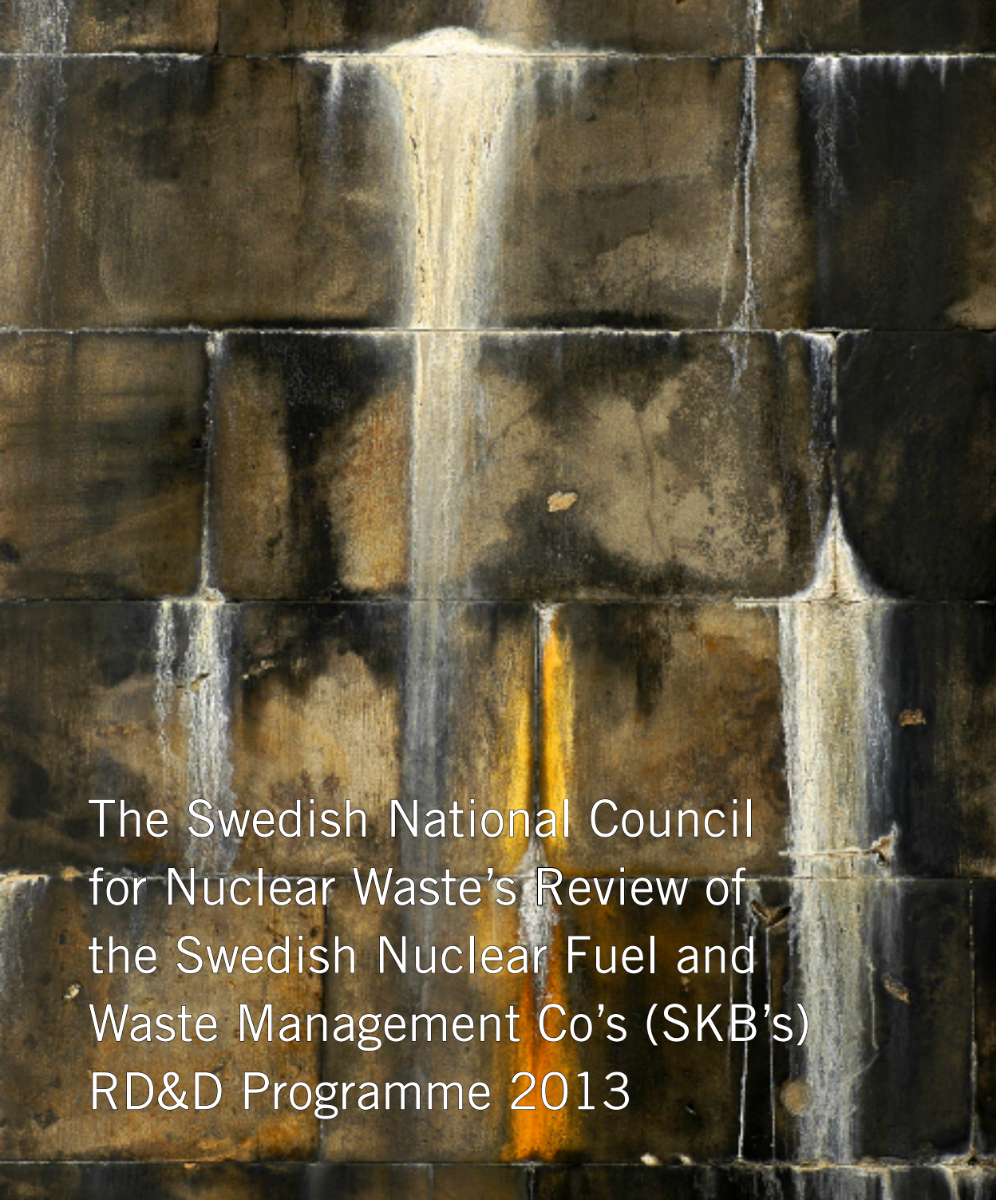

The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2013

KÄRNAVFALLSRÅDET
Swedish National Council for Nuclear Waste

SWEDISH GOVERNMENT INQUIRIES

SOU 2014:42

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The Swedish National Council for Nuclear Waste

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To the minister and head of the Ministry of the Environment

The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) programme for research, development and demonstration of methods for the management and disposal of nuclear waste.

According to the Government's terms of reference, the Swedish National Council for Nuclear Waste shall assess SKB's research, development and demonstration programmes (RD&D Programmes).[1] The present review contains the Council's assessment of RD&D Programme 2013. The review is based on the members' special areas of expertise.

All Members of the Council stand behind the Council's review: Hannu Hänninen and Ingvar Persson (experts), Holmfridur Bjarnadottir (Administrative Director), Anna Sanell (Administrative Director), Peter Andersson (secretary) and Johanna Swedin (assistant secretary).

Stockholm, June 2014

[1] M1992:A, Dir. 2009:31.

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1 Swedish National Council for Nuclear Waste's summary assessment

1.1 Premises for the Council's review

The Swedish National Council for Nuclear Waste has reviewed portions of Svensk Kärnbränslehantering AB's (SKB) research programme *RD&D Programme 2013. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste*, focusing on those areas in which the members of the Council possess special expertise. The review covers SKB's activities and plan of action, low- and intermediate-level waste, spent nuclear fuel, social science research and portions of the research for assessment of long-term safety.

Öivind Toverud from Bromma Geokonsult has administered the review work. The Council has engaged consultants to perform studies in geosphere and hydrology. These review reports can be downloaded at www.karnavfallsradet.se.

The Swedish National Council for Nuclear Waste can conclude after its review that SKB has, in its latest RD&D Programme, made considerable progress compared with previous years. For example, the Council appreciates the fact that more of SKB's research has been published in scientific journals. There are, however, areas which SKB should develop and improve in future RD&D Programmes.

In section 1.2 of the review, the Council presents the most important viewpoints with a brief explanation. More detailed accounts are given in later chapters. Section 1.3 contains a compilation of the Council's viewpoints, broken down by chapter.

1.2 The Council's most important viewpoints on SKB's RD&D Programme 2013

According to Section 12 of the Nuclear Activities Act, conditions may be imposed on the continued research and development activities. The Council proposes that the Government stipulate conditions requiring that future RD&D Programmes:

- provide more detailed references to the reported research results in the running text,
- present a research and development programme aimed at creating an organization that can transform a theoretically reasonably safe final repository for spent nuclear fuel into a built repository on the selected site that meets the safety assessment's requirements,
- report that a measurement programme is under development to monitor the water saturation of the buffer and other important processes in plugged parts of the repository,
- describe a joint programme for the research and development that is needed to support the decommissioning of the nuclear power reactors, including the Ågesta Nuclear Power Plant and other nuclear facilities adjacent to the reactors,
- present a new social science research programme closely linked to the technical-scientific research programme for the Spent Fuel Repository.

The Council's reasons

References in the text

In many cases, information is lacking about where the results of previous studies can be found. The RD&D Programme should contain a more detailed reference system with footnotes so that it is easier to check the original research results. Read more in sections 4.2 and 4.5.

Organization

The organization that will oversee construction of the final repository for spent nuclear fuel for roughly a century must be able to guarantee that the safety assessment's requirements are met always and everywhere in the repository. There must be no discrepancies between theory (the safety assessment) and practice (the built final repository), as this could have serious consequences for long-term safety.

A fuller description is needed of the organization that will ensure compliance with the building code (determined by the safety assessment) and thereby build a safe final repository. The project's long construction period and generational changes increases the risk that something will go wrong. It is therefore the Council's considered opinion that SKB must immediately start a research project on how the organization should be structured. Read more in Chapters 2, 4 and 5.

Measurement programme and methods

It is the Council's considered opinion that SKB has not offered sufficient reasons why a measurement programme is not needed for the Spent Fuel Repository. This is an issue that requires further discussion.

A measurement programme is important in several respects, not least to measure how the buffer is altered in the deposition holes. The buffer is a barrier that is safe only when it is water-saturated. The information that could be provided by a measurement programme could also be used to design future final repositories that may be built in Sweden or other parts of the world.

It is therefore still the Council's considered opinion that a monitoring system is needed to keep track of conditions in a few selected deposition holes with different degrees of water saturation. If SKB believes that such an expanded measurement programme is not needed, SKB must document the reasons for its position and keep this documentation continuously available to future decision-makers. Read more in sections 4.1.3 and 4.4.2.

Coordinated research on decommissioning and dismantling

SKB states in RD&D Programme 2013 that the reactor owners (Ringhals AB, OKG AB, Forsmarks Kraftgrupp AB and Barsebäck Kraft AB) have assigned SKB responsibility for the necessary research and development work and to otherwise help them to carry out future decommissioning activities. When it comes to the Ågesta nuclear power reactor, Vattenfall AB has, as the licensee, contracted AB SVAFO to preside over shutdown operation and to plan the decommissioning of the reactor. It is the Council's considered opinion that the RD&D Programme does not clearly explain how these parties are expected to cooperate. National coordination and a joint programme for research and development are needed to support the decommissioning of the nuclear power reactors, including the Ågesta NPP, and other nuclear facilities adjacent to the reactors. Read more in Chapter 3.

New social science research programme

Social science research is a fundamental part of the knowledge base in the nuclear waste issue. SKB is not opposed to carrying out occasional projects of this nature, but has no intention at present to initiate a new social science research programme. The Council questions SKB's arguments against starting future social science research programmes.

The Council proposes that SKB initiate a new social science research programme that should be closely linked to the technical-scientific research programme on final disposal of high-level spent nuclear fuel.

A future social science research programme should include research on:

- economic, political and social global changes that could affect the implementation of the final repository project,
- organization and safety culture,
- information preservation across generations.

Read more in Chapter 5.

1.3 Swedish National Council for Nuclear Waste's conclusions

The conclusions of the Swedish National Council for Nuclear Waste's review of SKB's RD&D Programme 2013 follow below. Detailed background and reasons for the viewpoints can be found in the relevant chapters of the review report.

The Council has not reviewed the following chapters in RD&D Programme 2013: chapters 5, 8, 10, 14–17, 19, 22–23 and 28.

1.3.1 SKB's activities and plan of action (the Council's review report Chapter 2)

In summary, the Swedish National Council for Nuclear Waste has the following viewpoints on RD&D Programme 2013, chapters 1–3.

Table summarizing chapters 1–3 (SKB's activities and plan of action) in RD&D 2013

Issue	Assessment
Continued RD&D work	It is the Council's considered opinion – that SKB should in future RD&D Programmes provide a more structured and focused account of the research and development work that needs to be carried out in order for the reactor owners to meet the requirements in the Nuclear Activities Act. Studies of alternative methods and courses of action should be pursued in parallel.
Facilities in the KBS-3 system	It is the Council's considered opinion – that the continued research and development work on the KBS-3 method should be reported in future RD&D Programmes, even after a licence has been issued for final disposal of spent nuclear fuel.
Financing	It is the Council's considered opinion – that SKB should in future RD&D Programmes present alternative strategies for fulfilling the reactor owners' obligations under the Nuclear Activities Act in the event that the assets in the Nuclear Waste Fund, including additional guarantees, should prove insufficient.
The plan of action	It is the Council's considered opinion – that SKB and the reactor owners should reconsider the assumptions made in RD&D Programme 2013 when it comes to the continued implementation of the nuclear waste programme.
Flexibility in the face of changed premises	It is the Council's considered opinion – that SKB should in future RD&D Programmes elaborate on its options for management, interim storage and final disposal of new types of nuclear fuel, the need for a possible extension of Clab and why recycling of the spent nuclear fuel is not a feasible alternative to direct disposal.

1.3.2 Short- and long-lived low- and intermediate-level waste (the Council's review report Chapter 3)

In summary, the Swedish National Council for Nuclear Waste has the following viewpoints on RD&D Programme 2013, chapters 4, 6–7, 9 and 20–21.

Table summarizing chapters 4 and 20 (SFR) in RD&D 2013

Issue SFR	Assessment
Design requirements	The Swedish National Council for Nuclear Waste proposes – that SKB should give a clearer account of how they intend to meet the requirements imposed on the design of SFR in view of the fact that the repository will also contain an appreciable quantity of long-lived radionuclides.
Experience feedback	It is the Council's considered opinion – that SKB should explain how they intend to systematically analyze and make use of experience from SFR 1 in the planning and construction of SFR 2. In particular, they should stipulate what improvements are needed in the design and how they intend to do this.
Research programme	It is the Council's considered opinion – that SKB should present a research programme for developing better methods for reconditioning and compaction to reduce the waste volume.

Table summarizing chapters 4, 6 and 21 (SFL) in RD&D 2013

Issue SFL	Assessment
Timetable	It is the Council's considered opinion – that SKB should in the next RD&D Programme present a clearer timetable for the different steps in the planning process.
Alternative timetables/ courses of action	It is the Council's considered opinion – that SKB should in the next RD&D Programme present a more detailed and clear account of the advantages and disadvantages of the different alternative courses of action for SFL, including stagewise commissioning.
Reconditioning	It is the Council's considered opinion – that SKB should in the next RD&D Programme present a more detailed account of what it would entail to recondition long-lived waste as well, as long as it is acceptable from a radiation protection viewpoint. What could this achieve? What are the risks?
Safety assessment	It is the Council's considered opinion – that SKB should in the next RD&D Programme give an account of how they intend to carry out the safety assessment for SFL.

Table summarizing Chapter 7 (Near-surface repositories) in RD&D 2013

Issue	Assessment
Waste volumes	It is the Council's considered opinion – that SKB should in future RD&D Programmes give an account of how the reactor owners can reduce the waste volumes for very low-level, short-lived waste before final disposal.

Table summarizing Chapter 9 (Responsibility, planning and technology for decommissioning of nuclear facilities) in RD&D 2013

Issue	Assessment
Joint RD&D Programme for decommissioning and dismantling	The Swedish National Council for Nuclear Waste proposes – that the reactor owners prepare a joint programme for the comprehensive research and development work and other measures needed to support the decommissioning of the nuclear facilities and present it in future RD&D Programmes. The programme should include the Ågesta NPP, – that SKB present a programme for research and development concerning the decommissioning of its own facilities.
Planning and obstacles for decommissioning and dismantling	It is the Council's considered opinion – that the reactor owners should review the timetables for their programmes for decommissioning, dismantling and demolition and give an account of possible obstacles that could affect the execution of the work, – that the causes of the delay in the decommissioning of the nuclear facilities in Barsebäck and Ågesta should be analyzed and presented in future RD&D Programmes.

1.3.3 Spent nuclear fuel and research for assessment of long-term safety (the Council's review report Chapter 4)

In summary, the Swedish National Council for Nuclear Waste has the following viewpoints on RD&D Programme 2013, chapters 11–13, 18 and 24–27.

Table summarizing Chapter 11 (Technology development, fuel handling) in RD&D 2013

Issue	Assessment
General text and references	It is the Council's considered opinion – that the text in Chapter 11 is couched in very general terms, which makes it difficult to judge the scientific quality and scope of the work, – that information is lacking in many cases about where the results of previous studies can be found.
Measurement programme for fuel	It is the Council's considered opinion – that many physical properties of the fuel have to be determined, but there is a lack of information regarding what measurements are planned and their specifications.

Table summarizing Chapter 18 (Safety assessment) in RD&D 2013

Issue	Assessment
Organization: Safety Assessment and Construction	The Swedish National Council for Nuclear Waste proposes – that SKB should start, as soon as possible, a research and development programme aimed at creating an organization that can transform a theoretically reasonably safe final repository into a built repository on the selected site that meets the safety assessment's requirements.
Measurement programme	The Swedish National Council for Nuclear Waste proposes – that SKB should develop a methodology (measurement programme) for monitoring the processes in plugged parts of the repository (see also below in the table summarizing chapters 13 and 25). If SKB believes that such an expanded measurement programme is not needed, SKB must document the reasons for its position and keep this documentation continuously available to future decision-makers.

Table summarizing chapters 12 and 24 (Canister) in RD&D 2013

Issue	Assessment
Technology development, canister	It is the Council's considered opinion – that SKB's continued research on design premises for the canister should be specified and designed so that their fulfillment can be verified by nondestructive testing methods or by industrial-scale tests and modelling, – that SKB should develop final testing methods and acceptance criteria for all parts of the canister that take into account material structure, material properties and defects. It must be possible to verify the quality requirements by nondestructive testing methods.
Canister processes	It is the Council's considered opinion – that SKB should develop a validated creep model with fundamental equations and implement models with the finite element method for a full-sized canister, – that SKB should intensify studies of the mechanism of stress corrosion cracking to understand how reliable the threshold values for stress corrosion cracking are, – that SKB should continue studies of the corrosion mechanism associated with gamma radiation.

Table summarizing chapters 13 and 25 (Buffer, backfill and closure) in RD&D-2013

Issue	Assessment
Measurement programme	The Swedish National Council for Nuclear Waste proposes – that methods for in situ monitoring of processes in the buffer should be developed, demonstrated and used in a few selected deposition holes during the operating period.
Continued research	It is the Council's considered opinion – that SKB's continued research on bentonite and backfill should pursued be at a more in-depth solution chemistry level.
Water saturation	It is the Council's considered opinion – that it is urgent that the process of water saturation of buffer and backfill be studied in the context of the conditions that are expected to prevail in a possible final repository in Forsmark.
Models	It is the Council's considered opinion – that adequate models for transport of radionuclides and corrosive substances from the groundwater through the buffer should be constructed.

Table summarizing Chapter 26 (Geosphere) in RD&D 2013

Issue	Assessment
General text	It is the Council's considered opinion – that SKB should present a clearer timetable for current and planned projects, as well as clearer reasons for initiated projects and how the results of these projects will be used in the safety assessment, – that source references in the text should be clearer.
Modelling	It is the Council's considered opinion – that reasons should be given for the choice of modelling tools for the integrated models, – that it should be clarified whether the cumulative effects of the thermo-hydro-mechanical processes will be modelled.
Rock mechanics	It is the Council's considered opinion – that proposals should be presented for technology and instrument development for characterization of the rock volume, – that the tunnelling method used for excavation of deposition tunnels should be considered

Table summarizing Chapter 27 (Surface ecosystems) in RD&D 2013

Issue	Assessment
Aquatic ecosystems	It is the Council's considered opinion – that SKB should carry out sensitivity and uncertainty analyses with regard to mechanistic ecosystem models for geochemical distribution of other substances besides carbon in the aquatic environment.
Hydrology and transport modelling	It is the Council's considered opinion – that a comparison of different modelling tools should be carried out when several alternative models are available and that the reasons should be given why one model has then be chosen as a basis for the reported conclusions.
System impact during construction of the final repository	It is the Council's considered opinion – that an evaluation is lacking of whether the construction of the final repository could affect the rock barrier and thereby alter the conditions for hydrology and transport, with consequences for the safety assessment.
The research programme for Surface Ecosystems	The Swedish National Council for Nuclear Waste would like – a summary assessment of how the research results obtained thus far influence the safety assessment as far as the rock barrier is concerned.

1.3.4 Social science research (the Council's review report Chapter 5)

In summary, the Swedish National Council for Nuclear Waste has the following viewpoints on RD&D Programme 2013, chapters 29 and 30.

Table summarizing chapters 29 and 30 (Social science research) in RD&D-2013

Issue	Assessment
Future SKB programme for social science research	The Swedish National Council for Nuclear Waste proposes – that SKB initiate a new social science research programme which, in contrast to the 2004–2010 programme, should be closely linked to the technical-scientific research programme and be aimed at facilitating decision-making in the final repository project.
Research on preservation of knowledge	It is the Council's considered opinion – that SKB should establish a systematic research programme based on identified needs for data collection methods and information preservation techniques and give an account of the quality assurance of the research projects, as well as an account of what the work plan for development of methods for information preservation looks like for 2016–2019.

2 SKB's activities and plan of action

2.1 Overall assessment of RD&D Programme – Management of radioactive waste and spent nuclear fuel

2.1.1 Introduction

In RD&D Programme 2013, SKB presents its plans for research, development and demonstration during the period 2014 to 2019. The programme is based on SKB's overall plan of action for low- and intermediate-level waste and for final disposal of the high-level waste from the Swedish nuclear power plants. This plan of action serves as a basis for SKB's plan for research, development and demonstration. In other words, the plan of action is of fundamental importance for understanding the different parts of the RD&D Programme and how SKB has chosen a direction for its research.

2.1.2 General about the continued research and development work

The account in RD&D Programme Part I provides a good summary of the reactor owners' and SKB's plans for the management of nuclear waste and spent nuclear fuel. The account in Part I is supplemented by chapters 4–8, where a detailed account is given of plans and strategies for final disposal of low- and intermediate-level waste. Chapter 9 presents the reactor owners' and SKB's plans for the decommissioning of the nuclear facilities and the development work that is being pursued within the

framework of these plans. Chapter 9 also describes the international development work that is being pursued in the area of decommissioning and technology for dismantling and demolition of nuclear facilities, which SKB is monitoring and participating in.

The long-term nature of nuclear waste management makes demands on more than just technical solutions. The operator should also have an organization designed and staffed to ensure safe and reliable operation of the activity and satisfy the requirement on effective countermeasures in an accident situation. The operator's organization must also guarantee that all contractors and clients observe the stipulated safety requirements.[1] Future issues with information preservation are also included in the reactor owners' long-term obligations and should be addressed in coming RD&D Programmes.[2]

According to the Nuclear Activities Act, the research programme shall be comprehensive and focused on the research and development that is needed to find a final solution to the problems surrounding safe management and final disposal of spent nuclear fuel and nuclear waste. However, certain sections of RD&D Programme 2013 are more focused on an account of planned activities and of when it may be necessary to build different facilities rather than on continued research and development work. This includes, for example, the sections dealing with decommissioning of nuclear facilities and the requirements on the mineral composition of the bentonite buffer.

The Swedish National Council for Nuclear Waste would in future RD&D Programmes like to see a more structured and focused account of the research and development work that needs to be carried out in order for the reactor owners to meet the requirements in the Nuclear Activities Act. Studies of alternative methods and courses of action should be pursued in parallel.

[1] Read more about the organization issue in section 4.1.2 of the review report.
[2] Read more about information preservation in section 5.3 of the review report.

2.1.3 Facilities in the KBS-3 system

In the current application for a licence to build and operate a final repository for spent nuclear fuel, the reactor owners, who are responsible for research and development, have finally committed themselves to the KBS-3 method. If the licence is granted by the Government, the reactor owners may be said to have fulfilled the Nuclear Activities Act's requirement on research and development to the extent that relates to final disposal of spent nuclear fuel within the framework of the current nuclear power programme.[3] After that there is no real legal support for requiring that the reactor owners shall, in future RD&D Programmes, give an account of continued research and development concerning final disposal of the nuclear fuel that has been generated.

SKB's repository licence application contains an extensive body of material indicating the need for supplementary research and development after the licence to build the final repository has been granted. This supplementary research and development may constitute one or more conditions in a stepwise licensing procedure for construction of the final repository. Continued research at the Äspö HRL will presumably be necessary.

Even though the continued research on the KBS-3 method will not formally be subject to sections 11 and 12 of the Nuclear Activities Act, it may be of great interest for concerned municipalities, interested members of the public, environmental organizations etc. to follow the work. It is therefore the Council's considered opinion that the continued research and development work on the KBS-3 method should be reported in future RD&D Programmes, even after a licence has been issued for final disposal of spent nuclear fuel.

2.1.4 Financing of the waste programme

A prerequisite for implementing all measures included in the RD&D Programme is that the allotted financial resources are sufficient. A reliable financing of the final repository is presumably of great importance for acceptance of the project in the concerned

[3] Cf. Secs. 11 and 12 in the Act (1984:3) on Nuclear Activities.

municipalities. The Swedish Radiation Safety Authority has been instructed by the Government to review the Financing Act and the Financing Ordinance. This assignment is being carried out in consultation with the National Debt Office and the Nuclear Waste Fund. A report was submitted to the Government in June 2013.[4] According to the report, the initial analyses reveal a deficit in the balance sheet for the nuclear waste system, due among other things to falling market rates. The Authority notes in the report that further analyses are needed, along with a comprehensive overview of the financing system with regard to decisions concerning fund management, fees and guarantees.

It is the Council's considered opinion that that future RD&D Programmes should present alternative strategies for fulfilling the reactor owners' obligations under the Nuclear Activities Act in the event that the assets in the Nuclear Waste Fund, including additional guarantees, should prove insufficient.

2.1.5 Plan of action for further implementation

The RD&D Programme bases its plans for continued management and final disposal of the spent nuclear fuel and the nuclear waste on the planned operating times stipulated by the reactor owners for their reactors. This is of course reasonable for the planning of the facilities for interim storage and final disposal that will be built or extended.

However, the Swedish National Council for Nuclear Waste notes that the timetables presented by SKB in RD&D Programme 2013 contain several "bottlenecks" that do not allow for any delays in the different projects. This includes both the main timetable and the plan of action for low- and intermediate-level waste. SKB is aware of the narrow timeframes and hints at some alternative solutions if the timetable cannot be kept. These include different ideas about extension of Clab or dry interim storage. These

[4] SSM(2013), *Förändringar i lagen (2006:647) om finansiella åtgärder för hanteringen av restprodukter från kärnteknisk verksamhet och förordningen (2008:715) om finansiella åtgärder för hanteringen av restprodukter från kärnteknisk verksamhet* ("Changes in the Act (2006:647) on Financial Measures for the Management of Residual Products from Nuclear Activities and the Ordinance (2008:715) on Financial Measures for the Management of Residual Products from Nuclear Activities", in Swedish). (Dnr: SSM2011-4690).

questions may be decisive in determining whether the waste programme can be executed within the financial framework assumed for the nuclear waste project. Ultimately, it is not really SKB but the reactor owners who bear financial responsibility for the execution of the nuclear waste programme.

According to the timetable, the final repository for long-lived low- and intermediate-level waste (SFL) lies far ahead in time. The Swedish National Council for Nuclear Waste would like to stress that SKB should act promptly to formulate acceptance criteria for the nuclear waste to be disposed of in SFL, so that the reactor owners can condition the waste in an appropriate manner.

Options for disposal of very low-level nuclear waste should be presented promptly, since the questions is of great importance for the choice of strategies for management and disposal the reactor owners should make regarding this type of waste.

The Swedish National Council for Nuclear Waste proposes that SKB and the reactor owners should reconsider the assumptions made in RD&D Programme 2013 when it comes to the continued implementation of the nuclear waste programme.

2.1.6 Flexibility in the face of changed premises

Chapter 3 of RD&D Programme 2013 describes the flexibility of the waste programme in the face of changed premises. The current time horizon according to the RD&D Programme is about 70 years.

The Swedish National Council for Nuclear Waste concurs that given the long time horizon, changes can occur in the planning premises, and that there may be revaluations of the assumptions made today. Under the provisions of the Nuclear Activities Act concerning periodical reviews of the reactor owners' and SKB's research and development programme, the rules are designed to handle changed premises.

Some matters should be given special attention. An example is the possibility that new nuclear power reactors may be built. Special consideration may be required when it comes to management, interim storage and final disposal of new types of nuclear fuel. This is particularly true when it comes to the need for

an extension of Clab with an additional rock cavern, or the need to store the fuel dry in special packagings.

Another question concerns new technology associated with future reactors of the fourth generation. The RD&D Programme briefly mentions the development of fourth-generation fast reactors that is currently being pursued in different parts of the world. It is claimed that these reactors have the potential to utilize uranium much more efficiently (50–100 times) than light water reactors. A great deal of development work remains to be done. SKB's assessment is therefore that the development of fast reactors does not affect the work with the spent fuel management.

The Swedish National Council for Nuclear Waste makes a different assessment than SKB, without in any way taking a position for another method than the one stipulated by SKB. New technology for management of spent nuclear fuel reduces the volume of high-level nuclear waste and its radiotoxicity and enables the components of the nuclear waste to be handled separately and to be destroyed or stored. Further, the remaining radioactive waste will decay much faster in the final repository than spent nuclear fuel that is directly disposed of. The final repository could also be designed differently.

One aspect that the Council believes should be considered is whether our generation may actually have an obligation to make it possible for future generations to utilize the residual energy present in the nuclear waste, if such a need should arise in the future. Future generations, who have not benefited from the energy extracted in nuclear reactors, may be forced to decide whether it is compatible with the protection of human health and the environment to dispose of large quantities of plutonium in the repository.

It is the Council's considered opinion that SKB should in future RD&D Programmes elaborate on why recycling of the spent nuclear fuel is not a feasible alternative to direct disposal. A point of departure for this could be Hans Forsström's (SKB International AB) report on fast reactors and how they affect the Swedish system for management of spent nuclear fuel.[5]

[5] Forsström, Hans (2013), *Utveckling av snabba reaktorer. Påverkan på det svenska systemet för hantering av använt bränsle* ("Development of fast reactors. Impact on the Swedish system for management of spent fuel", in Swedish). SKB P-13-33.

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Swedish Radiation Safety Authority, (2013) *Förändringar i lagen (2006:647) om finansiella åtgärder för hanteringen av restprodukter från kärnteknisk verksamhet och förordningen (2008:715) om finansiella åtgärder för hanteringen av restprodukter från kärnteknisk verksamhet* ("Changes in the Act (2006:647) on Financial Measures for the Management of Residual Products from Nuclear Activities and the Ordinance (2008:715) on Financial Measures for the Management of Residual Products from Nuclear Activities", in Swedish). (Dnr: SSM2011-4690).

Act (1984:3) on Nuclear Activities. Ministry of the Environment.

3 Short- and long-lived low- and intermediate-level waste

3.1 Management of low- and intermediate-level waste

3.1.1 Introduction

Low- and intermediate-level waste from the nuclear power reactors is generated by leakage from the fuel and from radionuclides that are formed when neutrons (emitted in the fuel) irradiate material near the core. Part II of RD&D Programme 2013 describes plans for the future management and disposal of low- and intermediate-level waste (LILW). In practice, it could be said that all radioactive waste aside from the spent nuclear fuel itself is classified as low- and intermediate-level waste in SKB's terminology.

3.1.2 Background

The programme for low- and intermediate-level waste (previously also called the LILW programme) describes how the radioactive waste that is not spent nuclear fuel is to be managed. During reactor operation, radionuclides are induced near the core by neutron irradiation, and small quantities of activity can leak out via the cooling water. The programme for low- and intermediate-level waste radioactive waste also includes radioactive waste deriving from the use of radioactive substances in research and medical care, as well as from other industrial activities. Waste from other activities than the nuclear power plants is initially collected by SVAFO and is treated and stored temporarily on the Studsvik site. All radioactive waste that is not spent nuclear fuel is classified as

low- and intermediate-level and will – regardless of origin and if it cannot be cleared from regulatory control – be disposed of in SFR, SFL or a near-surface repository. The control rods from PWRs that are integrated in the fuel comprise an exception, since they are deposited together with the fuel. An important part of the programme for low- and intermediate-level waste is planning for decommissioning and dismantling of nuclear facilities, as well as cleanup and clearance of former nuclear power plant sites.

In the RD&D Programmes since 2007, SKB has presented plans for the design of the envisioned repositories and for the management of low- and intermediate-level waste. In its review of RD&D Programme 2010, the Swedish National Council for Nuclear Waste presented its detailed viewpoints on the account of the design of the LILW programme that was presented there.[1] Overall, the Council finds that RD&D Programme 2013 is substantially improved compared with previous Programmes, but only about half of the viewpoints expressed by the Council regarding RD&D Programme 2010 have been addressed.

As one of the most important aspects of its comments on the last RD&D Programme, the Council called for a better account and analysis of the consequences of a delay of the extension of SFR. The Council also wondered how SKB will manage the low- and intermediate-level waste after 2023 if the planned expansion of SFR is not finished by then. Furthermore, the Council called for an alternative timetable if this should turn out to be the case. The plan of action that is now presented in Chapter 2 of RD&D Programme 2013 includes the timetable for the project for low- and intermediate-level waste. The Council finds that this timetable is tight and that unforeseen events could have consequences in the form of delays. Chapter 3.2 of the RD&D Programme poses the question of what the consequences will be if the extension of SFR is delayed. This would affect the planned interim storage of the decommissioning waste. Some possible alternative solutions are hinted at, but it is the Council's considered opinion that such solutions should be analyzed and described in greater detail. However, SKB has pointed out that they do not believe that delays

[1] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010.*

in the extension of SFR would have any negative consequences from a radiation protection viewpoint. The Council finds no reason to question this conclusion, but believes that there is a risk that the disturbance entailed by such a delay could indirectly, in one way or another, have a negative impact on safety, including radiation safety. Different categories of radioactive waste with varying half-lives have to be interim-stored somewhere else if SFR 1 becomes full.

Furthermore, a systematic analysis of waste transport between different interim storage facilities is called for. There will in particular be a great need for such transport when waste has to be moved from SFR to SFL. This will be a factor which SKB needs to take into consideration when selecting a site for SFL. One consequence may be that Forsmark is given preference for this reason. It is then important that this does not entail safety risks or other types of disadvantages from a radiation protection viewpoint. SKB should therefore carefully analyze and report the transport need, based on a strategy for where final disposal will take place. Among other things, an account is needed of the volume of waste that will need to be moved from SFR when SFL is finished.

Another question asked by the Council in connection with its review of RD&D Programme 2010 concerned the Decommissioning Group's role, composition and working methods. SKB has noted this viewpoint, but has not explicitly responded. RD&D Programme 2013 refers to the Decommissioning Group as a: "Liaison group for decommissioning issues relating to nuclear facilities established on SKB's initiative." This liaison group includes the different licensees. The Council notes that the question from 2010 remains unanswered.

SKB is planning different types of repositories, adapted to different categories of waste. Operational waste and decommissioning waste containing mainly short-lived radionuclides will be disposed of in SFR. The long-lived low- and intermediate-level waste will be disposed of in SFL. This repository will mainly contain core components. However, according to SKB, this repository will not be ready for operation for another 30–50 years. In the meantime, the fractions that will be disposed of in SFL will be interim-stored in SFR.

SKB is also studying the need for a centrally located near-surface repository for very low-level waste. This type of repository exists today for temporary storage at the nuclear power plants in Oskarshamn, Forsmark and Ringhals.

3.1.3 Final repository for short-lived radioactive waste, SFR

The first part of the final repository for short-lived low- and intermediate-level radioactive waste has been in operation since 1988 and is situated about 60 metres beneath the seabed near the Forsmark Nuclear Power Plant. This repository consists of four types of rock caverns, with different requirements on maximum dose rate for:

- silo
- rock vault for intermediate-level waste
- rock vault for concrete tanks
- rock vault for low-level waste

Since the capacity of this repository is not sufficient for future needs, an extension is needed. SKB intends to submit an application for this during 2014.

In RD&D Programme 2013, SKB does not specify which reference inventory or which radionuclide composition they intend to place in the different repositories for low- and intermediate-level waste. In a subsequently published SKB report entitled Låg- och medelaktivt avfall i SFR ("Low- and intermediate-level waste in SFR," in Swedish), published in December 2013, a radionuclide reference inventory is presented.[2] In actuality, the division between SFR and SFL appears to be based on quite other criteria than the half-lives of the radionuclides to be disposed of. Even though it is said that SFR is intended for short-lived low- and intermediate-level waste, a number of long-lived activation and fission products as well as actinides are discussed in the chapters in question (including Chapter 20). This is also clear from the report.[3]

Even though the proportion of long-lived radionuclides in SFR is small, the Swedish National Council for Nuclear Waste would like SKB to clarify how they intend to handle this and to what extent it will influence the design of SFR 2. It is problematic to

[2] SKB (2013), *Låg- och medelaktivt avfall i SFR. Referensinventarium för avfall 2013* ("Low- and intermediate-level waste in SFR. Reference inventory for waste 2013", in Swedish). SKB R-13-37.
[3] SKB (2013), *Låg- och medelaktivt avfall i SFR. Referensinventarium för avfall 2013* ("Low- and intermediate-level waste in SFR. Reference inventory for waste 2013", in Swedish).

assess design, safety assessment etc. based on the account in RD&D Programme 2013.

SKB plans to commission the extension to SFR in 2023. The capacity of this repository will be considerably greater than that of SFR 1. The extension is intended to be located adjacent to SFR 1. The Council considers it urgent that SKB should specify in the planning and design of the repository extension how they intend to make use of the experience from SFR 1, which has now been in operation for more than 25 years.

An account is given in Chapter 20 of a large number of issues on which research is currently being conducted. However, the account is more of a list of problems than a research programme. The purpose of these projects is to gather sufficient information as a basis for a safety assessment. Research on the concrete barrier is also reported by SKB.

It can in particular be noted that research is being conducted on carbon-14. This radionuclide demands special attention, since it can be incorporated in organic compounds. The Council therefore notes with satisfaction that SKB has recognized this and is participating in joint international efforts aimed at gaining a better understanding of carbon-14 in geological repositories.

There is also a great need to reduce the waste volume. However, no research programme aimed at developing better methods for reconditioning, compaction and possible recycling in order to reduce waste volumes is presented in RD&D Programme 2013.

3.1.4 Final repository for long-lived waste, SFL

SFL is intended for long-lived low- and intermediate-level waste. The contents of this repository are planned to consist mainly of core components plus reactor pressure vessels (RPVs) and control rods from BWRs. Furthermore, some of the waste that is now being stored at Studsvik will be disposed of there, along with long-lived waste from current and future Swedish research activities. The design and siting of this repository have not yet been decided. But SKB is currently assuming that SFL will be a geological repository containing concrete, gravel and bentonite as engineered barriers.

Core components that arise as decommissioning waste will be interim-stored in Clab or in the nuclear power plants' own pools until SFL is commissioned. The capacity available for this interim storage is judged to be sufficient with good margin. SKB makes the assessment that the total available volume exceeds the planned disposal volume. Long-lived waste can also be interim-stored in the extended SFR.

SFL is the last repository that will be commissioned. The previous planning gave 2045 as a target year for this. In connection with its review of RD&D Programme 2010, the Council requested that SKB should promptly investigate the possibilities of moving the start of operation of SFL forward. However, no such investigation was done, and in RD&D Programme 2013 SKB says that "commissioning in 2045 is an ambitious but not unreasonable goal." At the same time, an alternative plan is presented where SFL will not be commissioned until 2065. The steps that are to carried out in the process for establishment of SFL include:

- technology development
- evaluation of long-term safety (planned for 2016)
- site selection
- safety assessment
- application
- design
- construction and commissioning

SKB believes that these steps need to be carried out in a logical sequence. The alternative with commissioning 20 years later would, according to SKB, result in a shorter operating time of 10 years instead of 30 years. This could be an advantage in certain respects, but there are also disadvantages. A crucial factor in determining the timetable is when the need to dispose of the core components will arise. A reconditioning of parts of these components prior to disposal to permit clearance and possibly recycling of the material may require some time for an initially excessively high activity content to decay first, provided the half-lives of the radionuclides permit this within a reasonable time. This would enable the

material to be treated without causing unacceptable radiation doses to the personnel. A decay period of perhaps 50 years will entail a postponement by an equivalent length of time of the need for space in the repository for disposal of the material. The Council considers it urgent that SKB, in its planning of the realization of SFL, should also perform a thorough analysis of the possibilities of reconditioning, which also reduces the waste volume.

An alternative discussed in the RD&D Programme is "stagewise commissioning". The disposal vaults would be planned and built as the need for them arises. An initial stage could be commissioned on a small scale in 2045.

SKB mentions the safety assessment in RD&D Programme 2013, but does not explain how they intend to work with it. It is important that all aspects are included and that SKB describes, at a relatively early stage, how they intend to carry out the assessment. It is therefore the Council's considered opinion that SKB should in future RD&D Programmes give an account of how they intend to carry out the safety assessment for SFL.

3.1.5 Near-surface repositories

During 2013, SKB started a near-surface repository project. The purpose is to gather material as a basis for a decision as to whether a near-surface repository can serve as an environmentally satisfactory, radiologically safe and cost-effective alternative for disposal of portions of the waste from dismantling and demolition, and whether conventional waste facilities can in any way be used. If near-surface repository proves to be an advantageous disposal alternative, a decision must be made whether SKB should operate a central near-surface repository or whether the near-surface repositories that exist locally today at the nuclear power plants should be extended and used.

The Swedish National Council for Nuclear Waste would like to point out that the requirement on comprehensive research and development activities also applies to low-level- and short-lived waste. The RD&D Programme does not indicate that any such activities exist. It is urgent to take advantage of the options to reduce the waste volume as much as possible before disposal of the

waste. The near-surface repositories should be designed for minimal environmental impact. Short-term financial advantages must not outweigh the long-term advantages of volume reduction.

The Swedish National Council for Nuclear Waste proposes that future RD&D Programmes explore the options for reducing the waste volumes of low-level- and short-lived waste prior to disposal.

3.1.6 Responsibility, planning and technology for decommissioning

In Chapter 9 of RD&D Programme 2013, SKB gives a general account of the division of responsibilities between the reactor owners and SKB when it comes to decommissioning of the reactor owners' nuclear facilities, as well as the relevant law in this context.

According to SKB the reactor owners (Ringhals AB, OKG AB, Forsmarks Kraftgrupp AB and Barsebäck Kraft AB) have delegated responsibility to SKB to conduct the necessary research and development work and to otherwise help them in various ways to carry out future decommissioning activities. When it comes to the Ågesta nuclear power reactor, Vattenfall AB has, as the licensee, contracted AB SVAFO to preside over shutdown operation and to plan the decommissioning of the reactor.

SKB contends that a national coordination of decommissioning-related matters is needed between the different facilities. Although efforts are being pursued in a joint task group between the reactor owners and SKB that is focusing on technology and logistics and discussing choices of technical solutions, SKB believes that further coordination is needed to ensure an optimization of the system.

The Swedish National Council for Nuclear Waste finds that RD&D Programme 2013 does not make it clear how cooperation between SKB and the reactor owners is to be conducted. No specific joint research and development work by the reactor owners on decommissioning and dismantling is presented. The reactor owners' plans and strategies for decommissioning and dismantling of the nuclear power plants and the Ågesta combined heat and power plant, as well as SKB's plans for siting and establishing a final repository for long-lived waste (SFL), are briefly described. Clearance of land from regulatory control is

presented as a challenge, but the account is brief when it comes to how methods could be developed.

When it comes to the work of decommissioning and dismantling of the nuclear facilities, one problem is a lack of more concrete plans regarding siting and establishment of a final repository for long-lived waste (SFL). According to SKB, the first part of the site selection process will commence during the coming RD&D period. The site investigation phase is not expected to begin until around 2021 and will last between five and seven years. Nor does SKB present any specific research and development in preparation for the decommissioning of their own facilities. All that is presented is a new decommissioning plan for Clink.

The individual plans described by the different reactor owners are very ambitious. The plans are far-sighted when it comes to preparations so that decommissioning, dismantling and demolition can be commenced within a reasonably short period after a reactor has been permanently taken out of service. They are therefore sensitive to various kinds of changes in the already tight main timetable and the plan of action for low- and intermediate-level waste.

According to the Swedish National Council for Nuclear Waste, the reactor owners' timetables are based on assumptions that could very well change. The Council would like to stress that besides practical obstacles, there are also administrative obstacles that should be taken into account. Decommissioning of nuclear power reactors or other nuclear reactors requires a permit under the Environmental Code from the time when the reactor has been taken out of service and after defuelling operation, shutdown operation and decommissioning until all nuclear fuel and other radioactivity contaminated material has been permanently removed from the site.[4]

Before dismantling and demolition begin, the facility's safety analysis report must be revised.[5] Furthermore, an account in accordance with Article 37 of the Euratom Treaty is required, approved by the European Commission. These reports and approvals

[4] Cf. Chap. 22 Sec. 1 of Miljöprövningsförordning (2013:251) (Environmental Impact Assessment Ordinance).
[5] Cf. Chap. 9 Sec. 7 of SSMFS 2008:1.

require extensive accounts of, for example, the activity content in the facility after the reactor has been permanently taken out of service.

In the opinion of the Council, the reactor owners should provide a detailed account of what obstacles might affect the execution of the decommissioning work. The causes of the delayed decommissioning of Barsebäck and Ågesta should also be analyzed.

In view of the factors described above, the Swedish National Council for Nuclear Waste finds that the reactor owners have not fully complied with the requirements of the Nuclear Activities Act when it comes to responsibility, planning and technology for decommissioning of the nuclear facilities. It is the reactor owners who bear responsibility for conducting the comprehensive research and development work that is needed to meet what is stipulated regarding their responsibility for decommissioning and dismantling.[6] The reactor owners, in consultation with the other reactor owners, are also obligated to prepare, or have prepared, a programme for the comprehensive research and development work and other measures.[7] It is not clear whether Vattenfall AB or their contractor, AB SVAFO, have participated in the task group for decommissioning matters that has been established between the other reactor owners.

The Swedish National Council for Nuclear Waste shares SKB's opinion that further coordination is required to ensure an optimization of the system.

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SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010*. Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

[6] Cf. Sec. 11 of the Act (1984:3) on Nuclear Activities.
[7] Cf. Sec. 12 of the Act (1984:3) on Nuclear Activities.

Act (1984:3) on Nuclear Activities. Ministry of the Environment.

Miljöprövningsförordning (2013:251) ("Environmental Impact Assessment Ordinance"). Ministry of the Environment.

The Swedish Radiation Safety Authority's Regulations concerning Safety in Nuclear Facilities (SSMFS 2008:1).

4 Spent nuclear fuel and research for assessment of long-term safety

4.1 Safety assessment

4.1.1 Introduction: the roles of the safety assessment

In RD&D Programme 2013, SKB regards the Safety Assessment as a methodology for assessing the long-term safety of an envisioned theoretical final repository on the proposed site in Forsmark. Nowhere in RD&D Programme 2013 is there any discussion of the role of the Safety Assessment in the century-long process of putting a reasonably safe final repository in place in Forsmark. This process must guarantee a functioning interaction between Safety Assessment and Construction so that the Safety Assessment's requirements are met always and everywhere in the Spent Fuel Repository. It is the Council's considered opinion that this imposes very onerous and unique demands on the project organization and institutions surrounding the project organization. The Council finds that it is urgent to commence an analysis of interaction and organization and that the total lack of insight regarding the necessity of such an analysis in RD&D Programme 2013 arouses justified doubt as to the will and capability of the nuclear power industry to build a Spent Fuel Repository that meets all the requirements of the Safety Assessment.

The Swedish National Council for Nuclear Waste has – in its reviews of RD&D Programme 2007 and RD&D Programme 2010 and in its Nuclear Waste State-of-the-Art Report 2012 – discussed the different roles of the Safety Assessment and underscored the

importance of clarifying these roles.[1,2,3] The Safety Assessment's methodology has been developed over several decades. Both SSM's predecessors and SKB have, by international standards, made considerable contributions to this methodology development, and stakeholders can feel some confidence in the results of the Safety Assessment. Faced with the prospect of a realization of the Spent Fuel Repository and an extension of SFR, the Council found it important to clarify how the Safety Assessment should guarantee the construction of safe repositories. The shortcomings of RD&D Programme 2013 are particularly remarkable in the light of the aforementioned discussion of interaction between Safety Assessment and Construction which SKB initiated in RD&D Programme 2010. In this programme, SKB divided the activities during construction and commissioning" into two iterative main processes: Safety Assessment and Construction. In its review the Council found this subdivision reasonable and drew the conclusion:

> that the relationship between the two main processes is of fundamental importance. The Council finds that research and development to understand and handle this relationship is extremely important and should be highlighted as an important part of the RD&D Programme. In preparation for a positive decision on SKB's application, a research project aimed at this relationship should be initiated as soon as possible.[4]

The need to handle the relationship between the two main processes puts the focus on the project organization, and the Council underscores:

> the need for systematic studies of what the organization should look like in order to guarantee compliance with the building code and achievement of the initial state under the special conditions that prevail for the construction of a final repository. The Council believes that such studies should commence as soon as possible so that the

[1] SOU 2008:70 *Final Disposal of Nuclear Waste – The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2007.*
[2] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010.*
[3] SOU 2012:7 *Nuclear Waste State-of-the-Art Report 2012 – long-term safety, accidents and global survey.*
[4] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010*, p. 70.

> knowledge is available prior to a decision on the permissibility of a KBS-3 repository in Forsmark.[5]

The development of both design premises and a measurement programme are assigned to the Safety Assessment's new role. The design premises operationalize the System Analysis, i.e. they clarify what measurable requirements should be defined for a final repository. The measurement programme should enable the Safety Assessment to check that the repository is being developed towards the goal of a reasonably safe final repository.

Regarding the design premises, SKB has accepted the Council's viewpoints in the matter of verifiability but has not yet delivered a full set that fulfils this requirement. The Council finds that further discussions of the design premises can be held before the Land and Environment Court.

Regarding a measurement programme, the Council stated in its review of RD&D Programme 2010 that:

> SKB must develop a measurement programme that makes it possible to follow changes that occur in the conditions in the buffer, deposition holes and deposition tunnels as the tunnels are sealed.[6]

This requirement is not commented on at all in RD&D Programme 2013. The Council stands by its requirement for a measurement programme to monitor the situation in plugged parts of the repository, but with the added proviso that if SKB considers such a programme to be unnecessary, SKB must document the reasons for its position. If there is no measurement programme, such a document is an important reference for future decisions on closure of the repository.

The need for organization analysis and a measurement programme is discussed in greater detail in the following.

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[5] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010*, p. 73.
[6] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010*, p. 71.

4.1.2 Organization and relationship between the two main processes

Organization, requirements management and the two main processes are discussed in general terms in RD&D Programme 2010.[7] A discussion of the relationship between the main processes was also initiated in the section "Work methodology during construction and commissioning".[8]

An overall discussion concerning organization and the relationships between:

Safety Assessment -> Design Premises -> Initial State is also held in the main appendix SR to SKB's application to SSM and the Land and Environment Court,[9] as well as in TR-10-12 *Design and production of the KBS-3 repository*.[10]

The Swedish National Council for Nuclear Waste argued in its Nuclear Waste State-of-the-Art Report 2012 for research and development on the theme of organization and the relationship between the two main processes.[11]

The operational and structural organization of the final repository project has been discussed in a SKB report from 2010. [12] RD&D Programme 2013 observes that the overriding ambition for this report was to: "explore and clarify organizational factors for the units included in the upcoming final repository project" and to analyze the relationships with the project's stakeholders, primarily SKB's owners and the municipalities of Östhammar and Oskarshamn.[13] However, the report says nothing about the relationship between the two main processes, Safety Assessment and Construction, and therefore does not shed light on what the Council considers to be the key organizational issue for the project.

All discussions of organization and the two main processes have been omitted from RD&D Programme 2013. Some parts of an

[7] SKB, RD&D Programme 2010. See sections 1.4, 1.5 and 8.4.4.
[8] SKB, RD&D Programme 2010. See section 8.4.4.
[9] SKB (2011), *Long-term safety for the final repository for spent nuclear fuel at Forsmark. Main report of the SR-Site project.* SKB TR-11-01.
[10] SKB (2010), *Design and production of the KBS-3 repository.* SKB TR-10-12, pp. 26–27.
[11] SOU 2012:7 *Nuclear Waste State-of-the-Art Report 2012 – long-term safety, accidents and global survey.*
[12] Frostenson, Magnus (2010), *Slutförvarets industriella organisering. Fallgrop eller följdriktighet?* ("The Industrial organization of the final repository – Pitfall or consistency?", in Swedish). SKB R-10-55.
[13] SKB, RD&D Programme 2013, p. 513.

organizational structure are hinted at. A delivery control model is presented for the purpose of controlling technology development in the Nuclear Fuel Programme.[14] After a technical system has carried out the implementation phase in this model, the system can be "considered to be industrialized". Naturally, a delivery control system is an important component in an organization, but the term "industrialized" can instil a false sense of security and illustrates the problem. In a functioning industry there are two checkpoints for a product. The first is the producer's own verification of the properties of the product. This is presumably what is meant here by the term "industrialized". The second checkpoint is the judgement of the market. The industrial project "Spent Fuel Repository" does not produce for a market. It produces long-term safety, which is supposed to be verified by a Safety Assessment. The properties and functions of individual components in the repository, for example canister and buffer, should be measured, but the product of the Spent Fuel Repository project, i.e. long-term safety, can never be verified by any real process, but only by the safety assessment. It is this verification aspect that makes the repository unique and requires research and development to ensure an efficient, legitimate and authentic organization for producing the repository.

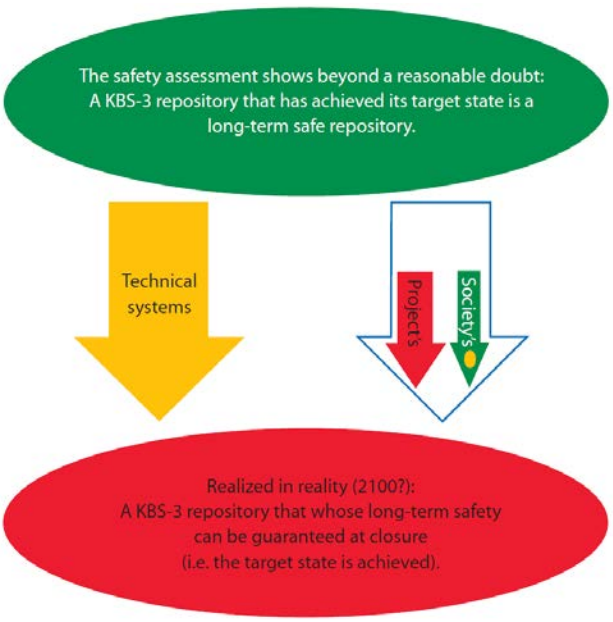
The organization shall continuously, over the course of a century, handle the relationship between the main processes, and in preparation for a decision on closure guarantee that all parts of the repository meet all the requirements of the safety assessment. Figure 1 illustrates that development and implementation of such an organization is a task that is fully comparable to the development and implementation of the technical systems. A reasonable conclusion from thirty years of safety assessment is that a repository that has achieved its target state with water-saturated buffers and oxygen-free conditions will be reasonably safe for 100,000 to a million years. In other words, it can be concluded that SKB has, in theory, solved the waste problem. The question is whether the initial state can be realized for all components so that the repository achieves this target state with certainty on the

[14] SKB, RD&D Programme 2013, p. 149, section 10.2.3.

selected site. This requires technical systems embedded in an efficient, legitimate and authentic organization.

Despite previous recommendations,[15] RD&D Programme 2013 lacks a research and development programme. The Swedish National Council for Nuclear Waste thus stands by its requirement from the review of RD&D Programme 2010 that SKB should immediately initiate a research and development programme that can transform a theoretically reasonably safe final repository into a reasonably safe final repository built on the selected site.

Figure 1 **Remaining development work to proceed from a theoretically safe final repository to a reasonably safe final repository built on the selected site**



Green:

– In theory, a KBS-3 repository in the target state is long-term safe.

[15] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010.*

– Society's decision processes: SKB is relatively well-embedded in a network of checks and assessments. Considering the long construction and operating period, it is important to assure the competence of public agencies to critically review SKB's work with safety assessment and cost calculations (concern for long-term skills retention in the government authority is indicated by the yellow spot in the green arrow).

Yellow:

– Technical systems: There are still big questions here, mainly with regard to the buffer's ability to meet all requirements made on it. It is also very troubling that SKB has not yet formulated a complete package of verifiable Design Premises. It must also be shown beyond a reasonable doubt that all systems will, from their initial states (according to SKB's definition of initial state), achieve their target states.

Red:

– Project organization: What should a project organization look like that will operate for a century and ensure with authenticity that the repository, in all its parts and at all times, is produced in accordance with the requirements of the Safety Assessment? A unique characteristic of this production is that it is not aimed at the Market but at the Safety Assessment, and at least three generations of contractors and employed personnel will pass through the system.
– The conclusion is that SKB has not yet shown that they can build a safe KBS-3 repository.

4.1.3 Measurement programme

The MoDeRn project, which is being carried out within the EU's 7th Framework Programme, is concerned with monitoring of final repositories during all phases, including: "staged closure, as well as a post-closure institutional control phase." The project includes a report on the state-of-the-art regarding monitoring techniques, but also in-situ demonstration of innovative monitoring techniques in

Work Package 3 (WP3).[16] One of the tasks in this Work Package is to:

- Demonstrate the capability to monitor events inside sealed and inaccessible repository areas, including the behaviour of the swelling clay plug.

The project has 18 partners from 17 countries including the USA and Japan. SKB represents Sweden in all the work packages except WP3.

Measurement programmes for monitoring changing conditions in sealed and inaccessible repository areas are thus being developed in various parts of the world. For example, ANDRA in France is developing such programmes in its project in Bure.

Since 2001, SKB has carried out measurements in the Prototype Repository in the Äspö HRL[17] and observes: "A general conclusion of the continuous data follow-up is that the measurement systems seem to work well."[18] In other words, SKB has good experience of measurement programmes in sealed areas. In the light of the Council's requirements on measurement programmes in its review of RD&D Programme 2010, it would be of interest for the Council's continued work to know the reason why SKB has refrained from participating in the more advanced part of the MoDeRn project.

The Council has, on a number of occasions, advocated development of a measurement programme to monitor changing conditions in plugged parts of the repository. SKB does not mention this or explain why such a programme is not needed in any part of RD&D Programme 2013.

In its reply[19] to the Land and Environment Court, the Swedish National Council for Nuclear Waste singled out three areas where a measurement programme is of benefit to the final repository

[16] http://www.modern-fp7.eu/work-packages/wp3-in-situ-demonstration-of-innovative-monitoring-techniques/ (downloaded 27 May 2014).
[17] SKB, RD&D Programme 2013, pp. 202–204.
[18] SKB, RD&D Programme 2013, p. 203.
[19] Swedish National Council for Nuclear Waste (2012), *The Swedish National Council for Nuclear Waste's viewpoints regarding the need for supplementary information in applications for licences for facilities in an integrated system for final disposal of spent nuclear fuel and nuclear waste (M 1333-11)*. (In Swedish Dnr 43/2012). Availabile in English translation see Appendix 3, SOU 2013:11 *Nuclear Waste State-of-the-Art Report 2013 - Final repository application under review: supplementary information and alternative futures.*

project by 1) developing design premises, 2) discovering hidden faults/mistakes in analysis and design, and 3) supporting monitoring programmes for discovering intentional or unintentional errors. A measurement programme would also provide valuable information for research and development on how a real repository evolves, e.g. with regard to water saturation of buffer. Such information is important for the design of other geological repositories, both inside and outside Sweden.

It is therefore the Council's considered opinion that a minimum requirement is that SKB document the reasons for its decision to abstain from measurement programmes, for example in a cost-benefit analysis, and keep this documentation updated and available to future decision-makers.

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SOU 2008:70 *Final Disposal of Nuclear Waste, The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2007.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

http://www.modern-fp7.eu/work-packages/wp3-in-situ-demonstration-of-innovative-monitoring-techniques/ (downloaded 27 May 2014).

4.2 Fuel

4.2.1 Introduction

The fuel handling plan in RD&D Programme 2013 is roughly the same as in previous years, with follow-up of issues that have previously been identified by SKB (such as criticality and decay heat), or by SKI/SSM during their reviews of RD&D Programmes 2007 and 2010. News in RD&D Programme 2013 is that:

- fuel requiring special handling is dealt with separately, in response to SSM's comments on previous RD&D Programmes
- previously there was only a description of safeguards, but now a programme for safeguards has been added.

4.2.2 The Council's assessment

The Swedish National Council for Nuclear Waste shares SKB's view that attention should be devoted to the specifically selected subareas of fuel handling and that these subareas are relevant to study from a research perspective. Several of the subareas are already the focus of research programmes, for example "Decay heat", "Water and water vapour" and "Criticality". The Council notes that the status report for these previously identified areas has basically the same content as in previous years, while the programme text contains additional research-relevant information. The subareas "Activity inventory and source terms," "Radiation protection and dose estimates," "Fuel and canister optimization" and "Safeguards" are new from a research programme perspective. The programme for "Safeguards" is by far the largest and addresses relevant questions surrounding encapsulation, transportation and final disposal.

It is the Council's considered opinion, in agreement with SKB, that the information presented in the fuel chapter is relevant, but that the textual presentation is often of such a general and vague nature that the scientific content is difficult to judge. For example, under the heading "Activity inventory and source terms" it is easy to agree with SKB that it is good that needs will be identified, supplementary data will be added and reports will be quality-assured. But there is no specification of what needs and supplementary data are referred to, or what is meant in practice by quality. Nor is there any information in the section on why or what type of "upgrade of activity inventory and source terms" will be done, despite the fact that the research programme explicitly mentions that this will be done. Similarly, the Council considers that it is of great importance in the area of Safeguards to heed the regulatory authorities' recommendations, to calculate fuel parameters, and to carry out verifying measurements. But without knowing what recommendations SKB is referring to, how or with what software the fuel parameters will be calculated or why, to what extent and with what instruments verifying measurements will be done, the text of the programme does not say very much.

The Swedish National Council for Nuclear Waste notes that the fuel chapter only contains references to three other SKB documents.

One refers to requirements and premises[20], one refers to results from calculations of activity inventory and source strengths[21], and a third presents previous calorimetric measurements[22]. Furthermore, there are external references to an international collaboration.[23,24] In the light of this, the Council finds that the chapter only to a limited extent follows up and presents results from previous RD&D Programmes so that the trend can be followed. At best, it is possible to find a sentence or two in the text that describes what has been done in general terms, but on the whole the Council finds that an account is lacking of previous years' research programmes, including references where the original results can be found.

Another viewpoint on the chapter is that SKB has realized that many technical fuel properties remain to be determined and included in documentation accompanying the fuel: activity inventory, radiation protection, dose estimates, decay heat, amounts of water vapour, criticality, fuel parameters, verification of nuclear material, etc. It is however surprising that the decay heat determination is the only one of the listed areas that explicitly mentions actual measurements. But it is not clear whether, for example, all fuel will be measured or only some, and how specifications or requirements on these measurements are to be arrived at. The Swedish National Council for Nuclear Waste thereby wonders to what extent SKB intends to measure fuel properties and fuel parameters, and to what extent SKB relies on calculation methods. The question of how evaluation methods are chosen and verified against actual data is relevant, as is the question of whether SKB intends to perform these validations itself.

[20] SKB (2010), *Spent nuclear fuel for disposal in the KBS-3 repository.* SKB TR-10-13.
[21] SKB (2009), *Referensrapport till SAR allmän del kapitel 6 – Källtermer* ("Reference report to SAR general part Chapter 6 – Activity Inventory", in Swedish). SKB doc 1179234 ver 1.0.
[22] SKB (2006), *Measurements of decay heat in spent nuclear fuel at the Swedish interim storage facility, Clab.* SKB R-05-62.
[23] USNRC (2010), *Spent fuel decay heat measurements performed at the Swedish Central Interim Storage Facility*. NUREG/CR-6971, U.S. Nuclear Regulatory Commission, Washington, DC.
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USNRC (2010), *Validation of SCALE 5 decay heat predictions for LWR spent nuclear fuel.* NUREG/ CR-6972, U.S. Nuclear Regulatory Commission, Washington, DC.

4.3 Canister

4.3.1 Introduction

The copper canister is the most important barrier in the KBS-3 system, since it contains the spent nuclear fuel and prevents radionuclides from escaping. The canister also attenuates ionizing radiation and prevents further uranium fission (criticality). It must therefore be fabricated and sealed with high reliability so that it can maintain its optimal function against corrosion and mechanical loads after deposition in the repository. SKB has chosen reference methods for fabrication of the canister's components and for welding and sealing. The Swedish National Council for Nuclear Waste has in previous reports and review statements offered viewpoints on fabrication processes, criteria for material structure, material properties and defects in both the copper shell and the cast iron insert, as well as on the underlying requirements for nondestructive testing.[25,26,27]

[25] Swedish National Council for Nuclear Waste (2007), *Time for final disposal of nuclear waste – society, technology and nature. An in-depth report supplementing KASAM's Nuclear Waste State-of-the-Art Report 2007 (SOU 2007:38e)*. Report 2007:3e.

In RD&D Programme 2013, SKB's goal is to develop methods for fabrication and inspection that meet stipulated quality requirements and have sufficiently high reliability to be used in future canister production and in Clink. Important processes are friction stir welding with a rotating tool and nondestructive testing, as well as production of full-size canisters. The industrial-scale production system for canisters (200 canisters per year) will also include external suppliers who fabricate copper components and nodular iron inserts for the canisters to SKB's specifications. Final machining, assembly and quality assurance of canister components will be done in SKB's canister factory (possibly jointly owned with Posiva).

It is the Council's considered opinion that the requirements that have to be made on fabrication, testing and inspection of the canister's components, as well as of the whole system, have not all been determined yet. SKB is still developing the design premises for the canister, and a compilation of the canister's strength and damage tolerance (design analysis) has recently been presented.[28] Acceptance criteria for the system and its operation have not yet been established, and the work of specifying these criteria is under way.

4.3.2 Technology development, canister

The work of defining design premises for the canister continues. The canister's barrier function in the repository is dependent on the ability of copper to withstand corrosion and on the cast iron insert, which gives the canister its high strength. The canister must withstand an isostatic load of 45 MPa, which is the sum of the swelling pressure in the buffer, the groundwater pressure and the hydrostatic pressure during a glaciation. The copper shell must remain intact after a shear movement in the rock of five centimetres.

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[26] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010.*
[27] SOU 2012:7 *Nuclear Waste State-of-the-Art Report 2012 – long-term safety, accidents and global survey.*
[28] Johansson, M., Raiko, H., Rydén, H. and Sandström, R. (2010), *Design analysis report for the canister.* SKB TR 10-28.

The toughness and ductility of the cast iron insert needs to be further verified by new tests. In the fabrication of cast iron inserts, the purpose is to get the mechanical properties in the entire insert to comply with the stipulated requirements. The link to mechanical properties such as ultimate elongation and fracture toughness should be evaluated by gaining a better understanding of casting parameters and the material's microstructure. A critical defect in the insert can in an unfavourable case only be allowed to have a depth of not more than 4.5 mm, which makes great demands on nondestructive testing of the insert.

Nondestructive testing of inserts, copper components and seal welds should continue with development of technology and methodology for characterization and size determination of defects. Technology for making relevant defects in test blocks (of both copper and cast iron) is important and necessary for verification of the testing system by means of demonstrations on test blocks. The relationship between material structure and ultrasonic testing must be established. The programme to minimize the occurrence of weld defects in seal welding is important, as is the development of nondestructive testing for detection of weld defects. Weld defects have an impact on the mechanical properties and mechanical integrity of the canister, especially on creep ductility. The presence of oxide particles in friction stir welds is important for creep properties, as is the extent of joint line hooking in the weld. The testing technology should be developed so that detected defects can be characterized with respect to the properties that are important for ensuring the integrity of the canister.

4.3.3 Canister processes

The copper canisters will thus contain the spent nuclear fuel and subsequently be deposited in the final repository when they meet the acceptance criteria made on fabrication and testing. According to SKB, the initial state of the canister is the state of the canisters when it has been emplaced in the deposition hole and will not be handled anymore. The safety assessment includes slow changes

such as corrosion, deformation and creep in the canister's copper shell and insert.

In order to limit corrosion of the insert, the amount of water in the canister will be limited to 600 g and the air in the canister will be replaced with argon (> 90% Ar). Corrosion leads to the evolution of hydrogen, and the effect of hydrogen on the material properties of nodular iron and copper must be studied. Hydrogen uptake in the canister material must be analyzed with respect to both corrosion mechanisms and the influence of radiation on the corrosion processes. Hydrogen affects mechanical properties, especially creep.

The creep properties of copper have not yet been adequately determined. The creep properties of e.g. welds have not been characterized, and the influence of cold working and multiaxial stress states needs further study. A validated creep model with fundamental equations and implementation in models with the finite element method is still lacking, and calculations for a full-sized canister are needed. The influence of phosphorus, sulphur, oxygen and hydrogen on the creep properties of copper must be further studied. Research should be done to obtain a deeper understanding of the material properties of copper.

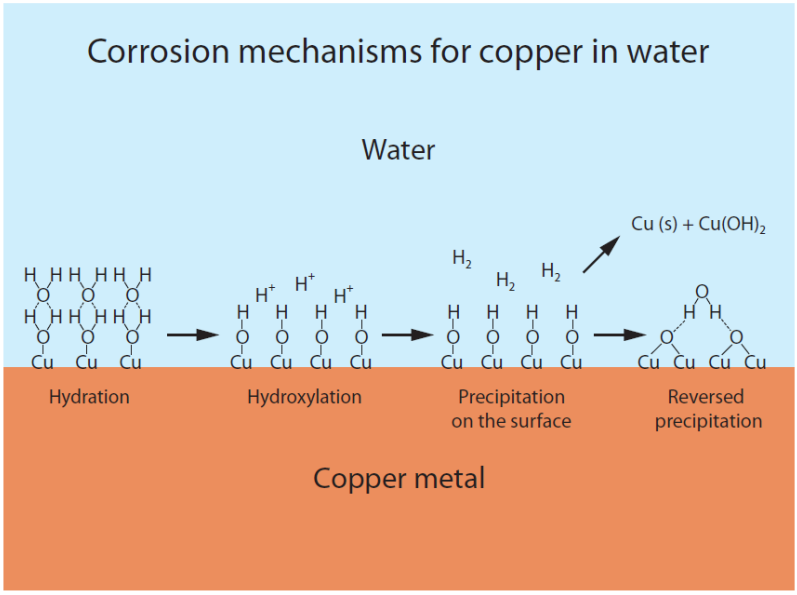
Copper corrosion in pure and oxygen-free water has been discussed a great deal in recent years, and the Swedish National Council for Nuclear Waste has presented its viewpoints in previous state-of-the-art reports. [29,30,31] The Council has consistently tried to find explanatory models that can serve as a point of departure for constructive dialogues that are acceptable to everyone and for an interpretation of the experimental results.

In this report, the Council proposes a reaction mechanism that could possible serve as a starting point for an in-depth discussion in the research groups that are currently investigating corrosion of copper in pure oxygen-free water and looking for a rational explanation of the results. The reaction model can be summarized in the following illustration (Figure 2). As is evident from the

[29] SOU 2012:7 *Nuclear Waste State-of-the-Art Report 2012 - long-term safety, accidents and global survey.*
[30] SOU 2011:14 *Nuclear Waste State of the Art Report 2011 - geology, barriers, alternatives.*
[31] SOU 2010:6 *Nuclear Waste State of the Art Report 2010 - challenges for the final repository programme.*

figure, a hypothetical reaction can be subdivided into a number of consecutive steps.

Figure 2 **Illustration of a possible mechanism for corrosion of copper in pure oxygen-free water**



The reaction model is intended to serve as a point of departure for discussions of possible causes for the evolution of hydrogen in a series of laboratory experiments.

Hydration of the surface entails formation of a diffuse layer of adsorbed water molecules that is dependent on their bipolar structure. The next step, hydroxylation, entails that a number of water molecules nearest the surface emit protons (H^+) to the solution and form hydroxide ions (OH^-) that are adsorbed on copper atoms in the interface with the water. These protons may contribute to the oxidation of copper atoms to form CuOH(s), which is precipitated on the surface. CuOH(s) is not stable in contact with water and can be transformed into precipitated Cu_2O ($2CuOH => Cu_2O + H_2O$) or be disproportionated. The kinetics and amount of the solid corrosion products (CuOH and Cu_2O) are strongly affected by the partial pressure of hydrogen.

It is the Council's considered opinion that the most important discussion concerns copper corrosion in the environment that will eventually dominate in the repository, i.e. when oxygen is depleted and has finally been consumed. Copper corrosion in an oxygen-free environment always results in hydrogen gas evolution, and the hydrogen pressure is therefore a crucial parameter. When the pressure reaches a certain level, corrosion ceases. Hydrogen can be absorbed in copper and the influence of the hydrogen on the properties of the copper material, such as creep, may then be important.[32] Hydrogen in OFP is probably present in the form of gas molecules, since the hydrogen content (limit < 0.6 ppm) exceeds the solubility of hydrogen in copper.

Stress corrosion cracking (SCC) can occur in copper when special conditions prevail with respect to tensile stress, aerobic environment and certain impurities (ammonium, nitrite etc.) as well as a very slow strain rate. SCC occurs in the presence of a Cu_2O/CuO complex film on the copper surface. In order to enable SCC to be excluded, the mechanism that causes it must be thoroughly researched. Stress corrosion cracking of copper occurs particularly in nitrite solutions. SKB uses threshold values for concentrations of nitrite, ammonium and acetate in the assessment. Threshold values from short laboratory experiments are unreliable, and the mechanism of SCC in these environments must be studied in order to understand how reliable these threshold values for SCC really are.

The Swedish National Council for Nuclear Waste has on several occasions explained the need to study the influence of gamma radiation on corrosion of copper Now SKB has begun conducting research in pure water under a nitrogen atmosphere at different radiation dose rates. The corrosion mechanism in conjunction with gamma radiation should be thoroughly studied, for example the morphology of film growth, local corrosion and possible hydrogen uptake in copper should be investigated.

[32] Yagodzinskyy, Y. et al. (2012),"Hydrogen-enhanced creep and cracking of oxygen-free phosphorus-doped copper". *Scripta Materialia* 67, pp. 931–934.

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Johansson, M., Raiko, H., Rydén, H. and Sandström, R. (2010), *Design analysis report for the canister.* SKB TR-10-28. Stockholm: Svensk Kärnbränslehantering AB.

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SOU 2012:7 *Nuclear Waste State-of-the-Art Report 2012- long-term safety, accidents and global survey.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

SOU 2011:14 *Nuclear Waste State-of-the-Art Report 2011: geology, barriers, alternatives.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

SOU 2010:6 *Nuclear Waste State-of-the-Art Report 2010 – challenges for the final repository programme.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

Yagodzinskyy, Y. et al. (2012), "Hydrogen-enhanced creep and cracking of oxygen-free phosphorus-doped copper." *Scripta Materialia* 67, pp. 931–934.

4.4 Buffer, backfill and closure

4.4.1 Introduction

The most important functions of the buffer are to prevent the copper canister from being exposed to a direct flow of groundwater and to filter out as much as possible of corrosive ions, colloids and microorganisms. The idea is that the bentonite should absorb groundwater and swell until it fills all voids and penetrates into fractures in the surrounding rock. At the same time, its density should increase to a level of about 2,000 kg/m^3, making the buffer

very tight. The bentonite buffer has a unique role among the barriers since it must, after deposition in the repository, undergo alteration in order to achieve optimal function.

In the applications for the Spent Fuel Repository, SKB has stipulated design premises for the buffer that include a minimum content of the clay mineral montmorillonite, 75–90 percent of the total dry weight. Furthermore there is a requirement on maximum content of organic carbon (<1 percent), total sulphur (< 1 percent) and sulphide (≤ 0.5 percent). The water-saturated density of the installed buffer shall be 1,950–2,050 kg/m^3. The latter has previously been criticized by the Swedish National Council for Nuclear Waste on the grounds that this design premise is not verifiable and does not have any real function. According to RD&D Programme 2013, SKB plans to replace the buffer density requirement with a requirement on minimum and maximum amount of buffer materials in a deposition hole and how these materials may be distributed at the time of deposition. This is a requirement that is very difficult to judge the value of at the present time and that must be further explained in order to be evaluated.

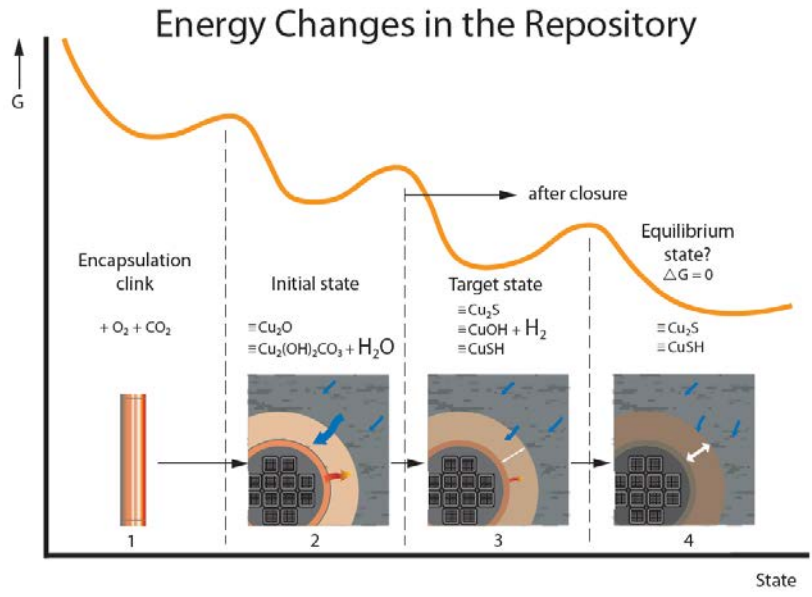
4.4.2 Development and quality requirements for buffer and backfill

It is the Council's considered opinion that, as a point of departure for SKB's research programme for buffer and backfill, the processes and measures that should lead to fulfillment of the design requirements should be investigated and determined. This includes (in the order given) optimizing the mineral composition with permitted impurities in the bentonite, the pore water composition in the bentonite, the fabrication of blocks and pellets for deposition holes and backfill, water saturation and swelling, erosion during the water saturation phase and after glaciation, the influence of γ-radiation in the repository, transport mechanism for ions from the groundwater and radionuclides from a damaged canister, freezing and thawing of bentonite blocks and pellets in the backfill, and long-term chemical and physical stability. It is how well SKB has focused on and succeeded in clarifying

uncertainties surrounding these processes and measures in the research programme that will be judged.

In other words, the period in the final repository can be defined in terms of different states, each including a number of processes that define the evolution in the repository and how well the repository fulfils its purpose of long-term isolation of the spent nuclear fuel from the surrounding environment (Figure 3).

Figure 3 **Summary of the changing energy state in the deposition holes, with an emphasis on possible reactions on the copper canister and transformations in the bentonite buffer**



The evolution of the buffer and backfill can be described in terms of the following states:

1. Production and transport

The bentonite buffer undergoes inspection and must meet requirements on content of minerals and impurities, pretreatment (addition of water, grinding), compaction of blocks, rings and pellets, logistics of internal transport of different grades of bentonite clays, and quality and storage of finished components prior to deposition.

2. Initial state after deposition
Rings of compacted bentonite are deposited together with copper canisters, which means that the buffer is exposed to decay heat and γ-radiation from the canister. Water saturation and swelling begin and do not end until the buffer has achieved its target state. A transition occurs from oxidizing (oxic) to reducing (anoxic) environment as oxygen in different forms is consumed by, for example, reactions with impurities.

Blocks and pellets in buffer and backfill can undergo erosion if the groundwater flow is great.

3. Target state after deposition
The buffer has been water-saturated, swelled and achieved the desired density. The temperature gradient through the buffer has declined or disappeared, and mineral transport in the bentonite has led to changes in mechanical strength and hydrological conductivity. The environment in the buffer is reducing.

Corrosive substances from the groundwater have been transported into the buffer and will slowly diffuse closer to the canister.

4. Remaining pre-closure period
Buffer and backfill are now equipped to fulfil their function as protectors of the copper canister. This means they must be able to protect the canister, cope with future climate variations (freezing and thawing) and minor earthquakes, and act as obstacles to radionuclide transport from a possible damaged canister.

Requirements on mineral composition of the bentonite and upper limit for impurities

It is important that the bentonite clay in buffer and backfill has the right content and quality. There are a number of clear requirements on the quality of the bentonite before it has been delivered to SKB and production of rings, blocks and pellets has started. Bentonite is a natural product consisting of a mixture of minerals with different properties as well as natural impurities. Bentonite from different suppliers will therefore have slightly different properties, and SKB has to establish well-balanced criteria for its composition in order to ensure optimal properties.

SKB's conclusions from the review reports from SSM and NEA of RD&D Programme 2010 concern improved criteria for concentrations of other substances (than carbon and sulphur) in the bentonite as well as for important properties such as sealing capacity, piping and erosion stability.

This is in accordance with the demands made by the Swedish National Council for Nuclear Waste in a series of previous reviews[33] of SKB's RD&D Programmes containing e.g. the following recommendations:

> The most important properties of the buffer material should be specified and limit values should be determined with respect to swelling potential, retention capacity against radionuclides, chemical stability, hydraulic diffusion, resistance to erosion and concentrations of impurities (inorganic as well as organic).
>
> Mechanical strength and chemical stability must be guaranteed for compacted components in the buffer.[34]

The Council's proposals and recommendations 10–15 years ago are still highly relevant today. This applies not least in the light of the concurring requirements recently expressed by other reviewing bodies (SSM and NEA).

One might wonder what experimental and theoretical support exists for the exact level of these limit values and the concentration of impurities in the bentonite types which SKB is currently evaluating.

Water saturation and swelling

Water saturation and swelling of bentonite blocks and pellets in buffer and backfill after deposition are key processes in the evolution of the repository. While SKB's programme for research

[33] For example SOU 2002:63 *Nuclear waste - research and technique development. KASAMS's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2001* and SOU 2005:47 *Nuclear waste – Barriers, Biosphere and Society. KASAMS's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2004 and* SOU 2008:70 *Final Disposal of Nuclear Waste – The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2007.*

[34] SOU 2008:70 *Final Disposal of Nuclear Waste – The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2007*, p. 67.

and development surrounding these processes is extensive, it is still mainly at a general mechanical/technical level.

Knowledge development on a molecular solution chemistry level is still inadequate.

In view of how important water saturation and swelling are for the long-term safety of the repository, more in-depth knowledge should be pursued, with a focus on the conditions that are expected to prevail in the repository.

The water saturation process has been described in detail in a number of reports from KASAM/the Swedish National Council for Nuclear Waste from 2001 and onward.[35] Due to the decay heat from the canister, a temperature gradient will be created through the buffer in the deposition hole, which means that the temperature will vary with the distance from the canister. This temperature difference is expected to exist for around 1,000 years and will influence the water saturation process. The diffusion coefficients of ions generally increase with the temperature, for instance. Ions with high mobility, particularly chloride and calcium, are greatly affected by a temperature increase. Diffusion of sodium is highly dependent on the mobility of anions such as the divalent sulphate ion, SO_4^{2-}, whose diffusion coefficient is relatively independent of temperature and salinity and is a power of ten lower than the equivalent values for chloride and calcium.[36]

It is interesting to note that SKB has now – after requirements from SSM – realized that the description of the water inflow into the buffer and the backfill is inadequate. Similar viewpoints have been expressed by the Swedish National Council for Nuclear Waste in a series of RD&D reviews and state-of-the-art reports.[37]

[35] SOU 2001:35 *Nuclear Waste State-of-the-Art Report 2011 Part III Groundwater rock* and for example SOU 2011:14 *Nuclear Waste State-of-the-Art Report 2011: geology, barriers, alternatives.*

[36] Martin, M., Cuevas, J. and Leguey, S. (2000), "Diffusion of soluble salts under a temperature gradient after the hydration of compacted bentonite", *Applied Clay Science* 17, pp. 55–70.

[37] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010* and SOU 2010:6 *Nuclear Waste State-of-the-Art Report 2010 – challenges for the final repository programme.*

Transport mechanisms for ions in the bentonite

The bentonite buffer has several important functions, one of the most important of which is to prevent or hinder corrosive substances in the groundwater from coming into contact with the copper canister. Such substances include sulphur anions such as hydrogen sulphide (HS^-) and sulphate (SO_4^{2-}), which can directly or indirectly initiate corrosion in the long term. An important factor is the temperature gradient that will exist in the buffer for several hundred years. SKB should increase its knowledge of how diffusion of ions from the groundwater is affected by this.

SKB needs to learn more about the kinetics of the transport of sulphur anions from the groundwater through the bentonite.

From oxidizing to reducing conditions

There is no special section in RD&D Programme 2013 about the transition from oxic (oxidizing) to anoxic (reducing) conditions in the buffer. This is surprising, since anoxic conditions are expected to prevail in the long term and are of great importance for e.g. minimizing corrosion of the copper canister. How rapidly and in what way molecular oxygen (O_2) is consumed is an important question in this context. The Swedish National Council for Nuclear Waste described this uncertainty in its state-of-the-art report 2012 and recommended that SKB describe mechanisms for oxygen consumption, how rapidly it proceeds and what reducing level is eventually attained.[38] This recommendation is still in effect.

Gas transport

SKB does not expect any early canister damage and therefore believes that gas transport in bentonite is no longer a priority issue. The Swedish National Council for Nuclear Waste does not agree, for when groundwater comes into contact with the copper canister, the corrosion processes will be initiated and hydrogen will be

[38] SOU 2012:7 *Nuclear Waste State-of-the-Art Report 2012 – long-term safety, accidents and global survey.*

evolved. The canister is protected from serious corrosion as long as the hydrogen can be kept close to the surface of the canister. How rapidly and in what way the hydrogen diffuses through the bentonite is therefore valuable knowledge which SKB should acquire.

Monitoring of the processes

In the Council's opinion, it is urgent that SKB continue knowledge acquisition on a molecular level about how these important processes in the buffer and backfill proceed under varying conditions. A monitoring system needs to be developed to keep track of conditions in some selected deposition holes during the operating period.[39] Among the parameters that can be measured in the buffer are the pressure exerted on the canister at different levels due to water saturation, oxygen consumption (which produces reducing conditions), and the temperature at different distances from the canister.

Erosion and piping

Water transport and swelling of the bentonite also entail a risk of piping and erosion. In these cases it is the strength of the bentonite in the form of rings, blocks and pellets that is important, and this strength is in turn dependent on the bentonite's mineral composition, impurities and density after compaction. The compaction method (uniaxial or isostatic pressing) can also create inhomogeneities that affect the buffer's resistance to erosion.

The risk of extensive erosion and piping is probably greatest when the bentonite has been allowed to swell without sufficient counterpressure, since this causes it to assume a gel-like and loose consistency where the particles are readily disintegrated and carried away by the water. This is presumably less of a problem in the deposition holes, where the counterpressure from the surrounding rock is normally great, but more of a problem at the interfaces between the backfill and the rock. SKB intends to backfill the

[39] Read also under section 4.1.3.

tunnels with blocks of compacted bentonite clay and create a seal against the surrounding rock using bentonite pellets. The large quantity of pellets needed to seal the spaces between blocks and rock can make the method very sensitive to piping and erosion.[40]

Meltwater after a glaciation is the next major challenge to the buffer and backfill, since the water is then very ion-poor and the ions that cause the bentonite particles to aggregate may be washed away. The result could be extensive erosion, but this will occur relatively far in the future.

Freezing of bentonite

SKB does not intend to conduct any more research in this field in the course of the coming period.

During the long operating period it will periodically be very cold and the bentonite in the backfill will partially freeze. The lower content of swelling minerals in the backfill will lead to a different water distribution than in the buffer, i.e. more pore water and less absorbed water. This will in turn affect the buffer's freezing properties and lead to exclusion of salts and impurities in the backfill. The Council urges SKB to conduct freeze-thaw tests on bentonite of lower swelling capacity in the same way as corresponding studies of the bentonite buffer. Moreover, in state-of-the-art report 2011 the Council urged SKB to conduct studies where bentonite that has been saturated with contaminated groundwater is allowed to freeze and then thaw.[41] This recommendation is still in effect.

Model for transport of radionuclides

Another primary function of the buffer is to retard the transport of radioactive nuclides following damage to the canister. This function is affected by organic substances in the buffer and groundwater. The Swedish National Council for Nuclear Waste has proposed for several years that SKB should construct a more

[40] SOU 2010:6 *Nuclear Waste State-of-the-Art Report 2010 – challenges for the final repository programme.*
[41] SOU 2011:14 *Nuclear Waste State-of-the-Art Report 2011: geology, barriers, alternatives.*

sophisticated model for diffusion of the most important nuclides through the bentonite buffer.[42] This includes both positive ions that can be neutralized by negatively charged anions in humic substances and those radionuclides that consist of negatively charged polyanions.

References

Martin, M., Cuevas, J. and Leguey, S. (2000), "Diffusion of soluble salts under a temperature gradient after the hydration of compacted bentonite", *Applied Clay Science* 17, pp. 55–70.

SOU 2012:7 *Nuclear Waste State-of-the-Art Report 2012 – long-term safety, accidents and global survey.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

SOU 2011:14 *Nuclear Waste State-of-the-Art Report 2011: geology, barriers, alternatives.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

SOU 2010:6 *Nuclear Waste State-of-the-Art Report 2010 – challenges for the final repository programme.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

SOU 2008:70 *Final Disposal of Nuclear Waste, The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2007.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

SOU 2005:47 *Nuclear waste – Barriers, Biosphere and Society. KASAM's Review of the Swedish Nuclear Fuel and Waste*

[42] For example SOU 2008:70 *Final Disposal of Nuclear Waste – The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2007* and SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010.*

Management Co's (SKB's) RD&D Programme 2004. Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

SOU 2002:63 *Nuclear waste – research and technique development. KASAMS's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2001.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

SOU 2001:35 *Nuclear Waste State-of-the-Art Report Part III Groundwater in hard rock.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

4.5 Geosphere

4.5.1 Introduction

The function of the bedrock is to retard the transport of radionuclides to the biosphere in the event canisters containing nuclear waste are damaged. In order for the rock to act as a transport barrier, both fracture frequency and water content must be low, since water can efficiently transport different types of impurities such as radionuclides, and fractures are good transport pathways for this water. It is therefore important to know how fractures in the rock are distributed, if and how new fractures form, and how the rock's hydrology interacts with them.

4.5.2 Hydrology and hydrogeology

In its review of RD&D Programme 2010, the Council noted that the way in which geological, hydrological, rock mechanical and thermal parameters interact under different conditions to which the repository is exposed was not well enough explained and that there were deficiencies in the way uncertainties and the verifiability of the models had been handled.[43] Since then SKB has initiated an extensive programme that describes several initiated studies that include integrated modelling where the interaction between thermal, hydrological and mechanical parameters will be

[43] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010.*

investigated and improved programming codes will be developed. This programme is presented in RD&D Programme 2013. Moreover, much has been done to strengthen the reliability of the hydrogeological models, where the results of field studies have been linked to and compared with the results of modelling. It is unfortunate that source references for cited data are often lacking in RD&D Programme 2013, since they are needed to evaluate certain claims from previous studies. For example, what are said by SKB to be the most important hydrogeological analyses have been published in a series in "Hydrogeology Journal", but the text does not contain references to year and volume.

The integrated modellings are very complex[44] and it would have been desirable if the weaknesses in the modellings and the reasons for the choice of modelling tool had been given. Due to the complex integrated system, there are great uncertainties in the model calculations, in addition to which so-called equifinality problems can arise,[45] which means that a false description of reality appears to provide a correct calculation model. The Swedish National Council for Nuclear Waste would like to know the reasons for the choice of modelling tool and the purpose for which the different modellings have been done, and would like a presentation of their strengths and weaknesses. The Council would also like a clearer presentation of the experiments that have been used for verification, calibration and validation of the models (see also section 4.6).

4.5.3 Rock mechanics

Source references are also blatantly inadequate in the chapters dealing with the bedrock and rock mechanical investigations. For example, the source of Figure 14-2 in SKB's report is not given. This figure shows the magnitude and orientation of rock stresses in Äspö measured by means of different methods (overcoring, OC, and Linear Variable Differential Transducer, LVDT). It is stated in

[44] Marklund, Lars (2014), *Granskning av FUD-program 2013: Hydrologi* ("Review of RD&D Programme 2013: Hydrology", in Swedish). Report to the Swedish National Council for Nuclear Waste. Tyréns. (Dnr. 18/2014).
[45] Marklund, Lars (2014), *Granskning av FUD-program 2013: Hydrologi* ("Review of RD&D Programme 2013: Hydrology", in Swedish).

the text that the OC and LVDT measurements agree, which is correct with respect to the magnitude of the stresses, but Figure 14-2 shows large variations in the orientation of σ2 measured by the different methods. Despite this, the LVDT cell shows good and reliable results.[46] The method is also used in mines and other underground projects. This means that it should be possible to determine the magnitude, orientation and variation of the rock stresses in Forsmark during the construction of the final repository.[47]

In section 26.7, under the subheading "Newfound knowledge since RD&D 2010," there are no references to the modelling result and where the information that the maximum temperature will not exceed 60 °C has been published. Similar values are given in Rutqvist och Tsang (2008)[48], while Börgesson et al. (2006)[49] present higher temperatures. The temperature increase in the buffer and surrounding rock is caused by heat generation from the spent nuclear fuel in the canisters, leading to expansion and consequently increased pressure; this takes place during the thermal phase.

Even though SKB does not believe that thermally induced spalling of the rock around the canisters is critical, a doctoral project has been initiated to judge the potential for spalling and to gain a better understanding of how fractures propagate in crystalline rock, which is welcomed by the Swedish National Council for Nuclear Waste. This project is important since it has emerged that the pressure increase during the thermal phase can lead to shear movements along gently dipping fractures, which have been shown to exist near the repository.[50,51]

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[46] Stephansson, Ove (2014), *Synpunkter på valda delar av SKB:s Fud-program 2013.* ("Viewpoints on selected parts of SKB's RD&D Programme 2013", in Swedish). Report to the Swedish National Council for Nuclear Waste. (Dnr. 19/2014).

[47] Stephansson, Ove (2014), *Synpunkter på valda delar av SKB:s Fud-program 2013.* ("Viewpoints on selected parts of SKB's RD&D Programme 2013", in Swedish).

[48] Rutqvist, J. and Tsang, C-F. (2008), *Review of SKB's Work on Coupled THM Processes Within SR-Can: External review contribution in support of SKI's review of SR-Can.* Swedish Nuclear Power Inspectorate Report 2008:08.

[49] Börgesson, L., Fälth, B. and Hernelind, J. (2006), *Water saturation phase of the buffer and backfill in the KBS-3V concept. Special emphasis given to the influence of the backfill on the wetting of the buffer.* SKB TR-06-14.

[50] Rutqvist, J. and Tsang, C-F. (2008), *Review of SKB's Work on Coupled THM Processes Within SR-Can: External review contribution in support of SKI's review of SR-Can.*

Modelling shows that the horizontal pressure increase during the thermal phase is greater than during a glaciation,[52] which could have consequences for the stability of the repository up to a thousand years after closure.[53] The Council therefore considers it to be of great importance that SKB conduct thermo-mechanical tests in Forsmark during the initial phase of the rock works in order to determine at an early stage the site-specific rock's response and spalling tendencies due to the expansion of the rock mass in connection with heat loading during the thermal phase.

An important scenario in the safety assessment is shear movements along major fractures that can cause them to propagate through deposition holes. According to SKB, a number of geophysical surveys, in combination with hydraulic tests, will be conducted during construction of the final repository in Forsmark, and are planned in Äspö, to identify and localize the presence of major fractures. It is of the utmost importance to characterize the rock in the disposal volume, not least with respect to long fractures which could potentially be activated and undergo shear,[54] but there are no proposals in RD&D Programme 2013 for development of technology and instruments to carry out this characterization.

The excavation-damaged zone (EDZ) that is formed during drill-and-blast excavation is larger than the EDZ formed when a tunnel boring machine (TBM) is used to excavate the repository. RD&D Programme 2010 says that SKB intends to use conventional drill-and-blast excavation in Forsmark. Minimizing a continuous EDZ is important, since it can otherwise provide flow paths for e.g. radionuclides from a damaged canister. According to SKB, results from earlier studies in Äspö using tomographic methods could not detect the presence of a continuous EDZ. Since then, however, Posiva has, in the ONKALO project, identified a continuous EDZ in the tunnel floor by means of geoelectric investigations. SKB now plans to conduct a similar study in Äspö.

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[51] Stephansson, O., Sonnerfelt, L., Bungum, H. and Lindholm, C. (2012), *Workshop on seismology.* SSM 2012:25.
[52] Rutqvist, J. and Tsang, C-F. (2008), *Review of SKB's Work on Coupled THM Processes Within SR-Can: External review contribution in support of SKI's review of SR-Can.*
[53] Stephansson, O., Sonnerfelt, L., Bungum, H. and Lindholm, C. (2012), *Workshop on seismology.* SSM 2012:25.
[54] Stephansson, Ove (2014), *Synpunkter på valda delar av SKB:s Fud-program 2013.* ("Viewpoints on selected parts of SKB's RD&D Programme 2013", in Swedish).

Development of TBM excavation is progressing rapidly,[55] and in view of the limited EDZ created by tunnel boring, the Swedish National Council for Nuclear Waste believes that SKB should consider whether this technology may be sufficiently developed for rock excavation in the construction of a final repository.

4.5.4 Seismicity

In Sweden, active movements in solid rock causing displacements (shear) along existing fractures are related to large-scale tectonic plate movements in combination with isostatic rebound of the Earth's crust (land uplift) following the last glaciation. The built-up stresses in the rock are relieved either by aseismic movement, i.e. creep, along existing fractures, which can then propagate, or by abrupt movement (seismic movement) that causes earthquakes along post-glacial faults.

In order to investigate slow movements in the rock, SKB has carried out GPS measurements in Forsmark in a number of campaigns between 2005 and 2009.[56] During this limited period, measurement data were gathered on 18 occasions over 3–7 days. These data collection periods are considered to be too short and too sporadic for any definite conclusions to be drawn.[57] In order to obtain better knowledge of slow movements in the rock in Forsmark, SKB is continuing to carry out GPS measurements with fixed stations. However, it is unclear whether data collection is being done in campaigns or continuously. Short measurement campaigns are not sufficient to obtain information on slow movements, or to evaluate possible rapid periodic changes. Continuous measurements are required for this, which was also pointed out in the Council's review of RD&D Programme 2010.[58]

[55] Stephansson, Ove (2014), *Synpunkter på valda delar av SKB:s Fud-program 2013.* ("Viewpoints on selected parts of SKB's RD&D Programme 2013", in Swedish).
[56] Gustavsson, L. and Ljungberg, A. (2010), *Forsmark site investigation. A deformation analysis of the Forsmark GPS monitoring network from 2005 to 2009.* SKB P-10-29.
[57] Ekman, L. and Ekman, M. (2013), *Quality control of GPS deformation data from Forsmark and analysis of crustal deformation in the local scale.* SKB R-13-11.
[58] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010.*

Continuous measurements are also recommended by Ekman and Ekman (2013).[59]

During the long time periods the repository will be intact, movements in the rock and in and around the repository may be caused by single or multiple processes. In addition to the processes already mentioned (plate tectonics, isostatic rebound following a glaciation and heating during the thermal phase), rock stresses and pore pressure also increase during the glaciation. This may entail a risk of earthquakes or creep in the rock. It is not evident from the extensive research programme described in RD&D Programme 2013 whether cumulative effects of these processes will be modelled in the thermo-hydro-mechanical programme, which the Council believes should be clarified.

References

Börgesson, L., Fälth, B. and Hernelind, J. (2006), *Water saturation phase of the buffer and backfill in the KBS-3V concept. Special emphasis given to the influence of the backfill on the wetting of the buffer.* SKB TR-06-14. Stockholm: Svensk Kärnbränslehantering AB.

Ekman, L. and Ekman, M. (2013), *Quality control of GPS deformation data from Forsmark and analysis of crustal deformation in the local scale.* SKB R-13-11. Stockholm: Svensk Kärnbränslehantering AB.

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Marklund, Lars (2014), *Granskning av FUD-program 2013: Hydrologi* ("Review of RD&D Programme 2013: Hydrology", in Swedish). Report to the Swedish National Council for Nuclear Waste. Tyréns. (Dnr. 18/2014).

Rutqvist, J. and Tsang, C-F. (2008), *Review of SKB's Work on Coupled THM Processes Within SR-Can: External review*

[59] Ekman, L. and Ekman, M. (2013), *Quality control of GPS deformation data from Forsmark and analysis of crustal deformation in the local scale.* SKB R-13-11.

contribution in support of SKI's review of SR-Can. Swedish Nuclear Power Inspectorate Report 2008:08.

SKB (2010), *RD&D Programme 2010. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste.* Stockholm: Svensk Kärnbränslehantering AB.

SKB (2013), *RD&D Programme 2013. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste.* Stockholm: Svensk Kärnbränslehantering AB.

SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010.* Swedish National Council for Nuclear Waste. Stockholm: Fritzes.

Stephansson, Ove (2014), *Synpunkter på valda delar av SKB:s Fudprogram 2013.* ("Viewpoints on selected parts of SKB's RD&D Programme 2013", in Swedish). Report to the Swedish National Council for Nuclear Waste. (Dnr. 19/2014).

Stephansson, O., Sonnerfelt, L., Bungum, H. and Lindholm, C. (2012), *Workshop on seismology.* SSM 2012:25.

4.6 Surface ecosystems

4.6.1 Introduction

Radionuclides in the surface ecosystems are the source of radiation doses to man and the environment. Radionuclide accumulation and cycling are an essential part of the safety assessment. RD&D Programme 2013 presents the state-of-the-art and the future research programmes which SKB intends to carry out with regard to surface ecosystems.

It is the Council's considered opinion that publication of SKB's research in the international press and at conferences is very valuable. Research on surface ecosystems is of very high quality and thereby of international interest.

4.6.2 Aquatic ecosystems

In RD&D Programme 2013, SKB has expanded its studies of geochemical behaviour in the aquatic systems to include other elements than carbon. Now the cycling of nitrogen and phosphorus has also been studied. Including elements other than carbon was something that the Council had asked for in its review of RD&D Programme 2010 and is regarded as an important step in the modelling of aquatic ecosystems.

SKB has developed mechanistic ecosystem models for the aquatic environment to describe cycling and accumulation of radionuclides in organisms and organic matter in sea and lakes as well as in adjoining wetlands. SKB plans to validate its model descriptions with existing field data from Forsmark.

4.6.3 Hydrology and transport

In SR-Site, SKB used particle tracking in hydrogeological models to calculate where groundwater that has passed through the repository volume reaches the surface system.[60] These discharge points serve as a basis for the identification and delimitation of the biosphere objects that are included in the biosphere modelling. SKB shows that, depending on which method is used for the modelling, differences in results can be obtained which can shed light on uncertainties in the robustness of the models.

The results from the studies in the Krycklan catchment situated along the Vindeln River in Västerbotten in northern Sweden reveal the great influence of the wetlands on the transport of elements on the landscape level, where the studied elements are accumulated to a much greater extent in catchments dominated by wetlands than in catchments dominated by forest.

[60] SKB (2011), *Long-term safety for the final repository for spent nuclear fuel at Forsmark. Main report of the SR-Site project. SKB TR-11-01.*

4.6.4 Effects of long-term variations

The Swedish National Council for Nuclear Waste noted in its review of RD&D Programme 2010 that a programme was lacking to describe the evolution of the biosphere in climates that are warmer than today.

4.6.5 Swedish National Council for Nuclear Waste's viewpoints

Aquatic ecosystems

In RD&D Programme 2013, SKB presents mechanistic ecosystem models for geochemical distribution of other elements than carbon in an aquatic environment. These models are however complex and have great uncertainties in input data as well as in parameters that cannot be measured. Evaluating and validating the model calculations is therefore a difficult task. When the model results are to be evaluated there are other uncertainties as well, for example there is great uncertainty regarding the future evolution of the areas. It is therefore important to have a clear plan for how these models are to be evaluated. It is reasonable that SKB should use field data for calibration and validation, especially if already collected data can be used. This plan should also include sensitivity and uncertainty analyses.

The Swedish National Council for Nuclear Waste would also like SKB to evaluate the possibilities of starting a programme to investigate how the construction of the repository will affect the nearby aquatic ecosystems and whether this can be of value for the ecosystem modelling.

Hydrology and transport

In RD&D Programme 2010, SKB presented plans to study specific hydrological objects that represent all succession stages in landscape evolution, from marine basins via eutrophic lakes to wetlands and watercourses. This is an important research area, which should be given priority. Similar studies should be also done

for watercourses, which are also discharge areas for groundwater and which furthermore interlink different wetlands and lakes.

Results from the surface hydrological model are used to determine the size of different flows in SKB's biosphere model. An "average object" is modelled with the surface hydrological model, and based on the modelling results, parameters that describe flows in the biosphere object are determined. When other biosphere objects are to be described, the parameter values are rescaled based on the size of the biosphere object and its catchments. The problem with this approach is that the hydrological relationships are seldom linear. Thus, SKB should have used more than one "average object" in the hydrological modelling. They should at least have done some kind of sensitivity analysis showing how great the difference can be between different objects and described to what extent the use of an "average object" entails a conservative approach.

A general reflection is that a comparison of different modelling tools should be carried out when several alternative models are available and that the reasons should be given why one model has then be chosen as a basis for the reported conclusions.

It may be questioned how general conclusions can be drawn on the basis of site-specific investigations. It is therefore positive that SKB plans to link newfound knowledge from the Krycklan catchment study to Forsmark and the investigation area on Greenland. It would also be desirable to conduct similar site-specific studies in e.g. Forsmark in order to verify regional differences.

Effects of long-term variations

In RD&D Programme 2013, the presentation of the coming three years' programme for "effects of long-term variations" is described in general terms without any more specific project details, which makes it difficult to determine SKB's objective for the coming three-year period.

References

SKB (2011), *Long-term safety for the final repository for spent nuclear fuel at Forsmark. Main report of the SR-Site project.* SKB TR-11-01. Stockholm: Svensk Kärnbränslehantering AB.

5 SKB's social science research programme and information preservation across generations

5.1 Introduction

The development of the nuclear waste issue over the past 30 years rests on a combination of technical and scientific studies and social interaction processes between actors making different choices and judgements based on their qualifications and values. A technical development process such as the Swedish final disposal process – which has to accommodate the interests of industry, municipal government, interest groups and national politics – cannot be completely value-neutral and objective. Each investigation, calculation, modelling, risk assessment, collaboration process, dialogue and RD&D Programme is made up of human choices that do not always rest on purely technical or scientific criteria. Nor is the actual execution and building of the final repository solely a technical construction-related issue. An important question is what safety culture is needed so that every person in the process can perform optimally; how is the "human factor" best handled during the building process? Nor are the choices of technology for and siting of the final repository based purely on technical or scientific considerations. What risks we are prepared to accept when it comes to safety in the final repository (it is not possible to guarantee 100 percent safety for 100,000 years) is one such political question that comes to mind. What global changes – war, resource availability, economy – threaten the realization of a final repository? Research dealing with how we as individuals and societies think about, handle practically and are affected by the issue of nuclear waste disposal (what we call social science research) will help us to see

what is often not readily apparent, i.e. strategic choices, values, risk perception, political and ethical standpoints, etc. We would like to highlight and discuss the human and societal dimensions of what are often perceived as purely objective and technical choices and principles in the final disposal process, repository design and long-term safety. Without a broad body of knowledge of the human and societal dimensions, decisions regarding the final repository will have no solid foundation.

Social science research can highlight and clarify social and political processes of crucial importance for well-founded and democratic decisions in this matter. In other words, it is not just a question of a secondary perspective or general reflections, but rather a perspective that bears on the very heart of the issue.

The Swedish National Council for Nuclear Waste finds that SKB's social science research programme has been carried out in a way that reinforces this view of the relevance and importance of social science research. However, the relevance of SKB's societal programme to the final repository project is somewhat unclear. It is therefore of crucial importance that humanistic and social science research in the field of nuclear waste[1] can continue and be deepened with actors as instigators and funders (see further under 5.4). Interest has intensified in many European countries in recent years.[2] The EU's new framework programme for research, Horizon 2020, opens the door for new projects in this area.

5.2 Previous RD&D reviews

In its previous RD&D reviews and state-of-the-art reports, the Swedish National Council for Nuclear Waste has expressed a positive view of SKB's social science research programme. The evaluations that have been done by the SKB programme's Social Science Advisory Group (2009)[3] and by Olof Söderberg (on behalf

[1] Hereafter, no strict distinction will be made between the humanities and the social sciences.
[2] SOU 2014:11 *Nuclear Waste State-of-the-Art Report 2014. Research debate, alternatives and decision-making*, pp. 71–83.
[3] Berner, B., Drottz Sjöberg, B. and Holm, E. (2009), *Samhällsforskningen 2004–2009 Teman, resultat och reflektioner ("Social science research 2004-2009 Themes, results and reflections", in Swedish).*

of SKB, 2012)[4] confirm this positive attitude. However, the Council has also had critical viewpoints on the aims of the programme and on the selection of completed research projects. We will return to this, but would like in this context to consider a section from the evaluation carried out for SKB by Söderberg in 2012.

In this evaluation, explicit criticism is levelled at the scientists who said in interviews at the time of the evaluation that the social science research programme should have had a broader purpose than it did. According to these scientists, the purpose should have included a "questioning" of the scientific and technological development work done at SKB. Such a broadening of the purpose is rejected in the evaluation with two arguments. The first is that such a questioning should have occurred long before, "perhaps as early as the '80s". The second is that it is unrealistic in the early 2000s to focus the social science research programme on a problematization of the proposed KBS-3 method when it has in principle been approved by the Government.[5] Moreover, the site selection process, based on the KBS-3 method, was already initiated. In the current RD&D Programme, SKB confirms the judgement of the evaluation and writes the following:

> This reasoning is rejected in the evaluation report, which says that it is not realistic to expect that SKB should, at the beginning of the 21st century, have formulated a purpose for its social science research programme implying that the results of this research could lead to a questioning of the direction of the technical and scientific development work that had been conducted for the past quarter century.[6]

It is the Council's considered opinion, in agreement with SKB, that a social science research programme pursued by SKB with the express purpose of questioning SKB's technical and scientific development work is not reasonable. (This purpose could have been reasonable for basic scientific research funded by other actors who wish to shed critical light on what scientific, value-related, democratic, knowledge-based, political and other grounds different

[4] Söderberg, Olof (2012), *SKB:s program för samhällsforskning 2004–2011. En utvärdering* ("SKB's programme for social science research 2004-2011. An evaluation", in Swedish).. *SKB P-12-14.*
[5] Söderberg, Olof (2012), *SKB:s program för samhällsforskning 2004–2011. En utvärdering* ("SKB's programme for social science research 2004-2011. An evaluation", in Swedish).
[6] SKB, RD&D Programme 2013, p. 518.

strategic choices have been based on in order to judge the quality of the process from various aspects.) More reasonable for SKB's programme is the Swedish National Council for Nuclear Waste's proposal in its RD&D reviews from 2005, 2008 and 2011, namely to retain SKB's original formulation of purpose from 2004. According to RD&D-Programme 2004, the purpose of the social science research programme should be to:

- Get a broader perspective on the societal aspects of the nuclear fuel programme. This will facilitate evaluation and assessment of the programme in a larger context.
- Provide deeper knowledge and a better body of data as a basis for site- and project-related studies and analyses. The results of the social science research will thereby provide a sounder basis for decisions *and the EIS.*
- Contribute data and analyses for research on the societal aspects of large industrial and infrastructure projects. In this way, experience gained from the nuclear fuel programme can benefit other similar projects.[7]

This purpose was modified in RD&D Programme 2007 with regard to one crucial point. The italicized passage has now been deleted – with no explanation.[8] In RD&D Programme 2010, SKB asserted on the contrary that: "The programme is independent of both the EIS and the licence applications."[9] In its RD&D review 2011, the Council took a critical view of this detachment of the social science research programme from the final repository licence application.[10] Surprisingly, this is not reported in the 2012 evaluation.[11]

The Swedish National Council for Nuclear Waste stands by its opinion that SKB's change of course was unfortunate and that the second point in the above formulation of purpose from 2004 should have been retained. The social science research programme

[7] SKB, RD&D Programme 2004, p. 301 (Council's italics).
[8] SKB, RD&D Programme 2007, p. 409.
[9] SKB, RD&D Programme 2010, p. 398.
[10] SOU 2011: 50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010*, pp. 104.
[11] Söderberg, Olof (2012), *SKB:s program för samhällsforskning 2004–2011. En utvärdering* ("SKB's programme for social science research 2004-2011. An evaluation", in Swedish).

would in this way have been linked to the licence application for the final repository and the execution of the final repository project. In other words, "Relevance to the company's activities"[12] should have been the guiding principle.

A clarifying example of what this research can contribute is provided in Chapter 30 of RD&D Programme 2013.[13] The topic of this chapter is the information on the design and location of the final repository that should be passed on to future generations. To this end, SKB is collaborating in an OECD-NEA project and with ANDRA (SKB's counterpart in France). At the beginning of 2012, a research project was also initiated at the Department of Cultural Sciences at Linnaeus University in Kalmar. Another project is under way at the Centre for Theology and Religious Studies at Lund University. In the Council's opinion, this work provides a good model for how the humanities and the social sciences can be directly relevant to the final disposal issue. Similar considerations could have fruitfully guided other parts of the now-completed social science research programme. Read more under research area 3 below.

5.3 Proposal regarding a future social science research programme

SKB states in RD&D Programme 2013 that it does not intend at present to initiate a new research programme of the type carried out in 2004–2011.[14] One reason for this is that an application has now been submitted and is being considered by the Land and Environment Court and SSM. Another reason is that further research in this area: "should primarily be funded in the manner that is customary in the academic world, i.e. by having researchers apply for funds to various research funding bodies, for example state and private research councils or the like."[15]

[12] Söderberg, Olof (2012), *SKB:s program för samhällsforskning 2004–2011. En utvärdering* ("SKB's programme for social science research 2004-2011. An evaluation", in Swedish), p. 66.
[13] SKB, RD&D Programme 2013, pp.523–525.
[14] SKB, RD&D Programme 2013, p. 521.
[15] SKB, RD&D Programme 2013, p. 521.

It is the Council's considered opinion that the reasons given for not pursuing a future social science research programme are not tenable. The fact that an application has already been submitted does not mean that future research is no longer needed. Future research is necessary in both the natural sciences (including technology) and the social sciences. There is in particular a need for social science research that is not funded by the Nuclear Waste Fund and that is conducted by independent researchers in higher education institutions (HEIs). But the Council does not believe that this excludes a future social science and humanistic SKB programme, which has previously been determined by the final repository project. In summary, the Swedish National Council for Nuclear Waste proposes that SKB start a social science research programme that should be funded by the Nuclear Waste Fund and that is of immediate relevance to the execution of the final repository project.

There are strong arguments for such a social science research programme. In the first place, a successful execution of the final repository project is dependent on a close interaction between SKB and society, particularly the population in the municipalities that have been chosen for the project. This has been noted by SKB's president Christopher Eckerberg[16] with a special emphasis on further social science research concerning e.g. the public's perception of the final repository project. In the second place, additional attention has been given to the interaction between science, technology and society within Science and Technology Studies (STS).[17] Such studies are of crucial importance for a successful execution of the final repository project. In the third place, the close relationship between technology, the natural sciences and the social sciences is a strong reason for SKB to assume direct responsibility for a new social science research programme.

SKB should initiate a new social science research programme which, in contrast to the 2004–2010 programme, should be closely linked to the technical-scientific research programme and be aimed at promoting the execution of the final repository project.

[16] Oral presentation at WM Symposium Phoenix 3 March 2014.
[17] http://socav.gu.se/forskning/teknik--och-vetenskapsstudier--sts-/ (downloaded 27 May 2014).

When it comes to studies of the human dimension of the final disposal issue, an interaction is required between the humanities, the social sciences, technology and the natural sciences. Here are some research areas that are of importance in this context:

***Research area 1**: Research on global economic, political and social changes.*

This viewpoint was voiced by municipalities and the Council in the review of RD&D 2004 against the background of the fact that SKB spoke in RD&D 2004[18] of fast, far-reaching and unpredictable societal changes. Here we are referring to the need for research on changes in society that are of importance for e.g. safety in the final repository with regard to human intrusion, supply of materials during the construction phase, technology development, etc. The research may concern e.g. the consequences for the nuclear waste programme of a change in national energy policy, for example regarding the future of nuclear power.

***Research area 2:** Research on organization and safety culture.*

The Swedish National Council for Nuclear Waste's state-of-the-art report 2007 dealt with questions of safety and the three barriers – the natural, technical and the social.[19] All three barriers contribute to preventing the spent nuclear fuel from harming man and the environment. Research on the social barrier has to do with e.g. the safety culture of implementing actors, the decision process, attitudes, collective memory, protection in the form of participation, preservation of information and societal control. The background to such a research project is described in greater detail in section 4.1.2.

[18] SKB, RD&D Programme 2004, Appendix A.
[19] SOU 2007:38 *Nuclear Waste State-of-the-Art Report 2007 – responsibility of current generation, freedom of future generations,* p. 82.

The need for such research has not been adequately met by SKB's social science research programme.[20]

Research area 3: Information preservation across generations.

SKB should establish a systematic research programme based on identified needs of data collection methods and information preservation techniques. They should also give an account of the quality assurance of the research projects and what the work plan for development of methods for information preservation looks like for 2016–2019.

SKB's RD&D Programme 2013 devotes relatively little attention to the problem of how information can and should be preserved over long time periods, in this case many generations. Here it is concluded that the work should primarily be focused on:

> to find ways and means to continue to keep the question of how to preserve information and knowledge on a final repository for radioactive waste after closure alive and updated.

Furthermore, SKB believes that an analysis is needed of the extent to which long-term preservation of data emerging from the work of developing the method for final disposal of spent nuclear fuel and building the final repository is necessary.[21]

To succeed in the above endeavours, SKB is participating in an OECD-NEA project for the purpose of inventorying the need for information preservation techniques and, ultimately, investigating problems related to information preservation with fresh eyes. OECD is focusing on this area because they consider that plans to establish and maintain information preservation techniques should be prepared now, when the interest is great and funding is available. The ongoing OECD/NEA project will be concluded in 2014, and it is unclear whether, and if so how, the work will be pursued

[20] The social science research programme 2004–2011 includes a research project by Magnus Frostenson – *Slutförvarets industriella organisering. Fallgrop eller följdriktighet?* ("The Industrial organization of the final repository – Pitfall or consistency?", in Swedish) (R-10-55) – but this project focuses on the external relationship between the project's execution and municipal activities. The project does not meet the need for research on the internal relationship between the requirements of the safety assessment and the industrial execution of the final repository project. See further in section 4.1.2.
[21] SKB, RD&D Programme 2013, p. 524.

thereafter. Moreover, SKB has initiated a three-year research project, "One hundred thousand years back and forth", at Linnaeus University in Kalmar.

The OECD/NEA-sponsored projects at Linnaeus University and Lund University are all expected to be finished during the next two years. In addition, SKB is collaborating in a project with its French counterpart ANDRA, which has an extensive programme for information preservation during "the next few years". However, it is unclear how SKB intends to continue to pursue questions relating to information preservation at the end of the coming three-year period and what plans exist for the subsequent three years.

All of these efforts suffer from two deficiencies. In the first place, no systematic research programme has been devised to give answers to clear and concrete problems within information and knowledge preservation that require more long-term efforts. It is the Council's considered opinion that SKB should, within three to six years, establish an ambitious long-term programme so that efforts in the area will be more systematic.

In the second place, no attempts have yet been made to combine research and development work in the social sciences and humanities with efforts in technology and the natural sciences to find new solutions.[22] For example, there are potential technology development opportunities if a research and development programme for information and knowledge preservation is linked with various types of monitoring and information technologies currently being discussed by SKB.[23] There are quite a few successful examples of how, for example, data on environmental conditions can be communicated to the public, such as light sculptures in the cityscape or via mobile phone apps.

[22] See further SOU 2014:11 *Nuclear Waste State-of-the-Art Report 2014. Research debate, alternatives and decision-making,* Chap. 6.
[23] SKB, RD&D Programme 2013, p. 214.

5.4 Concluding reflections

In conclusion, the Swedish National Council for Nuclear Waste would like to reiterate that there is also a need for nuclear-waste-related research in the social sciences and humanities that should be conducted outside of SKB's organized research programmes. The Council has called attention to the need for such research in different contexts – most recently in its RD&D review 2011.[24] The Council noted that there is:

> still a great need for social science research around nuclear waste, which should be (1) as free as possible of economic and political interests but still (2) of relevance to Swedish nuclear waste management.[25]

The organization and financing of such research is primarily a matter for the research councils. Several projects of this nature have been carried out in cooperation between European social scientists and new projects are being initiated. It is important that Sweden not fall behind in this field.

The Swedish National Council for Nuclear Waste also deems it urgent to note that the Swedish Radiation Safety Authority is supporting a large and important body of research within its sphere of activity. The current research allocation amounts to SEK 76 million may, according to the 2014 appropriations direction, be used for basic and applied research to develop national expertise within the Authority's sphere of activity and to support and develop the Authority's oversight.[26] The Authority conducts research in the areas of *Man, technology, organization* (human factors engineering) and *Risk analysis, instrumentation and inspection*. Both of these areas have a bearing on research which the Swedish National Council for Nuclear Waste finds urgent within the social science research related to nuclear waste disposal. The Council also believes that SSM could play an important role by providing a link to social science research regarding the fundamental premises for assessments of the final repository's long-term safety. The Swedish National Council for Nuclear Waste

[24] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010*, pp. 102.
[25] SOU 2011:50 *The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) RD&D Programme 2010*, p. 107.
[26] Appropriations direction 2014 (M2013/778/Ke).

has brought attention to the role and development of the safety assessment in a special in-depth report[27] supplementing the Nuclear Waste state-of-the-Art Report 2007 and in several state-of-the-art reports.[28]

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[27] Swedish National Council for Nuclear Waste (2007), *Safety assessment of final disposal of nuclear waste – role, development and challenge. An in-depth report supplementing KASAM's Nuclear Waste State-of-the-Art Report 2007 (SOU 2007:38e).* Report 2007:2e.
[28] For example SOU 2013:11 *Nuclear Waste State-of-the-Art Report 2013. Final repository application under review: supplementary information and alternative futures*, SOU 2012:7 *Nuclear Waste State-of-the-Art Report 2012 – long-term safety, accidents and global survey and SOU 2007:38 Nuclear Waste State-of-the-Art Report 2011 2007 – responsibility of current generation, freedom of future generations.*

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Appropriations direction 2014 (M2013/778/Ke).

Committee terms of reference 1992:72

Scientific committee charged with the task of investigating questions concerning nuclear waste and the decommissioning and dismantling of nuclear facilities etc.

Decision at Government meeting of 27 May 1992.

Conducted by the head of the Ministry of the Environment and Natural Resources, Minister Johansson.

My proposal

I propose that a special scientific committee be appointed charged with the task of investigating questions concerning nuclear waste and the decommissioning and dismantling of nuclear facilities and of giving advice in these matters to the Government and certain public authorities.

Background

In Gov. Bill 1991/92:99 regarding certain appropriation matters for the budget year 1992/93 and changes in the national organization in the nuclear waste field, the Government proposed that the National Board for Spent Nuclear Fuel be abolished as a separate agency and that its activities be transferred to the Swedish Nuclear Power Inspectorate. The Bill proposed that the scientific council --

KASAM -- tied to the National Board for Spent Nuclear Fuel be given a more independent position and be tied directly to the Ministry of the Environment and Natural Resources as a commission instead of being administratively tied to an authority.

The Government (1991/92:NU22, rskr. 226) has decided in favour of the Government's proposal for a changed national organization in the nuclear waste field.

Thus, a special scientific committee charged with the task of investigating questions concerning nuclear waste and the decommissioning and dismantling of nuclear facilities and of giving advice in these matters to the Government and certain public authorities should be appointed.

Task

The committee should

- every three years, starting in 1992, submit by not later than 1 June a special report describing its independent assessment of the state of the art in the nuclear waste field.

- not later than nine months after the point in time specified in Section 25 of the Ordinance (1984:14) on Nuclear Activities, submit a report describing its independent assessment of the programme for the comprehensive research and development work and other measures which the holder of a license to own or operate a nuclear reactor shall prepare or have prepared according to Section 12 of the Act (1984:3) of the Act on Nuclear Activities.

The committee should also offer advice in matters relating to nuclear waste to the Swedish Nuclear Power Inspectorate and the Swedish Radiation Protection Authority when requested to do so.

Whenever necessary and economically feasible, the committee should undertake foreign travel to study facilities and activity in the nuclear waste field and arrange seminars on general topics in nuclear waste management.

The committee should comply with the Government's instructions to state committees and special investigators as regards the thrust of its proposals (Dir. 1984:5) and the EU aspects of the investigations (Dir. 1988:43).

The committee should consist of a chairman and at most ten other members. It should also be allowed to engage outsiders for special assignment whenever necessary and economically feasible.

Chairman, members, experts, consultants, secretary and other assistants should be appointed for a defined term.

The committee's task shall be regarded as completed when the Government has made a decision on the license application for a final repository for spent nuclear fuel and high-level nuclear waste in Sweden.

Petition

With reference to the above, I petition that the Government authorize the head of the Ministry of the Environment and Natural Resources

to appoint a special scientific committee -- subject to the Committee Ordinance (1976:119) -- with not more than eleven members charged with the task of investigating questions concerning nuclear waste and the decommissioning and dismantling of nuclear facilities and of giving advice in these matters to the Government and certain public authorities,

to appoint chairman, members, experts, consultants, secretary and other assistants.

I further petition that the Government order that the costs be charged to appropriations under the fourteenth title "Commissions etc.".

Decision

The Government concurs with the rapporteur's suggestions and approves his petition.

Committee terms of reference 2009:31

Supplementary terms of reference for the Swedish National Council for Nuclear Waste (M 1992:A)

Decision at Government meeting of 8 April 2009

Summary of task

The Swedish National Council for Nuclear Waste was established by a decision at a Government meeting on 27 May 1992 (dir. 1992:72). The Swedish National Council for Nuclear Waste shall investigate and shed light on matters relating to nuclear waste and decommissioning and dismantling of nuclear facilities etc. and give advice to the Government in these matters. Aside from the Government, important target groups for the Swedish National Council for Nuclear Waste are also concerned public authorities, the nuclear power industry, municipalities, interested organizations, politicians and the mass media.

The Swedish National Council for Nuclear Waste shall possess broad scientific qualifications in natural science, technology, the social sciences and the humanities.

The task of the Council shall be regarded as completed when the Government has decided on a final repository for spent nuclear fuel and high-level nuclear waste in Sweden.

These terms of reference replace the terms of reference from 27 May 1992.

Task

The Swedish National Council for Nuclear Waste shall assess the Swedish Nuclear Fuel and Waste Management Co's research, development and demonstration programmes (RD&D programmes), applications and other reports of relevance for the final disposal of nuclear waste. The Council shall – not later than nine months after the Swedish Nuclear Fuel and Waste Management Co has submitted its RD&D programme in compliance with Section 12 of the Act (1984:3) on Nuclear Activities – submit its independent assessment of the research and development activities and the other measures described in the programme. The Council shall also follow the work being done on decommissioning and dismantling of nuclear facilities.

In the month of February every year, starting in 2010, the Council shall submit a report on its independent assessment of the state of the art in the nuclear waste field.

The Council shall investigate and shed light on important issues in the nuclear waste field, for example by holding hearings and seminars, so that it can make well-founded recommendations to the Government.

The Council shall also keep track of other countries' programmes for management and disposal of nuclear waste and spent nuclear fuel. The Council should also follow and, where necessary, participate in the work of international organizations on the nuclear waste issue.

These terms of reference replace the terms of reference from 27 May 1992 (dir. 1992:72).

Organization

The Swedish National Council for Nuclear Waste shall consist of a chairman and not more than ten other members (one of whom also acts as deputy chairman). The members shall have broad scientific qualifications in fields related to the nuclear waste issue. It can engage outsiders for special assignments whenever necessary and economically feasible. Chairman, members, experts, consultants, secretary and other assistants shall be appointed for a defined term.

Timetable

The task of the Council shall be regarded as completed when the Government has decided on a final repository for spent nuclear fuel and high-level nuclear waste in Sweden.

(Ministry of the Environment)

The Swedish National Council for Nuclear Waste's Review of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) Programme for research, development and demonstration of methods for the management and disposal of nuclear waste 2013.

The Swedish National Council for Nuclear Waste – Kärnavfallsrådet – is an independent scientific committee within the Ministry of the Environment. The members of the Council possess expertise in technology, science, ethics and the social sciences.

One of the Council's tasks is to assess SKB's research, development and demonstration programmes (RD&D programmes). In its review of the 2013 programme, the Council has focused on those areas in which the members of the Council possess special expertise.

The Council would particularly like to recommend that future RD&D programmes:

- provide more detailed references to the reported research results in the running text,
- present a research and development programme aimed at creating an organization that can transform a theoretically reasonably safe final repository for spent nuclear fuel into a built repository on the selected site that meets the safety assessment's requirements,
- report that a measurement programme is under development to monitor the water saturation of the buffer and other important processes in plugged parts of the repository,
- describe a joint programme for the research and development that is needed to support the decommissioning of the nuclear power reactors, including the Ågesta Nuclear Power Plant and other nuclear facilities adjacent to the reactors,
- present a new social science research programme closely linked to the technical-scientific research programme for the Spent Fuel Repository.

The report can be downloaded at www.karnavfallsradet.se/en.

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