THE SWEDISH FINAL REPOSITORY FOR RADIOACTIVE WASTE (SFR) SAFETY ASSESSMENT AND QUALITY ASSURANCE

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Abstract:

The Swedish Final Repository for Radioactive Waste (SFR) has been in operation since April 1988. In accordance with the requirements given by the Government 1983 the license to operate the repository was given to SKB by the competent authorities, the Swedish Nuclear Power Inspectorate (SKI) and the National Institute of Radiation Protection (SSI), based upon a Final Safety Report (FSR).

In the Swedish waste management system the radioactive waste is separated into three different groups: spent fuel, reactor waste (i.e. short lived operational waste) and decommissioning waste. In SFR the low- and intermediate level reactor waste will be deposited.

The safety assessments made in the FSR are meant to be realistically but conservatively chosen. The impact on the environment is consequently believed to be overestimated in the analyses.

The calculations are based on different assumptions, concerning for example the ground water flow, the physical and chemical behavior of the waste and the contents of radionuclides.

The accuracy of the assumptions made in the safety analysis are followed-up during the operational phase of the repository in a control program.

This paper gives a summary of the safety assessments made in the FSR and it also describes a methodology developed to ensure that the assessments are fulfilled. The paper will focus on the quality assurance of waste to be disposed of in the repository.

Waste type descriptions (WTD) are introduced as a tool for acceptance of waste for final disposal in SFR.

INTRODUCTION

In the Swedish waste management system, the radioactive waste is separated into three groups: Spent fuel (HLW), Reactor Waste (ILW/LLW) and Decommissioning waste (ILW/LLW). In SFR the intermediate and low level reactor waste (e.a. operational waste) will be disposed of. In the future also the decommissioning waste is planned for disposal in SFR.

The repository for reactor waste is in operation since April 1988. In total 90000 m^3 radioactive operational waste is prognosed in the Swedish nuclear program.

License to operate the repository was given by the Swedish competent authorities SKI and SSI based on a final safety report in which both operational and long term safety issues are discussed.

Different types of waste are allocated to different caverns in accordance with its activity content, chemical and physical properties, size, weight etc. In the safety analysis certain assumptions have been made for different types of waste and different disposal chambers.

In order to describe and make sure that the assessments are made conservatively every type of waste are described in a Waste Type Description (WTD). The WTD is a central part of the quality assurance program for the waste.

REPOSITORY DESIGN AND OPERATION

SFR is located close to the Forsmark Nuclear Power Plant, on the coast of the Baltic Sea.

The SFR has been designed to make possible a simple and controllable as well as a safe disposal of the low- and intermediate level radioactive material arising from the operation of the Nuclear power plants in Sweden.

The design and location should insure such isolation of the waste from the biosphere that the dose effects would not exceed the design limit, 0.1 mSv/a to the most exposed individual in the vicinity of the facility.

Safety during the post-closure period should not be dependent on checking or corrective measures.

General design of the repository

The repository is located in the bedrock under the Baltic Sea, with a rock cover of about 60 m (see Fig. 1). This location ensures a very small hydraulic gradient and thereby the groundwater flow is low in the repository area. Due to the land uplift a fresh-water based ecological system will form after, at least, 1000 years. At that time a rise in the flow rate is probable.

The SFR has been built in such a way that most of the radioactivity will decay within the repository.

The SFR has various storage chambers, with different barriers, depending on the waste to be disposed of. The

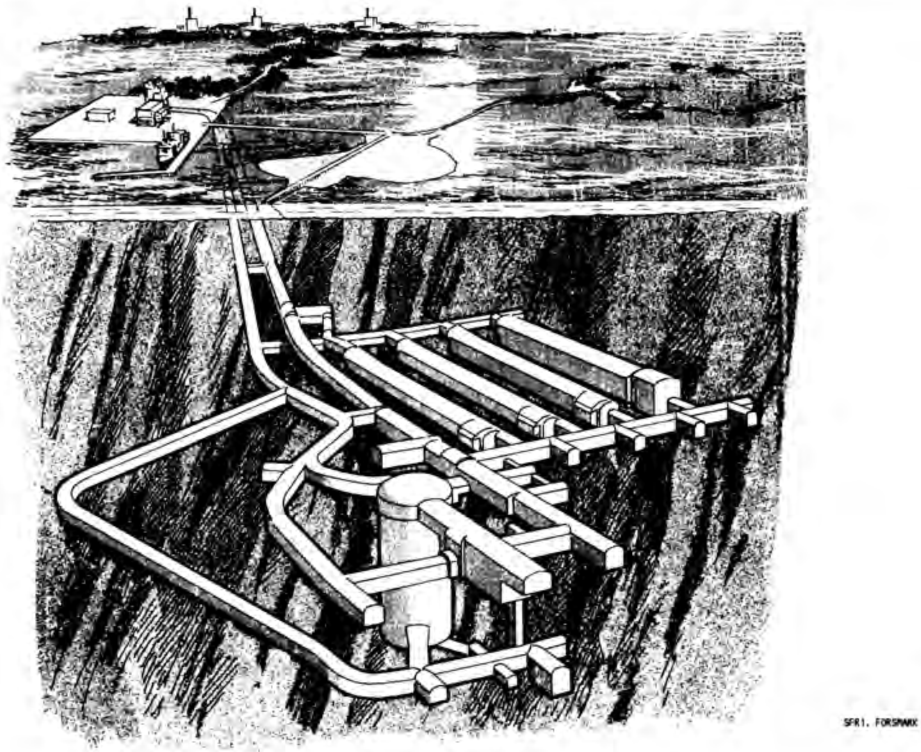

Fig. 1. General Layout of SFR.

function of the engineered barriers is to limit the release of radioactivity to the groundwater.

The most active waste is deposited in a concrete silo surrounded by a clay barrier with low permeability. This ensures a nuclide transport governed by diffusion.

Horizontal caverns are used for the less radioactive waste. The design of the caverns is dependent on the type and dose rate of the waste packages. The possible release of radionuclides from these caverns is mainly by the slow groundwater transport through the caverns.

Operation of the repository

The waste packages are transported in specially designed containers. Excluded are only very low level waste which do not require shielded transport containers.

The waste arrives to the repository site on board a special ship, m/s Sigyn. A transport vehicle carries the containers (with a weight of approx. 120 tons) down to the repository. Depending on the type of waste loaded in the container (only one type of waste at a time is loaded) the unloading takes place in one of the caverns or in the silo. Low level waste is handled by a shielded fork lift truck while the medium level waste is handled remotely by traverse cranes.

No visual inspection or measurements except for dose rate measurement on the transport container are performed at SFR. The control and measurement are performed at the production site.

SAFETY ASSESSMENTS

During the operational phase of SFR the safety matters are concerning transport and handling accidents, including fire. Equipment as well as waste packages are designed to meet very rigorous requirements on external exposure. As a consequence normal operation and more likely accidents will not cause any environmental impact. During normal operation, the dose to the staff are conservatively estimated to 25 mmanSv/a.

To clean up the repository after an accident the total dose has been estimated to less than 15 mmanSv.

According to current plans, the sealing of SFR is assumed to take place at the year 2015. In the safety assessments the possibility of keeping the repository opened and drained due to further utilization of SFR, e.g. for decommissioning waste, has not been taken into consideration.

When the sealing takes place, the pumping is interrupted and the repository is completely filled with water. After being filled with water, the hydraulic gradients will be restored in the repository area and it is possible for the groundwater to move through the caverns. In the silo the clay barrier prevent water from flowing through.

Based on hydrology measurements and calculations the groundwater is assumed to flow vertically through fissures in the rock. Dissolved isotopes are assumed to follow the groundwater as it moves through the caverns to the recipient, the Baltic Sea. To reach the groundwater from the silo, all transport is governed by diffusion.

This situation will be changed by time. One reason is that the engineered barriers will get weaker. Another is the land uplift in the area.

The safety analysis are divided into two time periods. The first covers the period during which the sea bed above SFR is still covered by the brackish water of the Baltic Sea, the Salt Water Period. The second time period covers the time after the drying out of the sea bed and formation of the fresh water-based ecological system, the Inland Period.

In the analyses the Salt Water Period is assumed to last 2500 years.

The need of barriers against transport of radionuclides from the repository differs between the different parts of the repository. The silo, with the highest activity content, need the most extensive barrier system while other rock chambers merely do not need any engineered barriers at all.

The most important barrier is the host rock with a hydraulic conductivity of 10^{-8} to 10^{-7} m/s. Considering the low hydraulic gradient (0.001 m/m during the Salt-Water period) this gives a very low rate of water replacement in the repository.

- The barrier functions can be summarized as follows:
- Transport restrictions inside the waste matrix
- Transport restrictions through the walls of the packaging
- Sorption on minerals (cement and ballast) inside the repository
- Low rate of water flow through the caverns
- Nuclide transport governed by diffusion through the walls of the silo
- Transport restrictions in the rock
- Sorption in the rock

All these barrier functions do not apply to all the different parts of the repository. Further, all barrier functions has not been taken into consideration in the safety assessment, either because they have no importance or due to lack of data.

For the calculations of the transport of radionuclides from the repository, a reference case has been developed for each chamber and time period. In the final safety report for SFR a number of variations has been analyzed in order to quantify the importance of different assumptions and conservatisms introduced in the simplified reference calculations.

Assumptions for the calculations are, for the reference case:

- The activity contents, in 90000 m^3 waste, are distributed between the different chambers so that 90 % is located to the silo. A total activity content of 1016Bq is assumed.
- All the radioisotopes are considered capable of being instantaneously dissolved in the pore water of the waste matrix.
- Ground water flow has an upward direction during the Salt Water Period. It is also assumed that the water flow takes place in a strongly canalized form. This implies that no sorption in the rock mass has been considered during this period.
- The Inland Period gives an increase in the ground water flow of a factor 10. The flow direction is now horizontal and at least 1000 m in length. Sorption has been taken into account in these calculations.
- The calculations for the Inland Period assume that no release of radionuclides have occurred the first 2500 years, only decay has been accounted for.
- Sorption of radionuclides on concrete and bentonite has been considered but with different capacities for the two time periods analyzed.

The calculations performed indicates a maximum dose commitment for the most affected individuals of about 10^{-7} Sv per year during the Salt Water Period. The dose-dominating isotopes are Cesium-137 and Strontium-90. Corresponding analyses for the Inland Period gives 10^{-5} Sv per year dominated by the Plutonium isotopes 239 and 240. The higher rate at the late stage is mainly due to the change of recipient, from the Sea to a fresh water lake and a well. The accumulated collective dose is caused mainly by release of Carbon-14.

During operation of SFR a control program is conducted. The program includes water chemistry, pressure head, water inflow measurement, deformation of the host rock and swelling pressure buildup in the clay surrounding the silo. The purpose of these activities is to collect data for the renewed safety analysis which will be performed before sealing of the repository. Combined with the information available for the actual waste deposited, it is believed that a more realistic estimation of the environmental impact from SFR during the post-closure period could be achieved.

QUALITY ASSURANCE PROGRAM FOR REACTOR WASTE

The QA-program for the waste covers all steps in the waste management system.

For the handling and transport of waste the purpose of the QA-program is to ensure that a safe function during normal and accidental conditions can be assured.

Concerning the storage phase the purposes of the Quality Assurance program for reactor waste is first to ensure that the assumptions made in the safety analysis are fulfilled. At least the assumptions should not be found to be nonconservative. A second purpose is to get a better understanding of the long term behaviour of the waste in order to, before sealing, make a more realistic calculation of the environmental impact from the repository.

The aim of the QA-program is to ensure that the product (waste package) fulfills relevant requirements on handling, transport, deposition and final disposal. The QA-program is also intended to be a link between the waste producer and the repository. Through the program limiting parameters on different characteristics are highlighted and quantified.

The procedure to establish and verify acceptable parameter values for a waste package for final disposal in SFR can be summarized in the following steps:

1.For each step from collection of raw waste through the final disposal the requirements on the function are set.
2.Each functional requirement are translated into requirements on properties. The envelope of these requirements are used as acceptable parameter values.
3.Control requirements are set on vital parameters. It should be noted that all requirements are not necessarily quantitative but could also be qualitative.

In addition all relevant information should be kept and transferred from the producer to the repository before the package is deposited. This is done by a computer system.

Every package has to be accepted not only by the producer and repository but also by the Swedish competent authorities, SKI and SSI. The packages (in total app. 50000) are divided into waste categories. Each category is described in a Waste Type Description (WTD) which acts as a safety report. The application for final disposal of a waste type is given to the authorities by SKB based on the WTD.

WASTE TYPE DESCRIPTIONS

Following the above mentioned procedure the contents of the WTDs has been developed. The organization is identical in all WTDs. An example is given below.

A waste category is defined by its origin, type of raw waste material, the way it is treated and the packaging to be used. Small differences within a category may result in a different waste type description (e.g. different cement processes are used for solidification of ion exchange resin).

Today (Feb 1989) 22 categories have been recognized and approximately 40 waste type descriptions have been produced. The procedure can be summarized as follows:

The waste producer prepare a WTD in cooperation with SKB

SKB has the formal responsibility for the licensing of the waste type. Based on the WTD an application for transport to SFR and disposal in SFR in a certain cavern is given to SKI/SSI for approval.

Since the matter is of mutual interest, SKI and SSI have organized a joint working group to review the application and give recommendations to their respective organization for decision.

The contents of a WTD covers all steps from collection of waste to the final disposal. The assumed function of the waste during handling and disposal is the base for requirements.

The following example illustrates the structure of a WTD.

Handling Sequence and Functional Requirements

All steps in the handling sequence, from collection/sorting of raw waste through production of waste packages, interim storage on site, transport to SFR, handling in SFR and final disposal, are reviewed. Functional requirements concerning normal and accidental conditions are defined for each step. It should be noted that functional requirements for final disposal could differ between different types of waste bound for the same cavern in SFR. The reason is that "good" properties in one waste type could be accounted for when setting the requirements for other waste types.

The functional requirements are not possible to measure in the process. Therefore these requirements are "translated" into characteristics that are measurable and corresponds to the functional requirement.

Requirements on Characteristics

For each step in the handling sequence significant properties are derived and if possible quantified. This reflects general handling and managerial requirements as well as radiological, chemical and mechanical properties. Limiting values on these properties are regarded as waste acceptance criteria.

Waste Type Data

The appropriate data on the waste type is given. The data are divided into the following groups:

- Raw waste material
- Solidification material
- Packaging
- Solidification Process
- Product composition, recipe

Results of tests and analyses

To verify the requirements, tests and analyses are performed. The results of these works are summarized in the WTD.

Control actions

The quality control measurements performed during the sequence from collection of raw waste to the final disposal of the waste package is defined. Control actions are mainly performed by the waste producers. The aim is to verify that the requirements given to the type are fulfilled. Defined control actions are complement to type tests performed.

Documentation

Documentation relevant for the waste type are stored in a SFR-reference-library

All adequate information on each individual waste packages are recorded and stored. The information includes not only parameters used in the safety analysis, such as radioactivity content, but also information that could be of any interest in the future. All information is transferred to a SFR-data-base before the packages is deposited in the repository.

The SFR-data-base includes restrictions and requirements concerning the handling and disposal of the waste such as information on the cavern to be used. After disposal the actual location of a waste package is recorded in the SFR-data-base.

CONCLUSIONS

The methodology for establishing relevant requirements on waste packages, presented in this paper, highlights the necessity of including the performance of a total waste management system in the program. It is important to see the interrelationship between the individual components in the total system in order to focus on relevant parameters. The standardized Waste Type Description is a useful tool to reach the goals; a safe and simple handling and storage of reactor waste with an optimal set of requirements on the waste.

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