



The Swedish National Council for Nuclear Waste's
Review of the Swedish Nuclear Fuel and Waste
Management Co's (SKB's) RD&D Programme 2016

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The Swedish National Council for Nuclear Waste

Stockholm 2017



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The Swedish National Council
for Nuclear Waste's Review of
the Swedish Nuclear Fuel and
Waste Management Co's (SKB's)
RD&D Programme 2016

To the minister and head of the Ministry of the Environment and Energy

This review concerns the Swedish National Council for Nuclear Waste's assessment of the Swedish Nuclear Fuel and Waste Management Co's (SKB's) *RD&D Programme 2016. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste.*

The Swedish National Council for Nuclear Waste is an interdisciplinary scientific committee whose mission is to advise the Government on matters relating to spent nuclear fuel, nuclear waste and decommissioning of nuclear facilities. According to the Government's terms of reference¹, the Swedish National Council for Nuclear Waste shall submit a report on its independent assessment of the measures described in SKB's RD&D programme.

The Council's scientific secretary Johanna Swedin has served as project manager for the review work.

This report is endorsed by all members and experts in the Swedish National Council for Nuclear Waste. Mikael Karlsson has submitted a special statement.

Stockholm, June 2017

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¹ M1992:A Kärnavfallsrådet, Dir. 2009:31.

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1 Introduction and recommendations to the Government

The Swedish National Council for Nuclear Waste has reviewed portions of Svensk Kärnbränslehantering AB's (SKB) research programme *RD&D programme 2016. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste* (RD&D programme 2016), focusing on those areas in which the members of the Council possess special expertise.² The Council has engaged a consultant to conduct a study within the area of the geosphere.³

The forms for and subjects covered by the RD&D programme are regulated by the Act (1984:3) on Nuclear Activities (the Nuclear Activities Act). The point of departure for the Council's review is the Nuclear Activities Act and its travaux préparatoires (legislative history),⁴ where it is stated that the research programme shall:

- be comprehensive
- focus the research on the method or methods found to be best with regard to safety and radiation protection
- describe the entire process chain including management, interim storage and disposal

² Within the limitations of its collective area of expertise, the Council has reviewed RD&D Programme 2016, except for the following areas: Chapter 13 *Climate and climate-related processes*; Chapter 17 *Planning for decommissioning of SKB's nuclear facilities*; Chapter 19 *Continued activities within decommissioning*.

³ Black, J. 2017. *Review of hydrogeological elements in 2016 RD&D programme of SKB (TR 16-15)*. External report at: www.karnavfallsradet.se

⁴ Gov. Bill 1983/84:60, pp. 40ff. and pp. 92f.

- adopt a long-term perspective and ensure that the reactor owners remain responsible until the nuclear material and the nuclear waste have been deposited in a closed and sealed final repository
- present both achieved research results and planned future research
- present an account and follow-up of alternative management and disposal methods that emerge during its own research as well as other national and international research
- provide transparency and insight into the problems that remain to be solved.

In Chapter 2, the Council presents its comments regarding RD&D programme 2016 with respect to comprehensiveness, insight and transparency. In Chapter 3, the Council highlights special comments that have emerged during the review. Chapter 4 contains comments on areas which the Council believes should be included in future RD&D programmes, 2019 and onward.

The Swedish National Council for Nuclear Waste's recommendations to the Government

In summary, the Swedish National Council for Nuclear Waste finds that the research and development activities described in the 2016 RD&D programme do not fulfil in all respects the requirements on the research activities that are prescribed in Section 11 of the Nuclear Activities Act. There are sections in the RD&D programme that need to be clarified and research that needs to be done to show that the research and development activities enable safe decommissioning and final disposal to take place.

The Council recommends that the Government urge SKB to carry out the following measures in connection with the continued research activities:

- that hereafter SKB make the RD&D programme more comprehensive and clear. In particular, the scope of the research programme should be defined by means of a timetable and a budget. The choice of cooperation partners should also be described and justified more clearly. (Read more in Chapter 2 *Comprehensiveness, insight and transparency*).

- that SKB remedy the deficiencies described by the Council (read more in Chapter 3 *Special comments on RD&D programme 2016*) before RD&D Programme 2019, even if the Government should grant a licence for a final repository for spent nuclear fuel. It is particularly urgent that safety-related research pertaining to the engineered barriers be planned and executed ASAP, in particular with regard to:
 - stress corrosion cracking – Chapter 3.2 section 8.1.5,
 - copper creep – Chapter 3.2 section 8.2.1, and
 - blue brittleness – Chapter 3.2 section 8.3.
- that continued research be included in the RD&D programme even if an activity receives a licence. This is important since a decision may be made to grant SKB a licence to construct and operate a final repository for spent nuclear fuel before RD&D programme 2019 is published, despite the fact that a great deal of research remains to be done. (Read more in Chapter 4.2 *Research related to approved licence applications should be included in future RD&D programmes*).

2 Comprehensiveness, insight and transparency

2.1 The RD&D programme shall be a comprehensive research programme

The Council's assessment is that RD&D programme 2016 often gives the impression of being more of an activity report than a comprehensive research, development and demonstration programme where SKB explains its research priorities. SKB describes its research plans in general terms, but does not specify how and why or what resources in time and money are required for their execution.

It is the Council's considered opinion that a comprehensive programme should (1) clearly describe and justify the planned research, (2) clarify why a given method has been chosen, (3) clarify what results have been achieved and present them in relation to the research being conducted within other organizations and institutions both nationally and internationally, (4) justify the choice of collaboration partners and clearly describe how the collaboration takes place, and (5) define the scope of different research programmes with the aid of budgets and timetables.

2.2 The RD&D programme shall provide insight and offer transparency

The RD&D programme should provide transparency and insight into SKB's work, making it possible to assess whether SKB's research and development is focused on the most essential questions and the problems that remain to be solved.

In order to provide better insight into its research and development activities, SKB needs to describe and justify its research

priorities more clearly. In order to serve as a good basis for the Government's decision, the RD&D programme should provide insight. It should show clearly what SKB knows today and what SKB needs to know in the future.

There is also a democratic perspective on transparency and insight. By means of a clear and complete presentation, information on how the spent nuclear fuel and the radioactive waste is managed can be conveyed so that even non-experts can understand which questions have been answered and which problems remain to be solved. This permits better communication with government authorities, non-governmental organizations and the public, not least in the concerned municipalities.

2.3 Deficiencies regarding comprehensiveness, insight and transparency

It is the Council's considered opinion that the different research programmes described in RD&D programme 2016 are often not described comprehensively enough, and therefore do not provide the desired transparency and insight. In the following we have compiled comments that have emerged regarding deficiencies in a number of research programmes.

Research issues should be described clearly and be fully justified

Some programmes lack clearly formulated issues and objectives. When the descriptions of research programmes are too brief, it is unclear what SKB plans to do and why. The different research programmes in Chapters 6–13 in RD&D programme 2016 should begin with a clear formulation of the issue and a descriptive background. In Chapter 3, the Council offers its views regarding these deficiencies in the programme, with a special focus on sections 6.1 *Radionuclide inventory*, 7.1 *Non-regular fuels* and 7.4 *Fuel information*.⁵

⁵ This comments also applies to sections 6.7, 7.3, 7.7, 8.1.6, 8.2 and 10.2 in RD&D programme 2016.

It should be clearly explained why a given method has been chosen

RD&D Programme 2016 should provide a better description of the research programmes and what types of experiments are to be done as well as what they are expected to lead to. In a number of instances the method is not clearly described, for example in sections 7.6 *Safeguards* and 11.1.2 *Critical structures*.⁶

In the research programmes, planned measurements and simulations should be clearly described along with the expected knowledge gain based on the current state of knowledge. In several research programmes, model simulations are presented as the chosen method. However, it is not always evident whether the simulation results can be verified by experiments. Examples can be found in Chapter 9 *Cementitious materials* and section 11.3 *Modelling of discrete fracture networks*.⁷

The research programmes should be better described in context

It is often unclear what the achieved results are and what is new since RD&D programme 2013.⁸ General information is lacking on similar research being conducted by other organizations. A well-executed external environmental analysis is also lacking. Current research elsewhere in the world should be presented, and SKB should take a stand on what they consider to be relevant and correct or less relevant and correct research results. See for example section 8.3 *Design*.⁹

Collaboration partners should be justified and collaborations clarified

In many cases it is unclear why SKB chooses to collaborate with certain organizations. Nor is it clear in some cases which actors they are actually collaborating with. It should be made clear what

⁶ This comments also applies to Chapter 6 and sections 7.3 and 8.2 in RD&D programme 2016.

⁷ This comments also applies to sections 7.7, 8.3 and 11.7 in RD&D programme 2016.

⁸ This comments also applies to sections 6.1, 6.7, 7.3, 7.4, 7.5, 11.1, 11.11 and 11.12 in RD&D programme 2016.

⁹ This comment also applies to Chapter 6 and section 7.3 in RD&D programme 2016.

role SKB has in all collaborations: Are they following the research passively? Is SKB merely a source of funding? Is SKB driving the actual research forward? An example of this deficiency can be found in section 7.2 *The ageing of fuel*.¹⁰

The scope of the research programmes should be defined – timetables and budgets are lacking

It is often stated in RD&D programme 2016 merely that the research programme will continue without further explanation. No timetable or budget is presented to define the scope of the research programmes.¹¹ It should be stated clearly how much research remains to be done. Summarizing each research programme with a timetable¹² showing when the research will be done and when the research results can be put to use would facilitate understanding and provide an overview.

¹⁰ This comments also applies to sections 5.2.3, 6.6, 6.7, 6.8, 7.1, 7.7 and 7.5 in RD&D programme 2016.

¹¹ This comments applies to sections 6.3, 6.6, 6.7, 7.3 and 7.4 in RD&D programme 2016.

¹² A good example is Figure 15-4 *Schematic overview of OKG's timetable for decommissioning in RD&D programme 2016*.

3 Special comments on RD&D programme 2016

More generally, the Council finds RD&D programme 2016 to be uneven; certain research programmes are well and fully described, while others are described too briefly and sketchily. Examples of well-described chapters are 9 *Cementitious materials* and 12 *Surface ecosystems*, while there are deficiencies in 6 *Low- and intermediate-level waste* and 8 *Canister*. The preceding chapter contains a presentation of the Council's comments on deficiencies that have been found to occur repeatedly during the review of RD&D programme 2016. This chapter contains special comments on RD&D programme 2016. To make it easier for the reader, the headings below follow the four parts of the RD&D programme and its division into chapters and sections.

3.1 Part I Activities and plan of action

Chapter 5 in RD&D programme 2016: Further research and technology development

5.2.3 *The Spent Fuel Repository and Clink*

SKB writes in RD&D programme 2016 that monitoring of the evolution of the repository's barriers from deposition up until closure can further enhance knowledge of the repository site and that this is an important confidence issue.¹³ It is good that SKB has now raised this issue, as previously requested by the Council. Monitoring is mentioned only in Chapter 5, which is a summarizing chapter, and

¹³ RD&D programme 2016, section 5.2.3 *The Spent Fuel Repository and Clink*, p. 86.

the fact that it is not more fully described in a slightly more detailed and specified research programme later in the report is seen as a deficiency.

Proposed remedy: A better description of the monitoring plans should be presented no later than in RD&D programme 2019.

3.2 Part II Waste and final disposal

Chapter 6 in RD&D programme 2016: Low- and intermediate-level waste

6.1 Radionuclide inventory

In principle, there are measurement methods for all difficult-to-measure radionuclides. SKB's task is to use these methods for the materials whose radioactivity needs to be determined. SKB says that they plan to use ICP-MS specifically for measurement of technetium-99 and iodine-129 in reactor water.

Proposed remedy: By no later than RD&D programme 2019, SKB should clarify how other radionuclides will be handled.

6.3 Conditioning of long-lived waste

The plan is to start decommissioning nuclear facilities in the early 2020s. SKB should begin now to develop acceptance criteria, a method and a facility for stabilization of waste in steel tanks so that they will be finished and ready in good time before the dismantling and demolition work starts.

Certain components in the long-lived waste have relatively high radioactivity levels, such as control rods and reactor pressure vessels. SKB plans to dispose of these components in the final repository for long-lived waste (SFL), which is planned to be commissioned in 2045 (project start 2030). SFL is only dealt with superficially in RD&D programme 2016, and no planned research is presented. The reason given is that the project lies so far in the future. In 2013, SKB published a concept study for the future SFL.¹⁴ It discusses

¹⁴ Elfving, M. et al. 2013. *SFL concept study. Main report*. SKB TR-13-14.

different alternative designs and research needs, among other things. In 2015, SKB began an evaluation of the safety of the current repository concept for SFL, which is expected to be finished in 2018. Both the concept study and the safety evaluation (which will constitute an important basis for SKB's continued work) should have been described in greater detail in RD&D programme 2016.

It is mentioned that conditioning of the waste may be necessary,¹⁵ but not how it will be done.

Proposed remedy: A detailed research programme that can serve as a basis for the design of SFL should be presented no later than in RD&D programme 2019, which should also stipulate whether the waste will be conditioned and if so how. The RD&D programme should also include more detailed descriptions of the plans for interim storage of the long-lived waste.¹⁶

6.6 Degradation products from organic materials and their interactions with radionuclides

The research on degradation of additives in cement is described very sketchily and inadequately.

Proposed remedy: By no later than in RD&D programme 2019, a description should be provided of what consequences the release of degradation products may have on the solubility and complexation of radioactive metals, as well as their adsorption to surfaces, and thereby on their mobility in aqueous systems.

Chapter 7 in RD&D programme 2016: Spent nuclear fuel

7.1 Non-regular fuels

SKB describes an existing method where damaged fuel is sawn up and handled in a hot cell. SKB further writes in its programme for future activities that: *a similar treatment of the damaged untreated*

¹⁵ RD&D programme 2016, section 3.3.4, p. 49.

¹⁶ SKB has decided not to interim-store long-lived waste in the planned SFR extension. Press release 2 May 2017 "Klargörande beslut i projektet för SFR-utbyggnad" ("Clarifying decision in the SFR extension project," in Swedish), see: www.skb.se/press (accessed 23 May 2017).

fuel in Clab will take place. This can be interpreted as indicating that SKB will dismantle and saw apart damaged fuel rods in Clab, and that this will be done in a hot cell. This would represent a major departure from the currently existing activity at Clab.

Proposed remedy: Clarification as to whether the activity at Clab will be modified, and if so what the consequences will be for the design of safeguards in the facility, should be provided no later than in RD&D programme 2019.

7.2 *The ageing of fuel*

It is good that SKB clearly identifies deficiencies that have been dealt with and thereby attempts to relate content and results to previous research, development and demonstration activities. However, SKB does not describe in concrete terms how the identified deficiencies have been remedied.

SKB does not describe environmental scanning and research results with sufficient detail and precision. It is also unclear whether SKB is already conducting or plans to conduct any research in the area themselves, or whether others are doing so. The RD&D programme says that SKB will actively participate in international forums, but not how this will be done.

Proposed remedy: A clearer description of how international collaboration takes place should be provided no later than in RD&D programme 2019.

7.4 *Fuel information*

The current situation and the ongoing research programme are described very sketchily and allow room for different interpretations. The proposed programme can be interpreted as if SKB and the nuclear power plants do not have a modus operandi that ensures complete documentation of all nuclear fuel that is handled. If so, this is very serious.

Proposed remedy: Research and results of importance for the documentation of nuclear fuel at the sites mentioned in the section should be described clearly no later than in RD&D programme 2019.

This includes identifying possible deficiencies and proposing how to remedy them.

7.6 Safeguards

The research programme in this section is inadequately described. It is not clear what results have been achieved or what the future research work involves. SKB describes neither the current status of equipment and methodology, nor what has happened during the latest RD&D period. Nor is it clear what types of tasks remain for SKB to carry out.

SKB gives an account of the special need for verification and inspection of nuclear material. SKB points out that: *The content [of nuclear material in the fuel] may be calculated either based on information from the fuel's operating history or based on measurements of gamma and neutron radiation in combination with calorimetric measurements.* There is a big difference between calculating an inventory and measuring it.

Proposed remedy: No later than in RD&D programme 2019, SKB should clarify and explain their position on calculating, as opposed to determining by measurement, the quantity of nuclear material. If SKB recommends calculation of the content of nuclear material, a clear explanation is required of (1) how and why calculations may be considered sufficient, (2) with what accuracy the inventory can be determined, and (3) how the calculations and their precision are to be verified without performing experimental measurements. If, on the other hand, SKB intends to perform measurements, they must explain how this is to be done.

7.7 Fuel dissolution and radionuclide chemistry

The description of the planned EU project is so inadequate that it is not possible to evaluate the need for and benefits of the project. Nor is an account given of what will happen with the research if the planned EU project does not get funding or whether alternative funding is available.¹⁷

¹⁷ RD&D Programme 2016, p. 122.

Proposed remedy: An account should be given of this no later than in RD&D programme 2019.

Chapter 8 in RD&D programme 2016: Canister

8.1.2 Localised corrosion (pitting)

This section describes the retrieval of full-scale copper canisters from the Prototype Repository in the Äspö HRL, where the greatest pit depth was 7 μm after 8 years in the repository. SKB should have analyzed the surfaces of the copper canisters before the start of the experiment so that clear conclusions could be drawn after the conclusion of the experiment.

8.1.3 Copper corrosion in pure, oxygen-free water

Research has been conducted on copper corrosion in pure, oxygen-free water for a long time in different research groups inside and outside Sweden, and SKB has contributed to enhancing the state of knowledge on this subject. SKB refers to its comprehensive report on copper corrosion in pure, oxygen-free water,^{18,19} but it should have been made clear in RD&D programme 2016 that different opinions still exist regarding, for example, how hydrogen formation takes place.

Proposed remedy: The Swedish National Council for Nuclear Waste assumes that SKB will continue to monitor the research and provide an account in RD&D programme 2019. If a breakthrough is achieved in the field, SKB should promptly apply the new knowledge to the conditions expected to prevail in SKB's final repository for spent nuclear fuel.

¹⁸ Hedin, A. et al. 2015. *Samlad redovisning om kopparkorrosion i syrgasfritt vatten* ("Integrated account of copper corrosion in oxygen-free water," in Swedish). SKBdoc 1473304 ver 1.0. Svensk Kärnbränslehantering AB.

¹⁹ SKB. 2016. *Ytterligare information om kopparkorrosion i syrgasfritt vatten* ("Further information on copper corrosion in oxygen-free water," in Swedish). SKBdoc 1540185 ver 1.0. Svensk Kärnbränslehantering AB.

8.1.4 Radiation-induced corrosion

The contention that corrosion of copper increases in the presence of gamma radiation due to the formation of copper oxide on the surface of the copper and uptake of hydrogen in the copper is correct. It is important that research continue to determine the reaction mechanism. The research programme on radiation-induced corrosion is very sketchily described.

Proposed remedy: The research programme should be described more thoroughly no later than in RD&D programme 2019.

8.1.5 Stress corrosion cracking

A well-documented mechanism is still lacking for stress corrosion cracking under both *reducing conditions* in a sulphidic, oxygen-free environment, and under *oxidizing conditions* in the presence of nitrite, ammonium or acetate ions. In both cases, the prerequisite for stress corrosion cracking is formation of a special passive film of copper(I)sulphide or copper(I)oxide, whose properties should be analyzed in detail. Under reducing conditions in a sulphidic, oxygen-free environment, sulphide corrosion can cause hydrogen uptake in copper and initiate stress corrosion cracking.

Proposed remedy: Studies should continue to be conducted regarding these corrosion mechanisms to enable conclusions to be drawn regarding the repository's long-term safety. The results should be presented as soon as possible, but no later than in RD&D programme 2019.

8.2.1 Impact of phosphorus

The Swedish National Council for Nuclear Waste shares the view that knowledge of the content and distribution of phosphorus in copper plays an important role in understanding these mechanical properties, and that research in this area must continue. However, the planned research is not described in sufficient detail to enable an uninitiated reader to understand what research needs to be done.

Proposed remedy: No later than in RD&D programme 2019, descriptions should be provided of what calculation methods are to

be used and what the purpose of the thermodynamic studies is, as well as what methods are to be used to study the distribution of phosphorus in copper.

Detailed knowledge of possible deformations in the copper shell at different loads and load directions is needed to be able to **validate a creep model**.

Proposed remedy: Continued research should be done on how trace elements such as phosphorus can alter the chemical and mechanical properties of copper. This is necessary in order to be able to evaluate the strength of the copper canister under repository conditions. The research on a validated creep model should be presented as soon as possible, but no later than in RD&D programme 2019.

8.3 Design

Research on the role of hydrogen in different copper corrosion mechanisms and in creep, and how the hydrogen affects the material properties of the copper, is important and should continue to be conducted in accordance with a described plan, along with studies of the influence of copper content on radiation-induced embrittlement of nodular cast iron.

Proposed remedy: The calculation studies must be supplemented by verified experimental studies and the result presented no later than in RD&D programme 2019.

The Council would like to urge SKB to take into account static and dynamic deformation ageing, so-called **blue brittleness**, which is an embrittlement mechanism in nodular cast iron that has not previously been studied.^{20,21} This form of mechanical weakening can have a negative impact on the mechanical properties of the insert.

Proposed remedy: A literature review of blue brittleness should be done as soon as possible, but no later than in RD&D programme 2019. This is important for being able to determine how seriously this could affect the mechanical properties of the KBS-3 canister and thereby long-term safety.

²⁰ Honeycombe, R.W.K. and Bhadeshia, H.K.D.H. 1995. *Steels: Microstructure and Properties*.

²¹ Pihlajamäki, T. 2017. *Characterization of Strain Aging with Full-field Strain Measurements*. MSc thesis.

When it comes to the design of the canister, a thorough external environmental analysis is lacking in RD&D programme 2016. A description should have been provided of the development of canisters that is under way in Canada, along with a comparison and an evaluation in relation to the KBS-3 canister.

Proposed remedy: The research being conducted on canisters in Canada should be presented no later than in RD&D programme 2019. A more general discussion should also be included of any development of and flexibility around the canister and the KBS-3 concept.

Chapter 9 in RD&D programme 2016: Cementitious materials

The research programme on cementitious materials is well described and explained. Modelled data have to some extent been verified by experimental studies.

Proposed remedy: Further verifications are needed of modelled results, such as in sections 9.1.6 *Impact of mineral additives* and 9.1.8 *Internal and external loads*, and should be presented no later than in RD&D programme 2019.

Chapter 10 in RD&D programme 2016: Buffer, backfill and closure

10.2 The bentonite material properties in the saturated state

Delayed water saturation of the buffer over a very long time should be dealt with, along with shear loads in the rock. The research programmes in this chapter are sketchily described, and it is not clear what research is planned. Merely stating that measurements will continue is not enough.

Proposed remedy: The planned research activities should be clarified and presented no later than in RD&D programme 2019.

10.3 Evolution of the bentonite material after water saturation

Error limits in the measurement values (see Figure 10–12) should be presented to permit evaluation of the results.

Proposed remedy: A presentation of the error limits in measurement values should be provided no later than in RD&D programme 2019.

Chapter 11 in RD&D programme 2016: Rock

11.1.2 Critical structures

An integrated interpretation of hydrogeological information gathered during the operating phase will be included in modelling in order to identify and characterize critical structures that have a negative impact on a final repository for spent nuclear fuel. According to SKB, a better characterization of critical structures can result in fewer deposition holes being rejected unnecessarily.

It is not evident from RD&D programme 2016 how observations and measurements of critical structures are to be used to reflect their actual spatial extent in three dimensions and how the modelled critical structures are to be verified.

Proposed remedy: A strategy should be presented no later than in RD&D programme 2019 for how unidentified but potentially critical structures that can affect the safety of the repository are to be handled. Clear criteria should also be defined for selection methods that can reduce the number of deposition holes that are rejected.

11.3 Modelling of discrete fracture networks (DFNs)

The bedrock consists of a heterogeneous material with fractures that are not circular. It is therefore necessary to simplify their geological complexity in modelling programs, which means that the DFN models (models of the fracture networks in the rock) do not fully reflect reality. In addition to the fact that the models are simplifications of reality, the discrete fracture network can be affected by changes in the rock due to the final repository, both during operation and after closure. It is also important that the models can be validated and that it can be explained how this is to be done.

Proposed remedy: A strategy should be presented no later than in RD&D programme 2019 for how modelling results and uncertainties are to be handled and how they can be validated.

11.7 The impact of the ice load on the flow and transport properties of the rock

The thermo-hydro-mechanical (THM) properties of the rock are important for safety, and the repository as such will influence these properties. SKB plans to develop a number of modelling tools that are able to integrate different processes such as flow, hydrogeo-chemistry, transport and microbiology. RD&D programme 2016 does not make it sufficiently clear which models will be integrated with or in the planned THM models. It is also not clear whether these models together will then be integrated with different climate scenarios.

Proposed remedy: It should be clarified no later than in RD&D programme 2019 which models will be integrated and whether they will be integrated with climate scenarios.

11.11 Seismic impact on post-closure safety

Seismic activity takes place primarily along existing structures and affects the fracture network in the bedrock. In order to obtain a better understanding of how both major and minor deformation zones are related to one another and to previous and ongoing seismic activity, they should be mapped and investigated in detail.

Proposed remedy: A plan to map and investigate in detail how both major and minor deformation zones are related to one another and to previous and ongoing seismic activity should be presented no later than in RD&D programme 2019.

11.13 Induced deformation in the rock mass caused by thermal, seismic or glacial load

There may be fractures that are not necessarily water-conducting during construction and operation, and they can also be very inconspicuous. Even if such fractures do not intersect a deposition

hole, they may be widened by creep movements and could thereby become potential transport channels for both water and released radionuclides if damage has occurred to canister and buffer.

Proposed remedy: Discriminating criteria for fracture properties associated with tunnels and deposition holes should be determined and presented no later than in RD&D programme 2019, since dry fractures can in time become conductive.

3.3 Part III Decommissioning of nuclear facilities

RD&D programme 2016 contains general accounts of the planned decommissioning work at Uniper and Vattenfall in the short-term perspective. No planned research for development or evaluation of the dismantling process is described.

SKB writes in RD&D programme 2016 that decommissioning and dismantling of reactors is a legal and organizational issue that can be solved with planning and logistics. SKB contends that it is a matter of adapting technology rather than conducting basic research.

Proposed remedy: RD&D programme 2019 should include explanations of SKB's views in this matter, especially considering how little experience exists in Sweden when it comes to decommissioning.

Chapter 14 in RD&D programme 2016: Premises for decommissioning of nuclear facilities

14.3 National and international coordination

It is good that SKB and the nuclear power companies are members of several international groups in the field of decommissioning and dismantling, but a more thorough external environmental analysis is needed. There are currently 447 operable nuclear power reactors in the world.²² More than 150 reactors have been shut down, and around 17 of these have been fully decommissioned. In other words,

²² <http://www.world-nuclear.org/nuclear-basics/global-number-of-nuclear-reactors.aspx> (accessed 23 May 2017).

some proven methods and equipment for dismantling nuclear facilities do exist.²³

Proposed remedy: A more complete description should be provided no later than in RD&D programme 2019 of existing international experience of decommissioning and dismantling. Research and development activities that may be needed to supplement the experience documented in connection with previous decommissionings should also be described.

3.4 Part IV Other issues

Chapter 20 in RD&D programme 2016: Preservation of information and knowledge through generations

It is positive that SKB is participating in various projects involving relevant issues pertaining to information and knowledge preservation. The project *Records, Knowledge and Memory across Generations* will, however, end in 2018.

In SKB's judgement, it is not possible for SKB, the regulatory authorities or other parts of society to determine definitively how best to proceed far in the future. SKB believes that the only meaningful plan of action is to keep the issue open and disseminate knowledge regarding the need. SKB also writes that a prerequisite for succeeding is an interest and involvement on the part of different societal sectors.

There is a great deal of international activity on this topic today, and the interdisciplinary field of societal memory is well-developed and should constitute an important basis for SKB's research on preservation of information and knowledge in the future.

Proposed remedy: Even if a definitive decision cannot be made on what measures are to be taken in the long term, RD&D programme 2019 should include a coherent scientific review of the current state of knowledge and the need for research.

²³ <http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/decommissioning-nuclear-facilities.aspx>. (accessed 23 May 2017). Here a list is provided of 150 closed reactors.

Chapter 21 in RD&D programme 2016: Disposal in deep boreholes

RD&D programme 2016 briefly describes the current situation regarding disposal in deep boreholes.

Proposed remedy: The Swedish National Council for Nuclear Waste assumes that SKB will continue to monitor research in the field and provide an account of the situation in RD&D programme 2019. If a technological breakthrough occurs and the method undergoes significant development, SKB should evaluate whether this affects the choice of best available technology.

4 Future RD&D programmes

4.1 Areas that should be included in future RD&D programmes

Summary for non-experts

Chapter 5 in Part I of RD&D programme 2016 contains an overview of SKB's future research and development needs, which in principle is good. However, it needs to be written in an even more popular style in order to be easily read by non-experts. The chapter also needs a brief informative survey of the research and development work that has been done and that remains to be done to facilitate insight by all concerned parties.

Proposed remedy: It is the Council's considered opinion that future RD&D programmes should include a more informative overview of those areas in which SKB deems that more research is needed, as well as the scope of the remaining research activities needed for long-term safe management and disposal of the nuclear waste and the spent nuclear fuel.

Competence management

A description is lacking in RD&D programme 2016 of how competence development and competence management are to be assured within the organization in a time perspective of 50–100 years. The strategic importance of this for Sweden, and not least for SKB, is demonstrated by the fact that the Government has assigned the Swedish Radiation Safety Authority (SSM) the task of investigating long-term competence management in SSM's sphere of responsibility, with a final report in September 2018.

It is important for the safety work that SKB maintain and strengthen its competence so that it can retain the confidence of the regulatory authorities and the public. A clear and informative RD&D programme can be a strategic tool for this.

Proposed remedy: Competence management issues should be described more thoroughly in RD&D programme 2019. An account should be given of the nuclear competence areas in which deficiencies may arise, and what the needs are for education and research at Swedish universities.

Social science research

SKB carried out a social science research programme during the period 2004–2011, but stated in RD&D programme 2013 that no new research programme is planned. SKB's view then was that future research activities in this field should be funded primarily by having researchers apply for funds to, for example, state or private research councils. However, SKB concluded by stating that SKB is prepared to fund research projects of a social-scientific nature within areas deemed to be of importance for SKB's activities, particularly in the municipalities of Oskarshamn and Östhammar.²⁴

RD&D programme 2016 only mentions social science research in connection with information preservation across generations. There is no discussion as to why this is all that is left.

Proposed remedy: SKB should follow through on its own proposal from 2013 to fund research projects of importance for the continued work in the affected municipalities, with whom they expect to collaborate in the decades to come.

The Swedish National Council for Nuclear Waste would also like to refer to its proposal from the review of RD&D programme 2013²⁵ that future RD&D programmes should describe:

- economic, political and social global changes that could affect the implementation of the final repository project.²⁶

²⁴ RD&D programme 2013, section 29.5, pp. 520f.

²⁵ Swedish National Council for Nuclear Waste. 2014. SOU 2014:42 *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*, pp. 87f.

- organization and safety culture. RD&D programme 2010 included the section “1.4 Competence and organization”. From now on, the RD&D programme should include an overview of SKB’s organization to make it clear how the company develops over time. When it comes to safety issues, SKB should follow research on MTO/human factors (MTO = man-technology-organization).

Cultural heritage and decommissioning of reactors

The first reactor in line to be decommissioned is the Ågesta reactor.^{27,28} It is unique and has a cultural-historical value.²⁹ Cultural heritage aspects are not dealt with when it comes to Ågesta or other reactors.

Proposed remedy: Future RD&D programmes should mention research and development related to the cultural heritage aspects of decommissioned reactors. This can be done in cooperation with e.g. the National Heritage Board.

Flexibility and best available technology

More detailed descriptions should be provided of what practical options are available when premises change. How should SKB keep track of research and assimilate the results of international research over a period of at least 80 years? It is not an unlikely assumption that research over the coming 80 years will bring technological advances, new knowledge and new findings, which in turn may set new standards that differ from those existing today. What is SKB’s policy regarding such new knowledge, and what flexibility exists in the system? It may be a question of entirely new concepts, or changes

²⁶ The Swedish National Council for Nuclear Waste has in SOU 2017:8 *Nuclear Waste State-of-the-Art Report 2017. Nuclear waste – an ever-changing issue*, written about future scenarios for the final repository project (Chap. 3).

²⁷ Comments on RD&D programmes 2016, pp. 250–252 concerning the decommissioning of the Ågesta reactor.

²⁸ Tafvelin Heldner et al. 2008. *Ågesta – kärnkraft som kulturarv: Dokumentationsrapport* (“Ågesta – nuclear power as cultural heritage: Documentation report,” in Swedish).

²⁹ Tafvelin Heldner et al. 2013. “Värdet av kärnkraftverk som kulturarv” (“The cultural heritage value of nuclear power plants,” in Swedish), pp. 85f.

and improvements in the KBS-3 concept. Other concepts are already being developed in other countries.³⁰

4.2 Research related to approved licence applications should be included in future RD&D programmes

It is the Council's considered opinion that all scientific research conducted by SKB should be discussed in future RD&D programmes, including research related to already licensed activities. This is necessary in order for future RD&D programmes to be comprehensive and provide transparency and insight into SKB's work.

The nuclear activities legislation prescribes a stepwise licensing of planned final repositories as well as of the various interim storage facilities that will have to be built in conjunction with the decommissioning and dismantling of the nuclear power reactors.³¹ When it comes to, for example, the construction and operation of a final repository for spent nuclear fuel, a great deal of scientific work remains to be done. It is the Council's considered opinion that since there are research questions that remain completely or partially unanswered, above all questions regarding safety and the reliability of the engineered barriers (the copper canister and the bentonite buffer), future RD&D programmes should continue to report on these issues. This should be done regardless of whether SKB obtains a licence or not, even if the remaining issues could be resolved via a continued stepwise licensing process. This would also provide universities and institutes of technology continued insight into all of SKB's scientific work and the consultation process surrounding the RD&D programme, which could contribute to the quality assurance of SKB's work. Research and development activities under Sections 11 and 12 of the Nuclear Activities Act should in the future not be reduced to being a matter that only concerns the nuclear power companies and the regulatory authority, SSM.

³⁰ See Chapter 3.2 of this review, section 8.3 *Design*.

³¹ SSMFS 2008:1, Chap. 4, Sec. 1 and 2 (*The Swedish Radiation Safety Authority's Regulations concerning Safety in Nuclear Facilities*).

Special statement concerning SKB's RD&D Programme 2016

Mikael Karlsson, member of Swedish National Council for Nuclear Waste

The Swedish National Council for Nuclear Waste has identified serious deficiencies in SKB's RD&D programme 2016. I share the Council's analysis and would like to emphasize the fact that the report does not meet the requirements of the law.

Certain deficiencies are so alarming from a safety perspective that they should be remedied prior to RD&D programme 2019. These include: (1) the three problems specifically referred to by the Council (stress corrosion cracking, copper creep and blue brittleness), (2) copper corrosion in pure, oxygen-free water and (3) deep boreholes.

When it comes to stress corrosion cracking, copper creep and blue brittleness, the deficiencies in RD&D programme 2016 are so great that the Government should, as it did in 2007, stipulate that RD&D programme 2016 be supplemented, preferably in line with the Council's proposed remedies.

With regard to copper corrosion in pure, oxygen-free water, scientific opinion is still divided. SKB should report on this matter in a supplement to RD&D programme 2016 that includes SKB's conclusions and describes how SKB thinks the scientific uncertainty should be handled from a safety perspective.

In conclusion, the Government should stipulate that RD&D programme 2016 be supplemented with: (1) a thorough and comprehensive account of the alternative method of deep boreholes, and (2) an account of what RD&D activities SKB plans to conduct during the interim up to the next RD&D report.

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Law, Gov. Bill and Ordinance

Act (1984:3) on Nuclear Activities.

Proposition 1983/84:60 med förslag till ny lagstiftning på kärnenergiområdet (Gov. Bill 1983/84:60 with proposals for new legislation in the nuclear energy field).

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

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) RD&D programme 2016. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste.

The Swedish National Council for Nuclear Waste – is an independent scientific committee whose members possess expertise in technology, science, ethics and the social sciences. One of the Council's tasks is to assess SKB's programmes for research, development and demonstration of methods (RD&D programmes).

The Council recommends that the Government urge SKB to carry out the following measures in connection with the continued research activities:

- *to make the RD&D programme more comprehensive and clear.* In particular, the scope of the research programme should be defined by means of a timetable and a budget. The choice of cooperation partners should also be described and justified more clearly.
- *to remedy the deficiencies described by the Council in Chapter 3 (Special viewpoints on RD&D programme 2016).* This should be done before RD&D programme 2019, even if the Government grants a licence for a final repository for spent nuclear fuel. It is particularly urgent that safety-related research pertaining to the engineered barriers be planned and executed as soon as possible.
- *to guarantee that continued research will be included in the RD&D programme even if an activity receives a licence.* This is important since a decision may be made to grant SKB a licence to construct and operate a final repository for spent nuclear fuel before RD&D programme 2019 is published and despite the fact that a great deal of research remains to be done.