
The safety case for deep geological disposal: GRS views on regulatory requirements and practice

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Abstract:

The paper provides information about the current state of regulation development for deep geological disposal in Germany. It describes GRS proposals for revised Safety Criteria and supporting guidelines with an emphasis on long-term (post-closure) safety aspects. In addition, experiences from regulatory processes in connection with four German projects are given.

1 DEVELOPMENT OF REGULATORY REQUIREMENTS IN GERMANY

1.1 Revision process of German Safety Criteria and Guidelines

The “Act on the Peaceful Utilization of Atomic Energy and the Protection against its Hazards (Atomic Energy Act)” in its most recent version (April 22, 2002) [1] requires “To phase out the use of nuclear energy for the commercial generation of electricity in a structured manner ...”. Shipments of spent nuclear fuel elements (SNF) from power reactors to reprocessing plants have been banned since July 1, 2005 [1]. Disposal of SNF which will arise after that date shall only take place in the form of direct final disposal.

Consequently, the volume of heat-generating radioactive waste and operational waste from nuclear power plants as well as the amount of waste from reprocessing to be disposed of is limited, and the total volume of these waste flows arising in Germany can be estimated with relative accuracy. Thus, reliable data relating to the required capacities are available for the planning of waste disposal facilities.

Presently, a new plan for the management of radioactive waste in Germany is under development.

It is the policy of Germany that radioactive material should be concentrated and contained rather than released and dispersed in the environment. According to the international consensus that long-lived radioactive waste has to be disposed of in deep geological formations in order to guarantee that man and the environment are protected in the long run from the effects of ionizing radiation by isolation of the radioactive waste, in Germany this waste has to be disposed of in a deep repository. In addition, all other radioactive waste in Germany will also be disposed of in a mine situated in a deep geological formation.

Amongst the important cornerstones of the new waste management plan are the development and implementation of a new siting procedure, developed and proposed by the so-called AkEnd (“Arbeitskreis Auswahlverfahren Endlagerstandorte” = Committee on a Selection Procedure for Repository Sites, 1999-2002) [2, 3], and a revision of the Safety Criteria for the disposal of radioactive waste in a mine which were issued in 1983 [4]. The revision is being carried out in order to account for the important developments in Germany and abroad in the fields of final radioactive waste disposal and repository performance assessment which have taken place over the last decades to comply with the international

state of the art in science and technology and to be consistent with the international development.

On the basis of the Atomic Energy Act, the fundamental principles of radiological protection, namely justification, optimisation, and limitation are incorporated into the Radiation Protection Ordinance [5], as are the Euratom Basic Safety Standards [6]. Safety Criteria for radioactive waste disposal need to account for these regulations.

It should also be noted that the Plan Approval Procedure (i.e. licensing procedure, "Planfeststellung") required by the Atomic Energy Act [1] for federal installations for the safekeeping and final disposal of radioactive waste, generally lasts for the whole duration of a project. A stepwise approach is not explicitly implemented. Nevertheless, such an approach where, at well-defined decision points, an assessment of safety based on the knowledge achieved so far will be carried out, communicated to regulators and other stakeholders and be utilised to support decisions about how to proceed ("Safety Case", [7]) could be applied within a Plan Approval Procedure. The Plan Approval Procedure has a so-called "concentrating effect" for several fields of law.

The presently valid (sub-statutory) Safety Criteria for underground disposal require proof that the site under consideration has favourable mechanical, technical and hydrogeological properties. In order to provide adequate protection of man and the environment, the criteria define the individual dose as the main safety indicator for the post-closure phase. A safety analysis based on models for scenarios postulating a radionuclide release, which cannot completely be excluded, has to be carried out. The analysis has to show that an individual dose limit of 0.3 mSv/a will not be exceeded. In 1988, the Reactor Safety Commission (RSK) and the Commission on Radiological Protection (SSK), which advise the government in technical questions concerning, amongst others, waste management safety, recommended to use the dose criterion for time frames up to 10,000 years but to utilise qualitative arguments for considerations going beyond this time [8]. Nevertheless, this recommendation did not become part of a licensing procedure for repositories.

On behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), GRS Köln drafted a proposal for the revision for the Safety Criteria. The drafting process was supported by a body composed of experts from several German organisations and from abroad. The proposal was reviewed by the BMU's advisory committees RSK and SSK. An updated draft which takes into account the committees' comments was submitted to the BMU and is currently considered in order to establish and issue updated Safety Criteria [9]. In parallel, supporting guidelines are being developed by GRS Köln, again with the support of experts from several German organisations and from abroad. These developments have had and will have further implications for the revision of the Safety Criteria. Amongst other things, the guidelines will provide requirements and recommendations for the post-closure Safety Case.

The revision process is accompanied by discussions within the scientific community [10, 11] and bilateral exchanges with regulatory organisations abroad (e.g. IRSN/France, SSI/Sweden, CNSC/CCSN/Canada).

1.2 Content of the revised Safety Criteria as proposed by GRS

The proposals for revised Criteria and for the guidelines are based on national laws and regulations, especially the Atomic Energy Act [1] and the Radiation Protection Ordinance [5] as well as on recent international regulations and recommendations such as:

- IAEA Regulations e.g. the Fundamental principles for the safe handling of radioactive wastes [12],
- The act on the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [13]
- Norms of the European Communities (e.g. [6])
- ICRP regulations (e.g. [14])

- OECD recommendations

Amongst the latter, the most recent NEA developments within the Integration Group for the Safety Case (IGSC) concerning the post-closure Safety Case for radioactive waste repositories, namely the drafting of the “Safety Case Brochure” [7], were of utmost importance.

Since siting criteria are addressed by the AkEnd proposal [2, 3], site requirements are not considered in the GRS proposal for revised Criteria. The underlying assumption is, however, that the repository site will comply with criteria similar to those proposed by the AKEnd. The AKEnd statement about the ability to find sites for which geoscientific prognoses can be made for at least one million years is reflected in the corresponding requirement of the proposal concerning the assessment timeframe.

The criteria are exclusively related to radiation protection objectives and requirements specifying the damage precaution required by the Atomic Energy Act [1]. They deal with the disposal of radioactive waste in a mine to be newly erected at a location to be chosen in accordance with a siting procedure. Retrieval of the disposed waste is not considered. The draft criteria require multi-barrier Safety Functions but place, in accordance with the AkEnd requirements, emphasis on the geologic barrier. They contain:

- a glossary,
- safety principles,
- radiation protection objectives for the operational and the post-operational phases,
- site requirements,
- planning principles for the Safety Concept,
- design and erection requirements,
- criteria for the operational phase, and
- criteria for the post-operational phase (Long-Term Safety Demonstration).

The GRS draft contains the following Safety Principles:

- The potential radiation exposure from the installation shall be low compared to natural radiation.
- The protection level in the future must comply with today's acceptance levels.
- The protection level beyond national borders must comply with levels accepted in Germany.
- The demonstration of safety for the operational, decommissioning and post-operational phases has to be performed according to the state of the art. It shall include site-specific safety analyses.
- The site selection and the design of the repository have to ensure long-term safety.
- The validity of the radiation protection objectives is unlimited in time, but the safety assessment has to cover the time span of geological prognosis. The site has to be chosen in a way that this would cover at least ca. 10^6 years.
- The safety in the post-operational phase must not rely on any active measures after sealing.

The radiation protection objectives for the post-operational phase are given as follows:

The major radiological protection objective is to limit the risk of an individual to sustain serious health effects from exposure to radiation. The assessment of this risk has to be based on the individual dose, which has to be determined based on present-day habits. There is no limitation in time for the validity of this objective. Protection of the environment is ensured by adherence to protection objectives for man. For releases of radionuclides occurring in nature it has to be ensured that present-day on-site conditions are not significantly changed. The evaluation of other radionuclide releases has to be based on dose assessment. Standards for other industrial practises apply for the releases of

chemotoxic substances. The goal of optimizing radiation protection is reached after demonstration of:

- long-term safety (demonstration by Safety Case),
- compliance with the safety principles and radiation protection objectives,
- realisation of the state of the art in technical and managerial principles,
- implementation of sensible measures against inadvertent human intrusion.

The elements required for the Long-Term Safety Demonstration are:

- site and system characterisation,
- geological and geotechnical long-term prognosis,
- realisation of the safety concept,
- fulfilment of the planning principles,
- proof of criticality safety,
- integrated safety assessment based on multiple lines of arguments using various performance and safety indicators, and
- demonstration of compliance with the safety goals.

The assessment calculations are seen as one of multiple lines of evidence. Their function is twofold: they allow achieving, improving and demonstrating the understanding how the repository system behaves. In addition, they serve for the demonstration of compliance with the safety goals. Although the protection objective's validity is unlimited in time, the assessment should only cover the timeframe for which reasonable geoscientific prognoses can be made. The site should be chosen in a way that this is possible for at least 10^6 years. Likelihoods of occurrence for scenarios should be characterised qualitatively while parameter uncertainties should be, as far as possible, addressed by probabilistic methods. The proposed dose targets are for likely scenarios 0.1 mSv/a and for less likely scenarios 1 mSv/a. No numerical target has been proposed for inadvertent human intrusion scenarios which have to be assessed based on reference scenarios to be formulated in technical guidelines. Intentional human intrusion is not to be considered. Assessment calculations are to be seen as one of multiple lines of evidence. The use of additional lines of evidence including several performance and safety indicators is encouraged.

1.3 Outlook

Presently, technical guidelines supporting the Safety Criteria are being developed. These guidelines will, amongst other issues, address long-term safety, operational safety, a reference biosphere, and reference scenarios for human intrusion. Most probably, these developments will have further implications for the revision of the Safety Criteria.

In the opinion of GRS Köln, the proposed Safety Criteria are widely consistent with international developments with regard to the Safety Case [7]. However, there might still be room for improvement of terminology and structure in order to make this more evident. Recent developments on regulatory issues in general (IAEA Draft safety standards DS154 [15]) and on technical issues such as Safety Functions [16, 17] as well as on Performance or Function Indicators [18] could be taken into account.

After a discussion with the wider scientific community and with stakeholders the revised Safety criteria can then be submitted to BMU.

2 REGULATORY PRACTISE: GRS EXPERIENCE WITH VARIOUS PROJECTS

In the following, an overview of GRS' regulatory activities and experiences with regard to various German projects will be given.

2.1 Morsleben (ERAM)

The „Endlager für Radioaktive Abfälle Morsleben“ (ERAM) is situated in the Federal State (Bundesland) of Saxony-Anhalt (Sachsen-Anhalt). LLW/ILW disposal in the former salt mine started in 1976. The disposal, which originally had taken place under the legislation of the German Democratic Republic (Eastern Germany), continued after the German unification until 1998. Since then, the Plan Approval procedure (“Planfeststellung”) for closure / decommissioning of the mine has been in progress.

The licenses for constructing and operating the Morsleben facility were granted under a legal system different from the current one. Decommissioning of the facility is not addressed in the existing license. The technical conditions of ERAM are also different from those one would expect for a new repository. The mine consists of a complicated system of mining vaults with considerable volume. Planning and construction principles which would apply in a new repository built in a salt formation (e.g. safety distances to potentially water-bearing features) were not necessarily accounted for in this case.

The ongoing Plan Approval Procedure (“Planfeststellung”) addresses exclusively the decommissioning / closure of the mine. In this procedure, GRS Köln fulfils supervision duties on behalf of the Federal Government. The licensing authority is the Federal State of Saxony-Anhalt.

Although the BMI Safety Criteria [4] referred to in the previous section are formally still in force, recent discussions and development work play a central role in the procedure. This is in accordance with the requirement of the Atomic Energy Act [1] for compliance with the state of the art. Nevertheless, the revised Safety Criteria proposed by GRS are not fully applicable since they refer to a new repository. They are accounted for as far as sensible. While, of course, the Radiation Protection Objectives fully apply, other components (e.g. principles for design and implementation) are not applicable. The Plan Approval Procedure is a highly iterative process where solutions are sought for in intensive discussions between the parties involved.

2.2 Asse

The former Asse salt mine is situated in the Federal State (Bundesland) of Lower Saxony (Niedersachsen). Starting in 1967, an in-situ experiment programme for waste disposal in salt took place in the facility. From 1972 to 1978, research disposal was carried out. Since 1995, the licensing for decommissioning / closure has been in progress. Like for Morsleben, decommissioning of the facility is not addressed in the existing license. Since Asse is legally not considered a repository, the licensing procedure is governed by Mining Law and not by the Atomic Energy Act. In the procedure, GRS Köln supports the licensing authority (the Mining Authority of the State of Lower Saxony).

Again, the technical conditions are considerably different from a new repository. Like Morsleben, the Asse facility consists of a complicated system of mining vaults with considerable volume. Although the licensing procedure is being carried out under the Mining Law, requirements of the Atomic Energy Act are accounted for. The involved parties strive for a decommissioning concept in accordance with recent discussions and development as reported in the previous section.

Again, the revised Safety Criteria proposed by GRS are not fully applicable since they refer to a new repository. The situation with regard to their applicability is comparable to the case

of the ERAM facility. As for Morsleben, the procedure is a highly iterative process where solutions are sought for in intensive discussions between the parties involved.

2.3 Konrad

After the decision to close the Konrad iron ore mine (Lower Saxony), the management and operational staff of the mine began to explore options concerning its further utilisation. Due to the extremely dry conditions in the mine, the idea of LILW (more precisely: waste with negligible heat generation) disposal emerged. After eight years of investigation it was concluded that the mine is suitable for such disposal. A Plan Approval Procedure was started in 1982. As required by law, a hearing was held from September 1992 to March 1993 in order to debate the objections made by members of the public. In 2002, after a procedure duration of 20 years, a license was granted. Lawsuits against the Konrad license are still pending.

Obviously the siting of Konrad had not been carried out according to a formal site selection procedure. Instead, the starting point was knowledge about the existing mine (dry conditions, clay cover, salinity gradient, low GW velocities, ...).

In the Plan Approval Procedure GRS Köln supported the licensing authority (the State of Lower Saxony). The activities carried out by the authority within the procedure comprise:

- review of the documents provided by the applicant
- review of the scenario development
- scrutiny of models and calculations used by applicant
- development of an independent geological / hydrogeological etc. site characterisation
- development of own data sets for groundwater modelling
- recalculation of the applicant's transport calculations with additional diverse codes
- uncertainty analyses to demonstrate the influence of different hydraulic parameters

Although, from a formal point of view, the BMI 1983 criteria were applicable, the procedure was carried out according to the state of the art as required by the Atomic Energy Act [1]. Consequently, the Konrad Plan contains the elements required for a Safety Case.

2.4 Gorleben

In the early 70s, a siting process for a “nuclear disposal centre” was initiated by the German federal authorities. According to the so-called integrated waste management concept which was favoured at that time, it was intended that such a centre should house a conditioning plant as well as interim storage and final disposal facilities for all types of solid or solidified waste, especially for heat-generating HLW/SNF. Based on U.S. experience, salt was seen as the favoured option for the repository host rock. A screening process based on environmental, safety and economical criteria was performed. As a result, the Gorleben salt dome in Lower Saxony appeared amongst the candidates, but 3 other sites in Northern Germany (Wahn, Weesen-Lutterloh, Lichtenhorst) were on top of two ranking lists which were derived using different weighting schemes for the criteria. Within this procedure, proximity to the border with the GDR was used as a screen-out criterion which applied to Gorleben. Site investigation work at Wahn was started but stopped soon due to local opposition.

In parallel, in the mid 70s authorities of the Bundesland (Federal State) of Lower Saxony (Niedersachsen) initiated a siting process which again was based on the assumption of an integrated waste management concept and on a preference for salt as host rock for the final repository. A screening process based on environmental, safety, infrastructural and economical criteria took place. Wahn, Lichtenhorst (both were on top of both “Federal lists”

as well), Höfer, and Gorleben appeared at the top of the ranking list. However, all of these sites except Gorleben did not comply with at least one screen-out criterion.

In the ensuing negotiations between the federal and the state governments it was, amongst other questions, debated whether or not proximity to the GDR border should be a reason to screen out a site. Gorleben was nominated by the government of Lower Saxony and was finally accepted by the federal government. Site investigation in connection with a still ongoing Plan Approval Procedure started and, according to the "integrated concept", a spent fuel interim storage facility was put into operation in 1984 and, in 1990, a first partial construction licence was granted for the nuclear installations of the pilot conditioning plant (PKA) [19, 20, 21].

In the following years, Gorleben became a symbol of the national anti-nuclear movement. One major criticism was that during the site selection process the public was never informed nor involved. In addition it was claimed that no formal site selection procedure had been carried out. Doubts about the suitability of Gorleben were expressed. Following the 2000 phase-out agreement between the federal government and the NPPs, exploration at Gorleben was interrupted for at least three and at most ten years in order to clarify conceptual safety questions.

The work on these questions was completed in autumn 2005. Thus, a decision about how to proceed needs to be taken. Obviously, there is a connection to the AkEnd proposal [2, 3] which deals with the selection and investigation of additional / alternative site(s).

In the opinion of GRS Köln, the work on the conceptual safety questions did not lead to site-specific conclusions on an acceptance or rejection of Gorleben. If the exploration were restarted it would be necessary to implement a stepwise approach according to the Safety Case Philosophy [7] including the effective involvement and information of regulatory bodies and other stakeholders on exploration results and interpretations. This would imply that, at well-defined decision points, an assessment of safety based on the site investigation results achieved so far will be carried out, communicated to regulators and other stakeholders and be utilised to support decisions about how to proceed.

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