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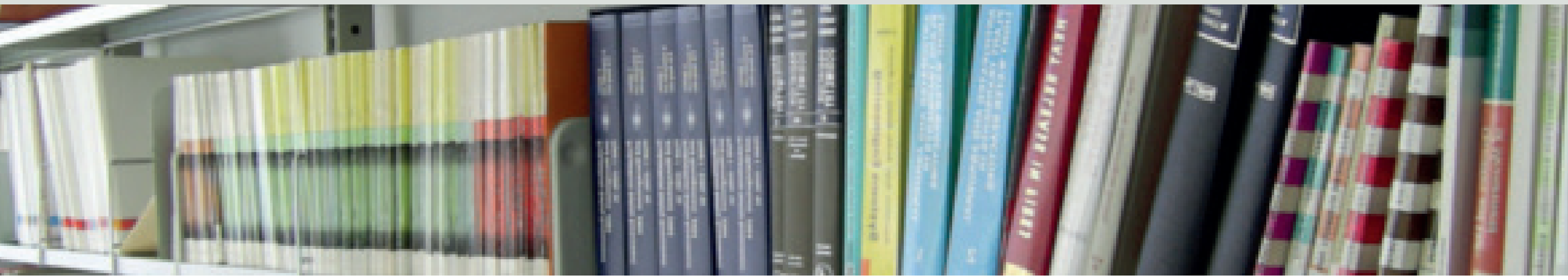

Deep Geological Repositories

Guideline for Swiss Nuclear Installations

ENSI-G03

Edition December 2020

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1 Introduction

The Swiss Federal Nuclear Safety Inspectorate (ENSI) is the regulatory authority responsible for nuclear safety and security of 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 uniform implementation practices. They also reflect the current state of the art of science and technology in concrete terms. ENSI may allow deviations in individual cases, provided that the suggested solution ensures at least an equivalent level of nuclear safety or security.

2 Legal Basis

This guideline is based on Article 11 paragraph 3 of the Nuclear Energy Ordinance of 10 December 2004 (NEO; SR 732.11) and Article 70 paragraph 1 letter a of the Nuclear Energy Act of 21 March 2003 (NEA; SR 732.1).

3 Subject and Scope

This guideline applies to deep geological repositories and the associated surface facilities and near-surface access structures. Pursuant to Article 3 letter c of the Nuclear Energy Act of 21 March 2003 (NEA; SR 732.1), a deep geological repository is a nuclear facility for the disposal of radiological waste in a deep geological formation, which may be closed, provided that passive barriers ensure permanent protection of humans and the environment. Pursuant to Article 49 paragraph 5 of the NEA, a nuclear installation also encompasses all exploitation facilities and installation sites associated with construction and operation.

The overriding principles and protection measures for deep geological repositories are defined in Articles 4 and 5 of the NEA and Articles 7 to 9, 11 and 65 to 70 of the NEO. This guideline specifies the protection objective and protection criteria. It specifies the design principles and the safety demonstration procedure.

Requirements are stipulated for operation of the facilities, insofar as these are specific to deep geological repositories and the associated surface facilities and near-surface access structures. Requirements applying to the security and control of fissile materials are regulated in the Ordinance issued by 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.

This guideline regulates the permitted radiological effects of deep geological repositories and the associated surface facilities and near-surface access structures. In doing so, it translates the nuclear energy and radiological protection legislation into practical terms. The provisions of other legislation (in particular environmental protection legislation, water protection legislation, fisheries legislation, forestry legislation, nature and cultural heritage protection legislation, land planning legislation), and in particular requirements relating to the release of chemically toxic substances from a deep geological repository, are not covered by this guideline.

The requirements for selecting repository sites for all waste categories are regulated in the conceptual part of the Sectoral Plan for Deep Geological Repositories as specified in Article 5 of the NEO.

4 Basic Requirements

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 Specific Design Principles for Deep Geological Disposal

In addition to the principles for the design of deep geological repositories referred to in Article 11, paragraph 2 of the NEO, the following specific design principles have to be taken into account in accordance with Article 11, paragraph 3 of the NEO:

a. A deep geological repository has to be designed so that no further measures are necessary to ensure long-term safety after the repository has been closed.

b. Possible future effects of deep geological disposal in Switzerland may not be higher in other countries than is permissible in Switzerland.

c. Possible future effects of deep geological disposal in Switzerland must not be greater than those permissible in Switzerland today.

d. The natural basis for the existence of humans and other living organisms has to be protected.

4.3 Protection Criteria

a. Quantitative protection criteria referred to in Sections 4.3.1 and 4.3.2 have to be used to assess whether the protection objective has been fulfilled, taking the specific design principles for deep geological repository into account.

b. Compliance with the protection criteria for the operational and post-closure phases has to be demonstrated in the safety case.

4.3.1 Operational Phase

a. A source-related dose constraint applies for normal operation of a deep geological repository as well as the associated surface facilities and auxiliary access facilities in accordance with Guideline ENSI-G15.

b. For accidents in a deep geological repository and the associated surface facilities and auxiliary access facilities, compliance with the dose criteria according to Article 123 paragraph 2 of the Radiological Protection Ordinance of 26 April 2017 (RPO; SR 814.501) has to be demonstrated.

4.3.2 Post-Closure Phase

a. Any future evolution of a deep geological repository must not lead to the release of radionuclides causing an individual dose exceeding 0.1 mSv per year, nor cause the risk value according to criterion (b) in paragraph 2.15 of IAEA Safety Standard SSR-5 to be exceeded.

b. During the assessment period, the radiological consequences of inadvertent human intrusion into the deep geological repository has to be assessed on the basis of criteria (c) and (e) as set out in paragraph 2.15 of IAEA Safety Standard SSR-5.

c. After the end of the assessment period, the effects on the surface must not be significantly higher than the average current radiation exposure of the Swiss population.

4.4 Safety Optimisation

a. Safety-relevant decisions regarding planning and implementation of a deep geological repository and the associated surface facilities and auxiliary access facilities have to be made as part of an optimisation procedure. This procedure has to be documented in the waste management programmes of the waste producers and updated if necessary.

b. Various alternatives and their significance for long-term safety have to be considered for each safety-relevant decision and a decision has to be taken that is, overall, favourable for safety.

c. Within the scope of the optimisation procedure, optimisation measures reflecting the state of the art in science and technology have to be identified when taking safety-relevant decisions and the reasons why these are appropriate have to be explained.

d. Potential effects on long-term safety have also to be taken into account when optimising radiological protection for the operational phase of a deep geological repository and the associated surface facilities and auxiliary access facilities in accordance with Article 4 of the RPO.

e. The waste producers have to demonstrate that high level waste remains completely contained in the disposal canisters for a period of at least one thousand years after their emplacement.

5 Design

5.1 Basic Requirements

a. The design of a deep geological repository and the associated surface facility and auxiliary access facilities should take particular account of the necessary measures

   1. for radiation protection including radiological monitoring and

   2. for controlling accidents in accordance with Articles 4 and 5 of the DETEC Ordinance on Hazard Assumptions and Evaluation of Protection against Accidents in Nuclear Installations, 17 June 2009 (SR 732.112.2).

b. Systems, structures and components have to be classified in terms of safety.

c. The escape and rescue routes have to be described and justified in an escape and rescue concept.

d. Appropriate measures have to be taken to ensure that nuclear criticality cannot occur either during the operational phase or after closure of a deep geological repository.

e. Required measures for ensuring safety during the operational phase as well as provisions for possible retrieval of radioactive waste or for temporary closure, must not impair long-term safety.

5.2 Additional Requirements

5.2.1 Surface Facility and Auxiliary Access Facilities

a. The surface facility and the auxiliary access facilities has to be designed to prevent water penetrating from the surface into a deep geological repository.

b. The repackaging cell for high level waste (HLW) has to be designed to withstand a safe shutdown earthquake (SSE).

c. The surface facility, in particular the encapsulation plant including the repackaging cell, has to be designed to guarantee the capacity and flexibility required for operation.

d. Provisions have to be made for handling damaged fuel elements or vitrified HLW for storage in a deep geological repository.

5.2.2 Underground Structures

a. The deep geological repository has to be designed in such a way that long-term safety and safety functions are ensured through the interaction of engineered and natural barriers. Special attention has to be paid to maintaining the properties of the natural (geological) barrier that are relevant for long-term safety.

b. Containment and retention of the radionuclides contained in the waste are ensured by multiple barrier systems with various staged, passively functioning engineered and natural barriers.

c. A deep geological repository has to be designed to prevent the engineered and natural barriers being adversely affected by the following:

    1. thermal input from heat-producing waste

    2. build-up of gas pressure

    3. chemical reactions between components, individual barriers and between barriers and waste (including possible physical consequences)

d. If engineered measures are necessary to control pressure build-up, their functionality has to be ensured over the required period of time.

e. A deep geological repository has to be designed in such a way that any possible interactions between different waste types do not impair safety.

f. A deep geological repository has to be designed to ensure appropriate spatial separation and separate ventilation of areas where radioactive waste is handled and areas where the emplacement capacity is simultaneously being expanded.

g. A deep geological repository has to be designed to avoid negative effects arising from hazards caused by the rock mass or to reduce these to an acceptable low level by operational or structural measures so as to ensure both safety during operation and long-term safety.

6 Monitoring, Pilot Facility and Marking

6.1 Monitoring

a. An integral monitoring programme has to be level-appropriately developed for the construction, operational and, if necessary, post-closure phases of a deep geological repository.

b. The integral monitoring programme has to include at least geological environment monitoring, radiological environmental monitoring, radiological monitoring during the operational phase, pilot facility monitoring and monitoring measurements during construction and operation.

c. The relationship between the various monitoring aspects has to be clearly shown in the integral monitoring programme.

d. The integral monitoring programme has to be periodically checked for suitability by the waste producers and when submitting licence applications for the deep geological repository. It has to be updated as necessary and submitted to ENSI.

e. Monitoring of a deep geological repository and its geological environment has to be started in good time – at the latest upon receipt of the general licence – and continued until the deep geological repository is no longer subject to nuclear energy legislation.

f. Monitoring has to take into account measurements from the site characterisation process.

g. The impact of the installations provided for monitoring purposes on long-term safety has to be demonstrated and minimised.

h. Monitoring results have to be documented with the periodic reporting and submitted to ENSI.

i. Retained samples have to be stored and made available to the authorities if necessary.

6.2 Pilot Facility

a. The design of the pilot facility has to allow for a monitoring programme to assess the evolution over time of the pilot facility and its geological environment.

b. Accidents in the pilot facility must not compromise the operational and long-term safety of the deep geological repository and vice versa.

c. A pilot facility has to be loaded, backfilled and sealed prior to emplacement of the corresponding waste in the main facility.

d. The design has to take into account the possibility of transferring waste from the pilot facility to a newly excavated emplacement drift.

6.3 Permanent Marking

a. A concept for permanent marking of the deep geological repository has to be submitted with the construction licence application. The permanent marking concept has to be specified in concrete terms in subsequent licensing steps.

b. Permanent marking pursuant to Article 40 of the NEA must not compromise long-term safety. This has to be taken into account in the safety case for the post-closure phase.

7 Activities for Deep Geological Disposal

7.1 Geological Investigations

a. Geological investigations have to be carried out so that reliable evidence of the operational and long-term safety of a deep geological repository can be put forward.

b. Geological investigations have to be carried out such that they do not compromise the long-term safety of a deep geological repository. Damage to the subsurface has to be limited to the minimum necessary compatible with obtaining the required knowledge.

c. A sufficient safety distance has to be demonstrated between safety-relevant parts of the deep geological repository and underground structures or exploratory boreholes created during geological investigations. Such evidence has to be submitted with the construction licence application.

7.2 Waste Emplacement

a. When accepting waste packages for emplacement in a deep geological repository, the repository operator has to issue waste acceptance criteria on the basis of the operating licence, taking into account possible licensing conditions.

b. Waste packages may only be accepted if the waste acceptance criteria are met.

c. The packaging procedures required for emplacement of waste packages in a deep geological repository and the evidence of compliance with the waste acceptance criteria for the planned deep geological repository (conformity checks) have to be submitted to ENSI for approval.

d. Waste packages damaged by improper handling and which no longer comply with the waste acceptance criteria for emplacement have to be assessed on a case-by-case basis to determine their impact on operational and long-term safety and reconditioned if necessary.

e. Prior to emplacement of waste packages, evidence has to be provided that the designated emplacement area (emplacement chambers or drifts) meets the suitability criteria set in the general licence according to Article 14 of the NEA.

f. Appropriate measures have to be taken to prevent the formation of flammable gas mixtures in the underground structures due to gas production from the waste packages or gas ingress from the host rock.

g. When carrying out construction, emplacement, backfilling, sealing or dismantling work at the same time, both operational and long-term safety have to be ensured.

7.3 Backfilling and Sealing

a. Following the emplacement of waste packages, emplacement drifts in the main facility for high level waste shall be backfilled continuously and sealed immediately after backfilling has been completed.

b. Backfilling and sealing of the emplacement caverns and drifts have to comply with long-term safety requirements. The seals have to have sufficient mechanical stability to protect the backfilled emplacement drifts and to withstand swelling and gas pressure in the emplacement drifts.

c. A sealing concept has to be submitted with the construction licence application. This has to include at the very least the requirements specified under letter b.

d. Before carrying out the sealing, evidence has to be provided that the intended sealing structures meet the requirements specified in the sealing concept.

7.4 Retrieval without Undue Effort

7.4.1 General Requirements

a. A deep geological repository including the disposal canisters has to be designed in such a way that the radioactive waste can be retrieved without undue effort up to the time of closure.

b. Retrieval or partial retrieval of the waste has to be carried out if the safety case can no longer be made during the operational phase and an effective repair of the safety barriers is not possible.

7.4.2 Concept for the Possible Retrieval of Radioactive Waste

a. The general licence application has to include a concept for the possible retrieval of radioactive waste. As a minimum requirement, the concept has to describe the planning, logistics, construction and monitoring steps required to ensure retrieval is possible up to the time at which the repository is closed.

b. The construction licence application has to include a more detailed concept for the possible retrieval of radioactive waste and a project for demonstrating the retrieval technology in the test areas.

c. The operating licence application has to include a concept for the possible retrieval of radioactive waste that has been updated based on the results in the test areas.

d. The concept for possible retrieval of radioactive waste has to be periodically updated during the operational phase and submitted to ENSI.

e. In the event of a fundamental change in the retrieval concept, demonstration experiments have to be carried out again in the test areas. The updated concept has to be submitted to ENSI for approval.

7.5 Temporary Closure During the Operational Phase

a. Engineering and operational precautions have to be taken for temporary closure so that the emplacement areas in a deep geological repository can be converted to a passive safe state at any time during the operational phase.

b. A temporary closure is intended to ensure that waste already emplaced in the repository remains safely contained even in the event of a collapse of emplacement areas that have not yet been backfilled.

c. Precautions relating to a temporary closure have to be shown to function in the test areas prior to waste emplacement.

d. The temporary closure has to be presented in a concept which will be submitted with the construction licence application and updated with the operating licence application. As a minimum requirement, the concept has to specify the implementation measures, the materials to be used and the time required.

7.6 Closure of a Deep Geological Repository

a. The plans submitted with the construction licence application for decommissioning of the surface facilities and auxiliary access facilities, closure of the deep geological repository and post-closure activities have to be updated with the operating license application.

b. The requirements for the sealing structures to ensure long-term safety and the resulting design of the sealing structures have to be specified in the closure plan.

c. Proof has to be provided – at the latest when the application for closure is submitted – that the intended sealing structures meet the requirements laid down in the closure plan.

d. The application for closure has to include an updated safety case incorporating the findings of the monitoring phase.

e. The application for the confirmation of orderly closure has to provide further proof for the post-closure phase, taking into account effective implementation of the closure activities.

8 Civil Engineering Design and Construction

8.1 Underground Structures

8.1.1 Basic Requirements

a. Underground access structures and other underground structures have to be designed, constructed and maintained in such a way that operational and long-term safety are ensured.

b. The rules, regulations and principles of the relevant SIA (Swiss Society of Engineers and Architects) standards have to be considered.

8.1.2 Design

a. As a basis for design, based on Article 16 paragraph 1 d of the NEA, a service criteria agreement according to SIA standards (SIA 197 and 260) has to be drawn up by the waste producers and updated before each design phase. Interdependencies between service requirements have to be taken into account and conflicting requirements have to be solved.

b. The foreseen underground structures have to be designed with the required level of detail for the corresponding design phase.

c. The projects of underground structures have to be based on reliable site-specific data and basic information.

d. The risks resulting from expected site-specific and repository-specific events during the construction work have to be determined by means of a risk analysis and compared with the corresponding requirements for the structures defined by the waste producers in the service criteria agreement. Possible impacts on operational and long-term safety have to be identified and reported.

e. Possible interactions between the lining of the emplacement drifts and caverns and the barriers have to be considered in the design. In particular, the change in the temperature gradient between the inner face of the lining (interior of emplacement drift or cavern) and the rock mass, as a result of the thermal input from heat-producing waste, has to be taken into account in the structural analysis and the dimensioning of the lining as a load case.

8.1.3 Construction

a. During construction of the underground structures, care has to be taken to maintain the properties of the natural barrier as much as possible. For this purpose, the measures taken have to include rock mass-protecting excavation methods and prompt installation of the excavation support of the emplacement drifts and caverns.

b. In addition to Article 16 paragraph 1 d of the NEA, the principles for construction inspections and monitoring according to standard SIA 197 have to be considered.

c. In addition to Article 18 of the NEA and Article 27 of the NEO, the construction documents of each underground structure have to be drawn up in accordance with the relevant SIA standards. A copy of the construction documents has to be submitted to ENSI upon completion of waste emplacement.

8.2 Surface Facility and Auxiliary Access Facilities

a. Design and construction, plus associated documentation have to be carried out in accordance with Annex 4 of the NEO and Appendix 2 of Guideline ENSI-A04 in the 4 hierarchy levels B1 to B4.

b. The design basis for hierarchy level B1 according to Annex 4 of the NEO has to be derived from the safety assessments.

c. With the exception of the determination of actions due to natural events, the structural design and construction of structures have to be in accordance with the standards SIA 260 to 267.

d. The impact of natural events has to be determined based on a natural event with a frequency of 10^{-3} per year and a natural event with a frequency of 10^{-4} per year in accordance with Article 8 paragraph 4bis of the NEO. Thereby:

   1. a natural event with a frequency of 10^{-3} per year has to be considered as a temporary design situation according to standard SIA 260, and

   2. a natural event with a frequency of 10^{-4} per year has to be considered as an accidental design situation according to standard SIA 260.

e. The structures have to be designed to ensure linear elastic structural behaviour. For the aircraft impact load case, locally limited plastic deformation of the supporting structure is permitted.

f. For concrete components with a barrier function, high requirements according to standard SIA 262 apply with regard to serviceability.

9 Safety Case

9.1 Basic Requirements

a. Compliance with the protection criteria has to be demonstrated in the safety case.

b. The level of detail of the safety case has to be based on the stage of the licensing procedure.

c. State-of-the-art scientific and engineering data, processes and model concepts has to be used for the safety case and any associated uncertainties have to be indicated.

d. The safety case has to be adapted periodically to the latest state of the facility and if new findings become available, submitted to ENSI accordingly.

e. The long-term safety case has to be updated when submitting the application for confirmation of final closure.

9.2 Safety Case for the Operational Phase

a. The safety case for the operational phase has to be based on comprehensive safety assessments for normal operation of the facility and for accidents.

b. The documents required for the safety case in connection with the construction and operating licence application have to be based on the information in Annex 3 and Annex 4 of the NEO and Article 124 paragraph 2 of the RPO.

c. The safety case for the operational phase has to include all parts of a deep geological repository and the associated surface facility and auxiliary access facilities.

d. In particular, the safety case has to address requirements that arise in the deep geological repository in the event of parallel construction and operation processes.

e. Safety assessments have to be carried out in accordance with the applicable regulations for nuclear installations, in particular in Article 8 of the NEO, the DETEC Ordinance on Hazard Assumptions and the Evaluation of Protection against Accidents in Nuclear Installations, 17 June 2009 (SR 732.112.2), and ENSI-A01, ENSI-A05, ENSI-A08 and ENSI-G14 guidelines.

f. The effects of accidents considered in the safety assessment on the long-term safety of a closed deep geological repository have to be presented.

9.3 Safety Case for the Post-Closure Phase

a. The safety case has to be based on the results of a comprehensive safety analysis which examines the long-term behaviour of a deep geological repository and the resulting safety-relevant impacts. In addition to quantitative considerations, the safety case has to assess also qualitative aspects.

b. The safety case has to provide an insight into the reliability of the statements made and on the safety relevance of uncertainties. Uncertainties have to be reduced as far as possible and necessary by research and data collection.

c. The effects of construction and operation on long-term safety have to be taken into account in the safety case for the post-closure phase.

d. The safety case has to take into account the available engineering and scientific data on the deep geological repository and its environment, information on the emplaced waste packages, knowledge gained during operation and the results of monitoring activities.

9.3.1 Safety Assessment

a. The safety assessment has to include at least the following aspects:

   1. Description of the deep geological repository
   2. Use of verified data about the geological conditions on the site
   3. Demonstration of the mode of operation, retention capacity and robustness of engineered and natural barriers
   4. Presentation and evaluation of the effects of coupled processes and gas formation and propagation on both engineered and natural barriers and on radionuclide transport
   5. Description of the expected long-term geological evolution of the site
   6. Description of the expected evolution of the materials in the deep geological repository, including the radioactive waste and engineered and natural barriers
   7. Scenario analysis and details of the calculation cases used to examine the anticipated evolution of the deep geological repository
   8. Justification as to why the assumptions and computer models used are applicable to the present situation
   9. Systematic sensitivity and uncertainty analysis to determine the influence of uncertainties in the data, processes and models on the calculation results

10. Consideration of envelope scenarios relating to possible evolutions, in particular the area morphology and climate as part of biosphere modelling

b. The description referred to under letter a number 6 has to take into account possible mutual interactions between the various materials.

c. For the scenario analysis and details of the calculation cases referred to under letter a number 7, safety FEPs (features, events and processes) have to be covered by the calculation cases. The radiological effects of future developments have to be assessed by using envelope variants or estimated by using conservative assumptions.

d. The importance of simplifications has to be explained in the justification required under letter a number 8.

9.3.2 Time Period for Assessment

a. An assessment period of up to one million years has to be specified for the safety case. The evolution of the radiological hazard potential of the emplaced waste over time and the predictability of long-term geological evolution has to be taken into account.

b. Dose calculations have to be carried out as part of the safety assessment up to the time of maximum radiological impact of the deep geological repository, or, in any event, at least until the end of the assessment period.

c. After the assessment period, the range of variation of possible radiological impacts of a deep geological repository has to be determined taking into account inherent uncertainties. Scenarios in which the deep geological repository area is increasingly exposed to surface influences as a result of geological processes have to be taken into consideration.

9.3.3 Assumptions Regarding Climate Change and Human Lifestyles

a. Even during times when human surface settlement within the area of influence of a deep geological repository can be ruled out, the protection criterion specified in section 4.3.2 letter a has to be fulfilled. For these periods, the presence of humans in a reference biosphere has to be assumed.

b. When calculating the radiation dose, assumptions have to be based on a representative individual from the population group most affected by the potential impact of a deep geological repository, with realistic living habits based on a present-day perspective. The analysis has to assume the following:

1. Possible climate change variants and associated biosphere models have to be defined and their significance for the long-term safety of the deep geological repository investigated.
2. The effect of ionising radiation on humans has to be based on current knowledge.
3. Scenarios in which the safety of the deep geological repository is influenced by human actions have to be handled in a way that appears credible from the perspective of present-day society.

9.3.4 Developments not to Be Considered

The safety assessment does not need to consider:

a. intentional human intrusion into a deep geological repository

b. intentional damage to a deep geological repository

c. occurrences with non-radiological effects that far exceed their radiological effects

10 Security and Safeguards

10.1 Security

a. The protection of a deep geological repository and the associated surface facility and auxiliary access facilities has to comply with the principle of staged defence in depth, which includes structural, engineering, organisational and administrative measures. The following provisions apply: Article 9 and Annex 2 of the NEO, the DETEC Ordinance on Hazard Assumptions and Security Measures for Nuclear Installations and Nuclear Materials (SR 732.112.1) and the Ordinance on Qualifications required by Personnel in Nuclear Installations (NPQO, SR 732.143.1), the Ordinance on Security Guards in Nuclear Installations (VBWK, SR 732.143.2) and the Ordinance on Personnel Security Checks in Nuclear Installations of 9 June 2006 (PSPVK; SR 732.143.3).

b. Proof of cyber security aspects has to be provided.

c. Security measures should not compromise the long-term safety of a deep geological repository.

d. Proof of security has to be documented in a security report in accordance with specifications laid down in Section 6.2 of Guideline ENSI-G09.

10.2 Safeguards

a. A deep geological repository and the associated surface facility and auxiliary access facilities have to be designed to facilitate fissile material controls.

b. The provisions for fissile material controls must not compromise the long-term safety of a deep geological repository.

11 Quality Assurance and Documentation

a. The quality of a deep geological repository required for safety purposes has to be guaranteed during planning and construction and for all safety-relevant activities, systems and components.

b. Quality requirements and measures for their fulfilment have to be defined in the management system in accordance with Guideline ENSI-G07.

c. Quality assurance measures have to be provided for handling data and performing quantitative analyses and qualitative assessments as part of the safety case. These have to be defined in the management system.

d. The requirements for long-term and operational safety have to be documented. Key decisions relating to deep geological disposal and the consequences of such decisions with regard to long-term safety and operational safety have to be traceable. This also includes the safety-relevant properties and requirements of elements of the multiple barrier system to fulfil their safety function.

e. Conflicting safety requirements have to be identified, documented and a system for handling these requirements should be described. A procedure has to be implemented for this purpose. If it is not possible to resolve contradictions, a decision has to be made based on the various safety requirements. The entire procedure has to be documented so that the resulting decision and the reasons for this decision can be traced at a later date.

f. The application for underground geological investigations has to include a documentation concept for all phases as set out in Appendix 2 to maintain knowledge relating to the deep geological repository over the long term.

g. Construction documentation has to be drawn up in accordance with Article 27 of the NEO and Guideline HSK-R-08; the operating documentation has to be drawn up in accordance with Article 41 of the NEO and Guideline ENSI-G09. The construction and operation documentation have to be supplemented as described in Standard SIA 197 to cover underground works.

h. In accordance with Article 71 of the NEO at least three copies of the documentation have to be provided. The long-term durability of the documentation has to be demonstrated and the necessary maintenance measures explained.

i. Further to the provisions of Article 71 of the NEO, the documentation has to contain the following information as a minimum requirement:

   1. description of the closed facility and site
   2. information on the emplacement and exact position of each disposal canister and on conditioning of the contained waste packages according to Guideline ENSI-B05
   3. information on interim storage, insofar as this may be relevant for any retrieval of radioactive waste or for long-term safety
   4. summary of monitoring results

12 List of References

IAEA Safety Standard SSR-5: Disposal of Radioactive Waste, 2011

Standard SIA 197: Design of Tunnels – Principles, Swiss Engineering and Architects Association

Standard SIA 260: Basis of Structural Design, Swiss Engineering and Architects Association

Standard SIA 262: Concrete Structures, Swiss Engineering and Architects Association

This guideline was approved by ENSI on 7 December 2020 and is valid from 1 January 2021.

ENSI Director: Signed by M. Kenzelmann

Annex 1: Terms and Definitions (According to the ENSI Glossary)

Access structures

Structures such as ramps or shafts that provide access to underground facilities from surface facilities.

Auxiliary access facilities

The auxiliary access facilities comprise those parts of the facility (structures, installations and equipment) on the surface and at the upper end of an access structure (shaft or tunnel) of a deep geological repository that are not used to transport radioactive waste. auxiliary access facilities ensure the tasks and functions of near-surface access and can be arranged alongside the surface facility or separately from it.

Backfilling

Closing of excavations through introduction of solid materials. 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 calculating the radiation exposure (individual dose) for the population group to be considered as a result of radionuclides released from the deep geological repository through the geosphere to the biosphere. 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.

Civil engineering design

Design is a planning phase and comprises conceptual design, structural analysis and dimensioning in accordance with Standard SIA 260. According to Standard SIA 197, it comprises the following sub-phases: strategic planning, preliminary studies, preliminary project, supporting project and construction project.

Encapsulation plant

Part of the surface facility in which the radioactive waste being emplaced is handled, from acceptance of the waste through to transfer to the 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 variants

Evolution variants for waste, engineered and natural barriers, the biosphere and human lifestyles 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 property over a long period of time, measurement of a parameter or the sum of all such observations and measurements.

Multiple barrier system

A multiple barrier system consisting of staged, passively functioning engineered and natural barriers for containment and retention of radioactive substances stored inside the deep repository. In the event that one barrier does not fulfil its intended function as planned, the system includes additional barriers that can compensate for this.

Natural barrier

The geological environment of a deep repository which, according to the safety concept, contributes passively to the retention of radionuclides.

Pilot facility

The pilot facility is an independent part of the deep geological repository which is separate 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.

Planning phase

A planning phase considers part of the entire life cycle of a structure. In accordance with Standard SIA 197, planning an underground structure is divided into three main phases: design, construction and management. These are divided into sub-phases.

Retrieval

Includes the removal, recovery and transport of emplaced radioactive waste from a deep geological repository to the surface.

Robustness

A characteristic of a system or component to guarantee safety functions even in consideration of uncertainties, influencing processes and events.

Safety optimisation

For a deep geological repository, safety optimisation is understood to be a step-by-step process, in which different alternatives and their importance for operating safety and for long-term safety are considered for each safety-relevant decision and a decision is taken that is favourable for safety in general terms.

Scenarios

Scenarios are possible variants for evolution of the waste, engineered and natural barriers in and around a repository, the biosphere and human lifestyles under the influence of assumed features, events and processes (FEPs).

Sealing structure

Engineered hydraulic barrier for sealing, supporting the rock mass and protecting the backfill.

Service criteria agreement

According to Standard SIA 260, the service criteria agreement describes the use and protection objectives of the builder or owner as well as the basic conditions, requirements and regulations for planning, design, use and maintenance of the structure. The service criteria agreement has to be drawn up on the basis of consultation between the builder and the project owner.

Surface facility

The surface facility comprises all the plant (structures, installations and equipment) on the surface (or near-surface) for receiving radioactive waste, preparing for emplacement (e.g. encapsulation) including delivery and return of all necessary containers and materials, for loading the disposal canisters, backfilling and sealing materials for transport as well as all required ancillary processes (e.g. supply and disposal facilities). The surface facility is located at the top end of the access structure, through which radioactive waste is transported into the deep geological repository.

Temporary closure

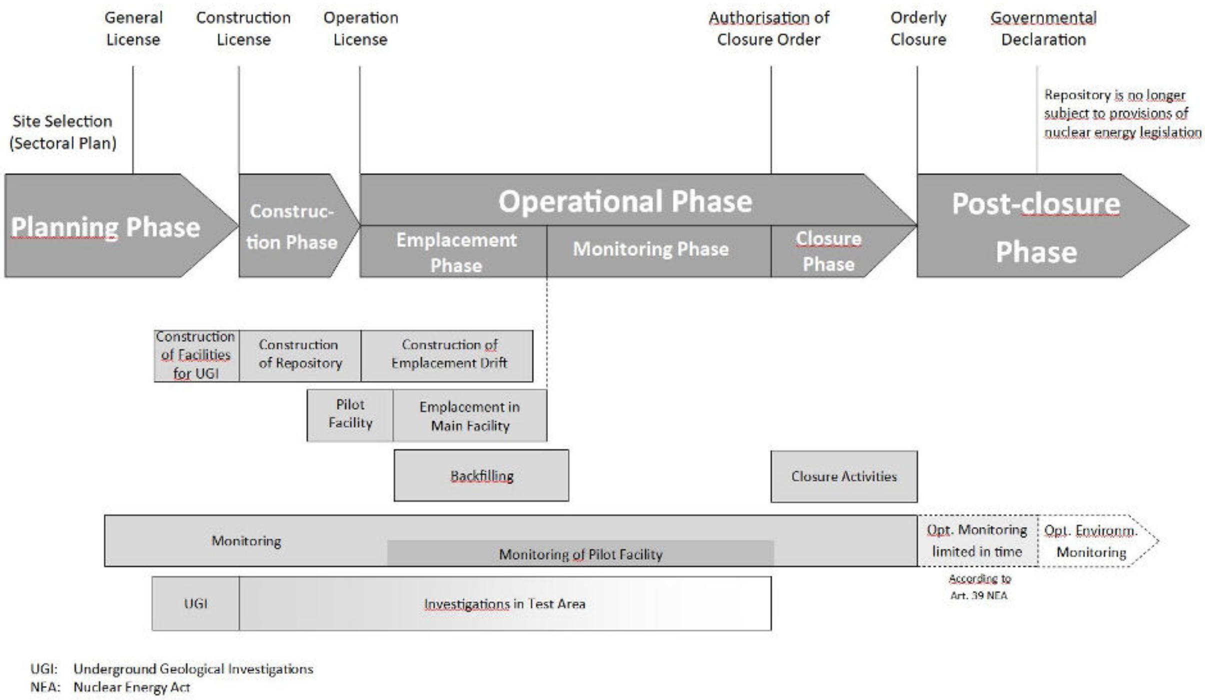
Temporary closure of a deep geological repository which takes several weeks to months to bring about; temporary closure has to remain effective for several decades to centuries.

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 safety-relevant technologies can be investigated and their correct functioning demonstrated.

Annex 2: Planning, Construction, Operation and Closure

The phases and licensing steps defined in the NEA and NEO for planning, construction, operation and closure of a deep geological repository apply:



The operational phase of a deep geological repository comprises waste emplacement, the monitoring phase and closure.

Closure work begins once the closure order has been awarded and ends with final closure.

Pursuant to Article 39 paragraph 3 of the NEA, the Federal Council may, after orderly closure, order further monitoring limited in time.

Pursuant to Article 39 paragraph 4 of the NEA, the Federal Council may declare that a deep geological repository is no longer subject to the provisions of nuclear energy legislation after orderly closure or after expiry of the additional monitoring period.

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