# Resolved and Remaining Issues for KBS-3 – SKB's Research, Development and Demonstration Programme 2013 – 14481

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## ABSTRACT

In Sweden, the holder of a license to own and operate a nuclear facility is responsible for managing and disposing of the radioactive waste and the spent nuclear fuel in a safe manner. The license holders have formed Swedish Nuclear Fuel and Waste Management Co. (SKB) to on their behalf develop and manage a programme for the research and development activities and other measures needed to manage and dispose of nuclear waste and spent nuclear fuel in a safe manner and to decommission and dismantle the nuclear power plants. Such a programme (RD&D Programme) has since 1986 been submitted every third year to the Swedish Radiation Safety Authority (SSM) for review as preparation for a Government decision on the programme.

After more than 30 years of research and development regarding final disposal of spent nuclear fuel, an application under the Nuclear Activities Act for final disposal of spent nuclear fuel and an application under the Environmental Code for the KBS-3 system was submitted in March 2011. These license applications provided a summary of the current status of the development of the KBS-3-system and included a safety assessment. However, the legal obligation to submit an RD&D programme is still in effect. The latest RD&D programme was submitted in September 2013.

Even though a large number of issues may be considered resolved regarding the KBS-3-system there are still substantial technology development and demonstration efforts planned before disposal can begin and the facilities be operated as an industrial enterprise.

## INTRODUCTION

The Swedish power industry has been generating electricity by means of nuclear power for more than 40 years. At the end of 2013, Sweden had 10 operating and 2 decommissioned nuclear reactors located at the four sites shown on Figure 1. Parts of the system that are needed to manage and dispose of the spent fuel from operation of the reactors have been built up during this time. The system includes the interim storage facility for spent nuclear fuel (Clab) plus the new ship m/s Sigrid and robust containers and casks for transport.

What remains to be done is to build and commission the system of facilities, the KBS-3 system, needed for final disposal shown on Figure 2. This includes building a facility part for encapsulation of the spent nuclear fuel at Clab, procuring transport casks for canisters of spent nuclear fuel, and building a final repository where the canisters will be deposited. The process of construction and commissioning a new facility or facility part consist of several different phases. In March 2011, SKB submitted an application under the Nuclear Activities Act for final disposal of spent nuclear fuel and an application under the Environmental Code for the KBS-3 system in a deep geological repository located adjacent to the Forsmark nuclear power plant site (Figure 1). An application under the Nuclear Activities Act for the encapsulation plant submitted in 2006 was amended in 2009 regarding integration of the encapsulation plant and Clab to a single facility, Clink, and in 2011 regarding parts dealing with the KBS-3 system as a whole.

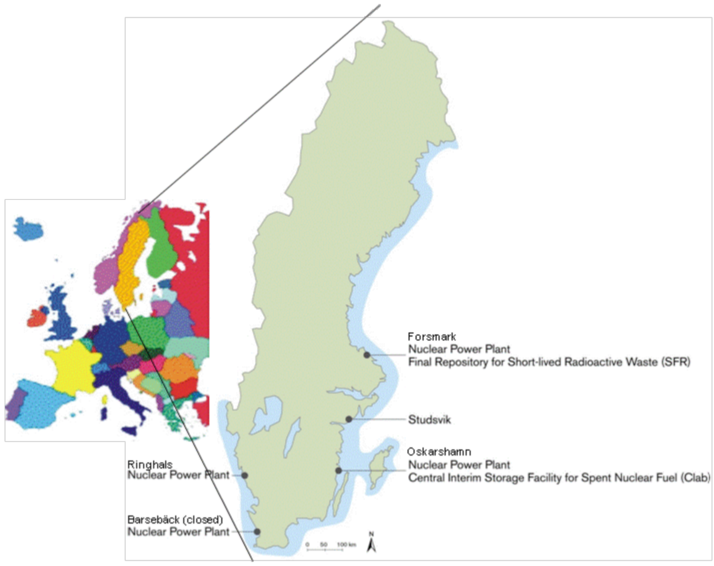


Fig. 1. Location of Swedish nuclear power plants and nuclear facilities.

The licensing process is under way and is expected to take several more years. In parallel with this, SKB is conducting the research and technology development needed to design, build and operate the KBS-3 system in a rational manner while complying with the requirements on long-term safety, low radiation dose and safety in the operation of the facilities as well as a good external environment.

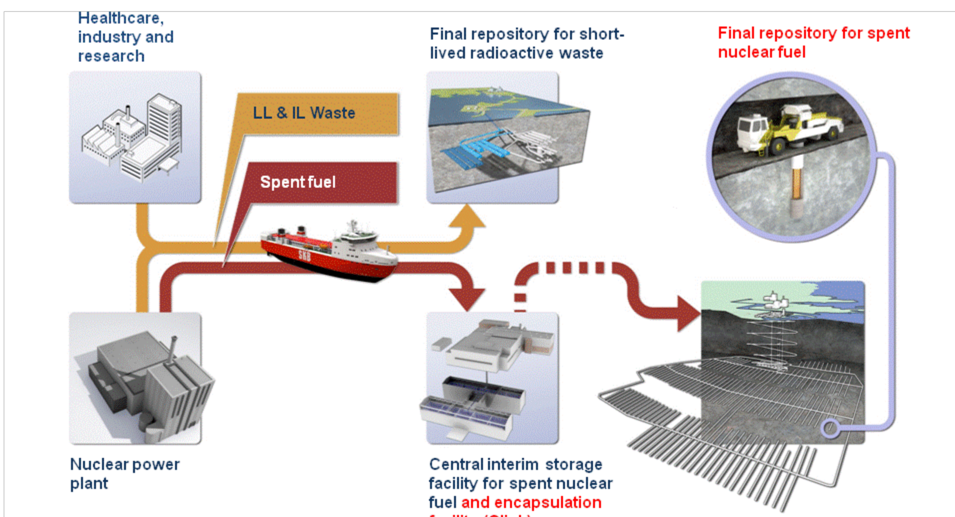


Fig. 2. The Swedish system for management of nuclear waste. The KBS-3-system is used for final disposal of spent fuel. Facilities to be built are indicated by red text.

## PLAN OF ACTION

Based on the 2011 applications, SKB has planned and structured the work that remains up until the start of operation of the remaining facilities included in the KBS-3 system (Figure 2).

The Clink Project includes planning, design, construction and commissioning of the integrated facility for interim storage and encapsulation in Oskarshamn.

The Spent Fuel Repository Project is established in Forsmark (Figure 1), and the final phase of system design of the final repository's facility parts and technical systems is currently under way. A long-range project is under way to build up the organization and competence needed to implement technology development and, in the future, safe operation of the Spent Fuel Repository. Compensatory environmental measures have been adopted at the Forsmark site, and the day-to-day work of monitoring the site and managing buildings, land and drilling sites is under way.

Work is under way with safety analysis reports for the facilities in the KBS-3 system (Figure 2) which have to be submitted prior to the start of construction. This work is based on experience from the preparation of the safety analysis reports submitted with the applications (SR-Site [1] for post closure safety and operational safety reports for the Spent Fuel Repository and Clink).

The estimated start of construction for the Spent Fuel Repository at Forsmark is 2019 and for the encapsulation part of Clink at Oskarshamn 2021. These facilities are then planned to be commissioned and commence full-scale operations in 2029.

The two construction projects and the work with safety analysis reports for the KBS-3 system are primary beneficiaries of the technology development and scientific research that is being carried out for the KBS-3 system.

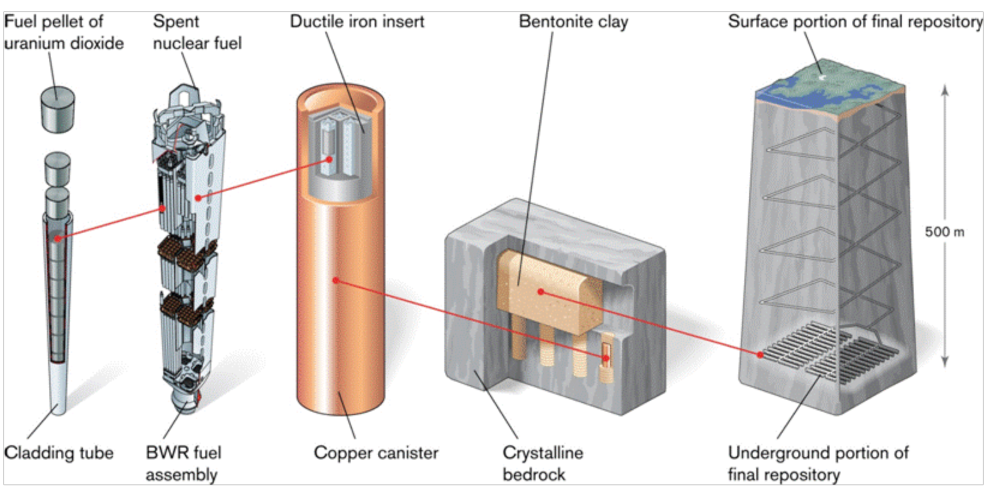


Fig. 3. The components of the KBS-3 method.

## TECHNOLOGY DEVELOPMENT AND DEMONSTRATIONS

The technology development for the KBS-3 system focuses on issues needed in order to design, build and operate the system in a rational manner while satisfying the requirements on long-term safety, low radiation dose during operation of the facilities and a good external environment. The applications submitted for the KBS-3 repository and Clink presents a reference design (Figure 3) that satisfies the design premises for the KBS-3 system [1]. At the same time, a feasible way towards production and an inspection programme has been described. Continued technology development is now being done to proceed from the schematic solutions outlined in the applications to solutions that conform to an industrialized process with specific requirements on quality, cost and time.

In the short term, the goal of technology development is to ensure that the technology needed to begin construction of the Spent Fuel Repository and the encapsulation part of Clink is available prior to the start of construction. In the case of the Spent Fuel Repository, this mainly refers to investigation methods and technology for construction of the repository accesses.

The time-critical steps of the detailed design work for systems in the encapsulation part of Clink will begin during the coming RD&D period (6 years). Moreover, the detailed design will begin with the technical systems that need to be finished prior to detailed design of the disposal area in the Spent Fuel Repository, the bentonite production building and the production facilities for canister manufacturing. This development work is expected to take several years and therefore needs to be started early before the detailed design of the different facility parts can begin. Figure 4 provides an overview of how far technology development must have come when some of the most important milestones are reached in the remaining work of designing and building the facilities in the KBS-3 system. Figure 4 shows several future milestones that lie beyond the coming RD&D period, but are shown to provide a complete picture of technology development.

The development work requires extensive technical resources. SKB’s own laboratories – the Äspö Hard Rock Laboratory (HRL), the Canister Laboratory and the Bentonite Laboratory – are equipped for full-scale tests, demonstrations and dress rehearsals. Many development activities will be conducted at these facilities. In addition, certain tests can, in cooperation with Posiva, be conducted at Posiva’s hard rock facility Onkalo, situated in Olkiluoto in Finland. There are also underground laboratories and laboratories for metallurgical research available in Europe and other parts of the world. In addition, there are industrial facilities in many countries with access to the knowledge and resources needed to carry out development work for SKB.

**Fuel Handling**

The spent nuclear fuel consists of fuel assemblies from the twelve Swedish nuclear reactors (BWR and PWR). In addition, a small quantity of odd fuels and fuel residues from the early part of the Swedish nuclear power programme, as well as from research, will be disposed of. SKB’s programme for handling of fuel comprises several parts, from requirements on information on the properties of the fuel before it is used in the fuel cycle to devising a programme for safeguards.

During the coming RD&D period, development work will be carried out pertaining to determination of decay heat. SKB has since the middle of the 1990s followed the development of calculation programmes for decay heat in spent nuclear fuel and measured, by a calorimeter method, decay heat in individual fuel assemblies. SKB will continue to perform calorimetric measurements and participate in joint international efforts to refine present-day calculation models. SKB will also continue to develop the method of determining decay heat via high-resolution gamma (or gamma-ray) spectrometry. The method will be developed and complemented with neutron measurements to improve the results.

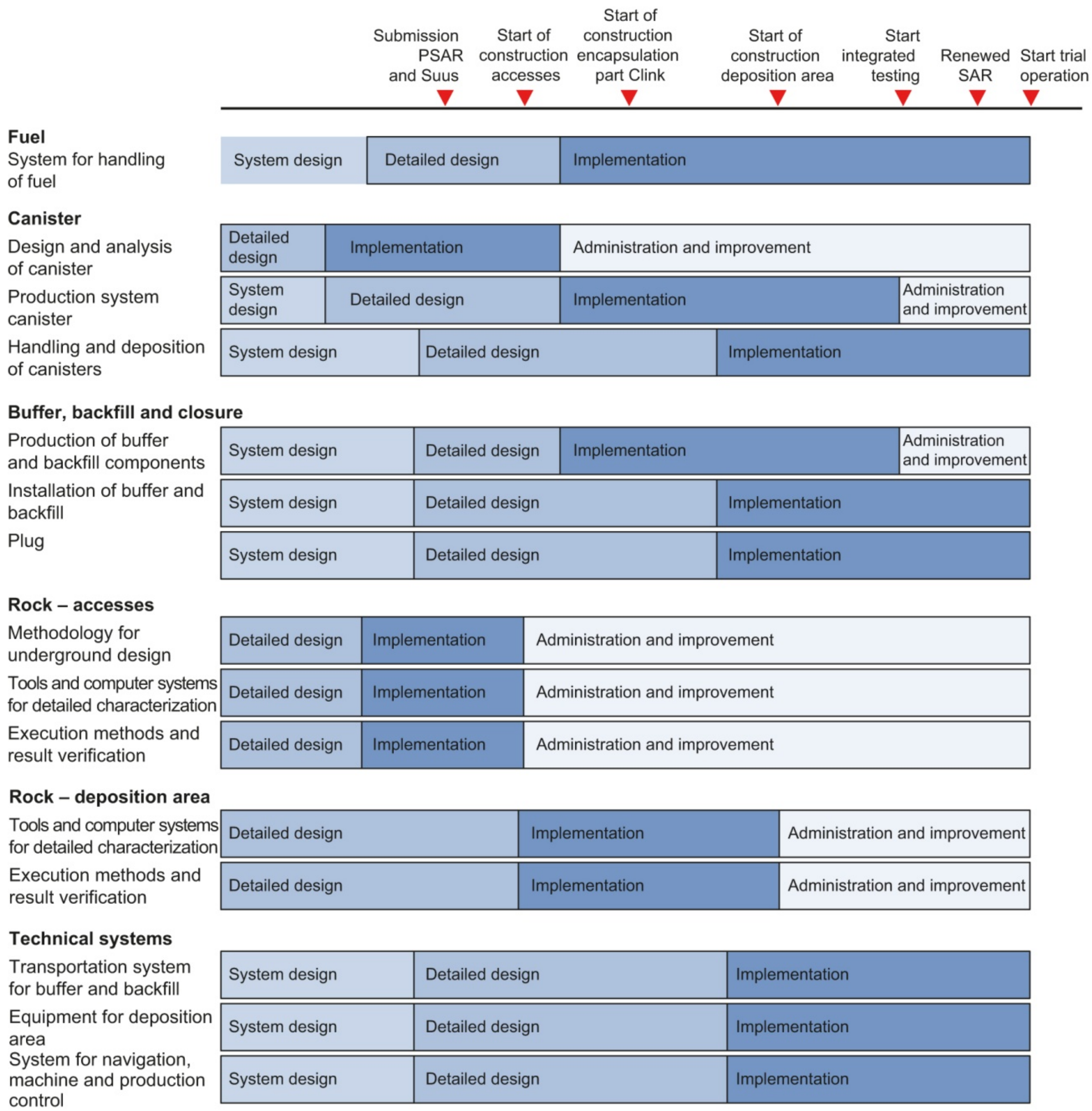


Fig. 4. Overview of how far technology development must have come when some of the most important milestones are reached in the remaining work of designing and building the different facilities in the KBS-3 system. Note that several of the future milestones lie beyond the coming RD&D period (which extends to the milestone Start of construction of accesses), but are shown here to provide a complete picture of technology development.

The overall goal of SKB's programme regarding deepened and broadened criticality analysis is that criticality analyses for all of SKB's present and future facilities should be done according to the same principles. This includes both methodology and calculation programs as well as the analysis itself. Development of the methodology and validation of calculation programs shall comply with modern internationally accepted standards and requirements.

Development of safeguards is an area where SKB works in close cooperation with international bodies.

## Canister Design and Fabrication

All spent fuel will be encapsulated in a copper canister before disposal (Figure 3). According to the reference design, the canister consists of a cylindrical container with a copper shell and a load-bearing nodular iron insert. Channel tubes of structural steel have been cast into the insert to hold the spent nuclear fuel. Two different designs of the insert have been developed where the size and number of the channels are adapted to receive fuel assemblies from pressurized-water or boiling-water reactors (PWR and BWR inserts). The odd fuels and fuel residues can be accommodated in any of these designs.

The development of the copper canister is now in the design phase, see Figure 4. SKB's work on mechanical analyses of the canister is based on FEM calculations and damage tolerance calculations. A large number of analyses and investigations for the insert are under way or planned, e.g. determination of acceptable defect depth, effects of radiation on fracture toughness, determination on requirements on the mechanical properties of the inserts. Concerning the copper shell the creep properties and effects of strains (plastic and creep) are in focus.

Reference methods have been selected for fabrication of the canister's components and welding of copper lids and bottoms. These methods enable canisters to be produced that conform to requirements on reproducibility and industrial production. SKB's production system for canisters consists of a number of external suppliers of the canister's various components. SKB intends to build a canister factory where the components are assembled and the properties of the canisters are inspected.

Work with insert fabrication by casting has been focused on getting the mechanical properties in the entire insert to conform to the stipulated requirements. Further development will focus on learning more about casting parameters and the material's microstructure, as well as the relationship between these factors and mechanical properties such as fracture toughness. Simulations of the casting process have been carried out as a complement to trial fabrication.

SKB has chosen extrusion as the reference method for fabrication of copper tubes. Extrusion is a robust method and fabricated tubes conform to the stipulated requirements. With the purpose to approve an alternative reference method, pierce and draw processing of copper tubes will be further developed. This method results in tubes with an integrated bottom. The lids and bottoms are forged, a method that gives cold deformation of the copper material. The forging process will be further developed and SKB plans to adopt heat treatment as a method to remove any cold deformation in the lids and bottoms of the copper tubes.

The copper lids and bottoms will be welded to the copper tube by friction stir welding (FSW). The latest three years of development at the Canister Laboratory has focused on fully automating the welding procedure. Control equipment keeps the welding tool temperature within an acceptable interval. The development programme includes investigations with the aim to reduce or eliminate the occurrence of defects in the welds, e.g. joint line hocking and oxides in the welds.

The technologies for non destructive testing (NDT) of the canister components and welds have been refined and adopted to the different geometries of the objects to be inspected. Ultrasonic testing is used for these inspections and arrays, used frequencies as well as the focusing of the sound and testing angles have been optimized. The past year's welds and fabricated copper components have been tested with eddy-current technology to acquire more knowledge of near-surface and surface-breaking defects. Further development of the technology for testing of the surfaces of the insert and ultrasonic testing of the bottom of the insert is planned. Studies will also be made of how the different testing methods (ultrasonic, radiographic and eddy-current testing) should be combined optimally in order to fulfil the detection goals of NDT.

**Technology Development of Buffer, Backfill and Closure**

When the licence applications were submitted in 2011, the development of buffer and backfill had passed the concept phase and reference designs for the bentonite buffer surrounding the canister in the deposition hole and the bentonite backfill including an arched plug in the deposition tunnel were presented. The reference design for the buffer consists of uniaxially compacted blocks and rings of bentonite clay where the gaps between the blocks and the deposition hole wall is filled with bentonite pellets. The deposition holes are backfilled with pre-compacted bentonite blocks surrounding the emplaced canister and bentonite pellets filling the gap between the bentonite blocks and the rock.

Detailed design for buffer, backfill and plugs will commence during the coming RD&D period. In parallel, already initiated studies of alternative designs of the buffer will continue. Furthermore, studies are planned to finalize the production system, with quality control, for the fabrication of buffer and backfill blocks and pellets. This includes the development of methods and design of the equipment for manufacturing and handling of the buffer and backfill blocks.

An industrial robot for installation of backfill blocks and pellets has been purchased and block stacking tests are being conducted in the Äspö HRL. A test where the robot will be used for installation of backfill blocks and pellets is planned for early 2014.The purpose of this trial is to ensure that the envisaged method for backfilling and inspection of the completed installation works as intended. Based on the trial, the reference design will be evaluated and modified, if necessary. At the end of the RD&D period, an integrated installation test will be performed of buffer and backfill.

A full-scale test of the complete system for plugging of deposition tunnels is being conducted in the Äspö HRL, at a depth of 450 metres. The experimental setup is included in a joint EU project called “Full Scale Demonstration of Plugs and Seals” (DOPAS). SKB’s goal of the continued development work is a finished system design for the plug before detailed design of the deposition area commences.

In 2001 and 2003 SKB installed a large scale test in the Äspö HRL, the Prototype Repository [2, 3]. The test consists of a total of six full-scale deposition holes with canisters and buffer in a deposition tunnel that has been backfilled with a mixture of bentonite and crushed rock. The overall goal of the Prototype Repository is to test and demonstrate the integrated function of subcomponents in a final repository, under realistic conditions and on a full scale. The plug in the outer section of the Prototype Repository was mined out at the end of 2010, and the backfill and the buffer and canisters in the two deposition holes were retrieved during 2011. The results of the field work and the laboratory programme for the outer section are now being compiled and evaluated preliminary conclusion is that the barriers have evolved more or less as expected.

**Rock**

Technology development for rock includes detailed characterization, design, construction and maintenance of the KBS-3 repository´s underground openings. The development work spans over a wide field and concerns methods for investigations and modelling. It also includes rock construction, including sealing and rock support measures, as well as development of special equipment with a focus on the rock conditions prevailing at the Forsmark site.

The related development activities are aimed at meeting the requirements on the repository's underground openings with respect to long-term safety, occupational safety and efficiency, as well as the current reference design. Specifications for execution of investigations, design and construction are being written to allow verification of requirements and documentation of the initial state of the rock. Detailed characterization is an integrated part of the design methodology and the construction process (rock excavation, sealing and rock support).

The Äspö HRL has been extended with new tunnels, which were finished in January 2013. This extension has made it possible for the first time to integrate detailed characterization, design including application of the Observational Method, and rock works where quality requirements on execution have been applied in production. The new tunnels permit testing of methods for detailed characterization. The test results will show how well the requirements made on tunnelling have managed to minimize the extent of the excavation disturbed zone (EDZ), especially in the floor.

The main tasks and goals of the technology development programme for rock include further development of the methodology for underground design and the application of the Observational Method. This programme mainly concerns strategies for detailed adaptation of deposition areas to varying host rock properties and coordination of detailed characterization with tunnel production.

The timetables for rock-related technology development differ somewhat from those for other technology developments. This is because essential parts of the rock-related technology must be ready for use at the start of construction. This applies to technology for investigations, design and construction of the accesses to the final repository, including shafts and ramp. The remaining technology must be ready to be put into operation as excavation of the central area and subsequent deposition areas at repository level progresses.

### Technical System

Several machines, vehicles and technical systems that will be used in the Spent Fuel Repository and Clink for handling and transport of canisters, buffer and backfill material, etc. are specific for SKB's activities and are not available on the open market. Technology development of SKB's specific systems proceeds incrementally and takes many years, which means it needs to start long before the equipment has to be in place. Prototypes are needed in some cases for verification and validation of the systems. Parts of today's technology development are therefore concerned with the development and design of prototypes. Examples of this are the prototype of the deposition machine that has been further developed and tested in the Äspö HRL and the robot that has been developed to install backfill blocks in the deposition tunnels.

## RESEARCH FOR ASSESSMENT OF LONG-TERM SAFETY

SKB's scientific research programme is being pursued with a view to the need to assess safety in connection with the final disposal of radioactive waste and spent nuclear fuel. The aims of the research are to:

1. find solutions to identified problems that affect safety at the final repositories or that reduce uncertainty in the assessment of the repositories' long-term safety,
2. follow scientific progress, in part to identify the consequences of new findings for SKB's activities, in part to benefit from new knowledge discovered by other organizations, and

3. maintain and develop the competence necessary to carry out assessment of long-term safety and inform regulatory authorities, reviewers and the public in a scientific manner.

The research covers both general issues that are shared by several repository systems and issues related to a specific repository system. The research that is conducted for the purpose of learning more about the long-term safety of the final repository for spent nuclear fuel has in recent years mainly been conducted within the framework of SKB´s latest safety assessment, SR-Site [1], underlying the application for a licence to build a final repository for spent nuclear fuel in Forsmark. The focus of this research is on processes that affect the engineered and natural barriers in the KBS-3 repository concept (Figure 3) or affect the consequences of a possible release of radionuclides. In SR-Site [1], SKB was showed that it is possible to build a final repository for spent nuclear fuel that meets SSM’s requirements on long-term, i.e., post-closure, safety and environmental protection.

The international peer review of the SR-Site (made by OECD/NEA on request from the Swedish Government to support the licensing review) identified a number of scientific issues that need further attention. The SKB research programme is continuing to address these issues and gain further knowledge and reduce remaining uncertainties (knowledge gaps). The greatest uncertainties concern corrosion of the copper canister and the long-term function of the bentonite clay. Knowledge of the host rock will increase as construction of the repository proceeds via observations and measurements that provide a more detailed picture of the variation of different properties in the rock, such as permeability, stresses and groundwater composition.

**Safety Assessment**

SKB’s safety assessment methodology has been developed over a long time, in parallel with the development of the KBS-3 system. The development needs during the coming RD&D period pertain to supplementary development of methods for sensitivity analyses and radionuclide transport, as well as further development of quality assurance of SKB’s safety assessments. In addition, preparedness exists to deal with any methodology-related viewpoints that may be expressed in conjunction with SSM’s ongoing review of the license applications.

**Climate Evolution**

In the time perspective in which safety is being studied for SKB’s different final repositories, i.e. hundreds of thousands of years, the climate in Scandinavia has varied enormously in the past. It has alternated between warm interglacial conditions similar to those we have today to periods with full ice age conditions. Even though the climate as such does not have a great direct impact on repository performance, other processes related to future climate variations might have great impact.

In the case of the Forsmark Spent Fuel Repository, attention is focused on processes that could affect the buffer and the canister up to a million years in the future. Future efforts will mainly be aimed at obtaining more information on historic thickness variations of the ice sheets. The purpose is to be able to set upper limits on how thick future ice sheets could become.

Other questions also have to do with what happens to the repository during an ice age and what the hydrogeological conditions look like beneath an ice sheet. To improve knowledge concerning these matters, SKB, together with Posiva of Finland and NWMO of Canada, has pursued a major research project on Greenland called the Greenland Analogue Project. The project, which has been going on since 2009 and is now in its final phase, has yielded valuable knowledge of benefit to several of SKB's research areas, in particular hydrogeology and hydrogeochemistry. This information is also useful when SKB looks at the behaviour of future inland ice sheets above a final repository.

Within the climate programme, SKB is also working with scenarios that describe future climates dominated by global warming in order to be able to assess what these climates would mean for the safety of the different repositories. The work includes aspects of both long- and short-term safety. The latter case includes gathering data on possible sea level increases as a basis for the geotechnical design and construction of the repository.

**Fuel**

Fuel dissolution is one of the important topics for SKB's continued fuel-related research. For example, research activities are planned to gather data on fuel dissolution under repository-like conditions and to shed light on the mechanisms of the different processes that contribute to fuel dissolution.

There are indications that high-burnup fuel contains a larger fraction of quickly released radionuclides, which has motivated further research into the properties of high-burnup fuels. Research is also being conducted to investigate new types of fuels, for example fuels to which chromium has been added to optimize the fuel's performance in the reactor. Investigations of these new fuel types are largely being undertaken in the form of joint international projects.

**Canister**

The copper canister is the engineered barrier that provides radionuclide containment in the KBS-3 repository. There are two factors that could cause breaches of containment for a canister; mechanical loads and copper corrosion. The central questions related to mechanical loads are how large isostatic loads the canister can withstand and how large shear movements in the rock surrounding the canister can be accepted without compromising the long-term integrity of the canister. The creep properties of copper are an important research area in that context.

Research initiatives in focus are on copper corrosion to investigate which processes can affect the canister. There are, for example, phenomena whose underlying processes need to be better understood. Experiments are in particular being conducted on copper in oxygen-free water where hydrogen gas is generated in quantities much greater than predicted by thermodynamic data.

At the same time, efforts to reduce uncertainties on processes that can affect the long-term durability of the canister are continuing. An example is research on sulphide corrosion, which in SR-Site was the corrosion process that made the greatest contribution to risk [1]. Stress corrosion cracking is another complex process on which further research is needed and being conducted.

**Buffer and Backfill**

In the KBS-3-repository design a protective buffer of bentonite clay surrounds the canister (Figure 3). The primary functions of the clay are to limit groundwater flow to the canister, and if a canister is breached, to retard the transport of radioactive particles out into the surrounding rock.

As long as the buffer is intact, there are no processes that could cause a breach in the canister. However, the buffer might under certain conditions dissolve and be carried out into fractures in the rock, a phenomenon known as buffer erosion. This could happen if large quantities of meltwater of low calcium content from an ice sheet penetrate down to the repository. The biggest research efforts therefore have to do with clarifying under what conditions the clay is stable, which is being done in an extensive experimental programme both in SKB's own projects and in large joint multi-national projects within the EU.

Efforts are also being made to develop a programme for clay characterization. Progress has been made here mainly based on results from an experiment in the Äspö HRL with alternative buffer materials. Progress has also been made in achieving a better understanding of the mechanisms behind changes in the clay, e.g. homogenization. In addition, new models have been developed to enhance simulation of this process in the clay, and development efforts in this area are continuing.

Bentonite clay will also be used to backfill the deposition tunnels in the KBS-3-repository design. The research being conducted on the buffer also covers the needs that arise in connection with the development work for the backfill.

**Geosphere**

The Pre-Cambrian basement bedrock is a stable environment where conditions change very little compared to what takes place on the ground surface. Based on the knowledge that the rock has been stable for millions of years, predictions can be confidently made regarding conditions in the rock for a long time to come. Research on the geosphere comprises four disciplines: geology, hydrogeology, hydrogeochemistry and transport properties of the rock. Future research in these disciplines will be aimed at broadening the knowledge base concerning rock conditions of great importance for the outcome of the safety assessments. SR-Site [1] clearly shows which properties and processes are of the greatest importance for the Forsmark Spent Fuel Repository. The aim is to obtain greater knowledge of how the properties vary in the rock volume and as a function of rock type. SKB also continually improves the modelling tools used to describe and predict the processes that take place in the rock over a very long time.

Research efforts in the discipline of geology will focus on:

- Gaining a better understanding of spalling caused by stresses in the rock and by high temperature;
- Methodology for identification of large fractures;
- Further studies of glacially induced faults; and
- Seismic measurements to support earthquake modelling and general knowledge accumulation regarding seismicity in Swedish bedrock.

Discrete fracture network models, which serve as a basis for analysis of rock movements and solute transport in fractures, is also a major field of research with a bearing on hydrogeology, geology and rock mechanics.

Data on the hydrogeology of surface systems is mainly being gathered in the investigations on Greenland. The goal is to be able to describe how the flow changes and varies during a period dominated by permafrost. The results are being used, for example, in the safety assessment for the extension of the Swedish operating repository for short-lived LLW and ILW (SFR) at Forsmark (Figure 1). Hydrogeological research on deep groundwater systems involves integrating data and models with other disciplines (geochemistry, rock mechanics and transport) and maintaining and improving the codes that are used for flow and transport calculations. Flow conditions during a glaciation with extensive permafrost have consequences for the situation at repository depth. Investigation data from the project on Greenland are being used both to understand the flow processes and optimize the modelling tools.

Research in the field of geochemistry continues to focus on reactions between water and rock and effects of movements of the water in the rock's fracture system. Efforts are being focused on models where geochemical conditions are integrated with hydrogeological conditions and the transport properties of the rock. Microbial processes are also an increasingly important topic. Examples are the importance of acetogens (acetate-generating microorganisms), the interaction between microbes and viruses in the rock, biofilms on fracture surfaces and microbial processes in the presence of hydrogen, methane and sulphide.

The programme examining how solutes are transported in groundwater includes studies of flow-related transport resistance, channelling (width and frequency of channels) and diffusion in stagnant zones. There are also plans to improve the radionuclide retention (Kd) concept for element-specific distribution coefficients where the hydrogeochemical conditions in fractures are taken into account. The related purpose is to be able to use the new knowledge in future safety assessments. International research is being pursued within the SKB Task Force for Groundwater Flow and Transport of Solutes. Modelling tasks are already being carried out by several groups from different organizations using data from experiments and investigations at the Äspö HRL or other hard rock laboratories.

## CONCLUSIONS

Even though a large number of issues may be considered resolved regarding the KBS-3-system there are still substantial technology development and demonstration efforts planned before disposal can begin and the facilities can be operated as an industrial enterprise. The existing prototype or conceptual designs of the canister, buffer and backfill components as well as the handling equipment need to be further refined into final designs which are approved (licensed) by the regulatory authorities and adapted to an industrialized process with stipulated requirements on quality, cost and time. A substantial part of this work will be undertaken at the SKB´s own research laboratories; the Äspö HRL, the Bentonite Laboratory, and the Canister Laboratory.

There are still a number of scientific issues that need further attention to strengthen the scientific basis on processes of importance for long term safety and to reduce uncertainties and facilitate better estimates of risk in future safety assessments. The issues will be addressed by the Programme during the coming years.

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