings. Sometimes one has to be careful with the wordings. In the Swedish case, anyway, the full retrievability is something that we often call the zero alternative. In case you are not allowed to go to the next step, you can always take a step backwards. This is normally not a new safety case. It is normally a part of the stepwise approach, which has already been taken care of in the safety analysis. So such a situation should not be referred to as a new safety case, which has not been assessed before.

E. Warnecke

Full retrievability, as I have explained it at the beginning is an extreme scenario where the disposal rooms are open until repository is filled and until a decision is taken to close it. The assumption was that all the waste is accessible. Of course, other approaches are possible which, as shown in the Swedish "reversibility" concept, have advantages in operational safety. I do not want to raise doubts on an eventual retrieval of the waste by mining operations.

CLOSING ADDRESS

C. Odhnoff

I would like to round this off with a few words. We started here in a foggy mess and we have gradually come to see the light, today even full sunshine.

The opening address was clear enough, sorting out good and bad. Mankind was divided into two camps, believers (in the feasibility of safe disposal) in one, and non believers in the other. The latter looking at nuclear waste as the real evil. For some reasons, the non believers later turned into retrievers. Why they would want to retrieve the devil, I do not quite understand.

We have then been discussing retrievability and scrutinised its various aspects. I found it very interesting here to hear that retrievability may be built into broader concepts by step by step decisions. Maybe it is not so controversial if you look at it in that way. Hans Blix pointed out that there are two main streams of arguments for retrievability. He had found that technical people may think that it would give a possibility to get useful raw material for a process, which we cannot yet imagine. He also found a more populistic view, that thinking of a final disposal is too drastic and should be given some degrees of freedom for reconsideration and also for retrieval.

We have definitely not reached a common standpoint. Even if there have been both gives and takes in the discussion, there is still a gap between the Agency and the charming lady who presented herself as “the people”.

KASAM has not aimed at any consensus. Personally, I find it much more exciting to meet people of different opinions. I do hope that the discussion here — in a friendly spirit of respect and ambition to understand different opinions, different aspects of approach, different levels and areas of knowledge and background — has developed our thinking and broadened our understanding. Mr. Tarvainen spoke about our need for new thinking. As a botanist I would like to think that we have each got at least one new thought with us, which like a seed will develop and produce some nourishment for our minds.

My sincere thanks to all participants! A very special thank to the speakers, who have all provided their manuscripts in advance, which made it possible for us to present a complete set of pre-prints at the start of the seminar. I would also like to thank my KASAM colleagues. Thanks also to Tor Leif Andersson and Nils Rydell of the KASAM staff, who have been involved in all practical details from planning to proceedings, hopefully to come, and Phil Richardson, who assisted us in the heavy work of picking all of you.

I will end with a picture I had above my desk, when I was doing Chemistry. I was working in a laboratory quite some time ago. There was an old professor, together with his students, saying: “Since we have now discovered, in the morning, the meaning of Life, what shall we do in the afternoon?” This question will follow us: “What shall we do in the afternoon”?

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