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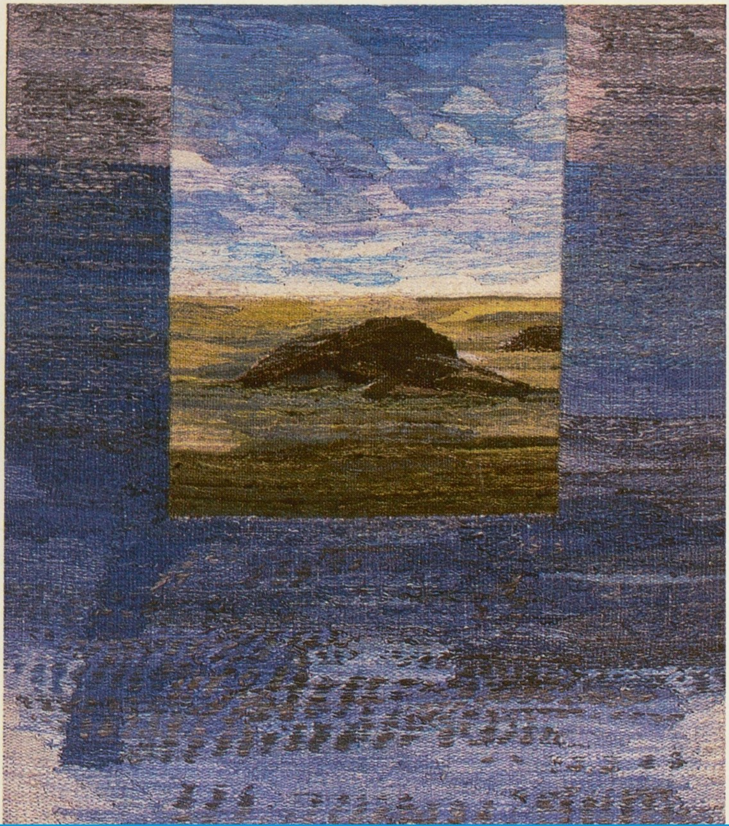

KASAM´s Review of the Swedish Nuclear Fuel and Waste Management Co´s (SKB´s) RD&D Programme 95

KASAM

STATENS RÅD FÖR KÄRNAVFALLSFRÅGOR

Swedish National Council for Nuclear Waste

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Summary

Main Features of the Programme

SKB's programme can be seen as two parts which must be developed in parallel with each other. One part comprises measures that SKB has the authority to implement. The second part comprises measures which require the permission of external parties before they can be implemented.

The first part comprises research, investigations, assessments of repository performance and safety, design, manufacturing and testing of components as well as the design and planning of final disposal facilities. RD&D Programme 95 shows that valuable progress has been made in this area. The second part comprises the siting of the planned facilities and the investigations which must be carried out before applications are submitted for permission to construct these facilities. SKB has not made similar progress in this part of the programme.

There may be reasons for the difficulties experienced by SKB in the siting work over which SKB has no control. One of these reasons may be a lack of transparency with regard to the veto issue. KASAM discusses the veto issue in Section 3.1. At the same time, in KASAM's view, there are possibilities for SKB to improve the credibility of its own work and its technical solution to the final disposal issue. A few such possibilities are discussed in the various chapters of this Review Report.

Radiation Protection Principles and Safety Analysis

The safety assessment is a central part of the evaluation of the safety of nuclear installations. The results of a safety analysis are compared with the basic principles for radiation protection (radiation protection standards). Even if these principles are established by the regulatory authorities in accordance with international and Nordic recommendations, continued discussion about their practical application is necessary. KASAM considers it to be important that SKB should continuously describe how the principles can be applied to spent fuel disposal, even if the detailed evaluation can only be made at the time that the licence application is prepared.

System-related Issues

In accordance with the Government's decision of May 18, 1995, SKB must present an integrated safety analysis of the final disposal system as a whole. KASAM considers this to be an important requirement. This is especially important with regard to how risks connected with individual parts of the system can be compared and weighed against each other and with regard to establishing the commitments made to the system as a whole on through decisions concerning individual parts of the system, such as which requirements must be made on the design and construction of the deep repository as a consequence of the selection of a particular canister design.

RD&D 95 does not specify how SKB intends to meet the Government's requirements. For example, SKB's Template for Safety Reports with Descriptive Example (SR 95), only deals with the final repository, and not the encapsulation plant. Furthermore, the transportation system is not discussed. As stated under the heading "Siting", KASAM is of the opinion that SKB should submit an application for a permit to carry out detailed characterization of a possible site of a deep repository at the same time, or before an application is submitted for permission to construct the encapsulation plant. KASAM emphasizes that this must not result in SKB postponing its account of how the overall safety analysis is to be carried out. Instead, it is important that this should be done as soon as possible. Such a report should primarily describe methodology for how principles for safety and radiation protection can be applied to the entire system so that different types of risks can be compared and weighed against each other. In KASAM's view, it is very important that this overall safety analysis should be prepared and subsequently evaluated by the regulatory authorities. This will provide a basis for the further design of the programme.

Transparency and Comprehensibility

The safety analysis must be developed to improve transparency and comprehensibility. KASAM wishes to emphasize, in particular, two approaches which can contribute to this aim:

- Facts, best estimates and opinions must be systematically presented. The latter will mainly be introduced into the analysis through the selection of scenarios.
- The safety analysis may appear to be very complicated, but often, the results are determined by a few basic physical and chemical principles,

e.g. solubility limitations and dilution. A systematic presentation of how the results from a safety analysis are dependent upon such factors should considerably improve the possibility of communicating the results to others, besides experts.

In KASAM's view, it is important that the scenario selection work should be prioritized in the programme. Scenarios can be selected even if the sites for the encapsulation plant and the repository have not yet been identified. The scenario analyses can contribute to the basis for decisions on the design of the repository and the siting of the repository.

Questions relating to safety analysis are also dealt with under the heading "Siting"

Siting

Municipal Veto and the Government's Right to Override a Municipal Veto

The veto issue is important for the municipalities which are, on a voluntary basis, currently participating or considering participating in feasibility studies for a deep repository. The issue concerns how the feasibility studies relate to the Government's subsequent formal possibility of overriding a veto, i.e. the Government's possibility of granting permission for detailed site characterization in spite of a municipal veto.

In Section 3.1, KASAM attempts to investigate the municipal veto right and the formal possibilities that the Government has of overriding a municipal veto, especially with regard to the selection of a site for detailed characterization. KASAM believes that the uncertainty surrounding this question has a considerable impact on municipal decisions and that this counteracts the efforts being made to locate a suitable site for a deep repository.

In KASAM's view, there are reasons which are strongly in favour of keeping the Government's formal possibility of overriding a municipal veto. However, because of the uncertainty that exists, KASAM recommends that the Government should clearly state the circumstances under which its possibility of overriding a municipal veto can be used. This is an important prerequisite for a transparent decision-making process.

Decision-making Process - Time-schedule and Co-ordination

In its review of RD&D 92, KASAM emphasized the importance of ensuring that the decision-making process is open and transparent and that it is also perceived as such by the general public. After the evaluation of RD&D 92, parts of the decision-making process concerning licensing were clarified by the Government in its decision. The decision stated i.a. that licensing in accordance with the Act concerning the Management of Natural Resources etc. and the Act on Nuclear Activities is to be carried out simultaneously. However, in KASAM's view, there are still some aspects of the decision-making process and the handling of the issues relating to the system which are unclear.

SKB's time-schedule shows that SKB intends to submit an application for permission to site and construct an encapsulation plant at around year-end 1997, whereas SKB does not intend to submit an application for permission to site and conduct detailed characterizations until the year 2002. On the whole, SKB treats the three main parts of the final disposal system (encapsulation, deep repository and transportation system) separately and the discussion of system-related issues is limited.

According to SKB's plan, when SKB submits an application for permission to site and construct an encapsulation plant, the site investigations will not have been completed. Consequently, KASAM envisages that it will be difficult to compile a complete basis for decision-making by that time. There are mainly two deficiencies which can reduce the credibility of the process:

- It will not be possible to make an evaluation of the alternative siting of the encapsulation plant next to the deep repository site since that site will not be known.
- There will be no data available from the actual deep repository candidate sites.

KASAM recommends that the application for a permit to site the encapsulation plant and the application for a permit to conduct detailed characterizations of a candidate site for a deep repository should be submitted at the same time. This procedure would also mean that a realistic description of the proposed transportation system can be included.

In KASAM's view, all of the stages in the decision-making process for the entire final disposal system must be described in an integrated manner in order to establish the basis upon which the different decisions will be made. It should be possible for the co-ordinator for nuclear waste, recently appointed by the Government, to participate in compiling such a description.

Site Selection Factors

The siting of a deep repository is an issue comprising scientific as well as political aspects. A site must be identified which is sufficiently safe for the final disposal of nuclear waste and which can be evaluated, in geological terms, as being a satisfactory site. SKB has specified a number of site selection factors within the areas of safety, technology, land and environment as well as societal aspects which, according to the Government's decision of May 18, 1995, should be a starting point for further siting work.

In its decision, the Government also requested that SKB submit a general siting study. SKB has now published General Siting Study 95 with general information concerning the Swedish bedrock which, in KASAM's view, should be supplemented. KASAM realizes the difficulties of a gradual and systematic site selection programme which is only based on geological and other safety-related factors. Thus, for example, the feasibility studies can only provide very limited information concerning the properties of the bedrock at repository depth at the sites which have been studied. On the other hand, it should be possible for studies on a national and regional level to provide better material for comparison than that provided by SKB's General Siting Study 95.

The site selection factors are generally specified by SKB. The range of values for the factors which can be accepted in order for a site to be considered suitable is not always specified. For a process to be credible, the factors must be more clearly defined than they have been so far. SKB must also specify what knowledge it expects to acquire about the factors at various stages in the site selection process, i.e. prior to the selection of sites for site investigations and prior to the selection of a site for detailed characterization. KASAM also finds that SKB's programme lacks a discussion of different main siting alternatives, such as the advantages and disadvantages of siting a repository in southern and northern Sweden, or of siting a repository on the coast or inland.

A detailed definition of the site selection factors which are important to safety should be achieved with the help of the safety analysis. General Siting Study 95 states that this shall only be done when the safety assessment for the encapsulation plant is prepared. In KASAM's view, this is too late if the site selection process is to be credible. The factors should be defined before the site investigations are started.

Furthermore, according to General Siting Study 95, SKB intends to present a site-specific safety assessment for a deep repository at the candidate site which is recommended by SKB for detailed characterization. However, in order for comparisons to be made, KASAM believes that site-specific safety assessments must be carried out for both of the sites where the site investigations are to be carried out.

Basis for Decision-Making at the Local and Regional Level

At present, SKB has reached the stage where it has carried out feasibility studies at two municipalities, Storuman and Malå. A referendum was held out at Storuman municipality. Because of the results obtained, the municipality is no longer eligible for further study. SKB has now started feasibility studies in the municipalities of Nyköping and Östhammar. The municipality of Oskarshamn is also considering whether to participate in a feasibility study.

SKB states that feasibility studies will be carried out in 5-10 municipalities in order to obtain a basis for selecting sites for site investigations. KASAM finds that the process which is underway may provide an adequate basis for selecting sites for site investigation. KASAM also believes that it is important that SKB should continue to describe, in a national perspective, the Swedish bedrock on a general and regional scale. The description can gradually focus on those regions which are of interest and, thereby, become increasingly detailed. This work is important for two reasons:

- The feasibility studies which are carried out must be put in a context so that the sites which are selected are found to have good geological conditions, seen from a national perspective.
- It cannot be guaranteed that the feasibility studies which have now been initiated will lead to acceptable sites or a sufficiently large range of sites. Consequently, more data may be necessary in order to identify additional suitable areas.

In KASAM's view, this part of SKB's work should be viewed as a natural continuation of the general siting studies which have been carried out and as a complement to the feasibility studies.

Environmental Impact Statements (EIS)

The Government considers the EIS to be very important and, in its decision of May 18, 1995, it emphasizes the importance of establishing a transparent process, or Environmental Impact Assessment (EIA) for the preparation of the Environmental Impact Statement (EIS) at an early stage. The county administrative boards will be given the responsibility for co-ordinating the EIA. However, no further guidance is provided on how "a transparent process" is to be established. Furthermore, SKB's RD&D Programme 95 does not provide any guidance on this subject.

As before, KASAM would like to emphasize the importance of the EIA. It should be possible for the National Co-ordinator for Nuclear Waste Disposal to provide assistance during the EIA. At the same time, KASAM would like to emphasize that it is the actual functions of the EIA that are important and not the formal framework.

Issues relating to the final disposal system are highly complex. Therefore, various parties involved will find it necessary to develop their knowledge of the subject before making the necessary decisions. KASAM proposes that a systematic programme should be established to achieve this. This should be included in the tasks of the National Co-ordinator for Nuclear Waste Disposal. This can be achieved in parallel to the investigations carried out by SKB which will result in an EIS and licence application. With such an arrangement, the parties involved can investigate, in various forms, individual issues which are considered to be of particular importance and difficult. This should contribute to an efficient development of competence within, e.g. the municipalities concerned. It must be emphasized that the aim is to make preparations for the decision-making process, not to initiate it by making evaluations, e.g. as regards to whether final disposal at a particular site will be safe.

Engineered Barriers

SKB has changed its canister design in three stages without providing a detailed motivation for the changes. The fuel canister is a prototype design and, at the same time, one of the most important barriers against the dispersion of radioactivity. Even if many aspects of the properties of the canister have now been studied by SKB, KASAM recommends that SKB should use the entire length of time at its disposal for development and further study and not commit itself exclusively to one alternative.

In KASAM's view, it is important that SKB should build confidence in the ultimately selected canister design as being a result of a process of maturity which has been carried sufficiently far. Thus, SKB should describe, in detail, the development process for the canister, the advantages and disadvantages of the alternatives studied and the reasons why SKB believes that the final design is sufficiently mature to be a basis for decision-making on the construction of the encapsulation plant and the manufacturing of canisters.

KASAM considers SKB's plans to establish a pilot facility for testing the sealing of the canisters and control of full-size canisters to be of value. This facility will prove valuable in focusing the verifying research on the specific properties of manufactured canisters. It will also enable Swedish researchers, to a greater extent than at present, to participate in research concerning manufacturing. This is important in order to develop the same high level of expertise with regard to the manufacturing of the canisters as there is with regard to the canister properties.

KASAM recommends that SKB should use the production capacity which must be developed by sub-contractors and the resources of the pilot facility to manufacture a relatively large number of sample canisters. This will be of great value in establishing the range of variations of the canister properties and in developing quality control methods. An extensive manufacturing of canisters on a pilot scale would allow for a more extensive trial deposition of inactive canisters in the Äspö Hard Rock Laboratory than SKB has so far intended.

Supporting R&D

General Comments

The nature of SKB's programme has successively changed from research to implementation in project form. At the same time there is a continuing need for supporting R&D. It is extremely important for credibility that SKB's research should be subjected to the same degree of peer review as that found at universities and institutes of technology. This cannot be achieved exclusively via SKB's normal international contacts through joint projects and in international organizations. SKB has compiled a large body of valuable knowledge in its reports. In order to improve the availability of such knowledge, SKB should also publish its research results in scientific publications to an increasing extent.

A critical stage of SKB's activities is when the research results are transferred to SKB's project work, especially when factors which may have a negative impact on safety are dismissed as insignificant. In this context, KASAM would like to mention the action of bacteria in promoting copper corrosion as an example of an area where greater knowledge is needed before SKB can dismiss microbial corrosion as insignificant.

Regardless of how much research is done, there will always be a degree of uncertainty. This is the case, for example, with regard to the hydrological description, where different models are possible. In KASAM's view, SKB must develop its approach to how such basic uncertainties should be handled.

Äspö Hard Rock Laboratory

KASAM recommends that SKB should expand the planned trial deposition of inactive canisters in the Äspö Hard Rock Laboratory. The methods and technology for the manufacturing and control of the engineered barriers as well as those for deposition must be verified. The integral performance of the canister and the buffer must be studied and analyzed. So far, SKB has only been able to describe the planned repository by using drawings and calculational data. A considerably more extensive trial deposition than that planned by SKB, which involves four canisters, should contribute to the early detection of any deficiencies in methods and technology and should contribute to the increased confidence and insight of those outside the group of experts into SKB's final disposal work.

European Union

A comprehensive research programme (Nuclear Fission Safety) is underway within the EU. A significant portion of the programme consists of nuclear waste management research. The current programme covers the period from 1994 to 1998. After that time, a new research programme is expected to be launched.

As a member of the EU, Sweden contributes to the funding of this research. The results of the research will have an effect on SKB's programme. In SKB's RD&D Programme 95, no strategy has been developed for how EU's research will be optimally utilized from a Swedish perspective. Sweden has to now become actively involved in the determining the content and structure of the programme for the next four-year period. In KASAM's view, it is especially important that the EU's nuclear waste management programme should also provide scope for work concerning EIA and public participation.

KASAM's recommendations

In summary, KASAM recommends that SKB should:

- continuously describe, how it intends to apply the principles for radiation protection;
- as soon as possible, prepare an integrated safety analysis for the entire final disposal system;
- develop the safety analysis in order to improve transparency and comprehensibility and incorporate a systematic presentation of facts, best estimates and opinion;
- define its site selection factors and specify how they can be used at different stages of the siting work;
- carry out general siting studies on a regional scale to provide a clearer basis for selecting municipalities for feasibility studies;
- modify its time-schedule so that the applications for a permit to site and construct an encapsulation plant and to carry out the detailed characterization of a candidate site for the deep repository are submitted at the same time;
- increase peer review of its research and investigation work.

Furthermore, KASAM recommends that the Government:

- clarify, as soon as possible, the conditions under which the Government can override the municipal veto;
- emphasize the importance of SKB, the regulatory authorities and Swedish researchers on the whole, actively participating in the EU's work on nuclear waste management and of Sweden participating to ensure that issues relating to democracy and public participation as well as environmental impact assessments are taken into account within such work.

Finally, KASAM recommends that the recently appointed National Co-ordinator for Nuclear Waste Disposal should organize a systematic programme for the preparation of those participating in the EIA prior to the evaluation of licence applications and EIS.

1. Introduction. Main Features of the Programme

Background

In its research programme 1992, SKB described extensive and significant changes in its planning of further work relating to the final disposal of spent nuclear fuel. At the same time, SKB presented concrete time-schedules for the construction of an encapsulation plant, for the siting of the repository and for the implementation of the first stage of the final disposal system. This more explicit direction of the programme was also expressed in a new title, RD&D Programme 92, Programme for Research, Development and Demonstration. The time-schedule contained deadlines for making binding commitments and for the licensing of the encapsulation plant and the detailed characterization for the siting of the repository. In KASAM's view, the time-schedule for the next six-year period was unrealistic. The work which remained to be done before SKB could present an adequate basis for decision-making was so extensive and time-consuming that there was hardly any scope for scheduling the deadlines for decision-making within the six-year period covered by the programme.

KASAM's Evaluation

RD&D Programme 95 is to a greater extent than RD&D Programme 92, an explicit plan of action with clearly defined projects within various subject areas which are co-ordinated within an overall time-schedule. The two most immediate main goals of the programme are to construct an encapsulation plant and to carry out a detailed characterization for the siting of a deep repository. SKB has scheduled the start of the construction of the encapsulation plant for just before the end of the century and the start of the detailed characterization for a couple of years later. However, SKB also states that the decision on the encapsulation plant is linked to the decision on the siting of the deep repository, where permission to conduct the detailed characterization is the critical point. Since this link exists, it will be possible to make these decisions no earlier than towards the end or after the end of the six-year period covered by RD&D Programme 95.

SKB's programme can be seen as two parts which must be developed in parallel with each other. One part comprises measures that SKB has the authority to implement. The second part comprises measures which require the permission of external parties before they can be implemented.

Measures which SKB can carry out on its own strength comprise research, studies, design, manufacturing and testing of components in the repository, the design and planning of facilities and assessments of the facilities' performance and safety. The measures are important in terms of gaining the acceptance of the technical/scientific community and of the competent authorities which evaluate SKB's solution to the final disposal problem. The time which this work will take can be fairly well estimated by SKB.

RD&D Programme 95 shows that valuable progress has been made in this area. Fuel canisters have been manufactured on a trial basis and a pilot facility for sealing and non-destructive testing has been contracted. The activities at the Äspö Hard Rock Laboratory are productive.

The second type of measure comprises the siting of the planned facilities and the investigations which must be carried out before applications are submitted for permission to construct these facilities. Progress has been made in the work on the encapsulation plant. An EIA forum has been established for the siting of the encapsulation plant. However, corresponding progress has not been achieved in the work on the siting of the repository. A review of the period of time that has elapsed since SKB presented its RD&D Programme 92 demonstrates this fact. The work which was planned, at that time, for the period from 1993 to 1998 for the siting and construction of a deep repository for demonstration deposition, was presented in Figure 9-7 of the RD&D Programme 92 (p. 72). According to the figure, feasibility studies would be carried out and completed in 1993. Candidate sites would then be selected and site investigations carried out during the period 1994-96, so that an application for a permit for detailed characterization could be submitted at the end of 1996. As yet, in June 1996, SKB has not obtained an adequate basis for the first stage of selecting candidate sites.

SKB has carried out feasibility studies with the participation of municipalities in two cases, Storuman and Malå. After a referendum, the municipality of Storuman decided not to volunteer for any continuation such as site investigations. The municipalities of Överkalix and Tranemo were asked whether they would like to participate in a feasibility study, but declined. SKB also contacted a number of municipalities with nuclear installations (Nyköping, Oskarshamn, Varberg and Östhammar) and proposed that feasibility studies should be carried out in these municipalities. SKB subsequently started feasibility studies in the municipalities of Nyköping and Östhammar. The municipality of Oskarshamn will shortly make a decision on the proposal, while the municipality of Varberg has declined.

Reasons beyond SKB's control may exist for a negative attitude to feasibility studies. However, KASAM can also discern some actual conditions which are not in SKB's favour but which SKB can influence. Many people may perceive the final disposal of spent nuclear fuel as a risky enterprise. SKB has developed a final disposal method but cannot demonstrate it in any other way than in the form of drawings and calculational data. SKB cannot refer to a model facility anywhere else in the world where someone who is interested in the issue can actually see a repository for spent nuclear fuel in operation. Thus, SKB is planning to do something that no-one has ever done before. Many people have experience of, or knowledge of the deficiencies which come to light when new technology and new materials are used, even within areas with old, established traditions, such as the construction industry. SKB, which has been deeply immersed in the problems and their possible solutions for many years, may have a firm conviction that such a comparison is unjustified. It is understandable that anyone who does not have SKB's deep knowledge of the problems may feel anxiety at the prospect of the final disposal of spent nuclear fuel in his or her own "backyard".

The situation is not improved by the fact that SKB's programme will focus so quickly on two sites and then on one of these sites. After a small number of feasibility studies, the next stage, according to SKB's plans, is to carry out site investigations at two sites. If any of the site investigations, or both, provide satisfactory results, SKB will submit an application for a permit to carry out a detailed characterization at one of the sites. Thus, a site investigation can be perceived in such a way that, with a 50 % probability, it will be followed by an application for a detailed characterization and thereby, potentially, by an application for a permit to construct a repository at the site. In addition to this, there is some uncertainty concerning site selection criteria as well as the possibility of the Government overriding a veto of a municipality in connection with SKB's application for permission to conduct a detailed characterization. As long as these uncertainties exist, it may be difficult for SKB to acquire the necessary information and knowledge for the siting of the planned facilities. In Chapter 3, KASAM discusses the issues relating to siting, including the link between the Government's possibility of overriding a municipal veto and the need for knowledge acquisition through site investigations.

In the light of the above, KASAM can perceive reasons and possibilities for SKB to supplement and partly re-evaluate its programme with the aim of increasing confidence in SKB's approach and technical methods for the final disposal of spent nuclear fuel. This point is further discussed in subsequent chapters.

2. Radiation Protection Principles and Safety Analysis

Background

SKB presented a series of safety analyses of the KBS final disposal method during the period of 1978-84. The bedrock was briefly described on the basis of data from surface-based investigations of a few reference sites. The analyses were evaluated in connection with the first fuelling of new nuclear power reactors. The conclusion drawn by the Government was that a KBS-type repository could be constructed in Swedish bedrock so that it fulfilled the requirements on radiation protection and safety. However, this does not mean that the safety of the KBS-type repository was proven once and for all or that the KBS method was decided upon as the basis for the design of a repository.

After 1984, SKB did not anticipate a requirement to present a complete safety assessment until it was time to submit an application for permission to site and construct an encapsulation plant and a repository. The period of grace was used for further investigation concerning final disposal and safety analysis models and methods. This work was described in a new safety analysis, SKB 91, which was updated with regard to data and calculational models and used the Finnsjö area in Uppland as an example of a repository site. The conclusion drawn by SKB in SKB 91 was expressed in RD&D Programme 92 (p. 68) so that "the rock's most important safety-related function for a final repository is to guarantee stable conditions for the engineered barriers over a long period of time. SKB's geoscientific research and the safety analysis, SKB 91, show that the rock at many places in Sweden is capable of performing this safety-related function." These conclusions were criticized, by KASAM and others, in the reviews of RD&D Programme 92 because the assumptions used in SKB 91 did not allow such extensive conclusions to be drawn.

KASAM's Evaluation

SKB's Description

SKB briefly summarizes the radiation protection principles for final disposal in RD&D 95. In other documents, such as Template for Safety Reports with

Descriptive Example (SR 95), the radiation protection issues are discussed as a part of the safety assessment. Without a doubt, radiation protection is an important part of the safety assessment. KASAM considers it to be important that SKB should continuously discuss in its RD& D programmes how the principles can be applied, even if the detailed evaluation can only be made in connection with subsequent licensing after the submission of a license application. The RD&D 92 Supplement provides such a discussion of principles and reference is made to international and Nordic recommendations. This discussion should have been developed in RD&D 95.

SKB describes its work on safety analysis in RD&D Programme 95 as well as in the background report, SR 95. In RD&D Programme 95, SKB presents its view of the state of knowledge regarding the deep disposal of spent nuclear fuel and other long-lived waste and puts forward its proposal for a further programme for safety analyses.

In SR-95, considerable attention is also given to the state of knowledge. However, this time it is the bedrock at Äspö which is used as an example of a repository site. Otherwise, the most important supplement to RD&D 95 is the description of the methodology for making a systematic inventory of relevant calculational cases within the scenario analysis which SKB intends to use. The example provided by SKB of an analysis of the possible siting of a repository at Äspö is very brief. Thus, in order to gain perspective on the situation concerning the safety-related properties of SKB's deep disposal system, KASAM also takes the previous safety analysis report, SKB 91, into consideration in its review.

Principles for Radiation Protection and Safety

The radioactive substances and the ionizing radiation emitted are the characteristics which distinguish a repository for high-level waste from other waste facilities. The fact that large quantities of radioactivity will remain over periods of time which are extensively long compared with the timescales so far discussed in other contexts is what distinguishes a repository for high-level waste from other nuclear installations. A repository for spent nuclear fuel must be designed so that the fuel cannot start a chain reaction, become a new "reactor", in the event of any changes which may take place inside the repository. Thus, radiation protection as well as nuclear safety must be discussed on a continuous basis during the work on final disposal.

It is the task of the regulatory authorities to stipulate which criteria must be fulfilled. The Swedish Radiation Protection Institute (SSI) has also issued preliminary radiation protection criteria for personnel and the public which will be affected by the disposal of spent nuclear fuel. KASAM considers it to be very important that SSI should complete this work.

There is currently a broad international consensus concerning the guiding principles for this type of protection work. The basic principles for radiation protection in connection with the disposal of solid high-level waste are:

- that the risk to human beings and the environment should be limited as well as
- that radiation protection should be optimized.

The risk level to individuals and communities which may exist in the future must be low and no higher than the level which is currently accepted. The same principle must be applied with regard to environmental impact.

Thus, the problem is not the principles but rather how they are to be applied to a repository - which is something of which no-one has any practical experience. The problem has to do with the long timescales involved and the associated uncertainties.

In 1993, the Nordic nuclear radiation protection and safety authorities published a booklet called "Disposal of High Level Radioactive Waste; Consideration of Some Basic Criteria". This publication, which only provides guidance for the authorities, proposes basic criteria for the final disposal of spent nuclear fuel. Like recommendations prepared by the IAEA and ICRP, these Nordic recommendations include dose as well as risk-based requirements for the protection of individuals. The dose must be limited to 0.1 mSv/year. The corresponding risk limitation is on the order of 1 in 100,000 for fatal cancers and severe genetic damage.

The way of limiting the risk to the individual is to calculate the radiation dose to what is known as a critical group. A critical group is a relatively small, homogeneous group of individuals whose place of residence and habits are such that they receive the highest radiation doses in the event of a radioactive release. The dose to the critical group refers to the dose to the average individual in the group. By, in this way, taking into account the risk to the most vulnerable group of a population, it is possible to avoid preventing an important activity from being realized or from becoming too costly on account of hypothetical risks to a few individuals under very special circumstances. Since the calculations must be extrapolated in time, the critical group is, in this case, a hypothetical group.

The reliability of such calculations decreases with time. It will never be possible to verify detailed assumptions concerning the biosphere and human behaviour in a remote future, which lies more than a few thousand years ahead. For very large timescales, it may be enough to estimate radionuclide outflows to the biosphere and make a simplified conversion to radiation doses.

Radiation doses to the critical group must be calculated using various assumptions concerning the future development of the final disposal system, i.e. using different calculational assumptions (scenarios). One of the most important tasks remaining in the safety-related work is that of establishing which scenarios must be included in the safety analysis. When this is established and the dose limitations have been applied to the critical group, the radiation protection level which will apply for the final disposal system will also be established, and thereby, the extent of the resources which must be utilized by our generation in order to secure the safety of future generations.

The optimization principle means that all measures which can be justified in terms of cost and social factors must be adopted in order to minimize the collective radiation dose from a particular source. The principle is attractive from a philosophical standpoint but difficult to implement in practice, with regard to radioactive waste, since the uncertainties in the calculations are so large. In order to be meaningful, the optimization process requires realistic assumptions which are not possible with regard to the remote future. However, it is easier to apply the optimization principle to the transportation system, encapsulation and operation of the repository as well as during the following first hundred years.

The results of the safety analysis and the radiological risk estimates must be presented in a manner that is as clear and easy to understand as possible in order to broaden the discussion concerning the balancing of safety against costs which must be made within this activity, as in many others. This is particularly important with regard to the anxiety that many people experience when they think of radioactivity, radiation and cancer risks. One difficulty is the difference between risk as a formally defined concept - the probability of an event occurring weighed against its consequences - and risk as a personal experience. For society, a probability of lethal effects of no more than one in a hundred thousand may be an acceptable radiation protection target for an activity. However, any individual who perceives that the lethal effect can apply to himself wants the probability to be zero, unless he voluntarily exposes himself to the risky activity because it provides some compensation in the form of an enhancement of the quality of his life.

Safety Analysis Programme

In accordance with the Government's decision of May 18, 1995, SKB must present an integrated safety analysis for the final disposal system as a whole. On this point, the decision states the following (KASAM's translation):

> The Government finds, on the basis of the report which has now been submitted by SKB, that the decisions made in Chapter 4 of the Act concerning the Management of Natural Resources etc. and § 5 of the Act on Nuclear Activities concerning the construction of the planned encapsulation plant may entail considerable commitments with regard to further handling and disposal methods. Thus, these decisions should, as far as can now be determined, not be made before a safety assessment of the entire final disposal system has been presented and the planned final disposal method has been demonstrated to be suitable. The Government finds that it should be possible for a safety analysis of the final disposal system to be successively presented to SKI, but that an overall, integrated analysis should be included in any applications for permission, in accordance with Chapter 4 of the Act concerning the Management of Natural Resources etc. and the Act on Nuclear Activities, to construct the planned encapsulation plant.

The construction of the encapsulation plant entails, as the Government has observed, that the subsequent work will be committed to a particular design of the KBS method, at least with regard to the first stage of the final disposal system. Further studies of variations within the framework of the KBS method and of other final disposal methods will probably be given even lower priority than has been the case so far. The Government has consistently emphasized safety as one of the decisive factors in the selection of a final disposal method. Thus, SKB should, in its integrated assessment of the radiation protection and safety-related issues, which is to be included in the application for permission to construct the encapsulation plant, carry out an in-depth comparison of safety-related characteristics for the variations on the KBS method which SKB has studied over the years and an overall comparison with other disposal methods which have been proposed for crystalline bedrock. The concept of an integrated assessment involves the assumption that aspects relating to safety and radiation protection will be taken into account and integrated with regard to the four phases of encapsulation, transportation, construction and operation of the repository as well as for the time after the closure of the repository.

Insight and Transparency

SKB's safety analysis of the proposed final disposal system has two important target groups - the competent authorities who must submit their evaluation to the Government before a decision is made concerning licensing for detailed characterizations, construction and operation of the repository as well as the other parties who will participate in the EIA and in decision-making at a local level. The information submitted to the safety authorities may have to be detailed, containing calculational models which require specialist knowledge in order to be understood and evaluated. KASAM would like to emphasize that a safety analysis, which aims at providing interested and perhaps critical parties, who do not have this specialist competence, the possibility of forming their own opinion of the safety of the final disposal system, must describe the safety in a way which is easier to understand, without unduly simplifying the problems which may exist.

Some of the concepts presented in Template for Safety Reports with Descriptive Example (SR 95) are difficult to understand: FEP (Features, Events, Processes), scenarios, reference scenario, process systems, interaction matrices, the RES method (Rock Engineering System), etc. It will not be easy for the public and decision-makers to understand the relationship between these different concepts. At the same time, the descriptive example from Äspö, the canister defect scenario, is so briefly presented that it is difficult for the reader to reach an understanding of the contribution of different barriers to the overall safety and to identify individual properties of the barriers which are particularly significant. In KASAM's view, an important task for SKB is to present its safety assessment in a more coherent manner than has so far been the case without necessarily simplifying the text to the level of a brochure. Below and in the appendix, KASAM presents some possibilities of presenting the analysis of the safety of the entire system and the contribution of the different barriers so that it is more transparent and more accessible to readers.

The calculational model for the repository with its links between different processes appears to be highly complex when it is described in the form of a series of interaction matrices or as a diagram with all of the components and processes and the inherent links in an overall model of the system. In reality, the calculational results are often determined by a few basic physical and chemical principles. Examples of such processes are solubility limitations for many of the radionuclides, diffusion and sorption which limit the leakage of the radionuclides from the buffer as well as the dilution of the radionuclides as they are transported from the repository to recipients in the biosphere. These processes usually occur sequentially, in stages. Quantities or concentrations of radionuclides can be described for each stage. This provides a coherent view of how different barriers reduce the potential radiation dose in stages (see Appendix).

The data and calculational models which must be included in a safety analysis are based, in certain cases, on fact. However, in other cases, they are based on best estimates. The scenarios and calculational cases covered by the analysis should be selected on the basis of assumptions of what can reasonably be expected to occur in the future and on the basis of what is considered to be a relevant basis for decision-making. It is important for SKB to systematically state what is fact, what is a best estimate, what is opinion and who has given this opinion.

One difficulty with regard to understanding and forming an independent opinion of the analysis results is the quantity of data. The development of methods for data transfer means that it is possible, at least from a technical point of view, for interested parties to gain insight into SKB's database. Thus, SKB should organize its database in a systematic fashion which corresponds to the structure of the safety analysis as well as make it accessible for transfer via electronic media.

Scenario Selection

In the introduction to the section under the heading "Scenario" on page 113 of SR 95, SKB states the following: "A scenario is defined by a set of external conditions which will influence processes in a PS. The external conditions determine how the processes in the PS are to be combined and modelled in describing the evolution of the scenario and evaluating its consequences." PS stands for Process System, i.e. the components in the final disposal system and the physical and chemical processes which are important for the performance of the system.

Henceforth, KASAM will use the concept "scenario" in the sense of a boundary condition for the calculation which cannot be influenced. SKB also uses the concept "scenario" to refer to the sequence of events which the scenario results in. This may contribute to a certain confusion between concepts.

The second concept which is necessary in a discussion about what a safety analysis should include is calculational cases which must cover uncertainties in the description of the internal functions of the system, such as calculations where different mathematical models of a process are used or input parameters are varied. In order for a safety analysis to be considered to be exhaustive, it should deal with reasonably probable scenarios. For each scenario, the calculations are performed for the number of cases which are justified by the nature of the scenario.

In SR 95, SKB provides examples of scenarios on page 127 and of calculational cases on page 220.

The reason why KASAM comments on the definitions is that SKB concludes the section "Scenario" on pp. 113-114 as follows: "Scenario selection, or the selection of premises for different scenarios, is done by experts." KASAM does not entirely share SKB's view. The inventory of calculational cases within a scenario is perhaps best carried out by experts. Experts can also make a valuable contribution to the description of a scenario, e.g. a future ice age. However, by nature, the selection of scenarios is not a science but a question of deciding which hypothetical future events need to be included in the safety assessment. This is a decision which cannot be considered to be reserved exclusively for "experts". These questions should be dealt with in the EIA as well as in the political debate.

In SR 95, SKB describes a methodology for scenario analysis, i.e. for providing a comprehensive picture of the ways in which the system could develop under various possible external circumstances. The methodology provides an inventory of calculational cases within different scenarios rather than an inventory of scenarios as defined by KASAM. Interaction matrices are designed for the purpose of identifying those components and processes within the system which are important to the performance of the system in the scenario's calculational cases. For this same purpose, SKI has developed a technique using influence diagrams and a structured approach in order to screen relevant calculational cases and calculational models within the scenario analysis. KASAM considers it to be valuable that two independent methods are available in Sweden for making inventories of calculational cases. This inventory has to be made carefully if the scenario analysis is to provide a comprehensive picture of the ways in which the final disposal system could develop in the future due to relevant changes in the external conditions.

In KASAM's view, it is important that the scenario selection work should be prioritized in the programme. Scenarios can be selected even if the sites for the encapsulation plant and repository have not yet been identified. For the final disposal system, the scenario analyses can contribute to the development of a basis for siting by establishing, in a comparable manner, the importance of, for example, different groundwater environments and changes in the groundwater on account of future climatic changes Scenarios where the integral performance of the engineered barriers is affected are particularly important (cf. conclusions in Appendix).

Template for Safety Reports with Descriptive Example (SR 95) as a Model for Future Safety Reports

SKB states (RD&D Programme 95, page 145) that the reporting of the operating safety of the nuclear power plants has been standardized and harmonized. However, there is no corresponding standard for the reporting of the long-term safety after the closure of a deep repository. "However, since the long-term safety will be described on several occasions during the development of the Swedish system for radioactive waste management, a proposal for a model for safety assessments has been presented in a separate report Template for Safety Reports with Descriptive Example (SR 95)."

This report only deals with the repository and its long-term safety. This prioritization is justified. There will be a recurrent assessment of the long-term safety of the deep repository at different stages. The assessment will become more and more explicit and detailed as the data improve. This will occur during the candidate site investigations prior to the application for a permit to conduct a detailed characterization, during the detailed characterization prior to the application for a permit to construct the repository and during its successive expansion prior to an application for a permit to close the repository. Unlike the repository, the encapsulation and transportation system will not be developed in stages.

The level of ambition for the assessment as it is presented on pp. TEMPLATE 4-9 of the synopsis of SR 95 is laudable. Because of the way in which the synopsis is structured, repetitions in the text are to be expected. The descriptive example in the report also contains many repetitions. However, this is a flaw rather than a fault. On the other hand, the descriptive example of a calculational case which is provided - the canister defect scenario - is far too brief and difficult to understand (see next section).

SKB's Example of Safety Analyses

The SKB 91 report presents a safety analysis of a deep repository located in the Finnsjö area of Uppland. The purpose of the report was to establish how the long-term safety of a repository is affected by the geological properties of the site. In order to avoid the importance of site-specific factors being hidden by possible uncertainties in the source terms, the near field performance or changes in the biosphere, the number of variations or scenarios for these sub-systems was restricted (SKB 91, p. 7).

SR 95 also provides an example of a safety analysis. This time the analysis concerns a demonstration-scale deep repository located at Äspö. KASAM has assumed that this report is an example of how the analysis will be reported in future.

In SKB 91, SKB presents its calculational results in stages. The calculations concern a case with a hole in the canister wall which caused the canister to become filled with water. In the first stage, radionuclide solubilities in the water outside the canister are presented in mol/l. These values could have been converted to Bq/l and compared with the concentration in Bq/l of the nuclide in question which can be allowed to be present in well water without exceeding the limit of 0.1 mSv/year. Several of the long-lived fission products would fall below this limit even inside the canister.

In the next stage, SKB describes the release of radionuclides from the buffer in mol/year, in an initial phase and over time. SKB could have supplemented this description with information on the volume of the water in m3/year in which these leaking radionuclides would have to be dissolved for the water to be acceptable for consumption. According to SKB's calculations, for all of the nuclides, the volume would be less than the water turnover which is needed in an aquifer for it to supply a well with water.

An easy-to-understand description is also lacking of the transport in the far field and thereby also the inflow to the biosphere of alpha- and beta-emitting radionuclides or the distribution of these in aquifers with different water flows.

In spite of these deficiencies, SKB 91 is more pedagogical in its description than SR 95. The latter, (page TEMPLATE 9) states that calculational results will be presented from various main cases, including the canister defect scenario. A description of this is provided in Chapter 12. In that chapter, the reader is presented with many input parameters and a few sub-results of the hydrogeological modelling. However, besides this, the final results of the calculations are only presented in the form of doses and release quantities. Such a description means that there is little possibility of the reader understanding how the different barriers contribute to the overall safety of the system. KASAM believes that a presentation of the safety assessment, in stages, from the fuel to the biosphere, would make it easier for the reader to understand how the disposal system works and understand the arguments for and against the final disposal alternative which SKB would like to have approved. This may be particularly valuable in connection with the EIS evaluation under the Act concerning the Management of Natural Resources etc.

Geohydrological Modelling of Groundwater Paths

The most unsatisfactory description in both examples is that of the transport paths of the radionuclides from the deposition holes through the far field into the biosphere.

In the near field, the canisters are emplaced with their upper edges 2.5 m below the floor of the deposition tunnel. The layout of the deposition tunnels is in a herring bone pattern above the deposition holes with a total tunnel length of more than 30 km (SKB 91, p. 59). The deposition and transport tunnels cover, at least in the conceptual layout of the repository, a surface area of almost 1 km^2 with a fairly even distribution of tunnels over the entire surface. In total, the volume of the tunnels is more than 400,000 m^3. The tunnels are to be backfilled by a mixture of sand and clay. The rock inside the tunnel wall will be cracked in the disturbed zone, regardless of whether the tunnel is blasted or drilled. SKB intends to attempt to seal the disturbed zone where it meets fracture zones intersecting the tunnel. SKB also intends to design the repository so that the deposition tunnels are located at right angles to the hydraulic gradient. In this way, the groundwater flux along the tunnels will be minimized.

SKB has counted on consistently successful results of all of these measures in its calculations of the reference case for groundwater transport of radionuclides through the far field in SKB 91, see Figures 8-9, 3 and 4 and Fig 9-6.3 and 9-7.3 etc. which show pathlines which all move in the northeastern direction of the hydraulic gradient, as if there were no repository there at all. The only way the presence of a repository can be discerned from the figures is that all of the pathlines start on one level.

There are several circumstances which show that this model is unrealisitic. It is impossible, in practice, to model the repository as a pre-determined, regular pattern of parallel tunnels. The deposition tunnels must be located in solid blocks of rock, regardless of whether these are parallel to or at right angles to the direction of the gradient. The model for groundwater flux must apply not only for the newly closed repository but also for the conditions that will prevail in 1,000, 5,000, 10,000 years' time etc. SKB cannot assume that the results of a recently developed backfilling technology will last for thousands of years. Furthermore, at least during the first few thousand years, the residual heat in the fuel will generate a thermal gradient which will result in an upwardly moving component in the hydraulic gradient. The impact will be to transport any radionuclides which have leaked out of the bentonite towards the deposition tunnels.

The ambition of rendering the tunnel system more leaktight than the rock may be praiseworthy but safety analyses must be based on robust assumptions. The cautious or conservative assumption in the safety analysis must be that the radionuclides outside the buffer will make their way through small cracks and travel the few metres up to the disturbed zone or the loosened backfill. From there, they will be transported with the groundwater movement to the larger cracks which, at some point, intersect the large surface area covered by the repository, and subsequently transported to a discharge area. In a safety analysis, the transport paths through the far field cannot, in all likelihood, be described as a skein of fine pathlines in the way portrayed in Figures 9-6 and 9-7 in SKB 91.

Conclusions

- In KASAM's view, it is important that SKB should continuously discuss the principles for the radiation protection-based evaluation, even if the detailed evaluation can only be made at the time that the licence application is prepared;
- as soon as possible, SKB should prepare an integrated safety analysis for the entire final disposal system;
- SKB should, in its integrated analysis of the radiation protection and safety-related issues which is to be part of the application for permission to construct the encapsulation plant, carry out an in-depth comparison of safety-related characteristics for the variations on the KBS method which SKB has studied over the years and an overall comparison with other disposal methods which have been proposed for crystalline bedrock;
- In KASAM's view, an important task for SKB is to present its safety analysis in a manner that is easier to comprehend than has so far been the case;
- As far as the data and calculational models in the safety analysis are concerned, SKB should systematically state what is fact, what is a best estimate and what is an opinion and who has given this opinion;
- The scenario selection work should be prioritized in the programme.

3. Siting

3.1 Municipal Veto Right

Background

FACTS
(KASAM's translation)

Act concerning the Management of Natural Resources etc., Chapter 4 § 3 first paragraph (veto right):
Permission, in accordance with § 1 or 2, may be granted if there is no obstacle on the basis of the stipulations of Chapter 2 or Chapter 3 or on the basis of other general planning considerations and if the municipal council has given its approval.

Act concerning the Management of Natural Resources etc., Chapter 4 § 3 second paragraph (the Government's right to override a municipal veto):
With regard to facilities as stated in Chapter 4 § 1 first paragraph 6, for the interim or final storage of nuclear materials or nuclear waste, or facilities as stated in Chapter 4 § 1 first paragraph 7, 8, 9 or 10, the Government may, if a facility is considered in the national interest to be particularly important, grant permission even if the municipal council has not given its approval. This does not apply if a suitable repository site has been identified within another municipality which it can be assumed will approve of the siting, or if another site elsewhere is judged to be more suitable.

In its 1993 Review Report (SOU 1993: 67) of SKB's RD&D Programme 92, KASAM dealt with questions concerning the precise meaning of the stipulations concerning the municipal veto right in Chapter 4 § 3 of the Act (1987) concerning the Management of Natural Resources etc. in connection with the process of siting the final repository for spent nuclear fuel. The central point of KASAM's discussion concerned at what stage of a siting process the Government has the formal right to grant permission to site a repository in spite of the fact that the municipal council has not approved the siting. This is referred to as the Government's right to override the municipal veto (see "FACTS", above).

The background to KASAM raising these questions is briefly described below.

In R&D programme 89, SKB presented plans to, on the basis of previous general studies of Swedish bedrock, select three sites in the country for pre-investigations (now called feasibility studies). The intention was to then carry out detailed characterizations at two of these sites. According to SKB's plans, the pre-investigation work was such that only the permission of the landowner was required. For the detailed characterizations, the permission of the municipality and county administrative board could also be required, primarily in accordance with the Planning and Building Act. The result of the detailed characterizations could be used as a basis for preparing an application under the Act concerning the Management of Natural Resources etc. for the siting of a repository for spent nuclear fuel.

In its decision of December 20, 1990, on account of SKB's R&D Programme 89, the Government stated that "SKB's selection of suitable sites for a repository will be evaluated by different competent authorities in connection with SKB's application for a licence for the detailed characterization of two such sites", in accordance with the Act concerning the Management of Natural Resources etc. This statement must be considered to mean that the Government has established that permission, in accordance with the Act concerning the Management of Natural Resources etc., is required already at the stage of the detailed characterization. Such a siting process means that the regulations in the Act concerning the Management of Natural Resources etc. concerning the municipal veto against the siting of certain facilities can be applied. Since, after July 1, 1990, the Act concerning the Management of Natural Resources etc. also contained the regulations described under "FACTS" above concerning the right of the Government to grant permission in spite of a municipal veto, these regulations can naturally also be applied.

In its RD&D Programme 92, SKB described changes in its plan for identifying a suitable site for a repository (siting process). According to this programme, the aim was to carry out i.a. "extensive pre-investigations at two candidate areas to obtain the necessary data for the application for permission to carry out detailed characterizations in accordance with the Act concerning the Management of Natural Resources etc." as well as to carry out "full-scale detailed characterization on one site". (Background Report to RD&D 92, "Siting of a Deep Repository", p. 30). In this connection, SKB used the concept "Detailed characterization including excavation of necessary shafts and tunnels to planned repository depth." (RD&D Programme 92, p.16, "Siting of a Deep Repository", p. 29). In its above-mentioned Review Report, KASAM stated that SKB should present a better motivation than it has for the change in methodology and also stated that it approved, at the same time, under certain conditions "of SKB limiting its application for a licence to conduct detailed site investigations (detailed characterizations) in accordance with NRL (the Act concerning the Management of Natural Resources etc.) to a single site" (SOU 1993:67, p. 34).

As has already been mentioned, KASAM raised, in its Review Report, the question of at what stage of a siting process the Government could formally exercise the right to override the municipal veto. One important question was the exact meaning of the concept of "detailed characterization". In KASAM's view, it was necessary to use different arguments depending on how this concept was defined.

If a "detailed characterization" were considered to be no more than an investigation of a conventional rock facility, in KASAM's view, the municipal veto right was unambiguous since the regulations concerning the Government's right to override the municipal veto do not apply to such facilities. If, on the other hand, a "detailed characterization" is considered to be an initial phase of the construction of a repository for nuclear waste, another approach must be taken. The basic principle concerning the municipal veto would always apply. However, the stipulations concerning the right of the Government to override the municipal veto could be applied, in principle. In KASAM's view, the formulation of the regulations concerning the Government's right to override the municipal veto meant that the Government would, in practice, not be able to grant permission for detailed characterizations if the municipality concerned had not approved the application, and that a municipality, also in this case would, in practice, have an unrestricted right to veto a detailed characterization. In its Review Report, KASAM further discussed the question of what possibilities would exist for the Government to exercise the right to override the municipal veto when the municipality had approved the detailed characterization, but then later rejected the application for permission to site a repository which was based on a detailed characterization.

KASAM also included, in its 1995 report on the state of knowledge in the nuclear waste area (SOU 1995:50), a discussion of the implications of the municipal veto and the Government's possibility of overriding a veto. After reviewing the preparatory documents for the legislation, KASAM observed that the legislation "must be applied with the greatest restriction", Thus, in practice, it will be very difficult for the Government - regardless of its political complexion - to "ride roughshod" over a municipal council veto against the siting of a certain facility (pp. 34-35).

The question of the municipal veto right and the possibility of the Government exercising its right to override the municipal veto has been the subject of great interest on the part of municipalities which have been involved in the feasibility studies. In a letter to the Ministry of the Environment, dated March 7, 1995, the municipality of Oskarshamn maintains that the Government's right to override the municipal veto is a threat against the credibility of an open siting process, that it is unjustified and that it should be revoked. In its review of RD&D Programme 95, the municipality has requested that the veto issue should be clarified.

Three statements were made by the Government in its decision of May 18, 1995, regarding the Supplement to RD&D Programme 92. These statements may be important when examining the question of when it would be possible for the Government to exercise the right to override the municipal veto.

Thus, the Government "finds" that "as far as can be seen from SKB's programme, the planned detailed characterization which will be carried out at one site in Sweden is a stage in the construction of a nuclear installation, which is to serve the function of a repository for spent nuclear fuel and nuclear waste."

Furthermore, the Government states that the applications for permission, in accordance with Chapter 4 of the Act concerning the Management of Natural Resources etc., "to construct a repository should contain material for comparative evaluations which show that site-specific feasibility studies have been carried out at 5-10 sites in Sweden and that site investigations have been carried out at no less than two sites. The reasons why these sites were selected should be specified."

In a third statement, the Government announces an amendment of the Ordinance (1993:191) on the Act (1987:12) concerning the Management of Natural Resources etc. so that the Swedish Nuclear Power Inspectorate (SKI), after consultations with the Swedish Radiation Protection Institute (SSI), the Swedish Environmental Protection Agency and the county administrative boards concerned, would "be given the responsibility of providing information concerning those geographical areas that the competent authorities consider to be in the national interest for this purpose." However, no such amendment of the Ordinance has been made.

KASAM's Evaluation

Experience from SKB's work on siting-related issues show that data collection which requires bedrock investigations has, in several cases, been rendered difficult or even prevented, by the anxiety or disinclination which the plans to carry out such investigations have provoked in the local communities and in their political representatives in the municipalities. These parties have requested clarification as regards the exact meaning of the municipal veto right and the Government's possibility of overriding a veto. One question which has been discussed is the following: Is it possible for a municipality to assert the basic principle of the right to veto the siting of a deep repository - or a detailed characterization - if the municipality has "voluntarily" accepted feasibility studies to be carried out by SKB and, on the basis of the results of these, site investigations as well?

In its decision of May 18, 1995, the Government stated that an application for permission to carry out a detailed characterization in accordance with the Act concerning the Management of Natural Resources etc. will be considered to concern a nuclear installation and that SKB must present material which makes it possible to evaluate the suitability of various alternative sites for a repository. Furthermore, the Government has announced its intention of making amendments to the Ordinance, the aim of which appears to be the possibility of granting the authorities the responsibility of identifying certain areas which are considered to be suitable for the siting of a repository.

KASAM considers it necessary to, once again, discuss the question of the veto.

KASAM has previously maintained that the Government cannot, in practice, grant permission for a detailed characterization against the wishes of the municipality concerned. In this connection, KASAM placed considerable emphasis on the explicit statements concerning restrictiveness which are made in the preparatory documents of the paragraph of the Act concerning the Management of Natural Resources etc. which deals with the possibility of the Government overriding a municipal veto.

However, the decisions and statements made in the Government's decision of May 18, 1995 may increase the doubtful attitude of the municipalities and communities involved concerning what is actually meant by the veto right and the possibility of the Government to override a veto in connection with detailed characterizations.

Thus, the situation may be interpreted to mean that the Government has certain possibilities of exercising the right to override a municipal veto already at the time when an application is submitted to conduct a detailed characterization. Let us assume that SKB has carried out feasibility studies at 5-10 sites. SKB then carries out site investigations at two of these sites (within municipality A and municipality B). SKB subsequently decides that a site within municipality A is most suitable for detailed characterization. Let us assume that municipality A says no to a detailed characterization. The Government would then have reason to maintain that there is no other site that is more suitable, since the site for the detailed characterization (which is to be considered to be a stage in the construction of a nuclear installation, in accordance with the Government's decision) has been successively identified in accordance with a certain selection process. In such a situation, the Government could grant permission even if the municipal council has not approved the application.

With regard to the previous stages in the siting process - according to SKB's plans, feasibility studies of 5-10 sites as well as site investigations at two of these sites - there are no requirements on special permission of government or local authorities with regard to studies or investigations as such. However, SKB's policy is to establish a mutual understanding with the municipalities concerned. In different contexts, the company has declared that it intends to carry out feasibility studies - and later detailed characterizations - only in municipalities where conditions for such a mutual understanding are considered to exist.

However, it may be interesting to further discuss the question of whether a municipality has the formal possibility of preventing a site investigation, if SKB wishes to carry out one in spite of the fact that the municipality has decided against it.

In order to carry out the trial drilling involved in the site investigations, only the permission of the landowner is required. During this stage, there may be a number of items of work which require municipal permission in accordance with the planning and building legislation. For example, this may concern permission to build a stretch of road to transport drilling equipment to an investigation site and to put up or construct buildings at the site. Theoretically, any municipality which is opposed to detailed characterizations could refuse to grant permission for such construction work. However, it should be possible to appeal against such municipal decisions in the usual way. Thus, no absolute guarantee can be considered to exist that the municipality, on its own legal strength, would be able to call a halt to site investigations.

The situations which KASAM has attempted to describe show that the questions regarding the possibility of a municipality opposing site investigations or exercising the veto right against detailed characterizations and the siting of a deep repository, in accordance with the Act concerning the Management of Natural Resources etc., appear to be unclear. Even if the most reasonable interpretation is that the veto right will remain, in an unrestricted form, in connection with the selection of a site for detailed characterization, it can be maintained that this is not certain. In KASAM's view, this uncertainty makes municipalities, on the whole, less inclined to participate in the site selection process. Can the municipality be sure that its veto right will remain untouched if it participates in a siting process which is conducted on a voluntary basis? If this is not the case, the representatives of a municipality must know when the siting process will make the transition from a voluntary to a non-voluntary process.

The above discussion applies to the Government's possibility of exercising the right to override a municipal veto in connection with the selection of a site for detailed characterization. Another question is whether, on the whole, it is desirable or not for the Government to have this possibility. One reason for retaining the right for the Government to override a municipal veto is that, in an international perspective (including within EU), it gives greater credibility to Sweden's policy that each country should dispose of its own nuclear waste. There is also a "democratic" reason , namely, that no single municipality should be able to prevent the implementation of the best solution to a national problem.

On the other hand, there are reasons in favour of revoking Government's right to override a municipal veto. The claim may be made that it only presents an obstacle in that it makes municipalities disinclined to participate in the siting process. Thereby, the Government's right to override a municipal veto may be considered to be counterproductive. It can also be very difficult, in practice, to make a political decision which is contrary to a strong local opinion on this controversial issue.

There is also a moral aspect to the question. Finding a solution to the final disposal problem is a matter of national importance. On the international front, Sweden is also ethically bound to assume full responsibility for its own nuclear waste. For those municipalities which are considered to be suitable participants in the site selection process, what this means is that they, in a specific way, bear an ethical commitment which has been made by the entire country. From the standpoint of the municipalities, they may naturally enough be tempted to shy away from assuming their share of the common responsibility, bearing in mind the unclear position concerning the meaning of the veto right, especially with regard to when exactly during the siting process the Government can exercise the right to override the municipal veto.

The reason for this may also have a moral dimension. In order to accept a moral obligation, it must be possible to envisage the long-term significance of the obligation. The anguish felt by many municipal representatives, already at the present stage, in the face of decisions about whether or not to participate in feasibility studies, may be due to the possibility that they feel that they are being confronted with a moral obligation, the future significance of which is unclear. The uncertainty which this entails may, in turn, be reinforced by the lack of transparency concerning the municipal veto right. In addition to this, there is another important factor. In the siting work, the overall national perspective has, to a large extent so far, been forced into the background due to the fact that the overall perspective of the siting process as a matter of national importance is lacking. The decisions of various municipalities have, thereby, been far too focused on their own individual municipalities. The necessary conditions have hardly existed for them to consider their decisions in the wider context of a shared national obligation.

The views put forward by KASAM should also be considered in the light of a statement made by the council of the county administrative board of Norrbotten in 1995. In the statement, the county administrative board rejects the storage of spent nuclear fuel in Norrbotten, as a result of its environmental policy. In a letter to SKB dated January 2, 1996, the county administrative board states that its decision is to a lesser extent based on technical-scientific conclusions than on a "desire to preserve Norrbotten as an undisturbed and intact region". (Cf. the statement of the Government in the above-mentioned decision of May 18, 1995, concerning the co-ordinating responsibility of the county administrative boards etc., which is dealt with in Section 3.4 below).

A possible decision by the Government to amend the Ordinance (1993:191) on the Act concerning the Management of Natural Resources etc. so that SKI is given the responsibility of providing information to the county administrative boards concerning areas which the authorities consider to be of national interest for the siting of a repository would, in KASAM's view, have a considerable significance as a matter of principle. This could be interpreted as an important shift in the responsibility of identifying a suitable site for the repository from SKB to the regulatory authorities. In KASAM's view, such a decision is, therefore, not compatible with the principles of the division of responsibilities between the nuclear power utilities and the authorities as expressed in the existing Act on Nuclear Activities. Thus, an amendment of the Act would probably be needed. This is an action that KASAM, also for other reasons, firmly rejects. In KASAM's view, the amendment of the ordinance which has been notified by the Government should not be implemented.

Conclusions

There are reasons in favour of retaining as well as reasons in favour of revoking the Government's right to override a municipal veto. However, in KASAM's view, there are stronger reasons for retaining the right to override a veto. In KASAM's view, there must be a formal possibility for the Government of Sweden to, under very special circumstances, be able to grant permission for the siting of a nuclear waste repository even if the municipal council has not approved the siting proposed in the application.

Furthermore, there are strong reasons against any shifting of the responsibility of finding a suitable site from the nuclear power industry - and thereby from SKB - to the state. Considerable efforts should be made by all concerned to reach a mutual agreement with the municipality in question. Thus, it should not be the task of a central government authority to identify certain areas as suitable for the siting of a repository.

The discussion concerning the meaning of the stipulations in the Act concerning the Management of Natural Resources etc. concerning the municipal veto right and the Government's possibility of overriding a veto in connection with the siting of a repository for spent nuclear fuel is characterized by uncertainty. This uncertainty is counterproductive to the work on locating a suitable site. Even if a negative attitude to trial drilling can be motivated by reasons other than the uncertainty surrounding the veto issue, for many, this issue appears to be a vital stumbling block. It may appear to a municipality which is under consideration for feasibility studies that the only "certain" decision is to oppose any form of investigation work within the boundaries of the municipality.

The Government should counteract this uncertainty by clarifying its view of the conditions under which the right to override the municipal veto, stipulated in the Act concerning the Management of Natural Resources etc., can be exercised. In KASAM's view, such a clarification should entail that municipalities which participate in necessary investigations, on a voluntary basis, and thereby indicate that they are prepared to assume their part of the shared, national responsibility for the nuclear waste issues, should be informed that the Government does not intend to exercise the right to override a veto in connection with applications for detailed characterizations. When the

Government announces this decision, it should also state that, at the time of a subsequent licensing for the siting of a repository, it will be bound by the statements regarding the restrictive application of the right to override a municipal veto which were made in preparatory documents for the current legislation (in particular Bill 1989/90:126). It would be possible to announce this decision to the municipalities to which the Swedish Nuclear Power Inspectorate, with the support of § 4 second paragraph of the Act on the Financing of Future Expenses for Spent Nuclear Fuel etc. (1992:1537) as well as § 7 of the Ordinance (1981:671) on the Financing of Future Expenses for Spent Nuclear Fuel etc., has granted funds from the Nuclear Waste Fund to compensate for certain expenses relating to community-related information.

In KASAM's view, if the Government finds that the approach provided here is not compatible with the regulations in Chapter 4 § 3 of the Act concerning the Management of Natural Resources etc., the Government should take the initiative to make the required legislative amendments. The demands of the communities living in areas under consideration for a repository, like their elected representatives in the municipal decision-making assemblies, are legitimate with regard to transparency and predictability in the legal system, if they should decide to participate in the necessary knowledge acquisition process for the siting of a repository.

3.2 Time-schedule and Co-ordination of the Deep Repository and Encapsulation Plant

Background

According to SKB's plans, site investigations will be started at around the end of 1996. If additional feasibility studies should be necessary late in 1996, SKB states that the site investigations can be postponed for a year or two.

A site investigation takes 4-5 years to perform. After that time, SKB can submit an application for permission to carry out a detailed characterization (p. 202, RD&D Programme 95). This will not take place before around the year 2001. SKB believes (p. 202) that it is realistic to assume that the site of the deep repository can be decided a couple of years after the turn of the century. This should mean at around the year 2002-2003. According to SKB, the detailed characterization will then take 5-6 years. SKB's goal is to start depositing the waste in the year 2008.

SKB plans to submit its application for permission to construct the encapsulation plant at the end of 1997. It is then assumed that the evaluation of the authorities will take place. Construction is expected to start in the year 2000. This would make it possible to start delivering canisters by the year 2008, when the repository is expected to be ready for the deposition of canisters. According to SKB, it will take about 7.5 years from the decision to construct the plant until the encapsulation plant can be taken into operation.

KASAM's Evaluation

SKB's programme is streamlined (canisters will be ready for delivery at exactly the time when the repository is completed, etc.). SKB emphasizes (p. 201) that the time-schedule mainly takes technical activities, which are relatively simple to schedule, into consideration. However, in KASAM's view, siting will, in practice, largely be determined by societal and political factors. KASAM can, already at this stage, perceive that the initial phase of the time-schedule, involving the feasibility studies, is unrealistic. In KASAM's view, this can partly be explained by the fact that a generally accepted procedure for site selection and EIA has so far been lacking (see Section 3.4). It should be possible for the National Co-ordinator for Nuclear Waste Disposal to participate in resolving this deficiency.

One question which has been raised by the municipality of Oskarshamn in its review of RD&D Programme 95 is how far the siting of the deep repository must have progressed when the application for permission to construct the encapsulation plant is submitted, or when such permission is granted. According to RD&D Programme 95, the site investigations will have been in progress for about one year of a total of 4-5 years at the time that an application for permission to construct the encapsulation plant is submitted and permission for construction of the plant will be granted about two years before the site investigations are completed.

KASAM is dubious as to whether this plan is the best from the standpoint of the system as a whole. One reason for this is that, in accordance with the Government's decision of May 18, 1995, SKB must present an integrated safety assessment for the entire final disposal system. If this assessment is submitted at too early a stage during the site investigations, it cannot be based on site-specific geological conditions for the repository. SKB's planning also means that the system alternative with the siting of the encapsulation plant next to the repository cannot be evaluated in an unbiased manner. Even if co-siting with

CLAB is the main alternative for the encapsulation plant, siting at the repository should be an alternative in the EIS. Furthermore, SKB's plan means that the decision on the encapsulation plant will be made before SKB has proposed a site for the repository, which may make the proposed host municipality for the encapsulation plant less inclined to make a decision on the siting issue. Furthermore, it cannot be excluded that a host municipality for the repository may be interested in co-siting the encapsulation plant.

One alternative to SKB's proposal is that the site investigations should be completed and an application for permission to carry out a detailed characterization submitted at the same time as the application for permission to construct the encapsulation plant. Since, in SKB's view, the construction of the encapsulation plant will take about two years longer than to complete the construction of the deep repository, this could mean that the deep repository can be constructed at a slower pace than that assumed by SKB. This could mean a greater possibility for in-depth investigations, different types of on-site experiments etc. One risk of construction work is that "the construction project" will take over at the cost of e.g. investigations concerning long-term safety. A longer construction time for the repository should entail advantages, even if this would probably be at the price of an increase in costs. On the other hand, 7.5 years seems to be somewhat long for the construction of an encapsulation plant. Thus, it should be possible to co-ordinate both applications without this resulting in too much delay.

Furthermore, it should be emphasized that the start of a detailed characterization is no guarantee that the deep repository will actually be constructed at that particular site. Thus, starting to construct the encapsulation plant would entail, also at this stage, SKB taking a risk. On the other hand, it does not seem reasonable to demand that the construction of the encapsulation plant must wait until the detailed characterization is completed.

Conclusions

KASAM recommends that SKB should change its time-schedule so that the application to construct the encapsulation plant is submitted at the same time as the application for the detailed characterization. In KASAM's view, this would have the following advantages:

- A decision on both applications can be made at the same time, which will mean that it will be highly credible that manufactured canisters containing spent nuclear fuel will actually be deposited in a repository.

- The safety assessment for the entire system will be better balanced since it will be site-specific, not only in terms of the repository but also with regard to the encapsulation plant and, thereby, also the transportation system. This will improve the possibility of evaluating different siting alternatives for both facilities.

3.3 SKB's Site Selection Factors

Background

SKB's view of the fundamental requirements on the bedrock which is to host the repository is presented in the conclusions of the SKB 91 report (p. 178): "The safety of such a repository is only slightly dependent on the ability of the surrounding rock to retard and sorb leaking radioactive materials. The primary function of the rock is to provide stable mechanical and chemical conditions over a long period of time so that the long-term performance of the engineered barriers is not jeopardized."

SKB referred to this conclusion in the Section "Fundamental Requirements and Important Siting Factors in Site Selection" in RD&D Programme 92 and added that "SKB's geoscientific research and the SKB 91 safety assessment show that the rock at many places in large parts of Sweden fulfils this safety-related function, " (p. 68).

KASAM criticized SKB's conclusions on the grounds that SKB had gone further in its conclusions from SKB 91 than the calculational assumptions allowed. Furthermore, in KASAM's view, it may be difficult to make site selection credible if SKB carries out measurements without prescribing acceptance limits in advance and then reports the results and declares that they show that the bedrock is suitable. In its decision made on the basis of RD&D Programme 92, the Government required that SKB should supplement its RD&D Programme by describing the criteria and methods on which the selection of suitable sites for a repository can be based.

In its RD&D Programme 92 Supplement, SKB provided a broad description of its siting factors and criteria. The criteria were specified, "chiefly in qualitative terms and in relation to what is considered normal for Swedish crystalline bedrock. Prior to the site investigations, SKB will clarify suitable parameter intervals and couplings between different factors, where necessary (p. 26)."

In General Siting Study 95, these factors have been applied on a national scale and SKB presents separate conclusions for each factor. However, the report emphasizes that many of the siting factors should, above all, be applied on a local scale in connection with feasibility studies and site investigations. According to SKB, the study is also a basis of information that can be used in connection with the planning of repository siting work.

In General Siting Study 95, SKB considers it to be unsuitable to site the deep repository in the mountain ranges, Skåne and Gotland. In general, General Siting Study provides no concrete guidance for the selection of municipalities for feasibility studies.

RD&D Programme 95 does not add any factual information concerning requirements and criteria even if the programme contains a detailed updating of knowledge about the bedrock.

KASAM's Evaluation

General Siting Studies

As KASAM states in its considerations concerning the Government's right to override a municipal veto, the overall national perspective has, to a large extent so far, been suppressed due to the fact that the overall perspective of the siting process as a matter of national concern is lacking. The decisions of various municipalities have, thereby, been far too focused on their own individual municipalities.

In its decision concerning SKB's RD&D Programme 92 Supplement, the Government states that, like several of the reviewing bodies, it considers that SKB should present its general siting studies and site-specific feasibility studies in an integrated fashion with the aim of providing background and prerequisites for the siting work. KASAM interprets this to mean that the Government recommends that a national perspective on siting should be maintained.

SKB presented its General Siting Study 95 in connection with RD&D Programme 95. As far as the feasibility studies are concerned, the RD&D Programme states that SKB has not yet obtained material which is adequate enough for an overall report and that the programme for future feasibility studies will be adapted to the specific conditions which exist at each municipality (Section 9.3.1. "Feasibility Studies", p. 128).

As KASAM initially stated in Chapter 1, KASAM perceives a difficulty in that the further work in SKB's programme is to be so rapidly focused on two, and then, one municipality and site. In its review of SKB's RD&D Programme 92 Supplement, KASAM recommended that the feasibility studies should focus on geological regions rather than on individual municipalities. KASAM adheres to this recommendation. Areas of geological interest do not necessarily end at the boundary of a municipality. There may be several reasons for more than one municipality being affected by the siting of a repository. Thus, the understanding of the local community which SKB seeks to achieve may have to be sought within a larger community than that of a municipality.

In its General Siting Study 95, SKB deals with the possibilities of interpreting the properties of the bedrock in stages with regard to mechanical stability and constructibility. Maps on a national scale describe soil covers and soil depths, rock type contacts, magnetic field homogeneities, well data and the extension of topographical lineaments. According to SKB, there is no reason to exclude or identify, on a national scale, any regions or areas as being of particular interest on the basis of the information provided in these maps. In KASAM's view, the greatest deficiency of General Siting Study 95 is the fact that no attempts have been made to proceed from a national scale to similar but more in-depth descriptions for selected geological regions.

If it is found that SKB does not have the possibility of carrying out the necessary number of feasibility studies within the next few years, SKB must still proceed with its siting work. One way of doing so, which KASAM considers to be suitable, is for SKB to focus its general siting studies on progressively more limited regions which are of special interest on account of their geological conditions. SKB should discuss the merits of different main siting alternatives, such as the advantages and disadvantages of siting a repository in southern and northern Sweden, or of siting a repository on the coast or inland.

Site Selection Criteria

SKB states that its own task is to, by the year 2001, prepare a basis for an application for the siting and construction of a deep repository at a specific site. According to SKB, this site must have very favourable safety-related conditions for the hosting of a repository. This does not only mean current conditions at the site, but also the conditions which may arise in a remote future, as far as these conditions can be established.

In certain cases, the site selection factors are described in general terms by SKB and the range of values which can be accepted in order for a site to be considered suitable is not always even specified. For a process to be credible, the factors must be more clearly defined than they have been so far. SKB must also specify what knowledge it expects to acquire about the factors at various stages in the site selection process, i.e. prior to the selection of sites for site investigations and prior to the selection of a site for detailed characterization. KASAM understands the difficulties of compiling a successive and systematic selection of sites for site investigations solely on the basis of feasibility studies of geological and other safety-related factors, since the feasibility studies only provide limited information on properties at the repository depth within the areas which have been studied. Only in connection with a site investigation can information be obtained for site-specific safety assessments. On the other hand, it should be possible for studies on a national and regional level to provide better material for comparison than that provided by SKB's General Siting Study 95.

In September 1994, KASAM and SKI arranged a joint seminar on acceptance criteria for the bedrock. The presentations and discussions were based on the requirements on site characteristics which had been proposed by the Nordic safety authorities as well as the requirements that SKB had identified, namely, that the bedrock at a repository site must:

- provide permanent protection for the engineered barriers,
- provide a stable and favourable environment for these barriers,
- have a low turnover of groundwater through the repository near field,
- be simple to characterize,
- provide favourable recipient conditions and
- be free from deposits of valuable minerals which may be worth mining.

SKB's safety-related siting factors, as described in RD&D Programme 92 Supplement, are classified in a similar way with regard to requirements on the chemical environment, mechanical stability, the ability of the rock to limit the transport of radioactive substances, human intrusion and recipient conditions. In KASAM's view, the scope of SKB's requirements and criteria is satisfactory, but so far, they are far too general. SKB's promise: "Prior to the site investigations, SKB will, where necessary, define suitable parameter ranges and links between different factors," is a step in the right direction. However, SKB still has to take this step.

In an appendix, at the end of this Review Report, KASAM provides a general review of the latest safety assessment reports presented by SKB and SKI. These reports show that it is the fuel canisters, buffer and rock closest to the buffer which have the greatest potential to isolate and retain the radioactive substances. On the other hand, the rest of the bedrock, the far field, only makes an insignificant contribution to the isolation of long-lived, weakly sorbing radionuclides from the biosphere.

This conclusion is in good agreement with the above-mentioned quotation which was taken from SKB 91: "The safety of such a repository is only slightly dependent on the ability of the surrounding rock to retard and sorb leaking radioactive materials", and does not contradict the assumption: "The primary function of the rock is to provide stable mechanical and chemical conditions over a long period of time so that the long-term performance of the engineered barriers is not jeopardized", (SKB 91, p. 178). However, it is not sufficient for the conditions surrounding the engineered barriers to be stable, they must also provide long-term protection. One condition for the good safety performance of the engineered barriers is that the buffer should, for a long time, be able to maintain the good properties that SKB considers it to have. For this to be possible, the buffer must be protected from being affected by those substances in the groundwater which can alter its properties, i.e. the buffer must be isolated as much as possible from moving groundwater. Thus, the safety of the repository places high demands on the parts of the rock where deposition holes are drilled, on the canister near field, and moderately high demands on the rest of the rock. SKB's statement that the site must have very good safety-related conditions for the final disposal of the waste can be clarified to mean that the bedrock at disposal depth must maintain a high frequency or extended volumes of large blocks of rock with low hydraulic conductivity where the deposition tunnels can be constructed.

However, in its description of the requirements on the barrier function (RD&D Programme 95, pp. 20-22), SKB does not make a sharp distinction between the canister near field and the rest of the bedrock. SKB makes the following general statement: "Tunnels and deposition holes should be situated in the repository rock so that rock formations unfavourable for safety or construction are avoided." In KASAM's view, SKB should formulate specific criteria for the canister near field on the basis of analyses of the function and properties of the buffer.

Conclusions

- SKB should elaborate its general siting studies by progressively focusing these studies on more limited regions which are of special interest on account of their geological conditions;
- SKB should also discuss different main siting alternatives, such as the advantages and disadvantages of siting a repository in southern and northern Sweden, or of siting a repository on the coast or inland;
- SKB should define the siting factors as well as specify the information that can be obtained from them after different stages in the site selection programme;
- SKB should formulate specific criteria for the canister near field, i.e. the parts of the rock where the deposition tunnels are to be constructed.

3.4 Siting Process and the EIA

Background

SKB plans to site the deep repository through feasibility studies in 5-10 municipalities, site investigations at two sites and, finally, a detailed characterization at one site. In its decision of May 18, 1995, the Government had no objection to this plan. With regard to the EIA, the Government states (p. 5) (KASAM's translation):

> .... like SKB that environmental impact statements (EIS) and the process of preparing these statements, the environmental impact assessments (EIA), are an important instrument in the contact between the regulatory authorities, municipalities concerned and the general public. In accordance with the Government's view, it is important that transparent forms for the EIA should be established at an early stage of the siting work.

The role designated to the county administrative boards is a central one (p. 6):

> The county administrative board has the responsibility for and supervises the management of natural resources. The Government assumes that the county administrative board of the county involved in feasibility studies, site investigations or detailed characterizations will take the responsibility for co-ordinating the contact with municipalities and government authorities which are necessary in order for SKB to be able to prepare the basis for an EIS for an

application for permission in accordance with Chapter 4 of the Act concerning the Management of Natural Resources etc.

Thus, the Government considers the EIS (Environmental Impact Statement) to be very important and emphasizes the necessity of establishing a transparent process (Environmental Impact Assessment, EIA) for the preparation of the EIS, at an early stage. The county administrative board will be given the responsibility of co-ordinating the EIA. No further guidance is provided on how "a transparent process" is to be established. Furthermore, SKB's RD&D Programme 95 does not provide any guidance on this subject.

At the invitation of the county administrative board in Kalmar and the municipality of Oskarshamn as well as with the support of SKI and SSI, representatives from decision-makers involved in feasibility studies met in Stockholm on December 6, 1995. The purpose of the meeting was to establish the need to co-ordinate the initial stages of the process which is to result in an EIS prior to the siting of a deep repository. The participants and KASAM were given the task of proposing to the Government to undertake urgent measures to facilitate the siting process. This was done in the form of a letter to the Ministry of the Environment on January 29, 1996. The letter referred to certain difficulties which had been encountered by SKB in its siting work, including the fact that one municipality (Storuman) had broken off its co-operation with SKB after a local referendum and the fact that a county administrative board (Norrbotten county) had decided to say no to the disposal of spent nuclear fuel within the county.

In its decision of May 15, 1996, the Government appointed a National Co-ordinator for Nuclear Waste Disposal. The task of the National Co-ordinator is to promote the co-ordination of the information which municipalities involved in SKB's studies concerning the siting of spent nuclear fuel and nuclear waste consider necessary. The National Co-ordinator is responsible for proposing forms for the exchange of information concerning the handling and final disposal of spent nuclear fuel and, in general, is to be prepared to co-ordinate the contacts between the municipalities and county administrative boards which are affected by the studies. SSI, SKI and KASAM are to be consulted when necessary and are to assist the National Co-ordinator to an appropriate extent.

The Government decisions of May 18, 1995 and May 15, 1996 provide two important points of departure for further work on siting and the EIA.

- It is important that transparent forms for the EIA should be established at an early stage of the siting work. The role designated to the county administrative boards is a central one.
- A National Co-ordinator for Nuclear Waste Disposal has now been appointed. This National Co-ordinator should, i.a. be able to contribute to a clarification of how the siting process and the EIA are to be conducted.

A transparent siting process means that the sites at different stages of the programme are selected on the basis of pre-determined criteria (see Section 3.3) and on the basis of information obtained from the different sites investigated at previous stages and which is of equal value. An important part of the EIA must be that of defining what is to be included in the basis for decision-making. For this to be done, work must be co-ordinated on the national level.

The following four principles should form the basis for the planning of the EIA with regard to the siting of a repository:

- A site selection process, which all parties have agreed upon, must be established.
- The information which can be obtained at different stages (e.g. feasibility studies) and how this information can be used to select sites for the next stage must be established. If it is carried out at an early stage, and for the entire site selection process, the process will be stronger.
- During each stage, the focus will be on issues which are decisive for the next stage.
- At the same time, issues which must be analyzed at a subsequent stage are identified.

One aim of the EIA is to provide a comprehensive basis for decision-making. This means that it must cover the entire deep repository system, in other words, it must also include the encapsulation plant and the transportation system. As stated in Section 3.2, there are clear links between the different parts of the system.

Normally, the purpose of the EIA is to scope those issues which the proponent should deal with in the application, the Environmental Impact Statement (EIS). This scoping phase is then followed by an investigatory phase during which the proponent prepares the EIS upon which the application will be based. However, questions relating to the final disposal system are highly complex. Therefore, various parties involved will find it necessary to develop their knowledge of the subject before making the necessary decisions. KASAM proposes that this should be carried out during the EIA, in parallel to the investigations carried out by SKB which will result in an EIS and licence application.

With such a procedure, the participants in the EIA can, while the proponent prepares the application, deal in different ways with special issues which are considered to be particularly important and problematic. A systematic programme, which should be adapted to different phases of SKB's work, can be established for this. The responsibility for doing so should be that of the newly appointed National Co-ordinator for Nuclear Waste Disposal. Such a process should be able to provide conditions for effectively developing competence within the municipalities concerned. It must be emphasized that the aim is to make preparations for the decision-making process, not to initiate it by making evaluations, as regards e.g. whether final disposal at a particular site will be safe.

In general, the issues which must be dealt with during the overall EIA can be classified into five categories:

- Method
- System
- Encapsulation
- Repository
- Transportation

Each category consists of a number of different areas. For the repository, the previously specified site selection factors can, for example, be a point of departure in the EIA. Examples of system-related questions include safety- and radiation protection-related issues for the entire system, the performance of the canister in the repository and the possibility of retrieving the deposited fuel after Stage 1 of the construction of the deep repository. Altogether, the five categories of issues are very extensive and everything cannot be simultaneously treated during the EIA. The order in which different questions are to be dealt with must be determined taking into consideration different deadlines for decision-making and different stages in the site selection process. However, it is important that the procedures for this should be determined at an early stage. In order to establish the best possible conditions for a stable process, the process must be defined up to the very end, i.e. up to the time when SKB submits its application.

Thus, KASAM proposes that a systematic programme should be organized and managed by the National Co-ordinator for Nuclear Waste Disposal. The purpose of the programme should be to prepare those participating in the EIA, especially representatives of municipalities and other local interests, prior to the evaluation of applications and the EIS. The method should entail seeking to define, at an early stage, what is to be included in the basis for decision-making at different stages of the siting process and to, thereby, identify and analyze issues of particular importance or which are controversial in nature. In particular, what is fact, what is to be considered a best estimate due to uncertainties, and what is opinion must be clarified. The programme which, e.g. can be implemented in the form of courses, seminars, debates and public hearings, should cover the entire waste disposal area, i.e. the method, system, deep repository, encapsulation plant and transportation. Specific questions should be selected for in-depth investigation.

Conclusions

- As before, KASAM would like to emphasize the importance of the EIA. At the same time, it should be possible for the National Co-ordinator for Nuclear Waste Disposal to contribute to clarifying the functions involved in an EIA. The function of the National Co-ordinator in relation to the EIA should therefore be defined. At the same time, KASAM would like to emphasize that it is the actual functions that are important and not the formal framework;
- KASAM proposes that a systematic programme should be established to study issues which are of particular importance. The aim of the programme is to effectively develop the competence of the parties involved prior to decision-making. It must be possible for all participants in the site selection process and EIA to be involved in this programme, which should start as soon as possible and should continue until a decision is made. The programme can be organized by the National Co-ordinator for Nuclear Waste Disposal.

4. Engineered Barriers

4.1 Encapsulation

Background

SKB's original canister design consisted of a copper cylinder surrounding a frame containing spent nuclear fuel. The area between the fuel and the copper cylinder was to be filled with molten lead or copper powder so that, after sealing, the canister would be a compact entity. In RD&D Programme 92, SKB changed the canister design. In the new design, the nuclear fuel was surrounded by a steel cylinder, which was the pressure-bearing element. This steel cylinder was, in turn, surrounded by a copper cylinder, which was to provide the desired corrosion protection. In its review of RD&D Programme 92, KASAM discussed advantages and disadvantages of the new design. KASAM believed that the advantages would probably outweigh the disadvantages and, therefore, KASAM supported SKB's steel-copper canister design as the main alternative for further investigation. At the same time, KASAM stated that it was necessary to study the new design further and recommended that SKB, in its RD&D programme should include studies of the filling materials inside the steel canister which can reinforce the function of the canister as a barrier.

Furthermore, in RD&D Programme 92, SKB announced its intention of applying for siting permission and a licence to construct an encapsulation plant at year-end 1996/97. Bearing in mind the fact that the canister design must, therefore, be established within the period to be covered by the RD&D programme, KASAM, like SKI, found it remarkable that SKB did not deal with the question of design or product criteria for the canister and did not allow for an evaluation of the canister design by the competent authorities in its time-schedules. This question was once again raised by KASAM in its review of SKB's RD&D Programme 92 Supplement since this did not deal with the canister criteria other than in general terms.

KASAM's Evaluation

SKB's RD&D Programme 95

SKB has now included in RD&D Programme 95, the information requested by KASAM and has also further modified the canister design. In the latest version, the canister consists of an outer copper shell and a solid inner component of steel or possibly bronze. The inner component (insert) is to fulfil the triple function of pressure-bearing element, filling material and support for the fuel assemblies. Rolling and roll forming or extrusion are the main alternative methods for the manufacturing of the copper cylinder. However, hot-isostatic pressing and electrodeposition of copper directly on the insert are being studied as alternative methods.

Design and Manufacturing Criteria

The criteria for the canister described by SKB on pages 75-76 of RD&D Programme 95 are an adequate response to the requests made by KASAM in its previous reviews of RD&D Programme 92 and the RD&D Programme 92 Supplement. The essential design requirements are dealt with and quantitative criteria are reported as far as this is possible at the present stage.

Canister Design

With the implementation of the encapsulation plant project, SKB is taking a decisive step in its work on the final disposal of spent nuclear fuel. The encapsulation plant is a major investment which is to be made at an early stage. When the plant is completed, any possibility of further developing the encapsulation method will be severely limited. In its RD&D Programme 95, SKB states, on page xviii that: "The work is currently in the preliminary design phase. The results of this phase will serve as a basis for SKB's decision to apply for a permit to build the facility. The work is being conducted in such a manner that it will be possible to submit the permit application during 1997." In the same paragraph, SKB fortunately makes the reservation that: "The date of the application will therefore be dependent upon how fast facility design, canister development and the safety assessment for canisters in the deep repository proceed."

As recently as in R&D Programme 89, it was stated that the most urgent areas for research during the period of 1990-95 were corrosion assessments for potential canister materials, testing of non-destructive testing methods and the identification of fracture mechanisms. A copper canister supported by a steel insert was mentioned as an interesting alternative for further study (R&D Programme 89, Part II, p. 96). In RD&D Programme 92, the copper-steel canister was the main alternative and in RD&D Programme 95, the copper canister with a solid steel insert is the reference alternative. It is not remarkable for a design to undergo many changes when the development work makes a transition from basic research to research applied to a specific project. Furthermore, it would not be remarkable if the changes which have so far been made must be followed by others. What is remarkable is that SKB, in the light of this, is planning to submit an application for a licence to construct an encapsulation plant as early as in 1997.

SKB has changed its canister design in three stages without providing a detailed motivation for the changes. The fuel canister is a prototype design and, at the same time, one of the most important barriers against the dispersion of radioactivity in SKB's final disposal system. The design must be described in an EIS as well as in an integrated safety assessment of the final disposal system in connection with the application for a permission to site and construct the encapsulation plant. One of the functions of the EIS is to provide a basis for decision-making where alternatives are described and compared. In KASAM's view, it is important that SKB should build confidence in the selected canister design as being a result of a process of maturity which has been carried sufficiently far. Thus, SKB should describe, in detail, the development process for the canister, the advantages and disadvantages of the alternatives studied and the reasons why SKB believes that the final design is sufficiently mature to be a basis for decision-making on the construction of the encapsulation plant and the manufacturing of canisters.

Supporting R&D for the Verification of Canister Properties

The ongoing basic research on corrosion properties, creep properties and fracture mechanisms in the copper canister should be pursued. However, the investigations should be more applied in nature. KASAM considers the fact that SKB is now planning to establish a pilot facility for testing the sealing of the canisters and control of full-size canisters to be of value. This facility will prove valuable in focusing the verifying research on the specific properties of manufactured canisters. It will also enable Swedish researchers, to a greater extent than at present, to participate in the research concerning manufacturing. This is important in order to develop the same high level of expertise with regard to the manufacturing of the canisters as there is with regard to the canister properties. In the light of Sweden's reputable research tradition with regard to manufacturing processes involving metals, every opportunity exists for achieving this aim.

In KASAM's view, SKB has put considerable work into selecting suitable materials and manufacturing methods, but is working with such an ambitious time-schedule that there is a risk that hasty decisions may be made. Consequently, KASAM would like to particularly emphasize a few questions relating to the canister properties and manufacturing method to which satisfactory answers must be found.

Manufacturing

The copper ingot, which will be processed into a cylinder, is coarse-grained. The processing method - rolling, roll forming or extrusion - may achieve a more favourable, more fine-grained microstructure, if correctly performed. The result of the processing method - in particular the homogeneity of the grain structure - must be controlled. Hot-working should be carried out on a laboratory scale to establish parameters which make it possible to model microstructure changes during various processing methods. The processing method can be optimized with the help of the models. Suitable software for carrying out these calculations is available in Sweden and has previously and successfully been used to analyze copper rolling. It is particularly important for the ingot, plate or billet to be kept at high temperatures for as short a time as possible and to ensure that there is sufficient reduction during working so that the above-mentioned grain refinement is obtained.

Mechanical Properties

The phosphorus-copper alloy material which has been investigated has demonstrated satisfactory creep ductility. However, the fact that largely fine-grained copper has been used in the experiments so far carried out must be taken into consideration. A coarse-grained structure normally results in a lower creep ductility and such a structure has been observed both after the processing of the parent metal and in the welded joint. Thus, it is important for creep properties to also be established for these types of structures. If a roll-formed canister is to be used without any subsequent annealing, the creep properties for cold-worked materials must also be studied.

One specific problem relating to the fuel canisters is the difficulty of extrapolating the creep strength and ductility over a long period of time. A new analysis should be performed on the experiments which have so far been carried out.

The cast insert is a new element in the canister design. The properties of the intended material - cast steel, nodular cast iron or bronze - must be studied. The mechanical properties demonstrated by these materials in conventional components are also adequate for the canister design. It is primarily a question of verifying that the corresponding properties can be achieved. For example, can narrow tolerances be maintained with regard to the inner dimensions of the copper shell, and can a material which is sufficiently free of defects be manufactured in the sizes and geometries that are required?

Corrosion Properties

The resistance of the copper shell to general corrosion as well as resistance to pitting seems to be adequate in the groundwater which can be expected at repository depth in Swedish crystalline bedrock. Even if stress corrosion has not yet been observed in the groundwater environment concerned, it is important to carry out further studies in order to, if possible, establish criteria so as to obtain a more certain estimate of the risk of this type of corrosion occurring after extended periods of time. These studies should also include long-term experiments.

Microbial corrosion is probably the area which deserves to be studied in greatest depth at this time. This type of corrosion can have serious consequences unless it is limited, since sulphate, which is in ample supply in the bentonite, can be converted by bacteria into sulphide, which in turn is an effective corrodant (see Section 4.3).

Manufacturing and Control

The copper canisters will be manufactured on a continuous basis over a period of twenty years or so. The classification into stages comprising pilot manufacturing with the possibility of pilot deposition of dummy canisters, manufacturing for demonstration-scale deposition of the fuel and manufacturing for the deposition of the remainder of the fuel makes it possible to improve design and manufacturing details, if necessary. SKB must, in any case, have a reliable control over the manufacturing quality already from the time that demonstration deposition is started.

Thus, KASAM recommends that SKB should use the production capacity which must be developed by sub-contractors and the resources of the pilot facility to manufacture a relatively large number of sample canisters. This will be of great value with regard to establishing the range of variations of the canister properties which may arise during mass production. These variations must be established through suitable control programmes. These control programmes are an important stage of development in themselves.

In Chapter 5, in the section on the Äspö Hard Rock Laboratory, KASAM recommends that the objective for the trial deposition of inactive canisters in the Äspö Hard Rock Laboratory should be expanded. An extensive pilot manufacturing programme for canisters fits in well with such a pilot deposition stage.

Conclusions

- Taking into account the central role of the canister as a barrier, it is important that further research concerning mechanical properties and corrosion should be carried out. This especially applies to factors which have only been studied to a limited extent previously, such as creep in welded joints and microbial corrosion;
- The development work which has so far been carried out on the manufacturing of the canister has mainly been engineering-oriented. It is important that it should be supplemented by a long-term competence development and research, particularly in Sweden;
- Even if many aspects of the properties of the canister have been studied by SKB, KASAM recommends that SKB should use the entire length of time at its disposal for development and further study and not commit itself exclusively to one alternative;
- SKB should manufacture a relatively large number of canisters for the verification of the product properties and the control programme. These canisters can then be used for pilot deposition in the Äspö Hard Rock Laboratory.

4.2 Buffer

The buffer surrounding the canisters fulfils several very important functions in the repository. It must prevent substances in the groundwater, including bacteria, which can corrode the copper shell, from reaching the canister, it must provide a counterpressure to that of the rock in order to stabilize the deposition hole, it must keep the canister in place and protect it against mechanical damage caused by movements in the surrounding bedrock, it must remove residual heat from the fuel and it must retain and retard any radionuclides leaking from the fuel, if the canister integrity is breached. RD&D Programme 95 gives the impression of overconfidence in the capacity of the bentonite to, first of all swell and then, for all time, retain its high density as well as to chemically bind water inside the pores so as to dry out and kill any bacteria. SKB's technical reports provide a more conservative interpretation and identify risks which should be further investigated. KASAM believes that it is important from the standpoint of confidence-building that SKB should dare to identify problems also in the RD&D programmes which have a much wider readership than the technical reports.

The engineered barriers surrounding the nuclear fuel must provide a satisfactory protection against leakage. SKB must show that a breach in the integrity of a barrier will not result in a breach in the integrity of other barriers. For example, a hole in a canister must not lead to such an extensive corrosion of the steel inside the canister that the hydrogen gas which is generated leads to the cracking of the bentonite which then causes it to dry out and lose its density. SKB maintains that the bentonite will recover its former properties once the gas has escaped and the pressure has dropped. However, SKB does not explain how the gas can leave the bentonite which is enclosed in a deposition hole and pressed down by a sealing plug which is sufficiently strong and dense to resist the swelling pressure of the bentonite.

One of the functions of the bentonite is to keep the canister in place. The swelling of the bentonite must fill the empty space around the canister and against the rock wall as well as plug any cracks in the wall. On page 35 of RD&D Programme 95, SKB states that the near-field rock allows water saturation and swelling to occur but that, at the same time, it counteracts cementation, mineralization and penetration of large cracks which would otherwise be able to considerably reduce the density of the bentonite. On page 37, SKB states that model calculations have shown that the buffer material nearest the heat source will dry out and shrink in volume. However, SKB does not discuss the extent of such shrinkage from drying and whether it can lead to cracking. How will all of the bentonite behave during the initial heat transient; will it first swell, then dry out on account of the heat from the canister, shrink and, perhaps, crack and then become rehumidified when the heat from the fuel decreases?

On page 36 of RD&D Programme 95, SKB also emphasizes that a necessary function of the backfill material is to counteract bentonite swelling from the deposition hole and that this is achieved by mixing bentonite with aggregate.

Unmixed aggregate can only be considered for use in those parts of the tunnel where it has been found that the water transport around the canister is not affected by the hydraulic conductivity in the tunnel. In such cases, the tunnel sections may have to be sealed at either end.

One may well ask how the backfill material can be packed so densely against the bottom of the tunnel that the packing material can counteract the upward swelling of the bentonite when it becomes water-saturated. It was obvious, when KASAM visited the Äspö tunnel during the backfill experiments, that it was difficult to follow the original plans for backfilling. Instead, SKB was forced to abandon the idea of mixing bentonite in the packing material since it was impossible to pack it densely with the swelling from the water present in the bottom of the tunnel.

Two alternatives have been provided for the emplacement of bentonite in the repository: Alternative 1, which is "in situ" compaction, seems difficult to implement particularly taking into account the fact that plans to mix bentonite with the backfill material had to be abandoned. Alternative 2 entails using pre-compacted bentonite blocks of a high density. This alternative presents a challenge in terms of precision and ensuring leaktight joints as well as in terms of the requirement of keeping the material pressurized before and during backfilling.

The chemical composition of bentonite varies considerably, e.g., it may contain about 65-80% montmorillonite (swelling clay) in MX-80 bentonite. Besides montmorillonite, whose surface chemistry affects the acid base properties, bentonite also contains varying concentrations of quartz and this results in other surface properties which have an effect similar to that of ion-exchangers. The complex composition of bentonite means that adsorption/diffusion and flows through the material may also vary. For example, can hydrogen sulphide ions diffuse through bentonite? The reliability of the chemical data for all of the structural variations of the bentonite with regard to nuclide permeability must also be confirmed.

When establishing possible chemical processes in the buffer and the near-field rock, as well as inside the canister, in the repository zone and in the far field, a series of variables (particularly the solubility, complexing and kinetics of radioactive substances) should be taken into account within and beyond the expected limits as well as the integrated effects of the variables. Therefore, the studies should be supported by state-of-the-art chemometric experimental planning, where Sweden occupies an advanced position in terms of research.

4.3 Bacterial Processes

With regard to research, there can be no doubt about the importance of focusing on the possible effect of bacteria on the corrosion of the copper canister. Micro-organisms (aerobic as well as anaerobic) actively participate in the sulphur conversion cycle where the reducing form, sulphide, H_2S, is corrosive to copper and steel. Many of the sulphate-reducing bacteria are not classified at present and, as far as the temperature-dependent varieties are concerned, quite little is still known since these varieties grow very slowly. Many may even grow with hydrogen as the only electron donor and carbon dioxide as the only source of carbon. The conditions surrounding the fuel canisters will be favourable for this type of bacteria. Carbon and hydrogen exist in both rock and bentonite. The presence of oxygen is not necessary since the optimum temperature of 65 C is included in the temperature range of the bentonite (50 - 80 C), and the pressure at a depth of 500 m does not present an obstacle to the growth of many of these bacteria.

In SKB's technical report, 95-27 (p. xii) the capacity of the bentonite is described in the conclusion that "there is no rapid mechanism of microbiologically induced sulphide corrosion inside a nuclear waste bentonite buffer if an a_w (water activity) of 0.96, or lower, is maintained." It is remarkable that these studies were carried out at a temperature of 30 C since it is known that the repository temperatures will be 50 - 80 C as well as that the optimum sulphate reduction occurs at around 65 C.

One conclusion of SKB's report 95-25 (p. 81) is that "the complete process of sulphate reduction is not yet known - e.g. the full role of inhibitors, accelerators, distribution, alternative electron donators - and needs further investigation." Can hydrogen gas be of benefit to sulphate-reducing bacteria? It is also known that sulphate reduction is common at greater depths than 100 m and especially in saline groundwater. In RD&D Programme (p. 38), SKB indicates the importance of limiting the action of sulphate-reducing bacteria and states that the bentonite buffer is the only barrier to their action. SKB's conclusion is that "the results so far indicate that the bacteria do not survive. If this proves true, then the bentonite constitutes a barrier to microbes." On page 80 (RD&D Programme 95), SKB states, with regard to microbial corrosion that "ongoing investigations of the growth of sulphate-reducing bacteria in compacted bentonite show that the bacteria cannot survive at densities above 1,500 kg/m^3. If this is true, microbial corrosion could not have any decisive effect on the life of the canister." When comparing these conclusions with the content of the technical reports and when estimating the potential size of this problem, KASAM considers that RD&D 95 presents a far too one-sidedly optimistic and vague, as well as possibly incorrect (cf. SKB 95-27, p. 19) interpretation of the current situation.

5. Certain Questions Concerning SKB's Research

Background

To a greater extent than in the previous programmes, the activities described by SKB in RD&D Programme 95 have the character of specific plans of action or projects within clearly separated sub-areas, but co-ordinated within a fairly tight time-schedule. The basic research presented in a separate volume in the previous R&D and RD&D programmes has, this time, been reduced to one chapter entitled "Supportive R&D". Within some of the project areas, e.g. encapsulation, SKB describes all of its activities as project work, and within others, e.g. safety assessment, the description of the project-oriented work is supplemented by brief accounts in the Chapter "Supportive R&D".

The presentation of the state of knowledge has developed in the opposite direction; it has been given increasingly greater scope in the programmes. With regard to SKB's early programmes, reviewing bodies requested a detailed description of SKB's view of the state of knowledge as a background to the research programme. The current scope of this description makes it a valuable part of RD&D Programme 95.

KASAM's Evaluation

Quality of Research

The supporting research carried out by SKB in its final disposal programme focuses, to a large extent, on obtaining a basis for SKB's assessments of the repository function and its possible impact on man and the environment through the leakage of radioactive substances in particular. The programme is being developed in an interaction between analyses of processes which can affect the barrier functions of the system, calculations of their consequences, identification of uncertainties in the input data and in the modelling of processes as well as in the focus of the supporting research on such data and processes where uncertainty can be of critical importance for the assessment of the system's performance. It is of the utmost importance for the credibility of SKB's claims that the final disposal of the spent nuclear fuel should not have a harmful impact on the environment and man, that the final disposal research should be carried out, published and subjected to peer review in accordance with standard practice within the research community at large. It may also be important to obtain knowledge which is not exclusively acquired by the research groups traditionally used by SKB. Thus, it is important to develop independent, Swedish competence of a high quality within all key areas. The possibilities which are now opening up within the EU's research programmes should be exploited.

RD&D Programme 95 does not include a system for quality control, renewal, concluding and evaluating research projects, in spite of the fact that it should be of the greatest importance for SKB to establish forms of, in all situations, exploiting the highest research competence that Sweden has to offer. Furthermore, it is unclear as to what type of examination SKB's technical research is currently subjected to prior to publication. Requirements should be made that results from SKB's research projects should be, to a greater extent, published in internationally known journals and subjected to scientific peer review.

Äspö Hard Rock Laboratory

The National Board for Spent Nuclear Fuel stated, in its evaluation of SKB's R&D Programme 89 that SKB should investigate whether the final disposal could be implemented in stages with "the possibility of re-evaluating the situation at the end of each stage and the possibility of adopting measures to remedy any deficiencies in the repository system. The hard rock laboratory provides the opportunity of testing the disposal technique and of closely monitoring the performance of the engineered barriers during the initial phase. In the next phase, a demonstration-scale repository can be constructed. The scale of the demonstration repository could be 5 to 10 per cent of the full-scale repository." (Evaluation of SKB R&D Programme 89, March 1990, p. 2).

SKB adopted the proposal of constructing the repository in stages. The idea of a trial deposition of fuel dummies in the Äspö Hard Rock Laboratory was not new to SKB. In R&D Programme 89, this is referred to as "Pilot Tests - Repository Systems" (p. 45). However, in its following programmes, SKB has not given the pilot tests a clear role as an important first stage in a series of three stages, where SKB's final disposal methods are tested and verified and the experience applied to design and planning before the next stage is started. The pilot tests are included in the Äspö programme presented in RD&D Programme 95, although on a modest scale - four canisters in all.

KASAM sees several reasons why SKB should expand the planned trial deposition of canisters. SKB needs to verify its methodology for the manufacturing and control of the engineered barriers - the canister, the buffer and the deposition methodology - to a greater extent than through four trial depositions. The integral performance of the water-saturated, compacted buffer, backfill plug and deposition hole during the initial heat transient must be studied and analyzed, for example in the near-field rock with different hydraulic conductivities. The heat transient lasts longer than a trial period. However, a trial period of a decade or so with continuous follow-up, should provide a good basis for extrapolation.

So far, SKB has only been able to describe the planned repository by using drawings and calculational data when SKB has informed communities involved in feasibility studies. It is understandable if such a presentation is viewed with a certain scepticism. SKB is planning to do something that no-one has ever done before. Experience has shown that new technology always has teething problems. A considerably more extensive trial deposition than that planned by SKB should contribute to the early detection of any deficiencies in methods and technology and should contribute to the increased confidence and insight of those outside the group of experts into SKB's final disposal work.

European Union

The EU is conducting a large research programme within the field of nuclear waste. The current framework programme covers a four-year period from 1995 to 1998. After that time, a new research programme is expected to be launched. As a member of the EU, Sweden contributes to the funding of this research.

Sweden's participation in the EU's research programme has, so far, been relatively limited. KASAM can understand, to a certain extent if SKB, now when the Swedish programme, which must be considered to be successful so far, is increasingly making the transition to a "project phase", wants to continue to limit its participation in the EU's research programme.

At the same time, the results from the EU's research programme will, inevitably affect the conditions for the Swedish programme, for example, by coming to conclusions concerning the importance of different uncertainties and issuing recommendations concerning important areas for research. Since the EU's programme is more oriented towards basic research than applied research, this should contribute to a greater degree of peer review by the scientific community. Furthermore, conditions should exist for ensuring that the resources which are available within EU can also contribute to resolving scientific issues which still exist in SKB's programme.

Swedish researchers are well aware that the EU's research programme is a possible source of funding. KASAM considers it to be important that SKB and the authorities should develop a strategy for the role that the EU's research should play in the Swedish programme and that they should actively participate in order to ensure that the structure of the next framework programme is of the greatest possible benefit for Sweden. It is also important that issues relating to democracy and public participation as well environmental impact assessments within nuclear waste, should be given adequate scope within EU´s reseach programmes in the future.

Appendix

Overall Description of the Safety-related Characteristics of the KBS Method

In the section "Insight and Transparency" in Chapter 2, KASAM proposed that SKB present its safety assessment in a more integrated fashion than it has so far. In this appendix, KASAM provides an example of a step-by-step description of the KBS system's barrier functions. The presentation is intended to be relatively easy for an interested layman to understand.

If a hole should occur in a canister so that the groundwater can penetrate into and cause the radionuclides to leach out of the fuel, a number of barriers will retain and retard the radionuclides on their way towards the biosphere. A clear way of describing these safety-related characteristics in a final disposal system would be to describe how the quantity or concentration of the radionuclides in the groundwater is affected by the barriers, step-by-step, from the fuel to the biosphere. An intrinsic value of such a step-by-step description of the radionuclide transport in the groundwater is that the function of the individual barriers and their contribution to safety is clearly shown and can provide a basis for decision-making concerning acceptance criteria and for prioritizing research concerning barrier properties. The values for the leakage of radionuclides from the engineered barriers, i.e. the fuel, canister and bentonite buffer, are of particular interest. The values show the extent to which these barriers can reduce the risk potential in the radioactive inventory of the spent nuclear fuel, and the function or functions which the rock should have in order for the system, as a whole, to provide the necessary level of safety.

If the safety analyses which have been carried out are reviewed, it can be seen that the functions of the different barriers can be described so that the canister isolates the fuel from the groundwater, the fuel material makes it difficult for the radionuclides to be dissolved in the groundwater, the bentonite buffer limits and retards radionuclide movement from the canister, after which the radionuclides in the groundwater are diluted as they are transported through the bedrock to the biosphere.

Criteria for Radioactive Releases from the Repository

In 1993, the Nordic nuclear radiation protection and safety authorities published a booklet called "Disposal of High Level Radioactive Waste; Consideration of Some Basic Criteria". This publication, although it only provides guidance for the authorities, proposes basic criteria for the final disposal of spent nuclear fuel.

The safety assessment must show that the radiation doses and radionuclide leakage to the biosphere are within the limits proposed in the regulations.

- The leakage of radionuclides to our living environment must be limited so that radiation doses to individuals do not exceed 0.1 mSv/year.
- The inflow of radionuclides to the biosphere, calculated as the mean value over a period of 10,000 years or more, must not exceed the range of 10 - 100 kBq/year for long lived alpha-emitters and 100 - 1,000 kBq/year for other long-lived radionuclides. The inflow must be calculated per tonne of natural uranium which is mined and processed to produce the spent nuclear fuel.

Calculations of radiation doses are carried out with the help of models for radionuclide transport through the biosphere to man. These models will be increasingly uncertain as they are used in dose predictions for an increasingly remote future. The inflow criterion was introduced as a complement to the radiation dose criterion, for time-scales beyond the next 10,000 years. The limits have been calculated on the basis of a comparison with the inflow to the biosphere of natural radioactive substances in our bedrock.

Calculation Process

KASAM has used data from SKB 91 to describe, in qualitative terms, the safety-related characteristics of the KBS method. This does not mean that KASAM has examined and approved the data and calculational models used in SKB 91. However, KASAM believes that they are sufficiently credible to be used in a qualitative description.

Tables 1 and 2 have been compiled and calculated with concentrations specified in Bq for various important radionuclides in the fuel taken from Tables 3-1 to 3-3 on page 25 of SKB 91. The tables have been converted to correspond to 2.1 tonnes of uranium in the fuel inside one canister. The free volume inside the canister has been calculated to 600 l. The solubilities expressed in mol/l converted into Bq/l, have been taken from Table 8-2 on page 110 in SKB 91. Pulse releases mean that all C-14, 10 % of the total inventory of I-129 and 5 % of the total inventory of Cs-135 is assumed to have leaked out of the uranium dioxide to the gap between the uranium dioxide and zircaloy cladding already when the fuel was in the reactor. The zircaloy cladding is assumed to leak so that these quantities are immediately dissolved in water when the water enters the canister. The quantities of Ra-226, Pa-231 and Np-237 will increase in the first 100,000 years or so after the fuel assemblies are removed from the reactors due to the fact that they are daughters of heavier nuclides in the fuel. These quantities are valid for the time 100,000 years after deposition in order not to underestimate their significance. The limit in Bq/l for drinking water has been calculated using the dose limit of 0.1 mSv/year and the dose factors for adults specified in the IAEA's International Basic Safety Standards for Protection against Ionizing Radiation (IAEA Safety Series No. 115). The consumption of drinking water by an individual has been estimated at 500 l/year.

Table 1. Source terms inside the canister

Nuclide	Half-life, years	Quantity in fuel Bq/canister	Concentration in water inside canister Bq/l	Limit for for drinking water Bq/l	Comments
C-14	5 730	$8x10^{10}$	120 000 000	340	Pulse release 100 %
Tc-99	214 000	$1.1x10^{12}$	1 200	310	
I-129	15 700 000	$2.7x10^{9}$	400 000	1.8	Pulse release 10 %
Cs-135	2 950 000	$3.8x10^{10}$	3 000 000	100	Pulse release 5 %
Ra-226	1 600	$8.4x10^{10}$	8 000 000	0.7	> 100 000 yrs
Pa-231	32 800	$1.6x10^{9}$	160 000	0.3	> 100 000 yrs
Np-237	2 140 000	$9x10^{10}$	12	1.8	> 100 000 yrs
Pu-239	24 100	$2.3x10^{13}$	8 000	0.8	
Pu-242	376 000	$1.7x10^{11}$	60	0.8	
Am-243	7 370	$1.9x10^{12}$	10 000	1.0	

As shown in Table 1, the actual fuel ceramic is already in itself an effective barrier against radionuclide leakage, due to the low solubility of uranium dioxide in oxygen-free groundwater. Several of the heavy, alpha-emitting nuclides and many of the long-lived fission products also have low solubilities. The result is that the quantity of these radionuclides in the water is much lower than in the fuel. On the other hand, a large share of the highly soluble nuclides are rapidly released to the water.

The bentonite contains groundwater in the pores between the clay particles but the water does not seep through the clay. Radionuclides, like all molecules, are mobile even in stagnant water due to their thermal mobility. However, the passages through the clay are narrow and many nuclides will become stuck to or sorb onto, the clay particles. This limits and retards the transport of radionuclides through the bentonite buffer.

The maximum values for leakage in Bq/year through the bentonite buffer have been taken from Table 8-4 on page 113 in SKB 91. The values are based on the assumption that there is a hole in the canister with an area of 5 mm^2. These values have been re-stated to take into account the fact that the canister, of the new design, has a much larger free volume for the penetrating water than the canister design upon which SKB 91 was based. This considerably lowers the concentration in the water inside the canister of the highly soluble nuclides C-14, I-129 and Cs-135 which are released in pulse releases. This affects the leakage through the bentonite since the diffusion through the buffer is proportional to the concentration in the water inside the canister. The leakage of the low-soluble nuclides is not affected by the water volume. The values for Ra 226 and Pa 231 have been taken from Figure 8-4 in SKB 91. The leakages for these two nuclides is calculated using a completely different and less accurate calculational model than the other values, but they have been included, in any case, since these nuclides are among the few that entail any significant risk.

Table 2. Outflows to the near field

Nuclide	Quantity in the water inside the canister Bq/canister	Maximum value of outflow from buffer during a year, Bq/canister	Time when the maximum value is reached, years	Limit for drinking water Bq/l	Dilution required for use as drinking water m^3/year
C-14	$8x10^{10}$	$1x10^{7}$	1400	340	30
Tc-99	800 000	<1	>500 000	310	<0.001
I-129	$2.7x10^{8}$	650	17 000	1.3	0.5
Cs-135	$1.9x10^{9}$	$2.1x10^{6}$	80	100	21
Ra-226	$5x10^{8}$	30 000	30 000	0.7	43
Pa-231	$7x10^{7}$	1 000	20 000	0.3	3.5
Np-237	8 000	0.06	>500 000	1.8	<0.001
Pu-239	5 000 000	0.001	>500 000	0.8	<0.001
Pu-242	40 000	0.06	>500 000	0.8	<0.001
Am-243	7 000 000	3	106 000	1.0	0.003

The radionuclides which leak out through the bentonite buffer will be diluted in the groundwater. With a certain dilution, the concentration of radionuclides will be so low that the groundwater can be used as drinking water without exceeding the dose limit of 0.1 mSv/year. The last column provides the calculated values of this dilution, expressed as the lowest volume of groundwater turnover required per year in an aquifer which is drained by a drinking water well. Any retardation of radionuclides on their way through the bedrock is not taken into consideration.

The limits concern the individual nuclides. If several nuclides occur at the same time in the water, the limit values must be adjusted so that the sum of the dose contributions does not exceed the established dose limit. The outflow of different nuclides from the buffer is distributed in time so that that weakly sorbing nuclides, C-14, I-129 and Cs-135, reach their maximum release rate within a relatively short time after a canister is damaged. Large quantities of C-14 can only be released if a canister is damaged within the first fifty thousand years since C-14 has a relatively short half-life. The high values for

Ra-226 and Pa-231 cannot be reached until thousands of years after deposition since these nuclides develop slowly in the fuel from decaying uranium-234 and uranium-235. These two nuclides also occur naturally in the bedrock.

According to SKB's calculations, it is only C-14 and Cs-135 which have annual leakages through the buffer in quantities which are within the permissible range for inflow to the biosphere. As far as other radionuclides are concerned, the near field already provides a limit on the outflow which adequately satisfies the requirement that the repository may only result in an insignificant contribution to the inflow of natural radioactive substances to the biosphere which occurs as a result of the weathering of outcropping bedrock.

The work on SKB 91 was carried out to investigate how different models for the prediction of the groundwater flow through the far field affected the level of safety. In spite of this aim, it is not possible to establish, on the basis of the data presented in the report, the extent of the outflow of radionuclides to the biosphere in any of the different calculational cases presented. On the other hand, a detailed account of the release of radionuclides from the bentonite is presented. Thus, information on how effective the far field is as a barrier to radionuclide transport cannot be extracted from SKB 91. In order to provide this information, data which SKI has provided in the report SKI Projekt 90 (Table 4.9.2, Table 6.2.1, column "Output to Far Field" and Fig. 6.4.1-4) have been used. A selection of these data is provided in Table 3.

Table 3. Reduction factors in the bedrock/far field

Nuclide	Half-life, years	Intake in Bq/year of nuclides which result in 0.1 mSv/year	Maximum value of releases to far field Bq/year	Maximum value of discharge to biosphere Bq/year	Reduction factors in the far field
Se-79	65 000	35 000	3 500	3 200	1.1
Tc-99	214 000	150 000	70	50	1.4
I-129	15 700 000	900	36 000	30 000	1.2
Cs-135	2 950 000	50 000	6 000	4 500	1.3
Pa-231	32 800	140	37	12	3
Np-237	2 140 000	900	0.6	0.06	10
Pu-239	24 100	400	5.3	0.075	70
Pu-240	6 570	400	0.2	3.5×10^{-5}	6000
Pu-242	376 000	400	2	0.1	20
Am-243	7 370	500	3.5	8×10^{-4}	4000

Some Conclusions

In its calculations of a reference scenario with canister damage, both SKB and SKI obtain very low values, for radionuclide releases, even deep in the bedrock. It is only C-14, I-129, Cs-135, Ra-226 and Pa-231 which, in any of the calculations, are released from the near field in greater quantities than the permissible annual intake for an individual. The release values are strongly dependent on assumptions concerning the size and area of the holes in the canister and the area on the outside of the bentonite which is in contact with water-bearing fractures.

The calculations have been carried out for a canister which has been damaged, allowing water to enter and reach the fuel. If several canisters are damaged at the same time the outflow to the far field will be correspondingly greater. The radiation doses will also be correspondingly large if the damaged canisters are placed close to each other in the repository and if they are damaged at around the same time. In other cases, the released radionuclides can take different routes to the biosphere and the largest outflows will be obtained at different times. In such cases, the radiation doses will not increase in proportion to the number of damaged canisters.

According to SKI's calculations, the contribution of the far field to the isolation of radionuclides from the biosphere is more or less negligible with regard to long-lived weakly sorbing radionuclides (Se-79, Tc-99, I-129 and Cs-135). The contribution is insignificant for strongly sorbing, long-lived radionuclides such as Np-237, Pu-239 and Pu-242. Pa-231 is special in the sense that it is newly formed in the rock as a daughter of leached U-235. Only strongly sorbing relatively short-lived nuclides such as Pu-240 and Am-243 are considerably reduced in the far field. However, these nuclides are retained so adequately by the engineered barriers that no additional barriers are needed.

The relatively insignificant difference for weakly sorbing, long-lived radionuclides between the outflow per year from the buffer and the total inflow to the biosphere per year is related to the performance of the buffer and the rock. In SKI's calculations, the outflow of Se-79, Tc-99, I-129 and Cs-135 from the near field only shows a very slow variation. If a substance, which reaches the groundwater at a constant rate, is transported by the groundwater and does not stick on the rock and does not have time to decay during the transport time, it will reach the biosphere at the same rate as it was originally supplied to the groundwater. The difference is that it will reach the biosphere at a later time and that it will be distributed over a much greater volume of water.

This type of calculation, which is carried out for a safety assessment, is carried out using data and models where the risks must not be underestimated, in order to be on the safe side. In reality, the contribution of the rock to safety, may be greater than the estimated contribution. However, in practice, it is impossible to carry out all of the measurements which would be required to demonstrate this.

If the barrier properties of the buffer are degraded, the far field will have a relatively greater importance for safety. However, its inherent capacity to isolate the radionuclides from the biosphere will not be affected. Thus, it is of decisive importance for the safety of the repository that the buffer's barrier properties, which are initially good, should be maintained to the same extent and for as long as possible. This places demands on the environment closest to the buffer; that the block of rock where the deposition hole has been drilled, must be solid.

As long as the buffer performs as intended, the most important contribution by the far field to safety will be to dilute the concentrations of radionuclides in the groundwater after leakage from the bentonite. Only in scenarios which are based on or lead to a simultaneous deterioration in the barrier properties of the canister and bentonite can the bedrock have any importance with regard to reducing the inflow of radionuclides to the biosphere. Thus, it is important to perform, as soon as possible, an integrated scenario analysis and describe the nature and probability of scenarios that involve different types of impacts on the integral performance of the engineered barriers.

KASAM

KASAM, the Swedish National Council for Nuclear Waste, was established in 1985 and is now an independent committee attached to the Ministry of the Environment. KASAM's task is to investigate issues relating to nuclear waste and the decommissioning of nuclear installations and to provide the Government and certain regulatory authorities with advice on these issues. The Government has authorized the Minister of the Environment to appoint the Chairman and up to ten other members.

KASAM's members are independent experts within various areas of importance for the final disposal of radioactive waste, not only in natural science and technology but also in areas such as ethics, law and social sciences.

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KASAM

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KASAM's members – who largely comprise professors from Swedish and Nordic universities and institutes of technology – represent independent expertise within different areas of importance for the final disposal of radioactive waste, not only in natural science and technology but also in areas such as ethics, law and social sciences.

KASAM is also responsible for presenting a special independent evaluation of the state of knowledge within the nuclear waste area every three years.

An important part of KASAM's activities is to provide a forum for alternative views and for experts in Sweden and abroad to discuss nuclear waste issues. Consequently, a number of seminars on various themes have been held.

KASAM is also responsible for evaluating the programme for research and development – concerning the final disposal of spent nuclear fuel – which the Swedish nuclear power utilities present every three years. This publication is KASAM´s review report to the Government of SKB`s RD&D Programme 95, Treatment and Final Disposal of Nuclear Waste.

This report is available in Swedish and in English.

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