Aspects on the acceptance of waste for disposal in SFR

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ABSTRACT

When licensing a final repository for radioactive waste certain assumptions have to be made concerning the waste. These assumptions cover radionuclide inventory and non-radiological materials and its physical and chemical impact on the waste, the repository and on the environment.

Development of new waste treatment systems and waste packages at the waste producer site aim at finding solutions and products that can be stored, transported and disposed of safely and are economically sound.

This paper discusses some aspects concerning development of new or modified waste products. It highlights the importance of analysing the whole sequence in treatment, handling and disposing the waste. The process should be to find an optimal solution for the whole system, considering the fact that what is best in one step it not necessary best for the whole system, including the post closure issues.

1. Introduction

When a nuclear facility plans for a new waste processing system or modification of an existing it is of outmost importance to analyse the whole chain of operations from the main operation of the facility to the final storage of the rest products produced as a consequence of the main operation. This analysis should contain aspects like cost of operation and for final storage of waste, safety of personnel, long-term storage considerations, etc.

This paper discusses some of these considerations from a repository operator's point of view, specifically for the SFR-repository (Final repository for operational radioactive waste) located near the Forsmark nuclear power plant.

2. Waste acceptance criteria on a waste package for final disposal

2.1 General set of Waste Acceptance Criteria for waste disposed off in SFR

A set of general and qualitative criteria for acceptance of waste for disposal in SFR has been developed. These criteria are given to the waste generators and SKB by the authorities, the Swedish Nuclear Power Inspectorate (SKI) and the Swedish Radiation Protection Agency (SSI). For each type of waste the criteria have to be quantified as far as possible. As a result there will be a unique set of acceptance criteria for each waste type.

Below is given a qualitative set of criteria that should be considered and when appropriate specified in the Waste Type Description (WTD) that must be delivered with each type of waste. The criteria are valid for all steps in the handling of waste. Limiting, quantitative values on each parameter are used as acceptance criteria.

<u>Design, geometry and dimensions</u>
The design, geometry and dimensions of a waste package shall be in compliance with the systems for handling and transportation and with the appropriate disposal part of the repository.

Weight

The weight of a waste package must not exceed the limits set by the handling and transport systems. The distribution of mass within a waste package must not jeopardise the stability during handling operations such as lifting and stacking.

Marking

Each waste package shall bear a unique identification marking. The marking shall be such that it pertains until backfilling around the package takes place in the emplacement vault. The marking shall be documented in the waste producer's register and in the SFR register. It shall also enable the package to be localised in the repository.

Radionuclide inventory

The contents of gamma emitting radionuclides shall be known in terms of species and quantities for each waste package.

An account of the contents of alpha and beta emitting radionuclides shall be given. The accuracy of this inventory shall be sufficient to assure compliance with given limits for different kinds of packages and different emplacement cavities in the SFR.

Surface dose rate and dose rate at a certain distance

The maximum external dose rate, measured and reported as surface dose rate and/or dose rate at a certain distance (normally 1 m) from the outer surface of the package, shall be lower than the limits applicable for the facilities where the packages are stored and the equipment used for their handling. Limits for transportation shall be taken into account.

Surface contamination

Transferable contamination by radionuclides, i.e. contamination that might be released from the outer surface of the waste packages during normal handling or pouring of water for a short time, shall be kept within authorised limits.

Internal radiation

Internal dose rates as well as the internal integrated radiation dose, must not be as great that processes induced by radiation, e.g. radiolysis, affect the properties of the waste form, packaging and the barrier functions in the repository to an unacceptable extent.

Homogeneity

Solidified liquid and wet waste shall be homogeneously distributed to an extent that radionuclides never occur in such concentrations that the above mentioned radiological properties will be affected to an unacceptable extent.

During package and grouting of solid waste, components etc., the active material shall be emplaced in the packaging in such a way that the activity becomes distributed throughout the packaging as homogeneously as possible so that the mechanical and physical-chemical properties assigned to the waste form from the aspects of safety and radiation protection are not jeopardised and can be assessed with sufficient accuracy.

Composition and structure

The chemical composition and structure of the waste form and its packaging shall be known and defined to such an extent that it allows an assessment of the material properties of the waste package.

Liquids

Waste packages are not allowed to contain free liquid that, due to leakage, might lead to unacceptable radiological consequences.

Corrosion resistance

Waste packaging shall have a durability against external and internal corrosive attacks that is sufficient with regard to conditions before backfilling around the package or sealing of the repository cavity.

Gas formation

Gas formation rate and volume, caused by the composition and structure of the waste form or package, shall not jeopardize the safety before closure of the repository or, after that, give rise to unacceptable disturbance of the barrier functions of the repository. Different mechanisms and processes for gas formation shall be regarded, e.g. radiolysis, biological decomposition, metal corrosion and other possible transformation processes. The content of organic substances and other biodegradable materials and metals whose corrosion might give rise to gas evolution shall be specified with sufficient accuracy to ascertain assessment of the consequences with respect to radiation protection. Wastes in the form of compressed gases are not to be disposed of in the repository.

Combustibility and fire-resistance

Combustible waste and waste forms shall be packaged in such a manner and have such characteristics that the risk of self ignition is negligible. Combustible waste shall be sufficiently well characterized and specified in terms of quantities and composition to permit the necessary precautions to be taken. Any fire shall be prevented from spreading through appropriate measures. Explosive materials are not allowed in the waste.

Chemical reactivity

Waste packages shall not contain substances that, due to their nature and quantities, might jeopardize the stability of the waste packages or the barrier functions of the repository to an unacceptable extent. Complexing agents shall be avoided as far as possible.

Leaching

Leaching of radionuclides from waste packages must be within the limits given for transport of radioactive materials. The leaching properties must be in compliance with the assumptions made for calculation of the long-term safety of the repository.

Mechanical strength against external stresses

The mechanical strength of the waste packages against external stresses such as pressure, strain, bending and impact, shall be sufficient to preclude unacceptable releases of radionuclides during foreseeable incidents and accidents. The waste form shall have a structure and homogeneity that is in compliance with this requirement.

Mechanical stability

The structure and volume of the waste shall be such that they do not deteriorate to an extent, leading to unforeseen release. Examples of such processes are swelling of the waste form under pressure build-up and degradation of mechanical strength caused by changes in temperature.

2.2 Important concerns regarding the long-term safety of the repository

Traditionally the major focus on waste management has been on production and workers safety at the waste generators site, during transport to interim storage and handling in the repository. These are all very important aspects but are not sufficient. As the level of knowledge and modelling abilities on final disposal have been more and more sophisticated, the requirements on analyses and reporting have increased on the Safety Analyses Report (SAR) of the final repository for operational waste.

Thus, already before a waste processing operation at the waste generator can be allowed to start or the mode of operation changed for their main operation, the waste generator must analyse all consequences that the production of the waste can have on the chain of events from processing at the site to the possible risk of high radiation doses to the environment in the future.

3. Case study for start of a new operation at an NPP

At the Ringhals nuclear power plant work is ongoing to reduce the overall water release to the recipient. A general principle is to try to use as little water as possible, but this can only decrease the use of water to a certain degree, still the dominating method to minimise water release is reuse of the water.

In an ambitious effort Ringhals NPP has started a project looking at all aspects on the water "issue". The project examines all waste water streams from the site's 3 PWR's and one BWR. Important questions that need to be studied and answered are e.g.: should all water be treated in one plant; in one for the PWR's and one for the BWR; or should Ringhals 1 and 2 (BWR and PWR) and Ringhals 3 and 4 (2 PWR's) have separate treatment facilities. Further, the plant is looking at methods to clean the water for reuse, and methods to produce a waste package that is well suited for production, handling and disposal in the SFR-repository.

3.1 Evaluating some vital factors influencing the long-term safety of the repository

Contrary to the "technical approach" to solving a problem, i.e. find a most efficient technical solution to the water clean-up, Ringhals decided to look at what properties a final waste package should have, so that the authorities could accept it for long-term storage in the SFR-repository without too much further investigations. Regardless of which method Ringhals finally will choose for purifying the water for reuse, the waste produced will be a radioactive more or less liquid salt residue. As the liquid waste water treatment plant in Ringhals is a cement solidification unit it is of vital importance to choose a solidification process that can be treated by the Ringhals waste plant, and that the properties of the produced waste package are such that the long-term safety of the SFR-repository will not be jeopardized.

One problem with cement solidification of PWR-waste is that boron is a cement retarder, hence, with an improper amount of boric acid in the waste stream it will not be possible to produce a solid cement waste matrix. Further, a high salt content is likely to significantly react with the cement matrix, in many cases without causing significant harm to the cement structure, but especially the anions sulphate, chloride and carbonate will react with the cement and can cause serious fractures and damage of the waste matrix, and in the worst case directly or indirectly by a swelling waste package cause damage on the main concrete structure of the SFR.

With these concerns in mind, Ringhals decided to thoroughly investigate how to produce a robust cement waste matrix, and how this cement waste matrix may interact with the SFR repository structure, and as a consequence how the long-term safety of the SFR repository may be influenced by this new waste type. Thus, Ringhals started a major laboratory programme studying different cement waste solidification formulas ("solidification recipes") in their newly equipped cement laboratory (This program will not be further discussed in this paper.). But they also studied the long-term influence this new waste type may have on the SFR-repository, in order to produce an as complete as possible WTD for the application to SKB and the authorities.

Three types of salt waste streams were studied both in laboratory and theoretical modelling, one with a fairly low salt content (ca 10-15% dry substance), one with significantly higher salt content, and finally one waste type with only the salt and basically no free liquid present.

3.2 Theoretical modelling of cement – salt interaction

The long-term salt - cement interactions were modelled using a modified version of the PHREEQC-2 code [1]. To the original PHREEQC-2 code were added subroutines for a "dynamic" porosity and diffusivity, i.e. after each run a new porosity was calculated based on the mineralogical changes of the system, and the diffusivity was calculated using the updated porosity. The work is on-going and will be presented by Ringhals later this year, but an example of the cement-salt mineralogical composition as a function of time up to 100 000 years after repository closure is given in Figure 1, and the porosity change as a function of time for the same part of the studied system is given in Figure 2.

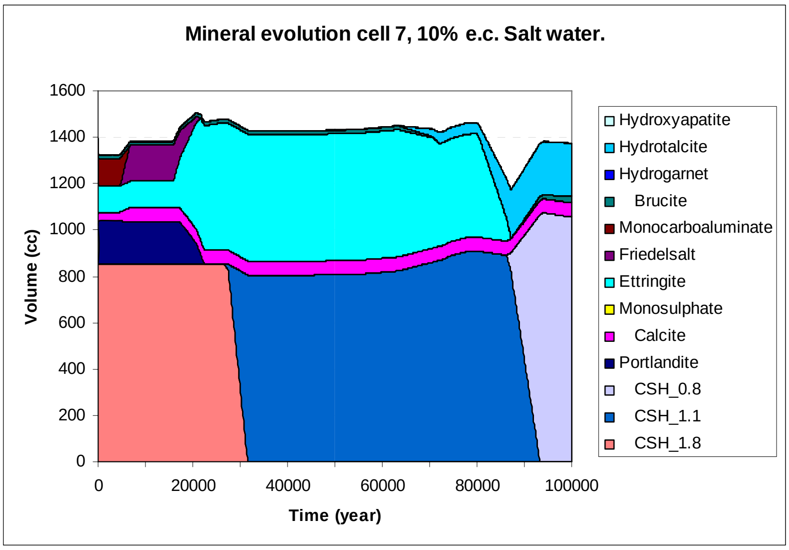

Figure 1. The mineral evolution in cell 7, the outer part of the cement-encapsulated evaporator concentrate, when exposed to salt water (10% e.c.). The order of the minerals is as given in the captions, i.e. from top to bottom.

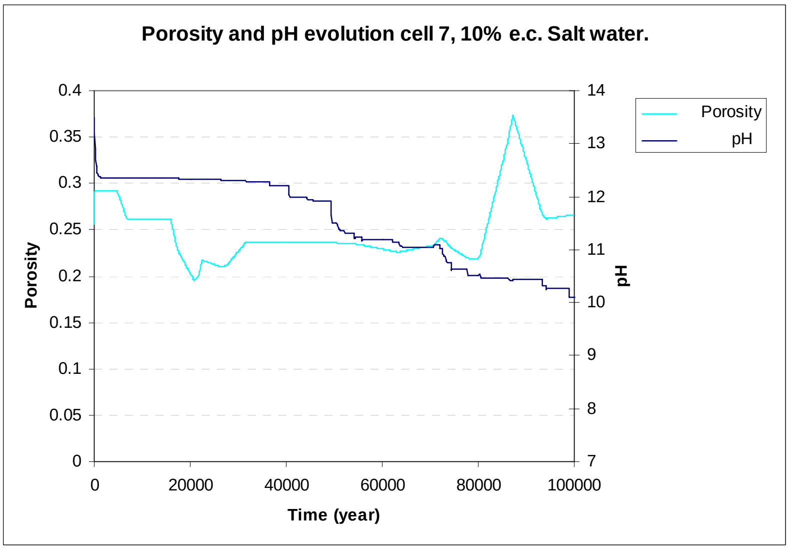

Figure 2. The porosity and pH evolution in cell 7, the outer part of the cement-encapsulated evaporator concentrate, when exposed to salt water (10% e.c.).

4 Conclusions

All aspects must be included in the evaluation of the best technique to use, when planning for a new or modifying an existing waste treatment facility which will produce a radioactive residue that need to be taken care off. To speed up the time from starting a project for treatment of radioactive waste, to when the system can go into "industrial operation" it is of outmost importance to look at the whole chain of operation including the final storage, and the influence the new waste type may have on the long-term safety of the final repository. Without this complete analysis it will be difficult or impossible for the competent authorities to issue a license for operation, and if the waste type is not well-suited for long-term storage, a proposed or in the worst case already commissioned treatment unit may have to be rebuilt or completely decommissioned.

5 References

1. Cronstrand Peter, "personal communication", August 2006.