Comments on plans for the final disposal of spent nuclear fuel

Translation of consultation documents submitted in 2009-2010 and comments on the R&D programme “Fud-10” by the Swedish Society for Nature Conservation (SSNC) and the Swedish NGO Office for Nuclear Waste Review MKG.

Draft report February, 2012

Part II

Preface

This document is Part Two of the final draft of a report to be published with translations into English of five documents produced between 2009 and 2011 by the Swedish Society of Nature Conservation, SSNC, and the Swedish NGO Office For Nuclear Waste Review. The documents present the view of the organisations on the Swedish programme for management and final disposal of spent nuclear fuel.

Part Two contains two documents:

- Risks regarding the man-made barrier system

- Fud-10

Previously translated documents presented in Part One:

- The selection of a site

- The draft Environmental Impact Statement

- The long-term safety report

For more information about the work of the organizations contact:

Dr. Johan Swahn
Director

The Swedish NGO Office for Nuclear Waste Review
Box 7005
SE-412 31 Göteborg, Sweden

E-mail: johan.swahn@mkg.se

Mobile: +46 70 467 37 31

Skype: jswahn

Table of Contents

PART I

Previously translated:

THE SELECTION OF A SITE
Joint comment on the part of the Swedish Society for Nature Conservation (SSNC) and MKG regarding the siting process for a final repository for spent nuclear fuel

THE DRAFT ENVIRONMENTAL IMPACT STATEMENT Joint comment on the part of the Swedish Society for Nature Conservation (SSNC) on the draft Environmental Impact Statement (EIS) for a system for the final disposal of spent nuclear fuel

THE LONG-TERM SAFETY REPORT
Joint comment on the part of the Swedish Society for Nature Conservation (SSNC) and MKG concerning the long-term safety of a system for the final disposal of spent nuclear fuel.

RISKS REGARDING THE MAN-MADE BARRIER SYSTEM

Joint comment on the part of the Swedish Society for Nature Conservation (SSNC) and MKG regarding the man-made barrier system of copper canisters and clay buffer in the KBS method for final disposal of spent nuclear fuel, and a demand for full disclosure of research reports.

Naturskyddsföreningen
Box 4625, 116 91 Stockholm
Tel.08-702 65 00
www.naturskyddsforeningen.se
info@naturskyddsforeningen.se

Miljöorganisationernas kärnavfallsgranskning
Box 7005, 402 31 Göteborg
Tel. 031-711 00 92
www.mkg.se
info@mkg.se

Dec 15th, 2010

Till: Svensk Kärnbränslehantering AB, SKB
(The Swedish Nuclear Fuel and Waste Management Company)
106 58 Stockholm

Comment from SSNC and MKG concerning the risk that the man-made barriers consisting of copper canisters and clay buffer in the KBS method for final storage of spent nuclear fuel will fail, and a demand that pertinent research findings be made public

This submission on the part of SSNC and MKG raises important issues in the EIA consultations concerning a final repository for spent nuclear fuel. The issues relate to the phenomenon of copper corrosion and the risk that corrosion of the copper canister may influence the long-term safety of a final repository of the KBS type. The comment also treats the risk that the performance of the bentonite clay buffer that is intended to provide long-term protection for the copper canister against corrosive groundwater may be impaired even during an early phase, before the clay has reached saturation. Another topic is the risk that the clay barrier may erode and be rinsed away. Finally, we demand that all research reports and documentation from research project meetings, even those the company may consider confidential, shall be made public.

Early problems with copper corrosion and the effects on clay

The long-term safety of the KBS method depends on the function of man-made barriers (copper canisters and a bentonite clay buffer), which shall isolate the highly radioactive nuclear waste from human beings and the environment for hundreds of thousands of years. Thus, the issues raised in the following paper are of decisive importance to the long-term safety of the planned final repository.

We, SSNC and MKG, have been given to understand that there is considerable uncertainty concerning the corrosion that can affect the copper canister that encloses the used fuel rods. Research findings in recent years give reason to fear that the copper canisters, given deposition in the bedrock at Forsmark, may become seriously compromised within the time frame of only a few centuries. Even if the corrosion process should take longer, copper from the canisters may impair the clay buffer to such an extent that it will not have the long-term protective function the method presumes. That a problem of such acuity should arise so early in the lifetime of the repository is a consequence of the heat of the canisters in the first few thousand years in combination with the long time required – up to a thousand years in the case of the relatively dry bedrock at Forsmark – for the clay buffer to swell and reach the so-called initial condition that is presumed in the analysis of long-term safety.

SSNC and MKG are of the opinion that the nuclear waste management company, SKB, must in the EIA consultations on long-term environmental safety demonstrate that the man-made barriers of copper and clay will not be damaged or destroyed in the first several hundreds or thousands of years. These issues are treated in further detail in section 2.

Problems of clay erosion in the long term
In recent years doubts have arisen as to whether the bentonite clay envisaged to protect the copper canister against corrosive groundwater will function in coming periods of advancing and receding glaciation, as is presumed in the safety analysis. A final repository system shall, according to the criteria set out in the long-term safety analysis withstand repeated glaciation cycles. The hydrological conditions that obtain in the course of glaciation may hasten the erosion of the buffer in relation to the rate previously assumed.

SSNC and MKG are of the opinion that the nuclear waste management company, SKB, must, in the EIA consultations on long-term environmental safety, demonstrate that there is no risk of early erosion of the clay buffer in the course of repeated glaciation cycles. These issues are treated in further detail in section 3.

Research reports and minutes from research meetings shall be made public
For a number of years now, MKG has examined the nuclear waste management company SKB's research relating to copper corrosion. The organization has had considerable difficulty in gaining access to the findings of that research, including the outcomes of experimentation carried out at the bedrock laboratory at Äspö, near the Oskarshamn nuclear power station. The correspondence surrounding our attempts to gain access to relevant research material is enclosed.[1]

---

1. The correspondence is not translated. For more information please contact the office. See preface for contact information.

In Spring 2010, SKB initiated studies of copper corrosion in pure, anoxic water. The company formed a reference group around these experiments, in which MKG took part. In the venue of the group MKG promptly expressed the need for similar access to other copper corrosion research that the company has undertaken or that is still in progress. In addition, MKG and other participants in the reference group pointed out that SKB should conduct research on several other aspects of copper corrosion and should retrieve more experimental packages in the Äspö hard rock laboratory in order to gain a better understanding of different corrosion phenomena. SKB responded evasively, for which reason MKG wrote a letter to SKB outlining the issues in question.

The Swedish Radiation Safety Authority (SSM), too, has taken an interest in the research on copper corrosion conducted at the Äspö laboratory, and in Spring 2010 SSM undertook a review of SKB's quality assurance of their work on this subject. The review resulted in a report (SSM 2010) that was harshly critical of the manner in which the company reported the findings of experiments on both copper corrosion and effects on the clay buffer. What is more, SKB was found to have suppressed some research findings, omitting them from an openly published report of the results from the project. Although SKB had previously refused to do so, MKG was able in Autumn 2010 to persuade the company to make public the two consultant's reports in question. MKG then wrote to the company, admonishing them to adhere better to established scientific praxis and make available all the results of experiments and other research having a bearing on the barrier system for public scrutiny. SKB responded, explaining that a series of reports from the research conducted in the Äspö laboratory (the IPR series: International Progress Reports) will be made public, but that other documents are to be considered working documents, internal to the company.

We, SSNC and MKG, do not consider this sufficient. Both our organizations have members with long experience of research and scientific work. SKB's refusal to publish research findings conflicts with established scientific ethics and arouses considerable surprise among the seasoned researchers in our ranks.

MKG has already had access to several reports in the IPR series and therefore knows that far from all research that has been conducted at Äspö is reported in the series. Virtually none of the most interesting experiments aiming to cast light on the phenomenon of copper corrosion and impacts on the clay buffer have been reported in the series. If the Radiation Safety Authority or, for that matter, any other body is to be able to examine the company's research in a scientific manner, all consultant's reports and other material that the company considers confidential must be available for examination in the context of the EIA consultation process. Minutes and other documentation from the project meetings where the research was discussed should also be made public.

Without access to these primary data the documentation presented for consultation can hardly be deemed complete or adequate.

SSNC and MKG demand that SKB, the party responsible for the spent nuclear fuel repository project, makes all the consultant's reports, other research documentation and documentation of research project meetings that relate to the experiments and the research at the Äspö laboratory on the phenomenon of copper corrosion and impacts on the clay buffer, as well as other findings relating to the barrier systems, available to the participants in the EIA consultation process. This issue is discussed in greater detail in section 4 below, where we also offer a partial list of the experimental projects for which we wish to have access to the consultant's reports as well as documentation of project meetings where the experiments have been discussed.

1. Background

On March 16th 2011, the nuclear waste management company, Svensk Kärnbränslehantering AB, SKB, intends to submit its application for permission to construct a final repository for spent nuclear fuel immediately south of the Forsmark nuclear power station in the Municipality of Östhammar (Uppland). The Swedish NGO Office for Nuclear Waste Review, MKG, has participated in the EIA consultations prescribed in the Environmental Code since the organization was founded in 2004. The Swedish Society for Nature Conservation, SSNC, together with SSNC chapters in Kalmar and Uppsala counties, Nature and Youth Sweden, and Oss (a local opinion organization in Östhammar), founded and together constitute MKG. SSNC has participated in the consultations as a member of MKG and, in later stages of the consultation process?, SSNC and MKG have submitted joint comments to the applicant and coordinator of the consultations, the nuclear waste management company, SKB.[2]

SKB has announced that they consider the EIA consultations will end once comments after the extra consultation meeting on the analysis of long-term safety held May 3rd 2010 in Östhammar have been received. SSNC and MKG disagree, contending that the consultations must continue until

2. Joint comment on siting, submitted 5 May 2009; comment on the preliminary EIS document, submitted 10 March 2010; and comment on the analysis of long-term safety, submitted 17 May 2010.

a complete set of pertinent primary data until a complete and adequate documentation in the consultation process has been presented. The documentation presented to date on the long-term environmental safety of the project, alternative sitings, or alternative solutions for the final repository facility is neither complete nor adequate. In the view of the organizations in MKG, the EIA consultations must continue at least until a preliminary version or versions of the long-term safety analysis, SR-Site, and preliminary versions of the separate documents on choice of site and choice of method, respectively, which SKB plans to submit as annexes to the application, have been presented for consultation. SKB has rejected this view, most recently in an exchange of e-letters in the latter part of June 2010.

This document treats issues relating to the long-term environmental safety of the KBS method, the most important issue and the prime focus of the coming assessment of the company's application.

2. The risk that copper canisters will corrode and destroy the clay buffer early in the post-closure phase

In early 2009 SKB announced its choice of the site for the final nuclear waste repository. The choice fell on a site adjacent to the Forsmark nuclear power plant in the Municipality of Östhammar rather than the other candidate site, Laxemar, near the Oskarshamn nuclear plant in Oskarshamn. SKB states that the choice was the outcome of weighing together factors having a bearing on safety.

In the discussion following the announcement it has been noted that in Forsmark the bedrock at the level of the repository has fewer cracks and fissures than the bedrock in Laxemar. This factor has been pointed out as decisive for the choice of Forsmark.[3] Few cracks and fissures may be an advantage in that it implies slower transport of radioactive nuclides from the repository to the surface, should the repository spring a leak. But, denser bedrock with its lesser flow of groundwater implies a much longer time frame for the successive saturation of bentonite in the deposition hole, which is of crucial importance to the long-term function of the man-made barriers posited in the analysis of long-term safety.
There are large differences in the water flow rates at Laxemar and Forsmark.

---

3. In an earlier comment submitted to SKB (5 May 2009) SSNC and MKG maintain that the nuclear waste management company needs to specify the basis for their choice of Forsmark in detail and explain what the company means by the phrase, "weighing together environmental aspects". SKB also needs to share the safety calculations that have been done for both Forsmark and Laxemar in a manner that permits comparison of the safety assessments for the respective candidate sites. See http://www.mkg.se/mkg-laxemar-samradsinlaga-till-industrin- om platsvalet).

- The corrosion conditions of the copper canister e.g. prevailing corrosion mechanisms and the corrosion rate related to each mechanism. It is likely that the copper canister corrode in Forsmark (but not in Laxemar) through e.g. atmospheric corrosion, evaporation induced corrosion and grain-boundary corrosion.

- Precipitation of salt present in the ground water in the bentonite and on the surface of the copper canister.

- Erosion of the bentonite surrounding the canisters, which results in cracks and channels in the bentonite.

The extensive formation of cracks in the rock at Laxemar gives high flow of groundwater, which results in filling of the boreholes with water within a limited time frame. The bentonite surrounding the copper canisters will then be saturated with water and swells.

The water flow is, according to SKB, very limited in Forsmark “An additional analysis of inflow into individual deposition holes/Svensson 2006b/ using the same model as described above indicates that 99.9% of all deposition holes in the Forsmark repository will have an inflow smaller than 0.01 l/min when no grouting is applied” see SR-CAN 2006 (page 212).

2.1 Flow of water to the boreholes

The rate of water flow to the boreholes is a critical parameter regarding several important issues;

- The corrosion conditions of the copper canister e.g. prevailing corrosion mechanisms and the corrosion rate related to each mechanism. It is likely that the copper canister corrode in Forsmark (but not in Laxemar) through e.g. atmospheric corrosion, evaporation induced corrosion and grain-boundary corrosion.

- Precipitation of salt present in the ground water in the bentonite and on the surface of the copper canister

- Erosion of the bentonite surrounding the canisters, which results in cracks and channels in the bentonite.

These issues are highly important in the safety analysis regarding the Forsmark case. It is clearly impossible to theoretically calculate the corrosion rate of the copper canisters if the prevailing corrosion mechanisms are largely unknown. It is therefore of utmost importance that SKB reports the expect water flow in dm3/minute to the deposition holes and how this flow rate is estimated to vary with time. It is also important that more knowledge is found about how the water flow will vary between different deposition holes. Due consideration must further be given to the following both at the theoretical analysis and at the actual experiments;

- The formation of cracks in the bedrock at blasting of the tunnels in the depository.

- The water flow from one or several cracks in the bed rock in the vicinity of the deposition hole and also for the case that there is no cracks.

- The filling of the deposition hole with water; does the water come from the bottom or vertical sides of the bedrock surrounding the deposition hole or from the tunnel above the deposition holes.

It is essential that SKB determines the water flow conditions to the deposition holes containing bentonite and copper canisters and then based on this information makes an accurate analysis how the incoming water reacts with bentonite and the warm copper canister.

It is quite possible that part of the incoming water to the deposition holes is evaporated when in contact with the bentonite and the warm (90 °C) copper canister. This must result in precipitation of salts dissolved in the ground water on the surface of the copper canister, in the bentonite and potentially also on the surface of the bedrocks in the deposition holes. It is essential that more knowledge be gathered regarding the amount of salt that is precipitated, where the salt is deposited in the deposition holes and the chemical composition of the deposited salts. It is further very important to clarify if the evaporation of incoming ground water in the deposition holes results in the formation of a corrosive water solution with very high contents of dissolved salts.

2.2. Temperature conditions in the boreholes

The flow of ground water to the deposition holes will vary substantially between different holes and probably also with time. The inflow of water has according to the KBS-3 concept some important functions;

- Saturate the bentonite in such a way that it swells and stabilise the canister.

- Facilitate heat transfer from the canister to the bedrock.

The ground water flow in the planned repository in Forsmark is probably very limited or even non-existent in some bore holes and this will result in substantially different temperature conditions in the bore holes compared with the normal case in Laxemar, which has a strong water flow. This has a direct effect on the water saturation of the bentonite in the boreholes, which potentially will be dry for many years in Forsmark due to the limited ground water flow rate.

It is evident from the Fud-programme 2010, table 23-2, pp. 268, that SKB does not consider that there is need for a research programme regarding the heat transfer in the deposition holes under the conditions prevailing in Forsmark. This is according to our opinion totally incorrect. Such a programme is according to our opinion of utmost importance and fundamental for the safety analysis.

SKB must elucidate how the limited ground water flow into the deposition holes influences the heat transfer from the cast iron insert with the spent nuclear fuel, through the copper canister and the bentonite layer to the rock bed. Critical issues in this respect are the heat transfer itself and the formation of temperature gradients. It is also important to clarify if air slots are formed between the copper canister and the bentonite as well as between the bentonite and the bedrock. More knowledge must further be collected regarding the evaporation of the ground water; more information is needed on the process itself, amount of water evaporated depending on the temperature conditions in the bore holes and does the evaporation process result in cracks and channels in the bentonite barrier.

2.3 Bentonite

The repository conditions are quite different in Forsmark compared with those at Laxemar. The limited ground water flow at Forsmark results in a very slow water saturation of the bentonite. It is likely that the becomes dry under very long time, in the order of at least some tenth of years and perhaps even up to 1000 years for some canisters. The extent of this dry period is dependent on the formation of cracks in the surrounding rock bed and the ground water flow through these cracks. There is thus no initial water saturation of the bentonite, which earlier has been regarded as decisive to enable the bentonite to act as a barrier.

The initial water content of the bentonite is 17% according to SR-CAN pp. 273. The effect of the simultaneous limited water flow and the heating of the bentonite from the canisters results in evaporation of the water in the bentonite and drying of the same.

SKB must therefore experimentally investigate how the physical and chemical properties of the bentonite are influenced by;

- Long time exposure to elevated temperature in the deposition holes
- Precipitation of salts from the ground water
- Precipitation of copper corrosion products
- Evaporation of water originally bounded to the bentonite

It is likely that the thermical and chemical exposure of the bentonite may alter its properties and hereby its function as a barrier for e.g. copper corrosion. Important issues are;

- Is there a formation of cracks or channels in the bentonite due to the evaporation of its original water?
- Is the water saturation of the bentonite influenced by precipitation of salts and corrosion products?
- Is there an embrittlement of the bentonite as a result of heating under a long time and in combination with precipitated high contents of copper compounds and salts?

2.4 Corrosion of the copper canister

There are a large number of issues related to the copper canister that is meant to protect the spent fuel in the repository. They concern the attempts that have, or have not, been performed to investigate how the copper behaves in a repository environment. They also concern the various corrosion processes that may take place in a repository.

2.4.1 Investigation of the LOT-, MiniCAN- and Retrieval-canisters

SKB has carried out several test series during the last 10 years at the Äspö-laboratory, where copper corrosion has been studied using canisters and sheets as test samples. The intention was to simulate the conditions prevailing at the final repository. This was done within the projects LOT, MiniCAN and Retrieval, which thus are important in the assessment of;

- The rate of the copper corrosion and hereby the life of the copper canisters in the future repository
- Prevailing corrosion mechanisms based on the chemical composition of the corrosion products on the copper surface

- Possible formation of uneven corrosion such as pitting

- Embrittlement of the copper due to dissolvement of hydrogen or sulphur

- Dissolution of copper in the water followed by precipitation of copper containing corrosion products in the bentonite layer

It is notable that SKB has consistently chosen not to examine, or just examine to a limited extent, the corrosion products obtained on the copper surface and in the bentonite, the occurrence of pitting corrosion, mechanical properties of copper or copper metallographic microstructure. Or rather, public declaration of such studies, eg the uptake of the test experimental package A2 of the LOT project where results of such studies are lacking (SKB 2009a).

It is particularly interesting that SKB has so far not reported the corrosion tests in the so called Retrieval-tests. These implied testing of a full-scale copper canister, heated internally, and placed in water-saturated bentonite. These tests took place during five years and the copper canister with surrounding bentonite was taken for evaluation in May 2006, see SKB report TR-07-10. It can be read in SKB TR-09-10, Äspö Hard Rock Laboratory, Annual Report 2008 on pp. 5 that the canister and the surrounding bentonite buffer were analyzed during the year 2008 and that the analysis were nearly finalized. Why has this report not been published?

It is now essential that SKB complete earlier reports with information and data on the corrosion rate of copper, corrosion mechanisms, chemical composition of the corrosion products, presence of pitting and grain boundary corrosion, the mechanical properties and microstructure and finally the presence of copper and copper compounds in the bentonite.

2.4.2 Corrosion of copper in oxygen-free water

Researchers at the Royal Institute of Technology in Stockholm have during the 1980’s as well as in recent years presented experimental support for the thesis that copper corrodes in anoxic water (Hultquist 1986, Szakàlos et al. 2007, Hultquist et al. 2008, Hultquist et al. 2009, Hultquist et al. 2011). The publication of these research findings have led to an intense debate about the possibility of corrosion of copper can take place in oxygen-free water, i.e. under anoxic/anaerobic conditions. Futher experiments are underway to examine if and how copper can corrode in oxygen-free distilled water.

This issue is of relevance also for the conditions in the final repository as SKB claims that copper cannot corrode in oxygen free water, with the exception sulphide corrosion. SKB stated further about 10 years ago that the transition was fast from oxygen containing (aerobic) water (with copper corrosion) to oxygen free (anaerobic) water (without copper corrosion) and would take only a few weeks in the final repository (SKB 2001a). The reason for this transition is according to SKB primarily the micro bacterial activity in the ground water and in the bentonite as well as chemical reactions taking place in the bentonite. Experiments performed at a later stage in Finland have confirmed the received results (Posiva 2006, Carlsson T. & Muurinen A. 2009). In addition, rapid oxygen consumption proved to take place in the MiniCan project at the Äspö Hard Rock Laboratory (SKB 2009c).

SKB has during the last years experimentally found in the LOT- and MiniCAN-project that copper corroded with a rate of 3-20 μm/year. This rate is 10 000 to 100 000 times larger than what SKB theoretically has found based on the assumption that the rate determining step is sulphide-corrosion.

SKB now claims that the LOT and MiniCan projects by mistake were conducted under aerobic conditions and thus in water containing dissolved oxygen. In the MiniCan projects however, results from electrode potential measurements are presented as well as oxygen concentration measurements, both showing that the conditions were anoxic – the water was oxygen-free (SKB 2009c).

Thus SKB admits themselves that they have failed to accomplish that two complete and important test series (LOT and MiniCAN) and possibly also the Retrieval-tests were run under conditions that presented air leakage during the 5 years testing period at the Äspö-laboratory. At the same time SKB states that the final repository in Forsmark will be sealed with bentonite and concrete in such a way that there will be no air leakage to the copper canisters for at least 100 000 years.

2.4.3 The conditions in Forsmark

The copper canisters in Forsmark will be exposed to an environment, which from a corrosion point of view is very different from the one in Laxemar and at the Äspö-laboratory. The copper canisters in Forsmark repository will due to the limited water flow be exposed to several corrosion mechanisms that would be of no or less importance for the case that the repository was placed in Laxemar.

It is estimated by SKB that the inflow of ground water in the Forsmark repository is less than 0.01 l/min and deposition hole. This volume can be estimated to be insufficient to saturate the bentonite and fill the deposition holes with water. A more realistic scenario is the incoming water will be evaporated under very long time and probably will the deposition holes, according to SKB’s calculations be “dry” for a period up to about 1 000 years.

The evaporation of water must inevitably lead to precipitation of salts dissolved in the ground water on the surfaces of the copper canisters, in the bentonite and perhaps also on the surfaces of the bed rock. When the water phase is finally formed in the deposition holes it must contain increased contents of dissolved salts and e.g. chloride and sulphide ions.

Rebak (2006) has commented on this situation for the case that a water phase is formed;

> *”The groundwater associated with the crystalline-rock formations should all be relatively benign to most materials because of their low ionic strengths, near neutral pH, and low concentrations of halide ions (6). The corrosivity of these waters could increase if significant groundwater vaporization occurs when high container temperatures exist during the early times following emplacement.”*

The conclusion from the above discussion must be that the experimental results obtained at the Äspö-laboratory, where the water flow is large, cannot be transferred to the Forsmark repository. The same applies also for the safety analysis, which at the present situation has been carried out without any experimental data or information regarding the corrosion rates and the corrosion mechanisms prevailing at Forsmark.

The copper canisters will be exposed in dry deposition holes to two corrosion mechanisms that do not exist under wet conditions e.g. those prevailing at the Äspö-laboratory. These mechanisms are;

- Atmospheric corrosion from remaining oxygen and water vapour in the deposition holes

- Evaporation induced corrosion from the salt layers precipitated on the copper surfaces and in the bentonite

There will be a further corrosion mechanism for the case that the water phase only reaches a certain height from the bottom of the deposition hole, but does not cover all the copper surfaces;

- Boundary layer corrosion at the three-phase boundary water-air-copper

There is thus a large necessity to acquire more knowledge and experimental results within the field corrosion of copper on the following seven issues.

2.4.4 Need for knowledge and experimental results in the field corrosion of copper

1. *Atmospheric corrosion*

SKB estimates in TR-01-23 that copper corrodes with a rate of 0.1 – 0.3 mm/year by atmospheric corrosion under the conditions that are initially in the repository and before the oxygen in the deposition holes is consumed. TR-01-23 (pp. 45) shows also a mass balance based on the assumption that the sealing of the deposition holes completely prevents air leakage to the deposition holes during the forthcoming 100 000 years. SKB must verify experimentally that air leakage can completely be avoided. It is appropriate to mention in this context that SKB according to their own assessment has failed to prevent air leakage of air at the LOT and MiniCan experiments during the 5 years these took place at the Äspö-laboratory.

2. *Evaporation induced corrosion*

SKB states in the report TR-09-22 (Design premises for a KBS-3V repository based on results from the safety assessment SR-Can and some subsequent analyses) on page 19 ”Corrosion of copper. Salt deposition is neglected if temperature on the canister is in the order of 100 °C.”. It is of crucial importance that SKB experimentally verify that evaporation induced corrosion can be neglected at the Forsmark repository.

3. *Corrosion caused by radiolysis*

Lillard et al and Butt et al from Los Alamos Laboratory in the USA have experimentally found very high corrosion rates in the order of 0.3-0.5 mm/year when copper is exposed to irradiated water at room temperature (radiolysis).

SKB states however in the report TR-09-22 (Design premises for a KBS-3V repository based on results from the safety assessment SR-Can and some subsequent analysis) and in the Fud-program 2010 that irradiation has no effect on the copper corrosion rate.

It is essential that SKB experimentally verifies that the radiation at the Forsmark depository does not have an influence on the corrosion rate of copper.

4. *Sulphide corrosion*

Arilahti et al from VTT, Finland (2010) emphasize on page 1 the following statement in their report;

> *”In scenarios where the density of bentonite locally decreases (e.g. piping, erosion-corrosion) the access of sulphide to the copper surface will be much easier.”*

SKB has developed the KBS-3 concept based on the assumption that the dominating corrosion mechanisms of the copper canisters is sulphide corrosion and that the rate determining step related to this mechanism is diffusion of sulphide ions through the water saturated bentonite layer.

It will take very long time before the bentonite is saturated with water for the case that the canisters are deposited in the Forsmark repository. There is an obvious risk that the bentonite will crack or water channels are developed during the water saturation period. These cracks and channels will facilitate the mass transport of e.g. sulphide ions to the copper surfaces that will substantially increase the corrosion rate caused by sulphides. The amount of sulphides in the bentonite will further be increased due to water evaporation.

SKB ought to evaluate how the sulphide corrosion rate is influenced by these changes of the conditions.

5. *Stress corrosion*

Taniguchi et al have found in 2008 that pure copper is sensitive to stress corrosion in anaerobic, synthetic seawater containing sulphide ions from sodium sulphide. The authors estimate that the threshold value at 80 °C for initiation of stress corrosion is in the range 0.005 – 0.01M sodium sulphide. Pure copper will thus according to Taniguchi et al be susceptible to stress corrosion if the content of sodium sulphide is higher than this threshold value.

SKB has now initiated experiments in order to verify these results. It is essential that SKB also investigates if there is a risk for stress corrosion of the copper canisters deposited at the Forsmark repository. The experiments must then be carried out in water solutions in which the content of dissolved salts is equivalent to the solutions that will surround the canisters in the deposition holes. This means that due consideration has to be taken to increased contents of dissolved salts as a result of water evaporation.

6. *Corrosion of copper through dissolution in the ground water + precipitation in the bentonite*

SKB has experimentally shown in the LOT-tests that copper dissolves in the ground water. The copper ions diffuse from the canister surfaces into the surrounding bentonite layer and are finally precipitated in the bentonite. Chemical analysis of the bentonite showed that the bentonite contained several percent of copper in a bentonite zone adjacent to the copper. The thickness of this zone was some centimetres. The copper corrosion rate can be estimated from the amount dissolved and precipitated solely on this corrosion mechanism to 10 – 20 µm/year. Equivalent analysis of the amount of dissolve/precipitated copper in the bentonite zone has likely been done by SKB also in the Retrieval-tests bur are not yet published. Fraser King (1992) has also studied copper corrosion in water-saturated bentonite and found that copper corroded after some years with a rate of 20 μm/year.

SKB ought to study this corrosion mechanism both theoretically and experimentally because corrosion by dissolution and precipitation is most likely of utmost importance for the life of the copper canisters and the function of the bentonite layer. The published results show so far that the bentonite accelerate the degradation of the copper and at the same time the precipitation of copper in the bentonite may influence its function as a barrier layer.

It is suggested that SKB in a first action makes the all results public from the LOT-, MiniCAN- and Retrieval-tests and especially those parts that consider dissolution of copper in the ground water and precipitation of corrosion products of copper in the bentonite.

7. *Intergranular corrosion*
Taniguchi et al and Al Kharafi et al have reported in 2008 experimental results that show that copper is exposed to intergranular corrosion in ground water containing low contents of sulphide ions.

It is of importance that SKB investigates the risk for intergranular corrosion of the copper canisters deposited in the Forsmark repository tentatively by;

- Studies of the surfaces by SEM and conventional metallographic examination of samples from the LOT-, MiniCAN- and Retrieval- tests

- New appropriate stress corrosion tests in which the corrosive environment simulates the conditions in Forsmark and with regard to increased contents of salt in the water as a result of water evaporation

In conclusion there is significant uncertainty about the state of knowledge regarding copper corrosion and impact on the clay in the early stages after closure if a repository is built in accordance to the KBS method in the Forsmark bedrock. There are clear indications are that there have been major shortcomings in SKB's research in this area. Given that the man-made barriers of copper and clay are what has to ensure long-term safety in a repository based on the KBS-concept, it is hardly reassuring that the nuclear waste company SKB says that the company is ready to apply for permission to build a repository without having conducted a single experiment under the prevailing conditions in Forsmark.

2.5 Mechanical properties and embrittlement mechanisms

Copper corrosion will lead to a weakening of the copper canister itself. But there are other embrittlement mechanisms that can weaken the canister mechanically. It is the combination of corrosion and embrittlement, that makes it possible to fear that the copper canisters could leak at an early stage.

2.5.1. Sulphur embrittlement

The ground water in Forsmark contains sulphide ions and these can also be formed in the water bentonite barrier surrounding the copper canisters by a bacterial process (SRB i.e. sulphate reduced bacteria).

Arilahti et al. (see pp. 4) from VTT, Finland has recently presented evidence on sulphide corrosion of pure copper (Int. Conf. Brugges, Belgium, 2010) and the authors states the following;

> *”Based on the results it is clear that sulphur can diffuse into the Cu OFP material when it is exposed at room temperature to saline groundwater with 100 to 200 mg/l sulphide. Indications were found that the in-diffusion preferentially occurs through grain boundaries. Individual grain boundaries were found to contain above 20 at % sulphur. Based on SEM/EDS studies of the surfaces the extent of diffusion depth of sulphide into Cu OFP was more than one millimetre per week”.*

These results are sensational and Arilahti et al describe a new embrittlement mechanism for copper not known earlier i.e. sulphur embrittlement. The authors have found that;

- The mass transport of sulphur from the ground water containing sulphide ions to the copper takes place at a high rate at room temperature for the case that the ground water contains 100 – 200 mg sulphide/litre

- The in-diffusion of sulphur in the copper goes very fast at room temperature with a rate of 1 mm/week and takes place primarily in the copper grain boundary

- The sulphur forms precipitates of copper sulphide in the grain boundaries

- The copper sulphide precipitates embrittle the copper

The occurrence of sulphur embrittlement of copper is, according to Arilahti et al, very serious for the whole KBS-3 concept and is most likely by itself sufficient to question the choice of copper as canister material for the Forsmark repository.

It highly essential that SKB now thoroughly examines this issue of sulphide embrittlement caused sulphide copper corrosion. Comprehensive mechanical testing must also take place of test samples that have been exposed to sulphide corrosion and with precipitates of copper sulphides in the copper grain boundaries.

2.5.2 Hydrogen embrittlement

SKB has during the last years initiated research regarding hydrogen take up in the copper as a result of corrosion and also on hydrogen dissolved in the copper on its mechanical properties, see Martensson et al (2008). Nakahara et al (1988) have earlier described the influence of hydrogen the ductility and the strength of copper.

The risk of hydrogen embrittlement of copper canister is a most important issue of the final repository. It is thus essential that SKB generally in the future conduct their experiments in such a way that they are relevant for the repository in Forsmark. The potential risk for hydrogen embrittlement must be clarified. This means that the tests must be carried out under long time in a water solution and static load conditions, while the copper at the same time is charged electrochemically with hydrogen atoms. The chemical composition of the water solution shall be equivalent to the ground water in Forsmark with due consideration to potential increase of dissolved salts as the result of water evaporation.

2.6 Summary

In the foregoing section we, SSNC and MKG, have broached a number of issues relating to the risk of corrosion and embrittlement of the copper canisters and negative impacts on the clay buffer, both of which barriers are crucial to the long-term safety of the KBS method. In our perception, SKB appears to lack knowledge of some critical factors that they need to know in order to say that the final repository of the KBS model will function as planned when spent nuclear fuel has been deposited in it. This uncertainty needs to be resolved before the company submits its application.

In the opinion of SSNC and MKG, the nuclear waste management company, SKB, must in the context of the EIA consultation demonstrate that the man-made barriers of copper and clay will not be damaged or ruined in the course of the first hundreds or thousands of years.

3. The risk that the clay buffer is destroyed under glacial conditions

In recent years, awareness has grown concerning the possibility that the clay buffer may erode due to changes in the chemical characteristics of groundwater due to freezing during a glacial cycle. The issue was raised in connection with the examination of the analysis in the safety report, SR-Can (SKI & SSI 2008). Since then, the nuclear waste management company has enlisted the services of the Division of Chemical Engineering at the Royal University of Technology, KTH, in Stockholm and the consultancy, Clay Technology, to study the problem. Both groups work almost exclusively for SKB and may nowadays be considered part of SKB's internal research organization. The results of SKB's work on the subject was made public in Autumn 2009 (SKB 2009e, SKB 2009f, SKB 2009g). The Nuclear Safety Authority, SSM, convened a special expert meeting with their BRITE group in November of 2009, which reached the conclusion that several uncertainties as to the risk of clay erosion still persisted. Since then, SKB has asked the above-mentioned Department at KTH to do yet another modelling study, but the result does not appear to have clarified the issue very much (SKB 2010b).

In the view of SSNC and MKG, there must be no uncertainty concerning the risk of clay erosion during a period of glaciation when the company's application is submitted. We also consider it important for SKB to consult others besides their 'own' research teams to study central and vital issues like this one. To enhance the credibility of their research, SKB should involve new and independent research groups to perform studies and/or review studies carried out by others.

In SSNC's and MKG's view the nuclear waste management company, SKB, needs, in the context of the EIA consultations on long-term safety, to demonstrate that there is no risk of early erosion (rinsing away) of the clay buffer in the course of repeated glacial cycles.

4. Greater transparency with regard to SKB's research and the publication of all research reports and documentation from research project meetings

A good share of the research and development work that SKB has done has been performed on commission from SKB by selected research institutes and consultancies. It is vital that this research, as well as the studies carried out within the waste management company itself, can be performed in an independent manner that observes the fundamental ethical principles of science, and not be influenced by economic interests. The findings of commissioned research must not be influenced, directly or indirectly, by the nuclear waste management company. The purpose of commissioned experiments and theoretical modelling, and the interpretation of the results, must not be primarily to confirm the merits of the KBS-3 concept or to rebut criticism of it. The institutes and firms that SKB employs must have assurance that their prospects of future work for SKB will not be endangered, should their findings raise questions about the KBS-3 method.

In the case of studies of the man-made barriers of copper and clay, SKB has relied on a handful of external research bodies. In MKG's examination of the work done to date, five organizations stand out as the companies SKB has principally relied on in recent years to study questions relating to the long-term safety of the man-made barriers of copper and clay: Clay Technology AB; the Division of Chemical Engineering at the Royal University of Technology, KTH (Ivars Neretnieks); Integrity Corrosion Consulting Ltd (Fraser King); Bo Rosborg Consulting; Sercom Assurance in association with two Bulgarian researchers.[4] In addition, work has been done (unknown by whom) in SKB's bentonite laboratory at Äspö, some of which studies appear to have bearing on the risk of buffer erosion.[5]

In its examination of SKB's research on copper corrosion the Radiation Safety Authority, SSM, discovered that some findings of a study or studies performed by Serco Assurance were suppressed in the report of research to date that SKB published (SSM 2010). In our view, there are good reasons to examine not only the work done by Serco Assurance, but all the commissioned research performed by companies and institutions that have strong ties to, and have become dependent on, the nuclear waste management company. As noted earlier in this submission, MKG has had to put considerable effort into obtaining information about SKB's work on copper corrosion and its effects on the performance of bentonite clay. The examination MKG has been able to perform leads SSNC and MKG to conclude that all the findings reported by the above-mentioned research bodies merit closer examination.

---

4. Martin Bojinov, Department of Physical Chemistry, University of Chemical Technology and Metallurgy, Sofia, and Iva Betova, Department of Chemistry, Technical University of Sofia. Both were previously attached to VTT Technical Research Centre, a not-for-profit network for applied research services in Finland. SKB has previously commissioned work from VTT, but the relationship moved to Bulgaria with the two researchers.
5. In administrative terms the bentonite laboratory is part of the Äspö Laboratory, but very little information about what is done there has been made public. There is no information about research in progress in the most recent annual report for the Äspö Laboratory, other than a couple of photographs of different experiments (SKB 2009b). In the status and planning reports for Äspö there are some descriptive passages about different experiments, but no results appear to have been reported.

It should be noted that Clay Technology AB has also been asked to study several other topics of vital importance to the long-term safety of the method, including how the clay in a final repository might be impacted by freezing due to permafrost; how glaciation-induced earthquakes might affect a KBS repository; the risk that the installation of a repository in the bedrock formation at Forsmark might compromise its stability to the extent that it breaks apart during glaciation. The underlying assumptions and argumentary support in the Clay Technology studies should be subjected to scrutiny.

With respect to studies of other aspects of the project on which SKB is particularly keen to have the company's standpoints reflected, e.g., alternative methods such as deep boreholes or the siting process, research teams in the consultancy Kemakta have been engaged on a number of occasions not 8. The base data underlying Kemakta's studies needs to be examined.

In SKB's response to MKG 19 November 2010. SKB explains that a series of reports entitled International Progress Reports (IPR series) will be made public, but that other research reports from the Äspö laboratory are confidential (internal working papers).

In our opinion this is hardly sufficient. Far from all the consultants' reports from research at the Äspö laboratory are included in the IPR series. Almost no reports from experiments that examine copper corrosion and its effects on the clay are included in the series. A prerequisite to any scientific review of SKB's research on these subjects, by the regulatory authority or others, is that all research documentation is made available for scrutiny in the context of the EIA consultations. This includes documentation that the company considers confidential. Furthermore, documentation of research meetings must be made available, as well.

It is difficult to list reports and other documentation, the existence of which is uncertain, but MKG and its member organizations have started to compile and inventory.

1. All reports that SKB has developed in the report series Technical Documents (TD) and International Technical Documents (ITD)[6]

2. Particularly the report SKB ITD-05-01, EDZ seminar at Arlanda December 13th, 2004. Presentations and summary of discussion, Svensk kärnbränslehantering AB, 2005

6. Reports published in the TD and ITD report series regarding research in the Äspö laboratory are mentioned in status and planning reports (IPR reports) for the Äspö laboratory. Preiviously, the reports were named, but since Autumn 2008 only the number of published reports are mentioned.

3. All reports in the SKB working paper TU series

4. Particularly the report SKB working paper TU-03-05/Posiva R&D Report 2003-01, Deep repository – Facility Design. Qualification of low-pH cementitious products in the deep repository

5. All consultants' reports and memorandums from meetings regarding the LOT-project (many Clay Technology reports, but also other consultants' reports)

6. All consultants' reports and memorandums from meetings regarding the canister retrieval project, particularly studies on copper and clay (mostly Clay Technology reports)

7. All consultants' reports and memorandums from meetings regarding the prototype repository (among them reports with results from corrosion measurements conducted by Rosborg Consulting)

8. All consultants' reports and memorandums from meetings regarding the MiniCan-project (mostly Serco Assurance reports)

9. Particularly the Serco Assurance report SERCO/TAS/E. 003110.01/ Issue 01, Miniature Canister (MiniCan) Corrosion Experiment Progress Report 1 for 2008-9, January 2010

10. Particularly the memorandums "N.R. Smart, Minutes of Model Canister Planning Meeting, 2 June 2009, SKB offices, Stockholm"

11. Particularly the Serco Assurance report, Serco/TAS/MCRL/19801/ C001 Issue 2, Interactions Between Iron Corrosion Products And Bentonite, 2008

12. Particularly the Serco Assurance report SA/EIG/15031/C001, Expansion Due to Anaerobic Corrosion of Iron, 2005

13. Particularly the Serco Assurance report SA/EIG/11080/C001, The design of the mini-canisters – Design of Model Canister Experiment, March 2005

14. All consultants' reports and memorandums from meetings regarding the project "Galvanic corrosion of copper-cast iron couples", reported in SKB TR-05-06 (mostly Serco Assurance-reports)

15. Particularly the Serco Assurance report, SAEIG/13974/C001, Galvanic Corrosion of Copper-Cast iron Couples, 2004

16. All consultants' reports and memorandums from meetings regarding the project ”Investigation of Eh, pH and corrosion potential of steel in anoxic groundwater”, reported in SKB TR-01-01

17. Particularly the report AEAT/R/PS-0028, issue 1, Investigation of Eh, pH and Corrosion Potential of Steel in Anoxic Groundwater, 2000

18. All consultants' reports and memorandums from meetings regarding the project ”Task Force on Engineered Barrier Systems”

19. All consultants' reports and memorandums from meetings regarding projects conducted in the benotnite laboratory

20. All consultants' reports and memorandums from meetings regarding projects conducted by the Departement of Chemical Engineering at the Royal Institute for Technology, supervised by Ivars Neretnieks

21. All consultants' reports and memorandums from meetings regarding projects conducted by the Department of Material Sciences at the Royal Institute for Technology, supervised by Rolf Sandström

SSNC and MKG will continue to examine SKB's research and may, in the context of the EIA consultations, request access to additional reports and documentation of the research. Of future interest are the experiments, Alternative Buffer Materials, Temperature Buffer Test, and Large Scale Gas Injection, currently in progress at the Äspö laboratory.

In sum: SSNC and MKG demand that the applicant, SKB, make available, in the context of the EIA consultations, all consultant's reports and other research reports, as well as documentation of research project meetings that treat the study of copper and clay at Äspö Laboratory and any other research that has a bearing on the man-made barriers of copper and clay.

References

Al Kharafi F.M., Ghayad I.M. & Ateya B.G.; Rapid Intergranular Corrosion of Copper in Sulfide-Polluted Salt Water. Electrochemical and Solid-State Letters 11 (4) G15-G18 (2008).

Arilahti E., Lehtikuusi T., Olin M., Saario T. & Varis P.; Evidence for internal diffusion of sulphide from groundwater into grain boundaries ahead of a crack tip in a CuOFP copper, 4th international workshop on long-term prediction of corrosion damage in nuclear waste systems. Brugges, Belgium, June 28 – July 2, 2010.

Butt D.P., Kanner G.S. & Lillard R.S.; Corrosion of Target and Structural Materials in Water Irradiated by an 800 MeV Proton Beam. The Proceedings of the 2nd Int. Conf. On accelerator-driven transmutation technologies and applications. June 1996, Kalmar Sweden.

Carlsson T. & Muurinen A. 2009. Identification of Oxygen-Depleting Components in MX-80 Bentonite, Mater. Res. Soc. Symp. Proc. Vol. 1124

King F., Litke C.D. & Ryan S.R.; A mechanistic study of the uniform corrosion of copper in compacted Na-montmorillonite/sand mixtures. Corrosion Science 33:12 (1992) 1979-1995.

Lillard R.S., Pile D.L. & Butt D.P.; The corrosion of materials in water irradiated by 800 MeV protons. J. of Nuclear Materials 278 (2000) 277-289.

Martinsson A. & Wu R.; Hydrogen charging of oxygen-free copper. KIMAB-2008-131

Nakahara S. & Okinaka Y.; The Hydrogen Effect in Copper. Materials Science and Engineering A, 101 (1988) 227-230.

Posiva 2006. Copper Corrosion in Bentonite: Studying of Parameters (pH, Eh/O2) of Importance for Cu Corrosion, Working Report 2007-62, Posiva, June 2007.

Rebak R.B. 2006. Selection of Corrosion Resistant Materials for Nuclear Waste Repositories. Materials Science and Technology 2006, Cincinnati, OH, United States, October 15, 2006 through October 19, 2006. UCRL-PROC-221893.

SKB 2001a. O2 depletion in granitic media, the REX project, TR-01-05, Svensk Kärnbränslehantering AB, February 2001.

SKB 2001b. Copper corrosion under expected conditions in a deep geologic repository, TR-01-23, Svensk Kärnbränslehantering AB.

SKB 2006. Long-term safety for KBS-3 repositories at Forsmark and Laxemar – a first evaluation. Main Report of the SR-Can project, TR-06-09, Svensk Kärnbränslehantering AB, October 2006.

SKB 2007. Äspö Hard Rock Laboratory: Annual report 2006, SKB TR-07-10, Svensk Kärnbränslehantering AB, June 2007.

SKB 2009a. Long term test of buffer material at the Äspö Hard Rock Laboratory, LOT project: Final report on the A2 test parcel, TR-09-29, Svensk Kärnbränslehantering AB, November 2009.

SKB 2009b. Äspö Hard Rock Laboratory: Annual Report, 2008, TR-09-10, Svensk Kärnbränslehantering AB, July 2009.

SKB 2009c. Miniature canister corrosion experiment – results of operations to May 2008, Svensk Kärnbränslehantering AB, July 2009.

SKB 2009d. Design premises for a KBS-3V repository based on results from the safety assessment SR-Can and some subsequent analyses), TR-09-22, Svensk Kärnbränslehantering AB, November 2009.

SKB 2009e. Bentonite erosion: Laboratory studies. TR-09-33, Svensk Kärnbränslehantering AB, November 2009.

SKB 2009f. Bentonite erosion: Final report. TR-09-34, Svensk Kärnbränslehantering AB, December 2009.

SKB 2009g. Mechanisms and models for bentonite erosion. TR-09-35, Svensk Kärnbränslehantering AB, December 2009.

SKB 2010a. Fud-program 2010: Program för forskning, utveckling och demonstration av metoder för hantering och slutförvaring av kärnavfall, Svensk Kärnbränslehantering AB, September 2010.

SKB 2010b. Modelling of erosion of bentonite gel by gel/sol flowTR-10-64, Svensk Kärnbränslehantering AB, November 2010.

SKI & SSI 2008. Björn Dyverstorp & Bo Strömberg, m fl. “SKI’s and SSI’s review of SKB’s safety report SR-Can”, SKI report 2008:23 & SSI report 2008:04 E, Mars.

SSM 2009. Record of SSM BRITE (Barrier Review, Integration, Tracking and Evaluation) Review Group Meetings, 4, 5 and 7 November 2009.

SSM 2010. Quality Assurance Review of SKB's Copper Corrosion Experiments, SSM Rapport 2010-17.

SSM 2011. Evolution of hydrogen by copper in ultrapure water without dissolved oxygen. SSM Report 2011:34.

Szakalos P., Hultquist G. & Wikmark G.; Corrosion of copper by water. Electrochemical and Solid State Letters 10 (2007) C63-C67.

Taniguchi N. & Kawasaki M.; Influence of sulfide concentration on the corrosion behavior of pure copper in synthetic seawater. J. of Nuclear Materials 379 (2008) 154-161.

FUD-10

Joint comment on the part of the Swedish Society for Nature Conservation (SSNC) and MKG concerning the Swedish Nuclear Waste Management Company's (SKB) R&D Programme on nuclear waste management (Fud-10): "*Programme for research, development and demonstration of methods for management and disposal of spent nuclear fuel*"

Naturskyddsföreningen
Box 4625, 116 91 Stockholm
Tel.08-702 65 00
www.naturskyddsforeningen.se
info@naturskyddsforeningen.se

Miljöorganisationernas kärnavfallsgranskning
Box 7005, 402 31 Göteborg
Tel. 031-711 00 92
www.mkg.se
info@mkg.se

Dec 21th, 2010

Till: Svensk Kärnbränslehantering AB, SKB
(The Swedish Nuclear Fuel and Waste Management Company)
106 58 Stockholm

Joint comments of the Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review, MKG, on the nuclear power industry's organ for nuclear waste management, Svensk Kärnbränslehantering AB's status report, "Fud-programme 2010: Programme for research, development and demonstration of methods for management and final disposal of spent nuclear fuel."

The Swedish Society for Nature Conservation (SSNC) and MKG wish to put forward the following comments on the industry's latest status report and programme for research and development, Fud-10. MKG and its member organizations are described in a missive that accompanies these comments; the missive also outlines how the member organizations have chosen to comment on the present Fud-programme.

The following document consists of five parts:

1. Background, with a brief description of the so-called 'Fud-process' [Fud standing for RD&D: Research, Development & Demonstration]

2. Overall issues relating to the Swedish model for the management and final disposal of spent nuclear fuel

3. More general issues relating to how the nuclear waste management company, SKB, has carried out its research

4. Issues that SKB treats in the "Fud-10" report that call for comment

5. Issues that SKB does not treat in "Fud-10" or treats only superficially, despite their gravity and importance – omission or treatment that therefore merits comment.

The comments submitted by SSNC and MKG on December 15th 2010 to the nuclear waste management company are attached to this document (Annex 1). Parts 2 and 3 of those comments raise a number of concerns relating to copper corrosion and stability, and erosion of clay, two phenomena which, in our estimation, the company has not treated in an adequately scientific manner. Part 4 treats scientific ethical aspects and an overall lack of transparency surrounding the research SKB has done. These latter comments relate to the discussion in Part 2 of the present document regarding a need for reform of 'the Swedish model' for management and final disposal of spent nuclear fuel.

1. A brief background

Every three years, the nuclear waste management company shall report its progress and submit a programme for the research it intends to conduct during the coming three years to the regulatory authority, the Swedish Radiation Safety Authority, SSM. The most recent report and programme is entitled "Fud-programme 2010: Programme for research, development and demonstration of methods for management and final storage of nuclear waste", commonly referred to as "Fud-10". SSM received the document (ref. no. SSM 2010/2116) in late September of 2010; it was then circulated broadly for comment. When SSM has received all comments, the authority will proceed to submit a recommendation no later than March 2011 to the Government on Fud-10. According to the terms of the Law on Nuclear Activities (1983:4, 26§), the recommendation should include a review and evaluation of the programme with respect to:

1. Planned research and development work
2. Reported research findings
3. Alternative methods of management and final disposal and
4. The measures to be taken.

The Council for Nuclear Waste, too, submits comment to the Government. Thereafter the Government will make its judgement on "Fud-10".

Submission of these periodic status and program reports is a condition attached to the authorization to operate a nuclear power plant, set out in the Law on Nuclear Activities (1983:4, 12§), which also states:
In conjunction with the examination and evaluation conditions may be imposed as deemed necessary concerning the continuation of the research and development program.
This passage is pivotal inasmuch as it represents the only legal basis for government intervention or steering of activities relating to nuclear waste management.

The waste management company, SKB, has announced its intention to submit an application to the Radiation Safety Authority and the Environmental Court for permission to build a final repository for spent nuclear fuel at Forsmark 16 March 2011. The initial examination of the application is expected to take 2-3 months; thereafter, the Authority and the Court will determine whether or not the application is good enough to form the basis of formal proceedings.

Should it be determined that the application is not good enough, there will have to be a thorough investigation to determine how such a situation could arise. In all events, the Government's decision regarding "Fud-10" should be taken after the Radiation Safety Authority and the Environmental Court have made their determination. If a formal examination cannot start, the Government should undertake a study to provide better guidance for their decision on the research programme.

2. Overall issues relating to the Swedish model for the management and final disposal of spent nuclear fuel

Having followed the progress of the final repository project from the start, SSNC has submitted many comments on the nuclear waste management company's research programmes over the years. Since 2005 SSNC, acting through MKG, has taken active part in the mandated EIA consultations that precede any company's application for permission to construct a final repository for spent nuclear fuel. Together, our two organizations have extensive experience and a good grasp of how 'the Swedish model' for nuclear waste management and storage works.

In recent years we have become aware of certain weaknesses in 'the Swedish model'. Since the review of "Fud-10" precedes a determination on the part of the Government that might lead to corrective measures, we find it important to include some comments of a 'systems' nature in this document.

The distribution of responsibility
Swedish legislation entrusts full responsibility for the management and final disposal of spent nuclear fuel to those who have concessions to operate nuclear power facilities. It is more than a question of 'the polluter pays'. Here, all responsibility is in the hands of the industry. In this respect the Swedish approach differs markedly from how responsibility is distributed in most other countries that have nuclear power reactors. The Swedish arrangement rests on an unshaken confidence that an industrial actor, in this case a branch-owned company, will be able to set aside the industry's parochial interests in favor of a process that satisfies a strong public

interest, namely, to achieve the best possible technical solution from the point of view of long-term environmental safety.

In our view, in order for 'the Swedish model' to succeed, the following requirements must be fulfilled:

> 1. A mandated pro-active role on the part of the regulatory authority that enables it to monitor the company's progress, examining and evaluating the company's activities on its own initiative;
>
> 2. Public funding of a scope that enables the regulator to commission pertinent research that is independent of the nuclear waste management company, as deemed necessary; and
>
> 3. Sufficient transparency to give authorities, civil society organizations and the public full insight into the work of the company, allowing independent assessments of the company's performance in relation to what is expected of them.

On the basis of many years' involvement in the three-yearly process to review the SKB research and development programme – the Fud-process – and, more recently, participation in the EIA consultations, we, SSNCF and MKG, find that in the present statutory framework the Swedish approach to assigning responsibility is not working very well. We support the polluter pays principle, but if the 'polluter' is to continue to be entrusted with full responsibility for the execution of the final repository project, the statutory and administrative frameworks need to be reformed.

The need for a forceful regulatory control

There is an obvious risk that the industry's interest in finding an adequate means to manage and dispose of Swedish spent nuclear fuel that is technically simple and economical may conflict with the public interest of finding a solution that affords the best possible long-term environmental safety. The public interest must be supported by an active role on the part of regulator. In retrospect, some aspects of the culture that prevailed in parts of the former regulatory agencies with respect to both the quality of their control and their independence vis-à-vis the industry can be questioned. The creation of the new regulatory body, the Swedish Radiation Safety Authority, SSM, marks a 'break with tradition' and takes a major step toward greater regulatory integrity. Still, however, the authority lacks the means to act forcefully to defend the interest of the public as relates to the problem of nuclear waste.

A principal flaw in the present system is that the regulator lacks statutory authority to examine the industry's work on spent nuclear fuel management and disposal of it, other than through the slow, yet superficial Fud-process. The authority needs to be given legal power to take action when it has reason to believe that all is not as it should be. As things stand today, SSM can inspect the quality of the industry's research only with the consent of the nuclear waste management company, and totally on the company's terms. The regulator does not even have the authority to demand access to research reports that the company is not willing to release for scrutiny.

In the opinion of SSNC and MKG, the regulator must be able to examine the industry's work on a final repository for spent nuclear fuel on a continuous basis and on its own initiative.

Funds for independent research
A lack of transparency has made it difficult to review the industry's R&D programme. One of the main reasons is the industry's total control over all research funding out of the Nuclear Waste Fund. From the point of view of the Swedish research community, the nuclear industry has been the source of relatively plenteous funding for studies in areas of relevance to the final repository project. Meanwhile, other sources of funding have retreated from this area, choosing instead to use their limited resources on research in other fields. Consequently, the industry has built up research environments that are to a significant degree, if not totally, dependent on its good offices, and only studies that the industry has asked for have been undertaken. Similarly, the industry has been able to develop relationships with selected consultancies that have become dependent on the industry's favor. Consultant firms are clearly under even greater pressure to conform to the client's wishes.

The problem is not that the research done is necessarily of poor quality, although in some cases questions may be raised, but that there has been no funding to explore aspects that the nuclear waste management company has not wanted to look into. It is quite clear that the industry has avoided some issues that do not serve their interests. When, what is more, the funding that authorities have had at their disposal is used primarily to replicate (and thereby falsify or confirm) experiments and studies that the company has done, the imbalance becomes even more acute. Furthermore, in some cases when studies commissioned by the authorities have indicated that there might be a problem – as in the case of copper corrosion – neither the company nor the authority has followed them up.

In other words, it is quite clear that 'the Swedish model' needs to be changed so that funding out of the Nuclear Waste Fund is made available for studies that are independent of the nuclear waste management company. Even today, the Radiation Safety Authority is able to draw money from the Fund to finance research that helps the Authority execute its regulatory functions. Considerably more funding needs to be made available for this purpose, and the Authority should draft a research policy that is broader in focus, and less closely tied to the industry's research agenda.

There has been a totally unfounded fear that the regulator, were it to undertake or commission independent research, might encroach on the industry's sphere of responsibility. But, the regulator has a duty to see to it that the public interest, too, is served in the body of research relating to the final repository project. Thus, the regulator may be seen to be duty-bound to undertake research quite independent of the industry. Otherwise, there is a risk that the regulator will not have the knowledge needed to be able to evaluate certain crucial issues such as those relating to the long-term environmental safety aspects of the method developed and site chosen by the industry through its company, SKB.

In order to ensure that the knowledge generated on the subject of spent nuclear fuel is the best that can be attained, there must also be systems for funding investigations initiated by members of the academic community. The money for this should be taken out of the Nuclear Waste Fund, and the announcement of available grants and evaluation of applications for those grants should be handled by a council consisting of representatives of the academic world and actors in the field of nuclear waste management. These structures may be arranged under the auspices of the Radiation Safety Authority, but they should be separate from the research conducted or commissioned by the regulator. This would create yet another level that might ensure that Swedish research in the field of nuclear waste is of the best possible quality.

SSNC and MKG call for a major increase in funding out of the Nuclear Waste Fund for research that is independent of the nuclear power industry.

The need for full insight into the work done on spent nuclear fuel
One obvious hindrance to all who are interested in examining, or have a duty to examine, the work of the industry that relates to spent nuclear fuel – members of the research community, mass media, civil society organizations and others – is the way the industry has organized its work on the subject. The creation of a subsidiary company, SKB AB, to pursue the project removes the work from the public sphere and renders all insight into, and assessment of, the company's work subject to the consent of the company. Not even the regulator, SSM, has the authority to examine material that the company chooses to consider internal, even though many

reports and documents from research meetings contain information that should be open to public scrutiny.

If the Swedish model of distributing responsibility is to succeed, this situation must change. However organized, accountability requires that the manner in which the nuclear waste management company uses money out of the Nuclear Waste Fund must be transparent, in accordance with the principle of freedom of information. This would greatly facilitate reviews and assessments of the industry's 'research, development and demonstration' efforts. It would, furthermore, enhance the company's accountability regarding how it uses the money it draws from the Nuclear Waste Fund.

It is our considered opinion that the industry's use of money out of the Nuclear Waste Fund must be reorganized in a way that affords full public insight into the company's activities.

3. More general issues relating to how the nuclear waste management company, SKB, has carried out its research

These past few years MKG has reviewed SKB's research in a number of areas in conjunction with the EIA consultations preceding to the submission of an application for permission to construct a final repository for spent nuclear fuel. To put it bluntly, the research often falls short of established standards of scientific praxis. Particularly problematic is the research relating to alternative methods (alternative to the KBS model) and the choice of site, but the problem is even more pronounced in the work relating to the barrier system.

Most recently, MKG has reviewed and analyzed SKB's research on copper corrosion. It required a great deal of effort for us to gain access to research findings from, for example, experimental studies performed in SKB's Äspö laboratory near the Oskarshamn nuclear power plant. The regulatory agency, SSM, has also looked into the problem of copper corrosion and in early 2010 reviewed the company's quality assurance of their research on the subject. SSM's report is strongly critical of the company's documentation of their experimental work on copper corrosion and its effects on clay (SSM rapport 2010:17). Among other things, SSM found that SKB had suppressed research findings in a published report from the project.

The problems that have surfaced in the area of copper corrosion are symptomatic of a deeper-lying problem relating to SKB's research and its non-conformity with scientific praxis. Had it not been for SSM's external control, the suppression of findings would never have been revealed. Had such a breach become known in an academic environment, it would in all probability have elicited an investigation of ethical misconduct. The nuclear waste management company, SKB, claims to work in a scientific fashion with high degree of transparency. Meanwhile, the company has on several occasions denied MKG access to findings from other research projects performed at the Äspö facility.

More serious is the apparent development of an unscientific attitude or culture among the staff of SKB that does not recognize the need to publicize results that are unexpected or do not 'fit' with the company's preconceptions. Despite the company's self-image as scientific and transparent, the fact is that SKB publishes only the findings that it finds suitable to make public. Experiments and analyses that produce results that the company's researchers cannot explain or that deviate from their expectations and they therefore do not "trust" are not made public. This established practice was revealed at a meeting where representatives of SKB and the Radiation Safety Authority discussed the problems turned up in the latter's review of SKB's research on copper corrosion in early 2010.

The fact that the company is entrusted with sole responsibility for developing the method of handling Swedish spent nuclear fuel in a manner that affords the greatest possible long-term environmental safety renders the situation troubling. Unfortunately, MKG's years-long experience of the EIA consultations leads us toward the conclusion that this attitude has prevailed within the company for many years. If this is so, the validity of portions of the material – the more controversial portions in particular – to which the company will refer in the coming application for permission to construct a final repository for spent nuclear fuel at Forsmark, may be called into question.

There is clearly a need for access to the results of SKB's research, from those doing the experiments themselves rather than via the heavily edited versions that are offered for public consumption (e.g., the R and TR series). To enable the scientific community, the regulatory agency and other actors to assess the company's research, documentation from project and research meetings should also be made available for scrutiny. SSNC and MKG have put forward such a demand in the context of the EIA consultations that precede SKB's application for permission to build a final repository for spent nuclear fuel (Annex 1).

4. Comments relating to issues that SKB does treat in "Fud-10"

In the following we comment on different aspects that SKB itself includes in the research program, "Fud-10". We, SSNC and MKG, have chosen to focus on issues relating to the final repository for spent nuclear fuel, and among those issues, primarily issues that relate to long-term environmental safety. Thus, our comments refer principally to portions of the document's Part I (Overall plan of action) and Part IV (Research for assessment of long-term safety).

We do not comment on the LILW program (Part II) [re Low and Intermediate-Level Waste], nor do we comment on the more practical aspects of the technology in Part III (The Nuclear Fuel Program), i.e., the material summarized in Table 9-1, pp 125f, and discussed in Section 11-16. Of Part IV, we do not comment on Sections 20 and 21, which deal with short-lived and intermediate-level waste, or Section 26, on near-surface ecological systems. We include no more than a few comments in the area of social science research (Part V), but comments on that research by Olov Holmstrand are attached to this document (Annex 3).

General comments on long-term environmental safety

First, some general comments on SKB's research on long-term environmental safety, as described in Table 17-1 on p 196. In the table, areas that SKB finds in need of some further research are indicated in fields of yellow, and areas in need of considerable amounts of research are indicated in fields of red. This is an improvement since Fud-07, where the corresponding table had no such assessment of the need for further research even though there was a similar table with assessments for further work regarding issues of more practical/technical aspects of the project.

What is problematic is that SKB notes major research needs within the coming three years in many different areas that have bearing on long-term environmental safety, yet they believe they will have sufficient knowledge to support an application for permission to construct a final repository for spent nuclear fuel in March 2011. What is more, several of the areas indicated concern issues relating to the integrity of the man-made barriers of copper and clay, which are crucial in relation to long-term safety. The safety analysis, "SR-Site", planned to accompany the application, consists of a set of models. Many of the aspects listed as requiring further research in Table 17-1 are vital to any assessment of the realism of the models in the safety analysis.

SSNC and MKG consider it important for the Radiation Safety Authority to assess the level of knowledge the nuclear waste company, SKB, demonstrates in relation to the attainment of the so-called 'initial condition', which needs to have been attained in order for the safety analysis to have any relevance whatsoever.

Copper corrosion and its influence on clay prior to saturation

Issues relating to corrosion of the copper canister are discussed in Section 23.2.7, pp 272ff. In the light of the discussion of SKB's research on copper corrosion in recent years, this section – both what it says and what it does not say – is highly interesting. Clearly, there are many things that SKB does not know about copper corrosion; it is also clear that the company shows rather little ambition to learn more. Moreover, in all probability SKB has not reported all of what it does know in this area, knowledge that may raise questions about the long-term environmental safety of the KBS method.

The reference to the fact that Fraser King, a long-time consultant to SKB, finds no problems with the company's various assumptions concerning copper corrosion and his opinion that those who have criticized the company's research are wrong carry no weight whatsoever. No references are offered in support of his judgements. King's assessment is hardly that of a dispassionate observer; he has worked for SKB as a consultant for many years and is highly biased in favour of the KBS method.

For a more detailed review of the research needs relating to copper corrosion and the behaviour of clay prior to saturation, please see Section 2 of SSNC's and MKG's comments submitted in the context of the EIA consultations (included as Annex 1 here). Some of the points are also touched on in the following.

Stress corrosion

Fud-10 lacks any reference to results from SKB's experiments on this subject, even though the company says that such results exist. These results must be made available for scrutiny, even if SKB considers them confidential. Therefore, it is a very good thing that the Radiation Safety Authority is performing its own experiments to study this phenomenon and will thus have a more solid basis on which to assess the need for further research.

The effects of radiation on copper and clay

Section 23.2.5, pp 271f, treats the effects of radiation on copper and clay. Only SKB has done theoretical work on this subject, but some experiments have demonstrated significant corrosive impacts and indicate that copper is particularly problematic in this regard. These effects have also been discussed in the reference group for the company's research on copper corrosion in anoxic environments. It turns out that SKB has no empirical support for discarding the issue as lacking significance. But neither does the company have any ambition to establish empirical support. This is an area that the Radiation Safety Authority should examine very carefully.

Saline precipitates
The precipitation of salts on the surface of the canister is a highly pertinent issue, given the relatively dry bedrock at Forsmark. The reference to the "LOT-A2" report in Fud-10 is misleading, as that report contains no information or data on this subject. It may be that the subject was treated in a consultant's report, the content of which was not included in LOT-A2, in which case it would be interesting to be able to read that report. The Radiation Safety Authority should demand access to detailed results on this subject, even if the only data are confidential.

The saturation process in the Forsmark bedrock
The question of how long it may take for the clay buffer to be fully saturated in the Forsmark bedrock appears to be treated in Section 24.2.5, pp 287ff, and 24.2.11, pp 302ff. There is a reference (p 287) to a report from 2001 (reference 24-13), which, however, relates to the SFR repository. Since the bedrock surrounding SFR is of an entirely different character, the reference is lacking in relevance. On page 302, SKB writes:

> *"The coupling of the THM processes during the saturation phase is not crucial for the safety of the final repository, but is important for an understanding of how the buffer is wetted, swells and is homogenized under the influence of temperature changes. It is also important for the understanding and evaluation of the field tests in the Äspö HRL."*

This is a very peculiar claim. If the clay is damaged or destroyed in the saturation phase, of course it will affect the long-term environmental safety of the repository. But SKB's models simply presume that the clay will be saturated as though it were a given, an absolute truth that requires no experimental verification. There is also mention of a project referred to as "FT EBS (Äspö Task Force on Engineered Barrier Systems)", but no reference to documentation. What is this project? Are there any reports or notes from project meetings, even if only confidential ones?

Erosion of the buffer
The problem of buffer erosion is treated in Section 24.2.20, pp. 316ff. The empirical work on this subject (reference 24-31) was performed by a team at the Royal Technical University in Stockholm that has very close ties to SKB, for which reason the documentation merits close scrutiny. The source of the figures and tables presented is a report (reference 24-12) from Clay Technology, a company also having close ties to SKB. The work done by Clay Technology should also be examined with a critical eye.

In SSNC's and MKG's view, the research on buffer erosion needs to be scrutinized carefully because the work has been performed with very little transparency in very close circles. We are aware that the Radiation Safety

Authority has a review of this subject in progress, and we urge the Authority (1) to examine how the company has assured the quality of their work on the subject, and (2) to demand access to all relevant internal documentation.

Climate change
It is important to bear in mind the various climate scenarios that may play out as a consequence of the anthropogenically enhanced greenhouse effect. SKB glosses over this subject in Section 19.1, pp 207ff.

Permafrost
The consequences of permafrost in a glacial cycle are treated in Section 19.4, pp 215ff; freezing is treated in Section 24.3.4, pp 285ff. Since freezing temperatures may have far-reaching effects on the function of the repository, SKB has put considerable resources into showing that there is no risk of freezing, and that freezing temperatures, should they occur, would not be a problem. SKB's work on this subject requires close examination. MKG also suggests that SSM take contact with Professor Matti Saarnisto in Finland, who has submitted comments to STUK on the problem of permafrost. As we understand it, Professor Saarnisto believes that permafrost can reach far greater depths than those foreseen in SKB's modelling.

Alternative methods
Issues relating to alternatives to the KBS method are treated in Section 27, pp 385-393. Deep boreholes are discussed in section 27.2, pp 389ff. SKB refers exclusively to its own work, which was done in 1998 and 2000 and to a report that will accompany the company's application for permission to build a final repository for spent nuclear fuel. Consequently, we cannot know the extent of SKB's knowledge about deep boreholes. There is no indication that the company has learned more since the most recent Fud-report, "Fud-07". We therefore presume that SKB has not developed its knowledge of deep boreholes to an extent that permits a proper comparison with the KBS method – although both the regulator and the Government have asked the company to do.

The treatment of deep boreholes in the foreign reports that SKB cites in Fud-10 is both superficial and biased. MKG has copies of these reports and will be pleased to make copies available on request.

Super-regional groundwater flows
Issues relating to regional groundwater flows on a macro scale are treated in Section 25.2.3, pp 330f. There is a reference to a new study, but the reference given (25-33) is incorrect, which makes it difficult to assess the basis for SKB's argumentation on this subject. SKB has told the regulator, SSM, that the correct reference is "Ericsson et al. Storregional grundvattenmodellering –

en känslighetsstudie av några utvalda konceptuella förenklingar [Modelling of super-regional groundwater: a sensitivity analysis of selected conceptual rectifications], SKB R-10-43" and that will be published in conjunction with the company's application to SSM and the Environmental Court. Thus, it is impossible to assess the need for further research in the area, but in view of how the company has manipulated publication of previous findings in this area, we have reason to believe that the need may be great in order to clarify the importance of these flows in the context of the choice of site.

Retrievability and physical protection/safeguards
Issues relating to retrievability are treated in Section 2.3.3, p 48. Otherwise, there is little mention other than brief references in reviews of others' studies of deep boreholes (p 393) and studies in the social sciences (p 411). Considering the topical interest in retrievability – indeed, the Nuclear Waste Council devoted a section of their most recent status report to the subject from in February [2010] – the nuclear waste company should accord the subject more attention. The experimental retrieval carried out in the Äspö laboratory lacks all relevance, unless the canisters are presumed to be retrieved only after several thousand years. The operation was not done by remote control, which would have to be the case as the the canisters would give high radiation doses.

Issues relating to the physical protection and safeguards surrounding nuclear materials are treated in Section 10.6, pp 130f. Physical protection/ safeguards is discussed only in relation to the operational phase, not after closure and sealing of the repository. Interestingly, in a reference to a social scientific project at the School of Business, University of Gothenburg, SKB writes (p 420): "The most obvious problem identified by the study with regard to responsibility for Sweden's international commitments to non-proliferation in connection with a final repository concerns the temporal extent of the responsibility after the operating phase is over and closure has taken place."

It is remarkable that the nuclear waste management company seems not to have any research ambitions on such an important aspect as safeguards/ physical protection after closure of the repository, not least in the context of retrievability. This gap must be filled.

Fuel with higher burn-up
Questions relating to disposal of spent nuclear fuel having a higher burn-up are treated on page 26. Higher burn-up implies higher levels of radiation and greater heat, but it also gives rise to different distributions of isotopes in the spent fuel, which may affect the risks involved if and when leakage from the repository occurs. For example, there will be greater amounts of

I-129, which is both very long-lived and volatile. These ramifications require further investigation.

5. Issues that SKB does *not* treat in Fud-10

Risks associated with earthquakes
The question of the impact of earthquakes of different magnitude and frequency on the repository does not appear to have been investigated in SKB's research programme. Considering how important they are to the long-term safety of the repository, the risks associated with seismic activity need to be established. The work should also be carried out by researchers not previously associated with SKB.

Risks associated with rock tension
There appears to be no programme for further study on the stress in the bedrock at Forsmark and the risk of major faulting or fractures with the repository as a fracture indication during glaciation. SKB has commissioned only one study, done by Clay Technology, which in view of the consultants' close association with SKB, may hardly be considered impartial. The Radiation Safety Authority should follow this subject up and see to it that the nuclear waste company also commissions studies by independent expertise.

Methane ice
There is no mention of continued research on the question of whether methane gas under extreme pressures and at low temperatures may turn into methane ice, which, when pressure and temperatures change (as may be expected after periods of glaciation and seismic waves), converts explosively to gas. Should such a phenomenon occur in a final repository, where there may be voids in tunnels and niches, it might be very problematic.

Other issues relating to choice of site, besides super-regional groundwater flows
SKB reports no plans to continue studying other siting issues besides super-regional groundwater flows. Among such issues is the risk involved in siting the repository in direct proximity to nuclear power reactors. The question is, what a serious accident in one of the reactors would imply for the operation and control of an adjacent repository. This question requires more research.

Scenarios that posit leakage during the first millennium
Since the possibility that the barrier systems may fail entirely cannot be ruled out, it is important to gain an understanding of what would happen to people and the environment if a repository failed even before 1 000 years

has passed.

Warning markers to coming generations and scenarios of intrusion
There is no research programme to study the possibility to communicate information and to warn future generations of the danger that intrusion into the repository represents. The problem of communication must be coupled with a study of various scenarios of future intrusion. It is not acceptable to say that future generations must take responsibility for their own acts when it is we, today, who are creating the hazard that may cause them harm – an act that they, obviously, have no part in and are not able to influence.

Research on the 'zero alternative'
The nuclear waste company should do more research on various options for interim storage in the event that the KBS system cannot be carried out. For example, long-term dry storage should be explored as part of the so-called 'zero alternative'.

6. Concluding remarks

We, the Swedish Society for Nature Conservation, SSNC, and the Swedish NGO Office for Nuclear Waste Review, MKG, are concerned about the status of the Swedish nuclear waste management programme. We have in the foregoing raised a number of issues on the level of overall responsibility and issues relating to the manner in which the nuclear waste management company, SKB, has conducted its research. We have pointed to a number of areas where we no longer have confidence in the validity of the results the company has made public from the closed world that its research environment has become.

We find a need for fundamental change in how Swedish research in the area is organized and urge the Swedish Radiation Safety Authority to reflect on this while preparing their recommendation to the Government. We urge the Government, too, to analyse these vital issues while making their assessment of the Fud-10 research programme.