Swedish Radiation Safety Authority Regulatory Code

Strål säkerhets myndigheten
Swedish Radiation Safety Authority

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The Swedish Radiation Safety Authority's regulations and general advice concerning safety in connection with the disposal of nuclear material and nuclear waste

Please note that translated versions of the Authority's regulations lack legal force and are for information purposes only.

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The Swedish Radiation Safety Authority's regulations concerning safety in connection with the disposal of nuclear material and nuclear waste;[1]

issued on 19 December 2008.

On the basis of Sections 20a and 21 of the Nuclear Activities Ordinance (1984:14), the Swedish Radiation Safety Authority hereby issues the following regulations.

Application

Section 1 These regulations apply to facilities for the disposal of nuclear material and nuclear waste (repositories).

The regulations do not apply to facilities for landfill disposal of low-level nuclear waste under Section 16 of the Nuclear Activities Ordinance (1984:14).

The regulations contain supplementary provisions to the Swedish Radiation Safety Authority's regulations (SSMFS 2008:1) concerning safety in nuclear facilities.

Barriers and their functions

Section 2 Safety after the closure of a repository shall be maintained through a system of passive barriers.

Section 3 The function of each barrier shall be to, in one or several ways, contribute to the containment and prevention or retention of dispersion of radioactive substances, either directly or indirectly by protecting other barriers in the barrier system.

Section 4 A deficiency in any of the repository's barrier functions that is detected during the construction or operational surveillance of the repository, and that can lead to a deterioration in safety after closure in addition to that anticipated in the safety analysis report,[2] shall be reported to the

[1] These regulations and the general advice were issued previously in the Swedish Nuclear Power Inspectorate's Regulatory Code (SKIFS 2002:1).
[2] Cf. Chapter 4, Section 2 of the Swedish Radiation Safety Authority's regulations (SSMFS 2008:1) concerning safety in nuclear facilities.

Swedish Radiation Safety Authority without unnecessary delay.[3] The same applies if such a deficiency is suspected to occur or if it is suspected that such a deficiency may possibly occur in the future.

Design and construction

Section 5 The barrier system shall be able to withstand such features, events and processes that can affect the post-closure performance of the barriers.

Section 6 The barrier system shall be designed and constructed taking into account the best available technique.[4]

Section 7 The barrier system shall comprise several barriers so that, as far as possible, the necessary safety is maintained despite a single deficiency in a barrier.

Section 8 The impact on safety of measures adopted to facilitate the monitoring or retrieval of disposed nuclear material or nuclear waste from the repository, or to make access to the repository difficult, shall be analysed and reported to the Swedish Radiation Safety Authority.

Safety analysis

Section 9 In addition to the provisions contained in Chapter 4, Section 1 of the Swedish Radiation Safety Authority's regulations (SSMFS 2008:1) concerning safety in nuclear facilities, the safety analyses shall also comprise features, events and processes that can lead to the dispersion of radioactive substances after closure, and such analyses shall be made before repository construction, before repository operation and before repository closure.

Section 10 A safety analysis shall comprise the requisite duration of barrier functions, though a minimum of ten thousand years.

Safety analysis reports

Section 11 The safety analysis report for a repository shall, in addition to what is required by Chapter 4, Section 2 of the Swedish Radiation Safety Authority's regulations (SSMFS 2008:1) concerning safety in nuclear facilities, contain the information shown in Appendix 1 of these regulations and which concerns the period of time following closure.

Prior to repository closure, the safety analysis report shall be renewed and subjected to a safety review in accordance with Chapter 4, Section 3 of the Swedish Radiation Safety Authority's regulations (SSMFS 2008:1)

[3] Cf. Chapter 2, Section 3 of the Swedish Radiation Safety Authority's regulations (SSMFS 2008:1) concerning safety in nuclear facilities.

[4] Cf. Chapter 2, Section 3 of the Swedish Environmental Code.

concerning safety in nuclear facilities and shall be reviewed and approved by the Swedish Radiation Safety Authority.

Exemptions

Section 12 If there are particular grounds, the Swedish Radiation Safety Authority may grant exemptions from these regulations if this can be done without circumventing the aim of the regulations and on the condition that safety can be maintained.

These regulations enter into force on 1 February 2009.

SWEDISH RADIATION SAFETY AUTHORITY

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Appendix 1

The following shall be reported with regard to analysis methods:

- how one or several methods have been used to describe the passive system of barriers in the repository, its performance and evolution over time; the method or methods shall contribute to providing a clear understanding of the features, events and processes that can affect the performance of the barriers and the links between these features, events and processes
- how one or several methods have been used to identify and describe relevant scenarios for sequences of events and conditions that can affect the future evolution of the repository; the scenarios shall include a main scenario that takes into account the most probable changes in the repository and its environment
- the applicability of models, parameter values and other assumptions used for the description and quantification of repository performance as far as reasonably achievable
- how uncertainties in the description of the barrier system's functions, scenarios, calculation models and calculation parameters as well as variations in barrier properties have been dealt with in the safety analysis, including the reporting of a sensitivity analysis showing how the uncertainties affect the description of the evolution of barrier performance and the analysis of the impact on human health and the environment

The following shall be reported with respect to the analysis of post-closure conditions:

- the safety analysis in accordance with Section 9 comprising descriptions of the evolution in the biosphere, geosphere and repository for selected scenarios; the environmental impact of the repository for selected scenarios, including the main scenario, thereby considering defects in engineered barriers and other identified uncertainties

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The Swedish Radiation Safety Authority's general advice on the application of the regulations (SSMFS 2008:21) concerning safety in connection with the disposal of nuclear material and nuclear waste;

issued on 19 December 2008.

The Swedish Radiation Safety Authority hereby issues the following general advice.

Section 1

According to Section 10 of the Act on Nuclear Activities (1984:3), the holder of a licence to conduct nuclear activities is responsible for ensuring that the necessary measures are implemented to safely dispose of nuclear waste generated by the activity or nuclear material that is not reused.

The Act stipulates that the Government can relieve a licensee of the obligations contained in Section 10 of the Act on Nuclear Activities.[1] One condition for being relieved of these obligations is by at the same time establishing that the obligations can be fulfilled in a satisfactory manner by another licensee.

According to Section 14 of the Act on Nuclear Activities, licensees retain their obligations to dispose of the nuclear waste and nuclear material in a safe manner until these obligations have been fulfilled. In accordance with Section 16 of the Act on Nuclear Activities, the Swedish Radiation Safety Authority determines whether these obligations are fulfilled. With respect to a repository, this can be achieved after the Swedish Radiation Safety Authority has approved the closure of the repository. As soon as the Swedish Radiation Safety Authority can establish that a licensee has fulfilled its obligations with respect to a repository, the obligation to comply with the provisions contained in these regulations on the part of the repository also ceases.

The purpose of the regulations is to promote the safety of a repository so that dispersion of radioactive substances is prevented or delayed. Thus,

[1] Cf. Section 14 of the Act on Nuclear Activities (1984:3).

capability of a repository to prevent the dispersion of radioactive substances.

An assumption of these regulations is that operational surveillance and maintenance of a repository will be conducted in accordance with the provisions of the Swedish Radiation Safety Authority's regulations (SSMFS 2008:1) concerning safety in nuclear facilities until such time that the repository has been closed. Closure entails backfilling of tunnels and shafts up to ground surface level in accordance with the safety analysis report for the facility (cf. Sections 9 and 11). The backfilling of (for instance) emplacement cavities conducted during the repository operating period (operational backfilling) is not considered to be closure in this respect.

The licensee of a repository should ensure that the measures implemented to comply with the requirements on management system, safety review, safety programme and periodic safety review in accordance with the Swedish Radiation Safety Authority's regulations (SSMFS 2008:1) concerning safety in nuclear facilities are also adequate with respect to post-closure safety.

Sections 2 and 3

The containment of radioactive substances provided by individual barriers in a repository does not need to be as complete as, for example, that for a leaktight container. Porous materials can also function as barriers through a low permeability to water (low hydraulic conductivity) and substances dissolved in the water (high resistance to diffusion). Parts of the repository or materials in the repository can also be considered barriers without necessarily comprising an obstacle to physical transport. This could for example be the case for materials that contribute to providing a chemical environment counteracting the transport of radioactive substances. Examples of this include a chemical environment that results in low solubility and a high sorption of radioactive substances. 'Barrier function' is a term used to designate the different ways that barriers function and the capability of a barrier to protect and preserve the function of other barriers. In this way, a single barrier can have several barrier functions and several barriers can have the same, or similar, barrier functions.

Barriers in a repository can be engineered (man-made) or natural.

Examples of engineered barriers include containers for nuclear material and nuclear waste, concrete structures and backfill materials consisting of clay, sand or concrete.

Examples of engineered barrier functions include mechanical protection of other barriers, complete containment of radioactive substances in leaktight containers, resistance to water flow and resistance to the diffusion of various substances as well as chemical properties that protect other barriers or help to prevent the dispersion of radioactive materials.

The geological formation at the repository site can in itself serve as a natural barrier. The formation (such as rock) can have several barrier functions, for instance isolation of the nuclear waste from the ground surface environment, including rendering human intrusion difficult, limitation of the damaging impact of air and water on engineered barriers, limitation of hydraulic flux in the repository and the contribution to a favourable chemical environment inside and in the vicinity of the repository which counteracts the transport of radioactive substances in the groundwater.

The barriers or barrier functions that are necessary in a repository depend on the radioactive inventory of the repository and other substances that affect the safety performance of the barriers and the design and location of the repository. These needs and how they are satisfied by the barrier system should be clearly described in the safety analysis report for the repository in accordance with Sections 9 to 11.

The repository site and repository depth should be chosen so that the geological formation provides adequately stable and favourable conditions to ensure that the repository barriers perform as intended over a sufficient period of time. The conditions intended primarily concern temperature-related, hydrological, mechanical (for example, rock mechanics and seismology) and chemical (geochemistry, including groundwater chemistry) factors. Furthermore, the repository site should be located at a secure distance from natural resources exploited today or which may be exploited in the future.

Section 4

In accordance with the provisions of Chapter 2, Section 10 of the Swedish Radiation Safety Authority's regulations (SSMFS 2008:1) concerning safety in nuclear facilities, it is the responsibility of the licensee, for as long as the repository is in operation, to keep continuously informed of the conditions of importance to an assessment of repository safety, also after closure. If, during the continuous analysis and safety assessment, a degradation in barrier performance compared to that stated in the safety analysis report for the facility (in accordance with Chapter 4, Section 2 of the Swedish Radiation Safety Authority's regulations (SSMFS 2008:1) concerning safety in nuclear facilities) should be detected or suspected after repository closure, the Swedish Radiation Safety Authority should be notified without delay apart from the time required to collect and process the necessary information.

Section 6

In this context, 'construction' means excavation of geological formations (such as rock or soil layers), the construction of facilities above or below ground and the manufacturing, application, control and testing of engineered barriers.

The use of the best available technique means that the technology, from a technical and financial standpoint, shall be industrially feasible for application within this area. This means that the technique must be available and not merely exist at an experimental stage. However, the technique need not be available in Sweden (see Government Bill 1997/98:45, Part I, p. 215 ff. for details).

Section 7

The provision of this Section can be fulfilled by showing in the safety analysis prepared in accordance with Section 9 how different types of deficiencies in barriers and barrier performance cannot on their own lead to unacceptable risks from dispersion of radioactive substances from the repository. It should be possible to show how this dispersion is limited by other barriers and barrier functions besides those affected by the deficiencies that have arisen. In order for the provision to be fulfilled, several barriers may be necessary, especially with respect to the disposal of spent nuclear fuel.

Section 8

Measures may be adopted during construction and operation for the monitoring of a repository's integrity and its barrier performance after closure. Such measures can also be adopted to maintain non-proliferation control ('safeguards'). Measures can also be adopted during construction and operation with the primary aim of facilitating the retrieval of disposed nuclear materials and nuclear waste from the repository, either during the operating period or after closure. Furthermore, measures can be adopted to make intrusion into the repository difficult or to caution against intrusion. The safety analysis report for the facility, in accordance with Section 9, should show that these measures either have a minor and negligible impact on repository safety, or that the measures result in an improvement of safety, compared with the situation that would arise if the measures were not adopted. These provisions are in agreement with the provisions of the Swedish Radiation Safety Authority's regulations SSMFS 2008:37.

Section 9 and Appendix

The safety of a repository after closure is analysed quantitatively, primarily by estimating the possible dispersion of radioactive substances and how it is distributed over time for a relevant selection of potential future sequences of events (scenarios). The purpose of the safety analysis is to show, inter alia, that the risks from these scenarios are acceptable in relation to the requirements on the protection of human health and the environment imposed by the Swedish Radiation Safety Authority (SSMFS 2008:37). The safety analysis should also aim to provide a basic understanding of repository performance during different time periods and to identify requirements regarding the performance and design of different repository components.

A ***scenario*** in the safety analysis comprises a description of how a given combination of external and internal conditions affects repository performance.

Two groups of such conditions are:
- external conditions in the form of features, events and processes which occur outside repository barriers; these include climate changes and their consequential impact on the repository environment, such as permafrost, glaciation, land subsidence, land uplift as well as the impact of human activities, and
- internal conditions in the form of features, events and processes which occur inside the repository; examples of such conditions are properties including defects, nuclear material, nuclear waste and engineered barriers and related processes, as well as properties of the surrounding geological formation and related processes.

Based on an analysis of the probability of occurrence of different types of scenarios in different time periods, scenarios with a significant impact on repository performance should be divided into different categories:
- main scenario
- less probable scenarios
- other scenarios or residual scenarios

The ***main scenario*** should be based on the probable evolution of external conditions and realistic, or where justified, conservative assumptions with respect to the internal conditions. It should comprise future external events which have a significant probability of occurrence or which cannot be shown to have a low probability of occurrence during the period of time covered in the safety analysis. Furthermore, it should as far as possible be based on credible assumptions with respect to internal conditions, including substantiated assumptions concerning the occurrence of manufacturing defects and other imperfections, and which allow for an analysis of the repository barrier performance (for example, it is insufficient to always base the analysis on leaktight waste containers over an extended period of time, even if this can be shown to be the most probable case). The main scenario should be used as the starting point when analysing the impact of uncertainties (see below), which means that the analysis of the main scenario also includes a number of calculation cases.

Less probable scenarios should be prepared for the evaluation of scenario uncertainty (see also below). This includes variations of the main scenario with alternative sequences of events and periods of time as well as scenarios that take into account the impact of future human activities, such as damage inflicted on barriers. (Detriment to humans intruding into the repository is illustrated by residual scenarios; see below.) An analysis of less probable scenarios should include analyses of uncertainties that are not evaluated within the framework of the main scenario.

Residual scenarios should include sequences of events and conditions that are selected and studied independently of probabilities in order to, inter alia, illustrate the significance of individual barriers and barrier functions. The residual scenarios should also include cases to illustrate detriment to humans intruding into the repository as well as cases to illustrate the consequences of an unclosed repository that is not monitored.

Lack of knowledge and other uncertainties in the calculation presumptions (assumptions, models, data) are in this context denoted as ***uncertainties***. These uncertainties can be classified as follows:
- scenario uncertainty: uncertainty with respect to external and internal conditions in terms of type, degree and time sequence
- system uncertainty: uncertainty as to the completeness of the description of the system of features, events and processes used in the analysis of both individual barrier performance and the performance of the repository as a whole
- model uncertainty: uncertainty in the calculation models used in the analysis
- parameter uncertainty: uncertainty in the parameter values (input data) used in the calculations
- spatial variation in the parameters used to describe the barrier performance of the rock (primarily with respect to hydraulic, mechanical and chemical conditions)

There are often no clear boundaries between the different types of uncertainties. The most important requirement is that the uncertainties are to be described and handled in a consistent and structured manner.

The evaluation of uncertainties is an important part of the safety analysis. This means that uncertainties should be discussed and examined in depth when selecting calculation cases, calculation models and parameter values, as well as in the assessment of calculation results.

The assumptions and calculation models used should be carefully selected with respect to the principle that the application and selection should be justified by means of a discussion of alternatives and with reference to science. In cases where there is doubt as to the applicability of a model, several models should be used to illustrate the impact of the uncertainty involved in the choice of model.

Both deterministic and probabilistic methods should be used so that they complement each other and, consequently, provide as comprehensive a picture of the risks as possible.

The ***probabilities*** of the scenarios and calculation cases actually occurring should be estimated as far as possible in order to calculate risk. Such estimates cannot be exact. Consequently, the estimates should be substantiated through the use of several methods, for example assessments by several independent experts. This can for instance be done through estimates of when different events can be expected to have occurred.

A number of ***design basis cases*** should be identified based on scenarios that can be shown to be especially important from the standpoint of risk. Together with other information, such as regarding manufacturing method and controllability, these cases should be used to substantiate the design basis, such as requirements on barrier properties.

Particularly in the case of disposal of nuclear material, for example spent nuclear fuel, it should be demonstrated that criticality cannot occur in the initial configuration of the nuclear material. With respect to the redistribution of the nuclear material through physical and chemical processes, which can lead to criticality, it should be demonstrated that such redistribution is very improbable.

The result of calculations in the safety analysis should contain such information and should be presented in such a way that an overall judgement of safety compliance with the requirements can be made.

The validity of assumptions used, such as models and parameter values, should be supported, for example by citing references to scientific literature, special investigations and research results, laboratory experiments on different scales, field experiments and studies of natural phenomena (natural analogues).

Scientific background material, such as from expert assessments, should be documented in a traceable manner by conscientiously referring to scientific literature and other material.

Section 10

The time period for which safety needs to be maintained and demonstrated should be a starting point for the safety analysis. One way of discussing and justifying the establishment of the relevant time period is to start from a comparison of the hazard of the radioactive inventory of the repository with the hazard of radioactive substances occurring in nature. However, it should also be possible to take into consideration the difficulties of conducting meaningful analyses for extremely long periods of time, beyond one million years, in some other way than by demonstrating how the hazard of the radioactive substances in the repository declines over time.

In the case of a repository intended for long-lived waste, the safety analysis may need to include scenarios taking greater expected climate changes into account, primarily in the form of future glaciations. For example, the next complete glacial cycle, currently estimated to be in the order of 100,000 years, should be particularly taken into account.

In the case of periods up to 1,000 years after closure, in accordance with the provisions of SSMFS 2008:37, the dose and risk calculated for current conditions in the biosphere constitute the basis for assessing repository safety and the repository's protective capabilities.

Furthermore, in the case of more extended periods of time, the assessment can be made using dose as one of several safety indicators. This should be taken into account in connection with calculations as well as presentation of analysis results. Examples of these supplementary safety indicators include the concentrations of radioactive substances from the repository which can build up in soils and near-surface groundwater as well as the calculated flow of radioactive substances to the biosphere.

This general advice applies as of 1 February 2009.

SWEDISH RADIATION SAFETY AUTHORITY

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