

Radioactive Waste Disposal Challenges in Germany - 11442

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ABSTRACT

In the Federal Republic of Germany the disposal of all types of solid and solidified radioactive waste in deep geological formations is still the preferred option. Actual principal issues in radioactive waste disposal are focused on activities further developing and detailing the German radioactive waste disposal concept as well as particularly on activities concerning the operation of the Konrad, Gorleben, Morsleben and Asse II sites. Of this, the draft Safety Requirements on the Disposal of Heat-Generating Radioactive Waste dated September 2010, the construction of the Konrad repository for low-level and intermediate-level radioactive waste, the preparation of disposal room investigations in the Asse II mine the results of which will serve as the essential prerequisite for the decision on waste retrieval / recovery, as well as the termination of the Gorleben Moratorium and the resumption of underground explorations of the Gorleben salt dome are the most important topics.

INTRODUCTION

Radioactive waste disposal policy in the Federal Republic of Germany is based on the Government decision that all types of radioactive waste with short-lived and long-lived radionuclides are to be disposed of in deep geological formations within the country. This decision entails the necessity to condition (i.e., to process and to package) the waste. Only solid and solidified radioactive waste is accepted for disposal; liquid and gaseous radioactive waste is excluded from disposal except when appropriately be conditioned. In Germany, radioactive waste disposal is a federal task the Atomic Energy Act giving the responsibility to the Federal Government with the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU - Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) as competent ministry, and - within the portfolio of BMU - the Federal Office for Radiation Protection (BfS - Bundesamt für Strahlenschutz) as the legally responsible authority for performing this task.

RADIOACTIVE WASTE ARISING

According to the German approach to disposal, radioactive waste is basically subdivided into waste with negligible heat generation (i.e., low-level waste (LLW) and intermediate-level waste (ILW)) and heat-generating waste (i.e., high-level waste (HLW) and spent nuclear fuel (SNF)). Radioactive waste with negligible heat generation comprises all types of radioactive waste originating from the operation, decommissioning and/or dismantling of nuclear facilities, e.g., nuclear power plants, reprocessing facilities, nuclear industry, research and development establishments, as well as smaller waste generators such as hospitals, industry and universities. Heat-generating radioactive waste comprises in particular waste originating from reprocessing such as vitrified fission product solution and high-pressure compacted hulls and ends, as well as spent nuclear fuel when declared to be waste. As to radioactive waste arising, BfS carries out on annual inquiry into the amounts of radioactive waste in Germany. According to the latest inquiry, about 20,700 m³ of radioactive residues, about 8,200 m³ of preconditioned waste and about 100,000 m³ of conditioned waste with negligible heat generation (i.e., LLW and ILW) had been accumulated by the end of December 2009. The amount of unconditioned/preconditioned and conditioned heat-generating waste (i.e., HLW and SNF) by the end of December 2009 was about 1,300 m³ and about 600 m³, respectively (without spent nuclear fuel). The amount of conditioned heat-generating waste comprises vitrified waste already repatriated from reprocessing German spent fuel in France.

Forecast waste amounts for the future are for approximately 280,000 m³ of conditioned waste with negligible heat generation and for approximately 28,000 m³ of conditioned heat-generating waste accumulated up to 2080.

DEVELOPMENTS OF THE GERMAN DISPOSAL CONCEPT

In Germany, principal issues in further developing and detailing the radioactive waste disposal concept comprise in particular the Safety Requirements on the Disposal of Heat-Generating Radioactive Waste and the finalisation of activities concerning the comparison of potential repository sites, i.e. the VerSi project.

Safety Requirements on the Disposal of Heat-Generating Radioactive Waste

Disposal of heat-generating radioactive waste is still a great challenge. So far, no repository specifically for heat-generating radioactive waste is world-wide in operation. Safety requirements for the disposal of heat-generating radioactive waste provide the safety-related framework that must be complied with in planning, constructing, operating, decommissioning and sealing a repository for this type of waste. In Germany, the then responsible Ministry for the Interior (BMI - Bundesministerium des Innern) published in 1983 the "Safety Criteria for the Disposal of Radioactive Waste in a Mine" [1].

The safety criteria of 1983 had to be revised with respect to the present state of science and technology and to latest international recommendations. The Company for Plant and Reactor Safety (GRS - Gesellschaft für Anlagen- und Reaktorsicherheit mbH) was charged by BMU with the preparation of a proposal for an update of the 1983 safety criteria. The GRS draft proposal of January 2007, which was intensively supported by BfS, considers both the further development of the state-of-the-art of science and technology as well as international recommendations published in particular by IAEA and ICRP most recently [2]. Its main features are the isolation of the heat-generating waste in the isolating rock zone, demonstration of safety (i.e., appropriate containment of radionuclides) for approximately one million years, conducting a stepwise approach, and executing a continuous safety- related optimization process.

On the basis of this draft proposal, its scientific discussion in a 2007 workshop on Safety Requirements on the Final Disposal of High-level Radioactive Waste, and a BfS statement [3] requested by BMU, the competent Federal Ministry started the preparation of the safety requirements on the disposal of high-level radioactive waste in deep geological formations. The elaboration of this important document was accompanied by further discussions with experts and the public, in particular in a 2008 International Radioactive Waste Disposal Symposium organized by BMU and a second workshop in 2009. In parallel to that, the draft documents were examined and evaluated in detail by the advisory bodies of BMU, i.e. the Reactor Safety Commission (RSK - Reaktor-Sicherheitskommission) and the Radiation Safety Commission (SSK - Strahlenschutzkommission), later on by the Waste Management Commission (ESK - Entsorgungskommission). Finally BMU issued the "Safety Requirements Governing the Final Disposal of Radioactive Waste" as of July 2009 [4], available at http://www.bmu.de/english/nuclear_safety/downloads/doc/44839.php. These requirements do address and regulate the following topics:

- Protection objectives.
- Safety principles.
- The step-by-step approach and optimization with respect to radiation protection, operational safety and reliability of the safe long-term containment/isolation of radioactive waste.
- Protection from damage caused by ionising radiation.
- Safety assessments and proof of operational and long-term safety (safety cases).

- Repository design requirements.
- Safety management.
- Documentation.

Subsequent to the July 2009 draft document, further discussions in particular with representatives of the Federal States (Länder) took place as well as the elaboration of a follow-up was performed by BMU resulting in the current September 2010 draft. According to this document essential adaptations and adjustments with respect to hitherto existing planning work concerning the disposal of heat-generating radioactive waste in rock salt are to be expected [5]. This is most notably due to the requirements that now

- the retrievability of the waste packages must be possible during the operational phase of the repository, and
- the recovery of the waste packages as a measure of an emergency situation must be possible for a period of time of 500 years after closure and sealing of the repository.

In particular, the requirement on the recovery of waste packages does mean a 500 years waste container lifetime or an appropriate waste package emplacement method ensuring their integrity during this period of time - a requirement which is controversially being dealt with. Nevertheless, BMU will continue the discussions with advisory bodies, experts, the public as well as with representatives of the Federal States [5]. Thus, the final preparation and publication of the Safety Requirements on the Disposal of Heat-generating Radioactive Waste, e.g., in the Federal Gazette, are still pending.

Comparison of Potential Repository Sites - The VerSi Project

Within the framework of political discussions and provisions on a revision of the German radioactive waste disposal concept it was suggested that, in addition to the Gorleben site, further sites in various host rocks had to be investigated for their suitability to host a repository. The final site should be selected on the basis of a safety-related comparison of potential sites, including the Gorleben site.

Such a comparison of different sites, i.e. different host rock formations such as salt, clay and granite, had previously not been carried out in Germany or elsewhere. Thus, BfS launched in 2006 the project Comparative Safety Assessments for Repository Systems to Evaluate Methodologies and Instruments (Vergleichende Sicherheitsanalysen für Endlagerstandorte zur Bewertung der Methoden und Instrumentarien) - the VerSi Project. The objective of this project is to enable a comparison of repository sites in different host rocks and to provide appropriate means. Therefore, the safety-analytical instruments and methodologies for a comparison of different repository sites are to be developed and tested accordingly. Work is being performed on the basis of long-term safety assessments taking into account geoscientific databases, radioactive waste inventories, corresponding disposal concepts, as well as appropriate backfilling and closure concepts.

The method should be developed by applying data that are as close to reality as possible. This includes repository concepts as well as site-specific parameters. However, it is not intended to prove the long-term safety of the studied site cases within the VerSi Project. The method is focused on long-term safety assessments in the post-operational phase of a repository. The operational phase of a repository, data uncertainties, the optimisation of the repository, and human intrusion issues remain unconsidered in the development of the method. Thus, within the VerSi Project, only a part of a complete comparison is considered, namely the comparison of safety assessments under given simplifying boundary conditions. Also, socio-scientific and planning-scientific aspects cannot be taken into account in this method development.

Within the scope of the VerSi Project, rock salt and clay stone are examined as potential host rocks. These host rocks exist in Germany and, due to the AkEnd recommendations [6], are basically

considered suitable to host a repository for heat-generating radioactive waste. For testing the tools, a HLW repository hosted in a salt dome (Gorleben) will be compared with a generic HLW repository in consolidated clay as host rock. Since in Germany no clay site has been investigated for hosting a HLW repository until now, the required data for comparison are transferred from international research projects and repository concepts. The VerSi Project does not comprise any geoscientific exploration at a distinct site nor a long-term safety analysis for a distinct site or a site selection itself.

As a result, two distinct and complementary methods were developed for the comparison of sites. The first one is a Verbal Argumentative Method in which the probabilities of occurrence of features, events, and processes (FEPs) are evaluated by the determination of weighting factors for the relevance and the robustness of safety functions in different time windows). The second one is a Probabilistic-calculations Based Method in which the consequences of FEPs are evaluated by comparing statistical measures of probabilistic calculations.

At present, there is no decision on the implementation of a site selection procedure [7]. Even in case that a comparison of potential repository sites within such a procedure will not be performed, the VerSi project supplies a sound basis for those tasks to be faced in future regarding the performance of preliminary safety assessments. Thus, the results of this project will serve as an important safety-related tool in future decision making.

DISPOSAL OF RADIOACTIVE WASTE

An outline of the most relevant activities concerning the operation of the Konrad, Gorleben, Morsleben and Asse II sites is provided in the following section.

The KONRAD Repository

The abandoned Konrad iron ore mine, located in the Federal State of Lower Saxony (Niedersachsen), was investigated for the disposal of all types of short-lived and long-lived radioactive waste with negligible heat generation, i.e., waste packages which do not increase the host rock temperature by more than 3 K on an average (low-level and intermediate-level radioactive waste (LLW and ILW)). The most essential waste-related planning data comprise an emplacement of waste packages up to 650,000 m³ with a total beta/gamma activity of 5.0×10^{18} Bq and an alpha emitter activity of 1.5×10^{17} Bq. Waste packages are intended to be emplaced at a depth of 800 m to 1,300 m in disposal rooms with a cross-section of 40 m² and a length of up to 1,000 m using the stacking technique.

The licensing procedure for the Konrad repository was started on August 31, 1982. The license was issued on May 22, 2002, for the emplacement of waste packages of 303,000 m³ at maximum. Of this, approximately 150,000 m³ will originate from the operation as well as from the decommissioning and dismantling of various nuclear facilities, respectively. The operational lifetime is expected to last for 30 or 40 years - a respective decision is still to be taken.

The license was immediately sued by several municipalities and private persons, i.e. challenged in court. It became unappealable on March 26, 2007, after non-acceptance of all claims and rejection of all appeals lodged against it by the Federal Administrative Court. On May 30, 2007, BMU charged BfS with the conversion of the Konrad mine into a repository. The main operating plan according to the Federal Mining Law for the construction of the Konrad repository was approved on January 15, 2008.

Subsequent to comprehensive preparatory measures and plannings the actual construction work started in the beginning of October 2009, i.e. by the assembly of new cable trays in drifts and galleries as well as cable-laying. With respect to shaft area Konrad 1, several buildings were demolished and will be newly constructed. The hoisting plant is being re-constructed. As to shaft area Konrad 2, nearly all buildings were demolished. For shaft transport an auxiliary hoisting plant was constructed and taken into operation. Prior to the start of above-ground construction work explosive ordnance clearance with subsequent remediation took place and was recently finished. Preservation and

reconstruction work for both shafts Konrad 1 and Konrad 2 are pushed. Underground activities are focused on the reconstruction of infrastructure galleries as well as on preparatory measures to excavate the disposal rooms of emplacement field 5/1 and subsequent excavation.

In addition to the actual construction work additional requirements imposed by the licensing authority in the Konrad license are to be realized and implemented. Thus, the Konrad waste acceptance requirements [7] and the measures for waste package quality assurance/quality control are being revised and intended to be published in spring 2011.

At present, the time schedule for constructing the Konrad repository is intensively being discussed and adjusted to actual planning necessities and, in particular, to interdependencies on contractors and, in particular, on other authorities involved. A very important problem immediately to be solved concerns the appointment of the competent authority being in charge for examining and licensing building applications. Different opinions between the competent Lower Saxonian ministry and the Salzgitter city building authority cause severe delays. At the end of this process reliable information on the construction period of the Konrad repository will be available. As a prerequisite to the actual start of operation, numerous test operations will have to be successfully performed.

Continuous and comprehensive information of the public on all aspects of constructing the Konrad repository is ensured by BfS.

GORLEBEN Exploration Mine

Since the end of the 1970s, the Gorleben salt dome, located in the northern part of the Federal State of Lower Saxony (Niedersachsen), has been investigated for its suitability to host a repository at depths between 840 m and 1,200 m for all types of radioactive waste, in particular for heat-generating waste originating from reprocessing and for spent nuclear fuel elements (direct disposal). The accumulated inventory of beta/gamma and alpha emitters was planned to be in the order of magnitude of 10^{21} Bq and 10^{19} Bq, respectively. Site-specific investigations were started in 1979. The above-ground investigation programme was finished and two shafts were completed. The underground investigation of the Gorleben salt dome was in progress, in particular the first exploration area (EB1 - Erkundungsbereich 1) in the north-eastern part of the Gorleben salt dome.

With the beginning of the Gorleben Moratorium, the underground exploration by heading, exploration drillings, and geotechnical measurements was stopped on October 01, 2000, and remains suspended up to now. Since that time only measurements and work have been carried out that are necessary to ensure mining safety and for operational reasons to maintain the exploration mine in a reliable state.

As a result of the latest federal elections which took place on September 27, 2009, a coalition of the Christian Democratic Parties (CDU and CSU) and the Liberal Democratic Party (FDP) came into power. The political aims of the Federal Government are given in the coalition agreement of CDU/CSU and FDP dated October 26, 2009 [8]. With respect to the Gorleben repository project the coalition partners have agreed upon the following:

- Immediate termination of the Gorleben Moratorium.
- Open-ended continuation of the Gorleben salt dome exploration.
- International Peer Review Group to accompany the Gorleben exploration work.

The Gorleben Moratorium ended on September 30, 2010. Since then main activities are concentrated on the performance of a preliminary site-specific safety assessment and the resumption of underground exploration work.

According to BMU a preliminary safety assessment for the Gorleben site including the hitherto available results of the underground exploration and an optimized repository concept is being carried

out by GRS. This assessment is targeting the question if a repository for heat-generating radioactive waste may be hosted by the Gorleben salt dome. In addition, necessary investigations and underground explorations for the determination of lacking geo-scientific and safety-related data are to be identified. Main topics to be investigated focus on the questions how reliable the predictions on the behaviour of the repository system are and what issues remain unsolved - hence needing future research and exploration. Work started in March 2010 and shall be finished in 2012. The envisaged international peer review process serves to check and to evaluate whether the safety assessment and its results are in line with the current state-of-the-art in science and technology. It cannot be excluded that this process may result in more detailed recommendations and requirements on future research and exploration work.

In parallel to the safety assessment BfS prepared the resumption of underground exploration work with respect to staff, machinery and mine ventilation. In parallel, BfS applied for the main operating plan which was approved by the Board of Mines in September 2010, i.e. prior to the termination of the Gorleben Moratorium. Thus, the re-start of investigating the Gorleben salt dome took place on November 11, 2010, with EMR measurements on the 840 m level. Underground excavation activities restricted to the northern drift way followed on December 03, 2010.

Regarding the public the development of a new information system has been initiated.

The results of the Gorleben preliminary safety assessment and the work of the international peer review group will form the basis for BMU to decide on the continuation of the Gorleben repository project or its abandonment.

MORSLEBEN Repository

Since 1971, low and intermediate level radioactive waste with mainly short-lived radionuclides and an alpha emitter concentration of up to 4.0×10^{11} Bq/m³ originating from the operation of nuclear power plants and the application of radioisotopes in research, medicine and industry in the former German Democratic Republic was disposed of in the Morsleben repository, an abandoned salt mine re-used for radioactive waste disposal. This facility is located in the western part of the Federal State of Saxony-Anhalt (Sachsen-Anhalt), very close to Niedersachsen. Since German unity on October 03, 1990, this facility has the status of a federal repository. Operated by BfS as licensee the Morsleben facility received radioactive waste from a broad range of origins and/or sources, in particular from nuclear power plants, research establishments and from smaller waste generators. From 1971 through 1998 radioactive waste with a total volume of about 36,800 m³ including about 6,600 spent sealed radiation sources was disposed of. The total activity of beta/gamma emitters amounts to about 5.0×10^{14} Bq (relating to 2005), that of alpha emitters to about 7.5×10^{11} Bq. According to September 25, 1998, as the result of a court order, BfS had to immediately stop further radioactive waste disposal in the eastern emplacement field. Thus, last waste emplacement operations were carried out on September 28, 1998.

The Morsleben repository will not resume emplacement operations. BfS stated on April 12, 2001, that this facility will definitely never again be used for radioactive waste disposal (renunciation of those parts of the Morsleben repository operation license dealing with the emplacement of radioactive waste). An application for the licensing procedure for decommissioning and closure was already filed on October 13, 1992. On May 09, 1997, BfS renewed this application. The main licensing document, the so-called Plan, has been provided - together with the Environmental Impact Assessment and further important documents - to the competent regulatory body (licensing authority) on September 13, 2005, and - in revised version - on January 26, 2009. On October 15, 2009, the involvement of the public started and the respective documents on the closure of the Morsleben repository were made available to the public from October 22 to December 21, 2009. In total, about 12,000 objections have been raised on the planned closure and sealing of the Morsleben repository. At present, these objections are being dealt with in order to prepare the public hearing. According to the competent licensing authority, this hearing may take place in fall 2011.

As to the closure of the Morsleben repository, it is planned to backfill large parts of the underground facilities and the shafts. The emplacement areas will be sealed by specially tailored dams in the access galleries. Altogether, the concept provides for an amount of backfill of about four million cubic metres of salt concrete. The shafts will be sealed with special shaft sealing materials. Backfilling and sealing are anticipated to last for about 15 years. Closure costs will probably amount to approx. 1.2 billion Euro.

With respect to closure, a very important measure is the backfilling of the highly excavated central part of the Morsleben repository. The backfilling of selected rooms of this part, which has not been used for radioactive waste disposal, is being undertaken to enhance geomechanical stability and integrity. Thus, an important safety-related prerequisite with respect to the future backfilling and sealing of the Morsleben repository will be provided by this action. The backfilling measures using a specifically tailored salt concrete were carried out from October 2003 until November 2009. In total, 24 rooms with a volume of approx. 800,000 m³ were backfilled.

For further enhancement of geo-mechanical stability, the additional backfilling of three rooms has been started and is expected to be finished in February 2011. The volume of backfill material needed is estimated to amount to approx. 150,000 m³.

ASSE II Repository

In the Asse II repository, a re-used salt mine located in the Federal State of Lower Saxony (Niedersachsen), about 125,000 drums of LLW were emplaced in 12 chambers at depths from 725 m to 750 m and about 1,300 drums of MLW in a chamber at a depth of 511 m from 1967 until 1978. The total activity inventory amounts to 3.1×10^{15} Bq (as of January 01, 2002), about 40 % of the inventory being contained in MLW. Subsequent to waste emplacement, the Asse II mine served as underground research laboratory until the decision on its closure was made.

In 1988, in the range of the southern flank at the 537 m level, a first influx of salt solution was observed. It was triggered by movement of the salt rock strata induced by mining activities. The solution, which presently enters at a quantity of 12.5 m³ per day [9], is fully collected and pumped to the surface. In order to stabilise the mine, old chambers in the southern flank were filled between August 1995 and December 2003. A total of about 2.1 million Mg (corresponding to 1.75 million m³) backfill material was inserted into the southern flank of the Asse II mine.

Insufficient information of the public, deficiencies in radiation protection issues, and lacking transparency in the planning of the Asse II closure gave rise to more and more criticism. Finally, on September 04, 2008, the competent Federal Ministries BMU and BMBF and the Ministry for the Environment and Climate Protection of Lower Saxony (NMU - Niedersächsisches Ministerium für Umwelt und Klimaschutz) agreed that BfS should take over responsibility for the decommissioning as future operator. The Asse II mine would be subjected to the legal procedure applying to repositories according to the Atomic Energy Act (AtG - Atomgesetz).

Since January 01, 2009 the Asse II mine has been under the responsibility of the BfS. The mine is run by the Asse GmbH which was founded at the beginning of 2009.

Initial BfS activities were focused on the improvement of radiation protection issues and on the salt solution management. Measures to improve the safety situation of the mine are performed by stabilizing of the southern flank by means of backfilling roof clefts. In the process of this measure, the cavities having occurred in the chambers of the southern flank due to the backfill material's large pore volume are backfilled with special Sorel concrete. The backfilling of roof clefts has started in the beginning of December 2009.

With respect to the final closure concept for the Asse II facility complementary and alternative closure concepts were prepared and evaluated. A basic decision was made on January 15, 2010. Accordingly, BfS' designated closure concept focuses on the retrieval / recovery of the waste packages disposed of.

Nevertheless, there exist uncertainties on the actual status of the emplacement chambers and of the waste packages as well as on the possibilities to handle the waste packages. Thus, in order to clarify these uncertainties, BfS is preparing underground investigations of two selected emplacement chambers on the 750 m level (chambers 7/750 and 12/750). This will be done in a stepwise process, starting with drilling activities, followed by the opening of the emplacement chambers and a tentative retrieval of waste packages for test purposes. Test operations were already successfully performed. The start of actual drilling activities is expected in the first half of 2011.

In parallel to the underground investigations, comprehensive planning work is performed to prepare the retrieval of all waste packages. This includes planning work for sinking a new shaft the construction of radioactive waste conditioning and storage facilities as well as the construction of necessary technical facilities and infrastructure areas underground.

Final decisions on the closure of the Asse II repository which will in particular reflect the results of the emplacement chamber investigations are still to be taken.

THE WAY AHEAD

In view of the current German situation on radioactive waste management it has to be stated that progress is definitively notable on waste disposal. The construction and future operation of the Konrad repository will ensure the emplacement of nearly all low-level and intermediate-level waste arising in Germany. The preparation of the Safety Requirements on the Disposal of Heat-Generating Radioactive Waste and the various Gorleben relevant activities are aiming at advancements and improvements with respect to heat-generating radioactive waste disposal.

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