Radioactive Waste Management

Competencies and Services

global research for safety

Overview

In the field of radioactive waste management, the competencies of GRS cover the entire spectrum of scientific issues and tasks. In this context, disposal is the thematic priority of its activities. Here, the work is two-fold: on the one hand, GRS is engaged in **disposal facility safety** research and on the other hand it provides **expert support to authorities**.

In its own **Disposal Facility Research Centre**, GRS conducts research and development, covering all essential scientific aspects of the disposal of radioactive waste. This starts off with the study of the physical and chemical properties of the potential host rock and the building and backfill materials introduced into the mine. Part of this research is carried out in the **geoscientific laboratory** at the GRS location in Braunschweig. In addition, scientists from GRS take part in **in-situ experiments in underground laboratories** in France, Sweden and Switzerland within the framework of long-standing co-operation projects. Being the leading German institution in this field, GRS develops software and databases with the help of which it is possible to run simulations of safety-relevant processes over long periods of time.

A further focus of our work is on the issue of the **safety case**. Before a disposal facility can be built, it has to be demonstrated in the licencing procedure that over a period of around one million years, the radionuclides contained in the waste will not be released from the »containment-providing rock zone« within the host rock.

GRS develops methods and computer codes for the compiling and assessing of such verifications. In this context, its research and development also covers scientific issues related to **site selection** and the **comparison of sites in different host rock types**. Whenever any technical and scientific issues need to be assessed during licensing or supervision, both federal and Länder authorities approach GRS. We support the Federal Environment Ministry in the **preparation of regulatory fundamentals**, both at national level and on technical committees of international organisations, such as the International Atomic Energy Agency (IAEA).

This brochure gives an overview of our major fields of competence, our research and development activities, and the services we provide as an expert organisation for those seeking advice in Germany and abroad.

Content:

1. Waste characterisation

A fundamental prerequisite for the management of radioactive waste is its qualification and characterisation. Reliable **data about the amount and condition of the waste** to be managed constitute the basis for answering any safety-relevant questions regarding storage and also for the development and assessment of container and disposal facility concepts. GRS has the necessary competencies to characterise the relevant radiological and hazardous chemical properties of the different types of radioactive waste with a view to the subsequent waste management steps.

Our work for the Federal Environment Ministry is a good example of the experience of GRS in this field. This work includes the acquisition and evaluation of the waste-related data that the operators of the German nuclear power plants have to submit as a mandatory part of the so-called »record of proper waste management«. Furthermore, GRS supports the Federal Government in meeting its international obligations of the Federal Republic of Germany within the framework of the »Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management« as well as in the development of the National Programme implementing Council Directive 2011/70/EURATOM.

2. Transport safety

The transport of radioactive materials is only allowed provided special safety requirements are fulfilled which are based world-wide on the transport regulations of the International Atomic Energy Agency (IAEA). According to these regulations, transport safety is predominantly ensured by the package itself. Here, the relevant aspects are the safe enclosure of the radioactive materials, the adequate shielding of the radiation, a controlled removal of the heat, and the guarantee of subcriticality. Compliance with the required safety standards according to the IAEA transport regulations has to be regularly verified.

In this topic, GRS carries out so-called **transport safety analyses**. These analyses include on the one hand the determination and assessment of the radiation exposure of individuals staying in the proximity of such transports, presuming that the **transport is accident-free**. On the other hand, possible releases of radionuclides in case of any **transport or handling accidents** and the resulting radiation exposure of individuals as well as the accidental contamination of the surrounding environment are studied. Beyond these expert analyses, the competencies of GRS in the area of transport safety also comprise the developments of analysis methods needed for such studies.

Source: Land collection facility of Rhineland-Palatinate (LUWG)

Source: Gesellschaft für Nuklearservice (GNS)

3. Storage and criticality safety

Prior to its emplacement in a disposal facility, radioactive waste has to be safely stored in a storage facility. The storage period may extend over several decades. Regarding Germany, one can already foresee today that for the heat-generating waste contained in CASTOR-type transport casks, this period of storage will clearly reach beyond the 40 years that have been licenced for the storage of these casks.

In order to be able to guarantee safe storage, it has to be demonstrated that various safety functions are fulfilled. For spent fuel assemblies, this includes not only **maintaining subcriticality** and ensuring **decay heat removal** but also **maintaining the integrity of the fuel cladding** and the **shielding function of the casks**. For the expert work carried out on behalf of authorities, GRS covers all relevant issues in this context. Apart from that, GRS furthermore develops and validates computer codes for corresponding analyses, e. g. regarding criticality and for the calculation of nuclear fuel burn-up.

Moreover, on the issue of storage, GRS is also highly competent when it comes to the physical protection of corresponding facilities. For many years, having been approached by both German and foreign authorities, we have been dealing at expert level and in advisory function with all relevant questions of the **physical protection of storage facilities** and other nuclear installations.

Criticality safety plays an important role not only in connection with storage but with disposal, too. Once the waste containers have been removed to a disposal facility and the latter has been sealed for good, it still has to be shown according to the current safety requirements for the disposal of heat-generating waste that subcriticality will be maintained for an observation period of 1,000,000 years.

GRS has carried out corresponding generic criticality studies in several research projects dealing with the host rock types salt, clay and crystalline. Besides the pure criticality analyses, this also includes studies into the **probability of occurrence of criticality conditions** as well as the possible **consequences** of hypothetical, postulated criticality conditions. Moreover, studies relating to a realistic disposal concept were also performed within the framework of the »Preliminary Safety Case of the Gorleben Site« research project.

Source: Energiewerke Nord (EWN)

4. Host rock types and barrier materials

The safety case of a disposal facility for radioactive waste requires a statement on the characteristics and the behaviour of the geological and geotechnical barriers as well as on the possible transport processes of radionuclides underground. GRS carries out research to obtain a better understanding of the determining, mutually influencing physical-chemical processes and develops host-rock-specific material models as well as tools for model calculations. GRS experts are vastly experienced in the **characterisation of host rock types**, of the waters encountered deep underground, and the **solubility behaviour of contaminants** in these waters.

The clay and salt rock formations considered in Germany so far as possible host rocks for a disposal facility for heat-generating radioactive waste are characterised by a high level of density, which is a prerequisite for potentially containing the radioactive waste safely in the long run. When a disposal facility is under construction, so-called »excavation-damaged zones« form and host rock degradation occurs in these ductile host rocks in the environment of the disposal facility mine. These may form back and »heal« with time. The velocity and the extent are influenced by pressure, humidity, and temperature. These processes and their influencing factors are studied by GRS.

To this end, GRS disposes of its own geoscientific laboratory at the Disposal Facility Research Centre and has also access to underground laboratories, such as the Mont Terri rock laboratory, providing natural and complex conditions. For example, the mechanical-hydraulic characteristics of the construction materials of **sealing structures for disposal facilities in salt rock and in clay** are studied i. a. as part of the EU-sponsored DOPAS project. In addition, the chemical longevity of the building materials is also verified. The aim of these analyses is to clarify to what extent mineralogical changes brought on by chemical corrosion processes will change the mechanical and hydraulic characteristics of the construction materials.

The qualification of the **material models and simulation codes** is done by comparing the calculation results with the results of well-documented laboratory and in-situ experiments. Within the framework of the EU-sponsored PEBS project, GRS has shown that the maximum values for the rock temperature and the corresponding pore water pressure (which occur with a time lag) of a drift emplacement experiment in the Mont Terri rock laboratory involving electrically heated waste containers can also be calculated well using 3-dimensional models.

Source: GRS

The transport of the contaminants released from the waste takes place either through flow processes of fluids (i. e. waters or gases) underground or, in the case of stagnating fluids, through diffusion. Retention processes (e. g. sorption) can slow down the **transport of dissolved radioactive materials** and at the same time reduce their concentration. This retention effect may, however, be significantly reduced by so-called colloids, to which radionuclides tend to adhere. Such colloids may form in a disposal facility e. g. from argillaceous materials.

The consequences of these effects on long-term safety strongly depend on the transport properties of the colloids and the interaction of the radionuclides with the colloids. GRS has been looking into such interaction since 2004, taking part in field experiments carried out in a fault zone in granite in the Grimsel rock laboratory (Switzerland) within the framework of the international »Colloid Filtration and Migration« (CFM) research project.

Source: swisstopo

5. Modelling of underground contaminant transport

The preparation of a long-term safety analysis for a disposal facility for radioactive waste in deep geological formations involves the determination of the environmental burden of a potential release of contaminants for relevant scenarios. Regarding the transport of contaminants from the disposal facility to humans, three subsystems are considered: the near-field, the geosphere, and the biosphere.

To model the transport of contaminants through the geosphere, it is necessary to understand the behaviour of the underground flow behaviour of groundwater. Together with different universities, GRS has developed the d^3f (distributed density-driven flow) computer code for a two- or **three-dimensional simulation of the flow field**. With d^3f it is possible to model groundwater flows as a function of variable density distributions in hydrogeologically-complex-structured areas on a large scale and over long periods of time.

For the **modelling of contaminant transport**, GRS and its partners have developed the r^3t (radionuclides, reaction, retardation, and transport) computer code. This code takes the radioactive decay (also for decay chains), linear and non-linear adsorption, and the precipitation of dissolved materials as solid bodies upon reaching solubility limits into account. It is furthermore possible to model adsorption as well as precipitation as a function of other entrained materials.

6. Assessment of disposal facility concepts and operation

The safety-related assessment of disposal facility concepts and disposal facility operation is one of the major fields of work of GRS in its expert advisory activities for licencing and supervisory authorities. For example, GRS has studied the construction, operation and sealing of disposal facilities for radioactive waste as part of the licencing procedures for the German Konrad, ERAM and Asse disposal facilities.

Within the framework of its own research, GRS looks into scientific issues that are necessary for the assessment of disposal facility concepts from the point of view of the operational phase, i. a. in the project »Analysis of operating experience and its relevance for the facility concept and the operation of a disposal facility for heat-generating waste«. The main topics here are i. a. the »robustness« of a disposal facility and cask concept under the aspect of nuclear and radiation safety. At international level, GRS is amongst others represented in groups of experts at the IAEA and the OECD-NEA, where the requirements for the **operational safety during the construction, operation and closure** of a disposal facility as well as their influence on long-term safety are discussed and assessed.

GRS also disposes of highly developed competencies with respect to the performance and assessment of safety analyses of the normal specified **operation of a disposal facility and possible accident scenarios** during operation as well as regarding the closure of disposal facilities. Expert analyses in this respect have been carried out for disposal facilities in different host rocks, both in Germany and abroad. In its evaluation of operating experience, GRS – on request of the Nuclear Waste Management Commission of the Federal Environment Ministry – analysed and assessed e. g. the events that occurred in 2014 at the WIPP disposal site in the US, where there had been a release of radionuclides.

An essential basis for such analyses is the detailed knowledge of the systems technology related to the handling and transport of the different disposal casks in geological disposal facilities. Combining this knowledge with the waste-specific competencies and the experience gained with the **performance and assessment of safety analyses** enables GRS to determine the requirements for the waste packages and the technical design of a disposal facility.

Source: DBE

7. Methods and tools for the safety case

A safety case comprises the examination and assessment of data, measures, analyses and arguments that demonstrate fulfilment of the mandatory requirements and hence furnish proof from the applicant's point of view that the disposal facility for radioactive waste is safe. In several R&D projects, GRS has further developed together with other partners the **safety concepts for disposal facilities in salt and in clay** as well as the fundamental demonstration strategies for the safety case for the post-closure phase. The safety concepts show which geological conditions and technical measures are to ensure the isolation of the radionuclides in the disposal facility.

Thanks to its competencies and long-standing experience, GRS is therefore also involved in all major research projects and represented on all relevant committees dealing with the safety case – at home and abroad. In Germany, we have our experts in the German Association for Repository Research (DAEF), and internationally GRS scientists are above all members on OECD committees (Radioactive Waste Management Committee – RWMC, Integration Group for the Safety Case – IGSC, Salt Club, Clay Club) and EU committees (Implementing Geological Disposal Technology Platform – IGD-TP).

Moreover, GRS co-operates with many countries within a framework of scientific-technical co-operation. The work in this connection is related i. a. to methods for handling uncertainties, the effects of human intrusion into the sealed disposal facility after knowledge about the disposal facility has been lost, and the comparison of processes developing within a disposal facility system with those taking place in natural geological systems (natural analogues).

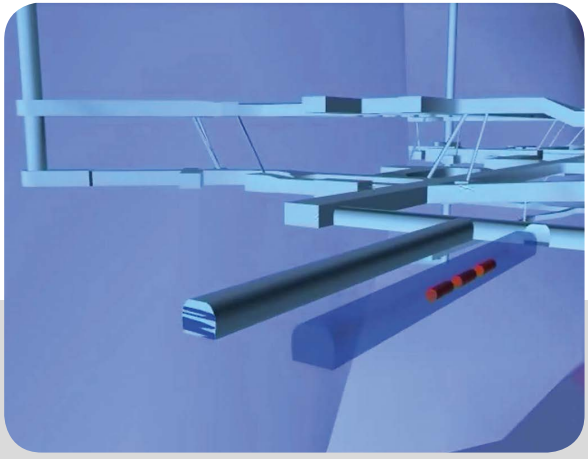
A key element of the safety case is the **long-term safety analysis**. This is a site-specific analysis of the function of a disposal facility system with respect to the radiological consequences. Essentially, this is about whether and to what extent any radioactive materials may reach into the biosphere. As part of its own disposal facility research, GRS develops tools that are necessary for long-term safety analyses of all kinds of radioactive waste disposal facilities and for all kinds of host rock formations. This includes amongst others the development of scenarios, models for describing the potential dispersion of contaminants, and computer codes for model calculations.

The basis for a development of scenarios that are to be considered in the long-term safety analysis is the so-called FEP Catalogue (FEP = Features, Events and Processes). It describes all components of a disposal facility with the relevant developing processes and shows in a substantiated manner how the processes impact on the disposal facility components. On the basis of the interactions defined in the FEP Catalogue it is possible to derive scenarios with regard to the future evolution of the disposal facility system. In the »Preliminary Safety Case of the Gorleben Site« research project, GRS – together with other institutions – prepared a FEP Catalogue for the first time for a real site and derived on its basis the likely and less likely evolution. In the current AnSichT project, GRS and other partners are jointly identifying the processes that need to be taken into account in a FEP Catalogue for a disposal facility site in clay.

When **describing the potential dispersion of contaminants** within the framework of a long-term safety analysis, it has to be considered that materials in a disposal facility may be transported by liquids as well as by gases. Relevant in this connection is also the so-called two-phase flow, i. e. the simultaneous transport of two immiscible fluids, like water and gas. In a project that began in 2013, GRS is developing the calculation tools and methods that are necessary for this purpose, testing them on real data from the Morsleben disposal facility for radioactive waste (ERAM).

A recent example of the development of computer codes is the **RepoTREND code**, which was developed by GRS. RepoTREND is a new, advanced tool for the analysis of the long-term safety of disposal facilities for radioactive waste. With this code, it is possible to simulate complex processes in a disposal facility system. Based on such a simulation, the potential radiation exposure of the humans affected can be calculated. RepoTREND consists of several independent calculation modules for various subareas of disposal facilities in different geological formations. For the analysis of uncertainties and the sensitivities of the model parameters, a large number of methods are implemented in RepoTREND.

Another example is the worldwide first-ever **virtual VIRTUS underground laboratory**, which GRS has developed with other partners. By its three-dimensional visualisation, VIRTUS facilitates the investigation of safety-relevant processes in a disposal facility and contributes to a more transparent and comprehensible representation of research results.



Source: BGR, DBETEC, GRS, IFF

8. Building a safety case

GRS also applies its own methods and calculation codes to the analysis of the long-term safety of disposal facility projects in deep geological formations. Here, generic sites (e. g. Gorleben as part of the VSG) as well as sites that are already in the phase of being closed (Asse, Morsleben) and disposal facilities under construction (Konrad mine) are considered.

For the Konrad mine, the Disposal Facility Research Centre of GRS (then still belonging to the Institute for Deep Disposal of the Gesellschaft für Strahlenforschung research institute) assessed within the framework of the plan approval procedure the aspect of long-term safety to do with the mobilisation and the transport of the radionuclides through the mine workings. Together with external partners, transport through the overburden and the subsequent radiation exposure in the biosphere were also investigated.

Over many years, GRS has been performing long-term safety analyses with a view to the closure of the Asse II mine and the Morsleben disposal facility for radioactive waste, in part in co-operation with international partners. These activities are pursued within the framework of nuclear licencing procedures on behalf of the Federal Office for Radiation Protection (BfS) as legally responsible operator.

Source: wikimedia commons/Johamar

9. Expert assessments of safety cases

One of the core tasks of GRS is the **expert assessment** of safety cases for the technical assistance of authorities in Germany and abroad. Within the framework of site selection procedures and licencing procedures for the construction or the closure of disposal facilities, it is above all the applicant's safety analyses that have to be assessed on the basis of regulatory provisions.

Here, GRS disposes of the necessary technical competencies and simulation codes as well as of the required know-how regarding the relevant regulatory requirements at national and international level. To keep this know-how up to date, analysis methods and the underlying mathematic-physical models are constantly adapted to the state of the art in science and technology, and the computer codes available at GRS for the expert assessment of safety cases are continuously developed accordingly.

One recent example is a research project aimed at the improvement and **development of methods for the safety-related assessment of disposal facilities** for waste with negligible heat generation. In this project, which runs until the end of 2015, the methods for demonstrating safety, ranging from the control of incidents during operation and accidents to long-term safety in general, will be examined and developed further, using the Konrad disposal facility as an example.

10. Methods for comparing disposal facility systems

Worldwide, the search is going on for suitable sites for radioactive waste disposal facilities. In Germany, a selection process is to be developed and carried out for this purpose with the aim to find the best-suitable site by comparing several possible locations.

Going by today's state of the art in science and technology, a comparison of sites cannot be restricted to the geological conditions alone but must also take the respective disposal facility concept into account. Such a **comparison of disposal facility systems** poses especially methodical challenges if sites in different host rock types are to be considered.

In the VerSi research project, GRS has developed – as the first institution worldwide – two methods that supplement each other for the comparison of long-term safety analyses of different disposal facility sites in different host rock types. The first one is a so-called verbal-argumentative method by which a safety-oriented comparison can be made by juxtaposition of the respective safety functions. The second method is a quantitative one, based on a probabilistic long-term safety analysis. Both methods were tested by using the Gorleben site and a generic site in a clay formation in order to examine the feasibility of the methods and the limits of their validity.

11. Advancement of safety requirements

National regulations for the disposal of radioactive waste must be in line with the international state of the art in science and technology and have to correspond with the requirements of international obligations. GRS takes an active part in numerous working groups of international institutions such as the IAEA, WENRA or OECD/NEA, who deal with fundamental regulatory issues and the harmonisation of the different safety philosophies in connection with the disposal of radioactive waste.

This collaboration is an important basis for the technical support of the Federal Environment Ministry (BMUB) in the **preparation of safety criteria and guidelines** for disposal. One example of this work performed by GRS is our participation in the development of the safety requirements for the disposal of heat-generating radioactive waste by which the BMUB established the safety-related framework in 2010 for the planning, construction, operation and closure of a disposal facility for heat-generating waste.

At international level, GRS supports the BMUB i. a. in the activities of WENRA towards the harmonisation of regulations. At present, the WENRA Radioactive Waste Disposal Facilities Safety Reference Levels are mirrored on the respective national regulations of the Member States and the corresponding consistencies and gaps or missing requirements are identified. Any differences are then to be levelled by the Member States through national action plans.

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