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Swiss Federal Nuclear Safety Inspectorate ENSI

Specific design principles for deep geological repositories and requirements for the safety case

Guideline for Swiss Nuclear Installations

ENSI-G03/e

April 2009

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1 Introduction

The Swiss Federal Nuclear Safety Inspectorate (ENSI) is the regulatory authority for nuclear safety and security of the nuclear installations in Switzerland. ENSI issues guidelines either in its capacity as regulatory authority or based on a mandate in an ordinance. Guidelines are support documents that formalise the implementation of legal requirements and facilitate uniformity of implementation practices. They further concretise the state-of-the-art in science and technology. ENSI may allow deviations from the guidelines in individual cases, provided that the suggested solution ensures at least an equivalent level of nuclear safety or security.

2 Subject and scope of application

This guideline applies to deep geological repositories as defined in Article 3 of the Nuclear Energy Act of 21 March 2003 (SR 732.1). It specifies the applicable protection objective and protection criteria and the requirements applying to a deep geological repository. It also sets out the details of the procedure to be followed for demonstrating the safety of a geological repository. It defines key terms in the area of geological disposal (Appendix 1) in so far as these are not addressed in the Nuclear Energy Act. Requirements are stipulated for the operation of facilities, in so far as these are specific to geological repositories and their closure. Where relevant, the provisions contained in other guidelines of the regulatory authority also apply to repository construction and operation.

This guideline regulates the radiological safety of deep geological repositories. Requirements relating to the release of chemo-toxic substances from a geological repository are dealt with in the relevant environmental protection legislation. Requirements applying to the security and control of fissile materials are regulated in the Ordinance of the Federal Department of the Environment, Transport, Energy and Communications (DETEC) on hazard assumptions and security measures for nuclear installations and nuclear materials of 16 April 2008 (SR 732.112.1) and are included here only if relevant for operational and long-term safety.

The explanatory report on guideline G03 contains explanations and examples of the pertinent requirements (available only in German).

3 Legal framework

The guideline is based on Article 11, paragraph 3 of the Nuclear Energy Ordinance of 10 December 2004 (SR 732.11), which calls on ENSI to regulate the design principles specific to geological repositories in the form of guidelines. The statutory requirements are contained in the Nuclear Energy Act and Ordinance. Provisions relating specifically to geological repositories are contained in Articles 37 to 41 of the Nuclear Energy Act and Articles 62 to 72 of the Nuclear Energy Ordinance.

Provisions from laws and ordinances are cited in this guideline only by way of exception, when this aids overall understanding.

4 Protection objective and criteria

4.1 Protection objective for deep geological disposal

Deep geological disposal of radioactive waste has to ensure the long-term protection of humans and the environment from the effects of ionising radiation, without imposing undue burdens and obligations on future generations.

4.2 Guiding principles for implementing the protection objective

The following principles have to be observed in deep geological disposal of radioactive waste. For completeness, the principles already set out in Article 11, paragraph 2 of the Nuclear Energy Ordinance are also mentioned here.

a. *Protection of humans*: The geological disposal of radioactive waste may result in only low additional radiation exposure to individual members of the population.

b. *Protection of the environment*: As the natural basis for the existence of humans and other living beings, the environment requires to be protected (Article 1 of the Nuclear Energy Act). Biodiversity may not be put at risk by geological disposal.

c. *Transboundary protection*: The risks resulting from geological disposal of radioactive waste in Switzerland may not be higher in other countries than is permissible in Switzerland.

d. *Future protection*: Risks arising in the future from geological disposal of radioactive waste may not be greater than those permissible in Switzerland today.

e. *Long-term safety*: A geological repository has to be designed in such a way that, after its closure, no further measures are required to ensure long-term safety.

f. *Safety barriers*: The long-term safety of a geological repository is to be assured by staged, passively functioning natural and engineered barriers (multiple barrier system, Article 11, paragraph 2b of the Nuclear Energy Ordinance).

g. *Monitoring and retrieval*: Any measures that would facilitate monitoring and maintenance of a geological repository or retrieval of the waste may not compromise the functioning of the passive safety barriers (Article 11, paragraph 2c of the Nuclear Energy Ordinance).

h. *Freedom from burdens*: The responsibility for geological disposal lies with the generation enjoying the benefits of the energy produced. No undue burdens may be placed on future generations.

i. *Natural resources*: The foreseeable future use of natural resources may not be unnecessarily restricted by the presence of a geological repository.

k. *Optimisation*: For decisions that form part of planning, construction and operation (including closure) of a repository, alternatives are to be considered and balanced with a view to optimising operational and long-term safety.

4.3 Protection criteria

Quantitative protection criteria are used to determine whether the protection objective has been fulfilled, taking the guiding principles for implementation into consideration. Compliance with the protection criteria has to be shown in a safety case.

4.3.1 Protection criteria for the operational phase of a deep geological repository and its surface facilities

The requirements contained in the Radiological Protection Ordinance of 22 June 1994 (SR 814.501) apply to the operational phase of a geological repository and its surface facilities. The radiological protection criteria for normal operation are further specified in guideline HSK-R-11 on radiological protection objectives for normal operation of nuclear installations. For the surface facilities, protection criteria 1 to 3 of guideline HSK-R-29 on interim storage of radioactive waste apply.

4.3.2 Protection criteria for the post-closure phase

The variants for future evolution of a sealed repository that are realistically conceivable are to be classified into likely and less likely and the selected classification has to be justified.

Protection criterion 1: For each future evolution classified as likely, the release of radionuclides may not lead to an individual dose exceeding 0.1 mSv per year.

Protection criterion 2: Future evolutions classified as less likely that are not considered under protection criterion 1 may not, taken together, constitute an additional individual radiological risk of health detriment exceeding one in a million per year.

5 Design, operation and closure

The phases and licensing steps set out in the Nuclear Energy Act and Ordinance for the planning, construction, operation and closure of a geological repository are presented schematically in Appendix 2. The operational phase of a repository comprises waste emplacement, the monitoring phase and closure. Closure activities begin once they have been ordered by the Federal Council and end with the final closure of the facility. After this, the Federal Council can, according to Article 39, paragraph 3 of the Nuclear Energy Act, order a further limited monitoring phase. Following final closure, or after expiry of the monitoring period, a geological repository is released from the provisions of the nuclear energy legislation by an appropriate order (Article 39, paragraph 4 of the Nuclear Energy Act).

5.1 Design of a geological repository and its surface facilities

A geological repository consists of the main facility, the pilot facility and the test areas (Article 64 of the Nuclear Energy Ordinance), as well as the necessary underground access structures. The repository and its surface facilities are to be designed in such a way that compliance with the principles for fulfilling the protection objective and criteria is achieved. The principles relating to nuclear safety and security contained in the nuclear energy legislation apply.

5.1.1 General requirements

a. It has to be ensured through administrative and technical measures that, neither in the operational phase (normal operation or incidents) nor after closure, can a state of nuclear criticality occur.

b. It is to be foreseen that the installations, exhaust air and effluents will be monitored radiologically during the operational phase.

c. It is to be foreseen that waste and effluents from the repository that are produced during normal operation or as the result of incidents and the management of their consequences, will be collected using a suitable system and disposed of in a controlled manner.

d. The areas accessible during the operational phase are to be dimensioned such that the necessary freedom of movement for operational radiological protection is assured. The requirements for zoned operation according to guideline HSK-R-07 on monitored zones in nuclear installations and the Paul Scherrer Institute have to be taken into account The expected ambient dose rate in areas that are entered routinely has to be kept low by designing facility components with a view to accommodating appropriate fixed or movable shielding.

e. Regarding construction, technical and organisational aspects of fire prevention, in addition to the applicable cantonal requirements the provisions of guideline HSK-R-50 on technical requirements for fire prevention in nuclear installations have to be observed. The measures for fire prevention may not compromise long-term safety.

f. During planning, the facilities are to be classified in terms of safety according to Appendix 4 of the Nuclear Energy Ordinance and designed in accordance with the classification.

5.1.2 Requirements relating to surface facilities and near-surface access structures

a. Where applicable, the provisions of guideline HSK-R-29 apply to surface facilities and near-surface access structures.

b. The surface facilities and near-surface access structures have to be designed in such a way as to prevent significant inflow of surface water into the geological repository.

5.1.3 Requirements relating to underground structures

a. The underground structures are to be designed and maintained in such a way that their safe operation is assured up till final closure of the repository. The stability of the underground structures has to be monitored.

b. When designing the geological repository, attention has to be paid to the thermal output of heat-producing waste and its compatibility with the engineered and natural barriers.

c. When designing the repository structures, including the engineered barriers, attention must be paid to physical and chemical compatibility with the waste and the natural barrier.

d. The design of the underground installations must ensure an appropriate spatial separation and separate ventilation of areas where radioactive waste is handled and areas where the disposal capacity is simultaneously being expanded. The expansion of the waste emplacement zones may not compromise the operational and long-term safety of the geological repository.

e. The access structures and the underground installations are to be dimensioned in such a way that they meet the requirements relating to normal operation and to management of incidents or accidents.

f. The construction of the underground installations must be such that significant inflow of water can be prevented as far as possible. If significant inflow of water cannot be ruled out, operational and structural measures must be undertaken to ensure the operational and long-term safety of the repository.

5.1.4 Retrieval without undue effort

Up to the time of repository closure, retrieval of the waste has to be possible without undue effort (Article 37 of the Nuclear Energy Act). The mechanical stability of the disposal containers therefore has to be such that they can be retrieved without undue effort up till the end of the monitoring phase. Measures taken to secure retrieval may not compromise the passive safety barriers and hence the long-term safety of the repository (Article 11, paragraph 2c of the Nuclear Energy Ordinance).

The concept for retrieval of the waste has to be presented to ENSI for review and approval together with the construction licence application for the repository. The retrieval concept has to contain an estimate of the expected radiation exposure of operating personnel and the local population.

5.1.5 Pilot facility

The behaviour of the waste, the backfill and the host rock are to be observed in the pilot facility up to the end of the monitoring phase. During monitoring, data are to be collected to support the safety case with a view to repository closure (Article 66, paragraph 1 of the Nuclear Energy Ordinance).

The pilot facility is to be designed in accordance with Article 66, paragraph 3 of the Nuclear Energy Ordinance and equipped with the instrumentation required for monitoring activities. The pilot facility can consist of one or more caverns or one or more tunnel sections. Incidents in the pilot facility may not compromise the operational and long-term safety of the main facility and vice versa. The possibility of having to transfer waste from the pilot facility to the main facility has to be considered in the facility design.

5.1.6 Temporary closure during the operational phase

In the case of an unfavourable development in the boundary conditions that could threaten the safety of the repository or could bring normal closure into question, technical and operational measures have to be put in place for temporary closure, to allow the emplacement zones of a repository to be transformed rapidly into a passively safe state during the operational phase (Appendix 2).

The measures for temporary closure have to be presented in a concept submitted together with the construction licence application for the repository. The functioning of these measures has to be demonstrated in the test areas before any waste is emplaced. These measures may not compromise the long-term safety of the repository.

5.1.7 Security and control of fissile materials

The necessary administrative, organisational and layout-related measures for ensuring security have to be implemented. This is covered by the provisions of Article 9 of the Nuclear Energy Ordinance, the DETEC Ordinance on risks and security measures for nuclear installations and nuclear materials (SR 732.112.1), the Safeguards Ordinance (SR 732.12) and guideline HSK-R-49 on requirements applying to the security of nuclear installations.

A geological repository has to be designed in such a way that controls of fissile materials are possible in accordance with the Safeguards Ordinance. The measures taken to ensure security and control of fissile materials may not compromise the long-term safety of the repository.

5.2 Operation of a deep geological repository

5.2.1 Monitoring

The environmental monitoring of a geological repository must be initiated sufficiently early before the start of underground construction to allow reliable data to be collected for the purpose of preservation of evidence. Monitoring must continue until the facility is released from the provisions of the nuclear energy legislation. It includes monitoring the radioactivity of springs and groundwater, soils, water bodies and the atmosphere in the area potentially influenced by the repository. The delivery and chemical composition of spring waters also have to be investigated for the purpose of preservation of evidence.

As a continuation of underground site characterisation, monitoring of the geological environment surrounding the underground structures has to be carried out up till closure. Monitoring has to include, in particular, the hydrogeological conditions, water composition, rock parameters that are relevant for safety and the geometry of excavations. This supplements the geological and hydrogeological databases used for evaluating the long-term evolution of the repository.

For a geological repository and its surface facilities, suitable radiological monitoring measures have to demonstrate compliance with the source-related dose limit. The requirements of the guideline HSK-G14 on calculating radiation exposure in the environment due to emissions of radioactive substances from nuclear installations have to be taken into consideration. This monitoring has to continue until the facilities are released from the provisions of the nuclear energy legislation.

Monitoring may not compromise the passive safety barriers. The suitability of the monitoring programmes has to be checked periodically. The monitoring programmes and their results are to be submitted periodically to ENSI for review.

5.2.2 Operation of the pilot facility

The pilot facility has to be loaded with waste and backfilled before the start of waste emplacement in the main facility.

It has to be operated in such a way that

a. the barrier system of the main facility is adequately reproduced and

b. the selection of waste packages is representative of the inventory of the main facility.

The monitoring programme of the pilot facility must measure the evolution with time of the pilot facility and its geological environment in such a way as to provide information

a. on safety-relevant conditions and processes in the pilot facility and its geological environment

b. for early recognition of unexpected developments

c. on the effectiveness of the barrier system

d. to support the confirmation of the safety assessment.

The information must be transferable to the situation in the main facility and its geological environment.

The suitability of the monitoring programme for the pilot facility has to be checked periodically. The monitoring programme and its results are to be submitted periodically to ENSI for review.

If the condition of the safety barriers of the pilot facility at the end of the monitoring phase no longer fulfils the safety requirements due to unforeseen processes or planned interventions, and adequate maintenance and repair measures are impossible, the waste has to be removed from the pilot facility and emplaced in the main facility.

5.2.3 Investigations in underground test areas

In accordance with Article 65 of the Nuclear Energy Ordinance, the safety-relevant properties of the host rock have to be investigated in greater detail in test areas of a geological repository. Safety-relevant technologies for emplacing the backfill material (or its removal if retrieval is necessary), for retrieving waste packages and for sealing of caverns and tunnels have to be tested and their operational reliability demonstrated.

The investigations in the test areas have to be carried out in such a way that they do not compromise the long-term safety of the repository as a whole.

5.2.4 Waste emplacement

The repository operator has to specify criteria for acceptance of waste packages for emplacement in a geological repository. Waste packages can only be accepted if their chemical and radiological inventory is compatible with the corresponding requirements of the safety case.

The procedures for emplacement of waste packages in a geological repository, and the demonstration that the acceptance criteria for the repository are fulfilled (conformity check), have to be submitted to ENSI for review.

The emplacement of waste packages in a geological repository requires clearance by ENSI. Clearance can relate to individual waste packages or to waste package types. Packages damaged by incorrect handling or by incidents, and that no longer meet the acceptance criteria for emplacement, have to be assessed on a case-by-case basis in terms of their impact on operational and long-term safety and reconditioned if necessary.

Measures are to be taken to limit radiation exposure during the operational phase; the administrative and technical measures required for preventing incidents and for managing their consequences have to be identified and prepared. In particular

a. the premises, exhaust air and effluents have to be monitored radiologically in accordance with the Radiological Protection Ordinance and any resulting raw waste has to be collected, treated and disposed of in a controlled manner;

b. suitable measures have to be taken to prevent the formation of flammable gas mixtures in underground areas due to gas generation from the waste packages or gas influx from the host rock.

When emplacing waste packages containing fissile material, the provisions of the Safeguards Ordinance have to be observed.

5.2.5 Backfilling

The backfilling of the disposal excavations has to be in line with the requirements relating to long-term safety. The backfilling of the disposal excavations of the main facility for high-level waste is to be carried out continuously following the emplacement of the waste packages.

5.2.6 Retrieval without undue effort

If there are indications of failure of the barrier system during the operational phase, adequate repair is impossible and the long-term safety of the geological repository can thus no longer be assured, the waste packages have to be retrieved.

5.2.7 Reporting

The duty to inform and submit reports to ENSI on the operation, radiological status and deviations from normal operation are regulated by the guidelines ENSI-B02 on periodic reporting on nuclear installations and ENSI-B03 on information from nuclear installations.

5.3 Closure and marking of a deep geological repository

5.3.1 Closure

Closure involves transforming the repository into a condition in which no further measures are required for assuring long-term safety. Closure includes backfilling all parts of the repository that are still open following the monitoring phase, transferring the pilot facility into a state that is safe in the long term and sealing of all components that are important for long-term safety and security (Article 69, Nuclear Energy Ordinance).

An application to close the repository has to be submitted by the facility operator. The application has to contain an updated safety assessment that includes information from the entire monitoring phase. Before any work on closure is carried out, it has to be demonstrated that the planned sealing structures fulfil the requirements placed on them.

After final closure, long-term safety must once again be confirmed by a safety assessment that takes into account the effective implementation of the closure activities. This safety assessment forms the basis for granting the order releasing the repository from the provisions of the nuclear energy legislation.

5.3.2 Marking a geological repository

The repository operator has to submit a concept for marking the repository as part of the construction licence application. The concept then has to be put in concrete terms in subsequent licensing steps. Permanent marking in accordance with Article 40 of the Nuclear Energy Act may not compromise long-term safety and has to be considered in the safety case.

6 Optimisation, quality management and documentation

6.1 Optimising the operational phase and the long-term safety of a geological repository

Radiological protection during the operational phase of a geological repository and its surface facilities has to be optimised in accordance with Article 6 of the Radiological Protection Ordinance. Any potential impacts on long-term safety have to be taken into consideration.

The radiological impact of the repository and its surface facilities has to be reduced to the extent that is possible and reasonable based on the state-of-the-art in science and technology.

For every step in realising the repository, various alternatives and their significance for long-term safety have to be considered qualitatively for each safety-relevant decision and a decision shall be made that is, overall, favourable for safety. This optimisation process has to be documented.

From the viewpoint of optimising long-term safety, the disposal containers for high-level waste have to be designed to ensure complete containment of radionuclides for a period of one thousand years after emplacement. The waste producers have to provide evidence for this containment capability over time.

6.2 Quality management

A quality management programme, which is in accordance with international standards and which covers all safety-relevant work on planning, construction, operation, monitoring and closure of a repository, has to be prepared and applied and its implementation documented (Articles 16 and 20 of the Nuclear Energy Act and Articles 25 and 31 of the Nuclear Energy Ordinance). As far as practicable, decisions based on judgment have to be documented as such.

Quality assurance measures for handling data and performing quantitative or qualitative analyses as part of the safety assessments have to be put in place and documented.

The quality management programmes foreseen for the planned work activities are to be submitted in advance to ENSI for comment.

6.3 Documentation

The emplacement of all waste packages in the repository has to be documented. In addition to the documentation on construction in accordance with Article 27 of the Nuclear Energy Ordinance and on operation in accordance with Article 41 of the Nuclear Energy Ordinance, documentation has to be prepared on long-term securing of knowledge on the geological repository according to Article 71 of the Nuclear Energy Ordinance. At least three copies of this documentation have to be provided following final closure of the repository and archived in different locations. The long-term durability of the documentation has to be demonstrated and the required maintenance measures explained. In addition to the requirements of Article 71 of the Nuclear Energy Ordinance, the documentation has to contain at least the following information:

a. A description of the closed facility and its location. This includes the location and extent of the underground installations and the geometry and properties of the surrounding rock layers;
b. Information on each emplaced waste package, with its exact position and the documentation produced for its conditioning and emplacement;
c. Information on interim storage and any subsequent conditioning of waste packages in so far as this relates to properties of the waste packages that deviate from the documented standard design and the information is relevant for possible retrieval of the waste or long-term safety;
d. A summary of the results from the monitoring phase;
e. Results of the updated safety assessment.

7 Demonstrating the safety of a geological repository

For the licence applications for a geological repository (general, construction and operating licences) and the application for closure of the repository, the Nuclear Energy Act requires a safety case to be provided for the operational phase (demonstration of operational safety) and the post-closure phase (assessment of long-term safety) of the repository. A further safety case has to accompany the application for the confirmation of final closure. The required degree of detail of the safety case depends on the stage of the licensing procedure. The safety case has to be updated periodically to reflect the current condition of the facility and the state-of-the-art in science and technology.

7.1 Safety demonstration for the operational phase

The operational phase begins with the operating licence and ends with the final closure of the repository (Appendix 2). The safety demonstration for the operational phase has to be supported by a systematic, comprehensive analysis of both normal operation of the facility and of the impact of incidents. The required documentation is based on the information in Appendix 4 of the Nuclear Energy Ordinance. Safety-relevant aspects of the operation of an encapsulation plant constructed at the same site have to be included in the safety demonstration for the operational phase of the repository.

The safety demonstration has to be documented in a safety report. Besides the requirements in Article 95, paragraph 2 of the Radiological Protection Ordinance, the safety report has to cover the following aspects:

a. It must contain a description of the surface and underground installations, from which the spatial conditions and the typical working procedures for normal operations can be derived. The description must include all structures, facilities and installations that are relevant for safety under normal operating conditions and for managing accidents or incidents.

b. The measures taken for radiation protection during normal operations have to be presented. The expected radiation exposure of personnel and the local population has to be indicated.

c. The accident analysis has to consider at least the types of accident listed in Article 8, paragraphs 2 and 3 of the Nuclear Energy Ordinance, in so far as they are relevant for the facility. The accidents are to be divided into classes depending on the likelihood of their occurrence according to the DETEC Ordinance on hazard assumptions and evaluation of protection against accidents in nuclear installations. Other types of accident that are specific to the facility and site in question are to be documented and divided in the same way.

d. Details have to be provided on assumptions regarding the course of incidents and their possible radiological consequences. It has to be shown that the limits specified in Article 94 of the Radiological Protection Ordinance can be observed, and the requirements in guideline HSK-G14 are to be taken into account. The impact of accidents or incidents on the long-term safety of a closed repository also has to be presented.

e. A probabilistic safety analysis has to be carried out for the operational phase. A risk analysis for external events such as earthquakes, floods, etc. has to be carried out as specified in the DETEC Ordinance on hazard assumptions and evaluation of protection against accidents in nuclear installations. The results of the probabilistic safety analysis have to be discussed, the procedures that dominate risk described and, if appropriate, reasonable measures for improvement proposed.

7.2 Safety case for the post-closure phase

7.2.1 Safety case

The safety case is an overall evaluation of the long-term safety of a closed geological repository. It is based on the results of a comprehensive safety assessment that investigates the long-term evolution of the repository and the resulting radiological impacts.

The safety case also contains an evaluation of the methods and data used for the safety assessment. If necessary, it can also present further supporting arguments for the fundamental assumptions and results of the safety assessment. Where possible, the statements made in the safety assessment should also be supported by observations of natural systems (natural analogues).

The safety case has to be carried out in accordance with the state-of-the-art in science and technology. The available scientific and technical data on the repository and its environment and on the emplaced waste packages, and the information and results acquired during the operational phase and from the monitoring programmes, have to be taken into account. The scientific and technical data must be such that they allow an assessment to be made of the retention capacity of the barrier system and of the processes and parameters that are important for limiting radionuclide release from the repository.

The safety case must be documented in a safety report. This report also has to present and quantify uncertainties and their relevance for safety. This includes uncertainties relating to parameters, scenarios and conceptual models. The safety report has to be updated periodically, taking into account new information for the assessment of long-term safety.

7.2.2 Safety assessment

The safety assessment is a systematic quantitative evaluation aimed at determining whether the repository fulfils the safety requirements. The assessment must address at least the following aspects:

a. Detailed description of the geological repository (waste inventory, barrier system, geological situation).
b. Description of the evolution with time of the radiotoxicity of the emplaced waste.
c. Description of the functioning and robustness of the engineered and natural barriers. The retention capacity of the barrier system must be assessed using mathematical models.
d. Description of the expected long-term geological evolution.

e. Description of the expected evolution of the materials in the repository, including the radioactive waste and the engineered and natural barriers. The description has to take into account possible mutual influences of the different materials.

f. Performing a scenario analysis and identifying calculation cases that are used to investigate the evolution of the repository. The possible radiological impacts of future evolutions have to be assessed using envelope variants.

g. Determination of the range of variation of possible releases of radioactive substances to the biosphere and of the maximum dose for all scenarios using model calculations.

h. Justification that the models used in the calculations are applicable to the situation considered. The significance of simplifications in the models compared to the actual natural situation has to be explained.

i. Performing a sensitivity analysis to show the extent to which changes in parameter values affect the calculation results.

k. Analysis of existing uncertainties in data, processes and models and calculation of the resulting range of radionuclide release and doses.

The dataset for the safety assessment must be updated periodically during the implementation of the repository. The dataset has to be such that it allows long-term safety to be evaluated for the different licensing steps according to the Nuclear Energy Act.

Determining individual doses

The release and migration of radionuclides contained in a geological repository through the barrier system and into the human environment has to be calculated. Protection criteria 1 and 2 relate to the radiation exposure of an average individual within the population group most affected by the potential impacts of the repository.

Time period for assessment

Humans and the environment have to be protected permanently from the ionising radiation from the waste. The evaluation of potential radiological impacts from a repository must take into account the inevitable uncertainties that increase with consideration of longer time periods. A differing degree of predictability over time is associated with the engineered barriers, the host rock, the surrounding geological formations, the biosphere and human habits.

Decisive for determining the time span for the safety case are the evolution with time of the radiological hazard potential of the emplaced waste and the predictability of long-term geological evolution. Dose and risk calculations up to the time of maximum radiological impact of the repository have to be carried out as part of the safety assessment.

For a period up to one million years, it has to be shown as part of the safety case that the protection criteria can be met. For longer time periods, the range of variation of the possible regional radiological impacts from the repository has to be estimated taking into account inherent uncertainties. These impacts may not be significantly higher than natural radiological exposure. Calculations of radiological impacts in the distant future are not to be understood as predicted radiation exposures for a definable population group, but rather as indicators for evaluating potential radionuclide release to the biosphere. Scenarios in which the underground disposal area is increasingly exposed to surface influences as a result of geological processes have to be taken into consideration.

Restricting release in the absence of human settlement

In time periods when human settlement at the surface within the area of influence of the geological repository can be temporarily ruled out, the release from the repository must nevertheless not exceed the limits set out in protection criteria 1 and 2. For these periods, the presence of humans in a reference biosphere is to be assumed.

Assumptions regarding climate evolution and human living habits

To calculate radiation dose in the distant future, a potentially affected population group with living habits that are realistic based on a present-day perspective is assumed. In particular:

a. possible variants for climate evolution and associated biosphere models have to be defined and their significance for the long-term safety of the repository investigated;

b. the effects of ionising radiation on humans have to be based on current understanding;

c. scenarios in which the safety of the repository is influenced by human activities are to be handled in a way that appears credible from the perspective of present-day society.

Developments not to be considered

The safety assessment does not have to be carried out for scenarios containing the following events:

a. intentional human intrusion into a repository;

b. intentional damage to a repository;

c. extremely rare occurrences such as the impact of a large meteorite.

Handling uncertainties

Uncertainties in data, processes and conceptual models and in the future evolution of the geological repository are inevitable. These uncertainties have to be reduced as far as necessary by appropriate research and data collection. Where uncertainties remain, the maximum radiological consequences have to be estimated in the safety assessment by calculating envelope variants or by making conservative assumptions.

The influence of uncertainties on the calculated results has to be shown systematically and the conclusions for long-term safety presented.

8 Security demonstration

To demonstrate compliance with security requirements and with the required measures for controlling fissile materials, the requirements set out in the DETEC Ordinance on hazard assumptions and security measures for nuclear installations and nuclear materials, the Safeguards Ordinance and the requirements in guideline HSK-R-49 apply. Compliance with security requirements is to be documented in a classified report according to the requirements of the authorities.

This guideline was approved by ENSI on 19 March 2009.

Director of ENSI: signed U. Schmocker

Appendix 1: Glossary

The terms monitoring phase, deep geological repository and closure are defined in Article 3 of the Nuclear Energy Act.

The following terms are used in this guideline:

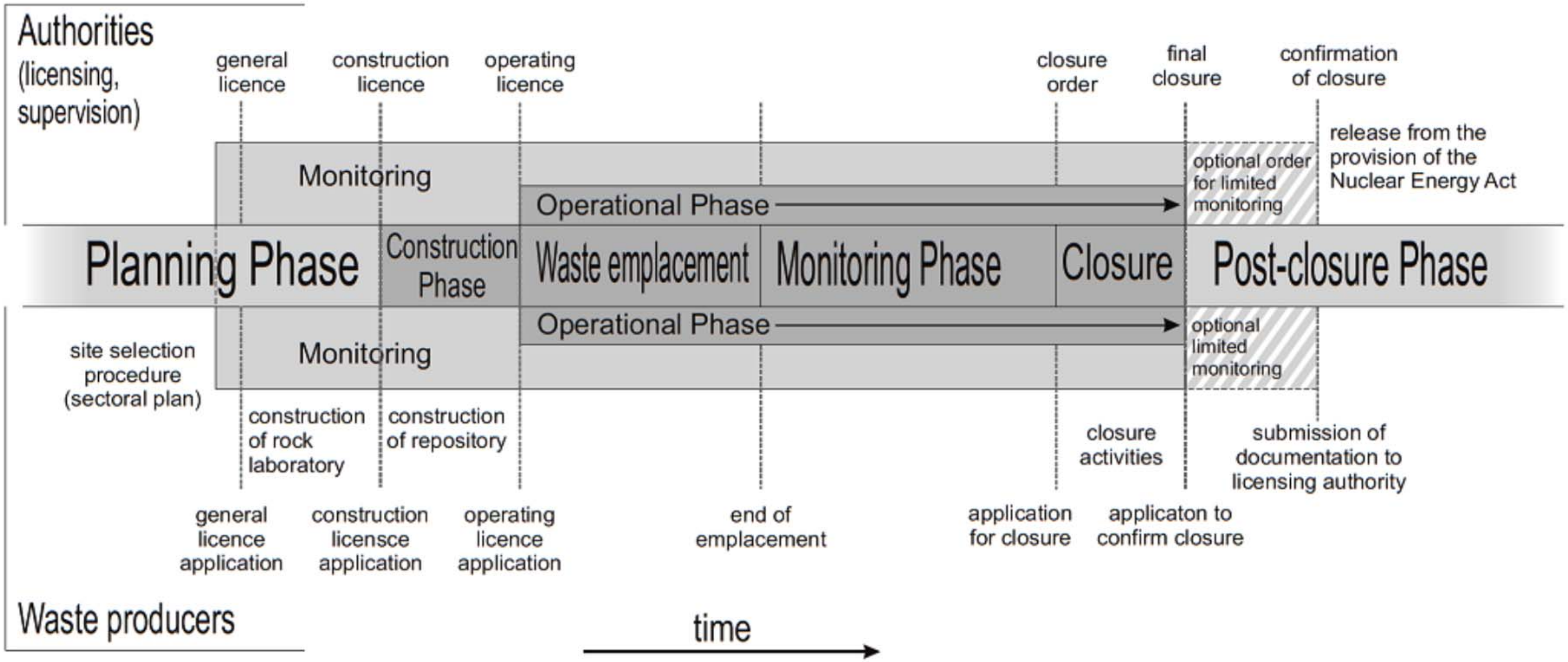
Access structures	Accesses to the main and pilot facilities and the test areas.
Backfilling	Closing of excavations through introduction of solid materials. The backfilling may be for the purpose of mechanical stabilisation, spatial separation or ensuring the safety functions of the natural and engineered barriers.
Biosphere model	Transport and exposure model used for converting radionuclide releases from the geosphere to the biosphere into a radiation exposure for the population group to be considered (in this case individual dose). The basis is a transport and accumulation model used for calculating radionuclide migration in the human environment (water, air, soil) and a model used for calculating radiation dose taking into account radionuclide uptake via drinking water, food and air, as well as direct radiation.
Conservative assumption	Assumptions are termed conservative when they lead to the radiological impact for humans and the environment being overestimated with a high likelihood. Conservative assumptions often represent simplifications of the actual situation that are used to compensate for gaps in data or understanding.
Disposal container	Disposal containers can be used as overpacks around the waste packages. The mechanical stability of the disposal container has to be assured up to the end of the monitoring phase.
Dose	Measure for assessing the health-related risk from ionising radiation. In this guideline, the effective dose is meant, i.e. the sum of the equivalent doses in all organs and tissues weighted using weighting factors w_T. The unit of dose is the Sievert (Sv) (Radiological Protection Ordinance).
Encapsulation plant	Nuclear installation at the surface used to load the disposal containers for emplacement in a geological repository.

Engineered barrier	Engineered component in a geological repository that remains after closure of the facility and, based on the safety concept, functions passively to retain radionuclides.
Envelope variant	Evolution variants for the waste, the engineered and natural barriers in and around a repository, the biosphere and human living habits whose radiological impact over the time period under consideration is highly likely to be larger than that of actual future evolutions.
Long-term safety	The safety of a deep geological repository for humans and the environment after its closure.
Main facility	Part of a deep geological repository in which most of the radioactive waste is emplaced.
Monitoring	Continuous or periodic observation of a relevant property over longer time periods or measurement of a parameter or the sum of all such observations or measurements.
Multiple barrier system	A system of staged, passively functioning engineered and natural barriers for containment and retention of radionuclides contained in the waste. The effectiveness of the multiple barrier system may not depend unduly on the effectiveness of one single barrier.
Natural analogue	Geosystems, materials and processes found in nature that are relevant for a geological repository and whose behaviour can be studied over long periods in the past. They include anthropogenic materials that have been exposed to natural processes over long times. Investigation of natural analogues helps in assessing possible evolutions and the long-term safety of a geological repository.
Natural barrier	The natural environment of a geological repository that, according to the safety concept, contributes passively to the retention of radionuclides.
Optimisation	For a geological repository, optimisation is understood as a stepwise process in which various alternatives and their significance for operational and long-term safety are considered qualitatively for every safety-relevant decision, and a decision is made that is, overall, favourable for safety.

Pilot facility	Independent part of a deep geological repository that is separated from the main facility and is used to monitor the behaviour of the waste, the backfill and the host rock up to the end of the monitoring phase.
Radiological health risk	Product of the potential extent of damage due to radiation exposure and the likelihood of this damage occurring, as well as the sum of such products. It includes both the risk of cancer and the risk of genetic damage.
Retrieval	Includes the removal recovery and transport of emplaced radioactive waste from a geological repository to the surface.
Robustness	A characteristic of the system under consideration that describes its insensitivity to uncertainties and to detrimental processes and events.
Safety assessment	Systematic quantitative evaluation aimed at determining whether the repository fulfils the safety requirements.
Safety case	Synthesis of calculations and supporting arguments for an overall evaluation of the safety of a geological repository during the operational phase (safety demonstration) and during the post-closure phase (safety assessment), and of the reliability of the corresponding safety assessments carried out.
Safety demonstration	Systematic and comprehensive analysis of both normal operation of the facility and of the impact of incidents during the operational phase.
Sealing structure	Engineered hydraulic barrier with a rock-supporting function that also serves to protect the backfill.
Security demonstration	Shows that the measures taken for protection against active hazards and internal and external malicious acts and for controlling fissile materials comply with regulatory requirements for protection of a geological repository and the associated surface facilities. The security report is a classified document.
Sensitivity analysis	Investigates the changes in modelling results caused by changing input parameters, thus allowing parameters that are decisive for safety to be identified.

Scenario	Possible variant for the evolution of the waste, the engineered and natural barriers in and around a repository, the biosphere and human living habits under the effects of assumed features, events and processes.
Temporary closure	Rapid closure of the facility within several weeks to months; temporary closure has to remain effective for several decades to centuries.
Test areas	Independent parts of the geological repository, where the safety-relevant properties of the host rock or the engineered barriers can be investigated in more detail in order to support the safety case, or where required technologies can be investigated and their correct functioning demonstrated.

Appendix 2: Simplified schematic representation of the processes involved in planning, construction, operation and closing a deep geological repository



Published by: Swiss Federal Nuclear Safety Inspectorate ENSI, CH-5232 Villigen-ENSI
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