

The Importance of International Cooperation for German R&D on Radwaste Management

W. Steininger
Forschungszentrum Karlsruhe GmbH
Water Technology and Waste Management Division
Project Management Agency Karlsruhe (PTKA)
Hermann-von-Helmholtz-Platz 1, 76021 Karlsruhe,
Germany

ABSTRACT

Participation in international R&D projects and programs is of great importance for German R&D institutions. This is underlined by a lot of past and present R&D activities. These activities are embedded in the non-site specific research work funded by the Ministry of Economics and Technology (BMWi) which is the responsible ministry. The paper will focus on this R&D work.

The paper addresses briefly the present status of the nuclear waste management policy in Germany, the responsibilities, and objectives of R&D related to High-Level Waste (HLW) disposal. International collaboration in projects conducted in foreign underground research laboratories (URL) and disposal programs as well as activities within the 6th Framework Program of the European Commission (EC) are described.

INTRODUCTION

At the end of 2005, 17 reactors at 12 nuclear power plants (NPP) were in operation after the shut down of the NPP at Obrigheim in May 2005. The reactors, with a net power of about 21 GW, produced a total output power of about 163 TWh. The output power of all NPP still corresponds to about 30 % of the total electricity production. To date 19 reactors were decommissioned.

In September 2005 early general elections were held. The new Federal Government became established by a coalition between Christian Democrats and Social Democrats. During the coalition negotiation talks the nuclear policy was a matter of the discussion. Finally, it was decided to maintain the status-quo because of differences in opinion concerning the future use of nuclear energy for electricity production. This means that the consensus agreement, which was signed in 2001 between the then red-green government and the electric utility companies, and which was the basis for the nuclear phase-out, still is valid with all its consequences for nuclear.[1] Nevertheless, it was stated that research that supports the safe operation of NPP will be continued and extended. There also is the intention to solve the question of disposing of radioactive waste within this legislative period.[2]

CURRENT NUCLEAR WASTE POLICY

Reprocessing

Since July 1st 2005 reprocessing of spent fuel elements in France (La Hague) and in the UK (Sellafield) has stopped. Spent fuel elements are to be disposed of directly. The vitrified HLW which still is in France and in the UK will be taken back in due time according to existing international agreements. After being stored in a central storage facility during an interim storage time of about 30 years vitrified HLW will finally be disposed of in a German deep geological repository.

Interim Storage

Two central interim storage facilities are operational. At Ahaus (North Rhine-Westphalia) the BZA (Brennelement-Zwischenlager Ahaus) facility is used to store both spent fuel elements and thorium high-temperature reactor (THTR) fuel elements. At Gorleben (Lower Saxony) the BLG (Brennelement-Lager Gorleben) facility is used to store spent fuel elements and the reprocessed vitrified HLW. Two decentralized interim storage facilities for spent fuel elements at the sites of two decommissioned reactors are in operation.

At each NPP site decentralized on-site storage facilities will be operated to keep the spent fuel for a storage period of 40 years. All facilities are licensed by the Federal Office for Radiation Protection (BfS), becoming operational in 2005/2006.[3]

Shipment

After the stop of shipments to the reprocessing plants in France and the UK becoming effective in middle of 2005, only the shipment of the reprocessed waste from France and the UK to the central interim storage facilities is allowed. As soon as a deep geological repository is in operation the waste (vitrified HLW and spent fuel) will be transported from the interim storage facilities or the on-site storage facilities to the repository site.

Operation Lifetime

The lifetime of existing nuclear reactors is determined by the limited electrical output (Atomic Energy Act, 2002). That means that the last reactor will be shut down when all reactors will have generated about 2000 TWh of electrical energy. Hence, the last reactor will stop energy production in the year 2021. Nevertheless, the issue of prolongation of operation lifetime is currently a matter of lively discussions. It might be one of the topics within the Government's new energy concept that will be discussed at the national energy summit in April 2006.

Disposal

Unanimously there is consensus to dispose of all types of wastes in deep underground repositories in Germany, e.g. neither export nor import of radioactive waste is allowed. To dispose of heat producing spent fuel and vitrified HLW rock salt was and still is a favorable host rock. However, argillaceous or crystalline rocks are also subject of R&D efforts concerning a governmental decree to investigate all types of host rocks concerning their suitability to host a deep geological repository. The Federal Ministry for the Environment, Nature conservation and Nuclear Safety (BMU) demands to have only one single repository for all kinds of radioactive waste. This concept and its consequences are a matter of discussions in politics and in the scientific community.[4, 5]

Moreover, a decision about the rock type that will finally host a repository is still pending and will be possibly drawn after comparing all host rock alternatives. This will postpone the very ambitious target for a HLW repository start-up in 2030.

The moratorium on further exploration of the Gorleben salt dome is still imposed. The measures to maintain the Gorleben site are ongoing, and the necessary legal steps were undertaken to secure the position of the Federal Government in order to make the project secure from interventions of third parties. One point in connection with the moratorium was to clarify questions related to conceptual and safety-related issues for all suitable host rock types. Issues to be addressed were e.g., gas, criticality, retrievability, use of natural analogues, safety indicators, etc. The final reports, reviewed by experts, were presented and discussed during an internal workshop in September 2005 organized by the Federal Office for Radiation Protection (BfS). The reports and the final synthesis report are available at the BfS homepage.[6] At present the synthesis report, its conclusions and the consequences for the Gorleben moratorium are under discussion.[7, 8]

Still unsolved is the question of implementing the site selection procedure - combining scientific and social criteria - that was recommended by the then Committee on a Site Selection Procedure for Repository Sites (AkEnd).[9] This might be a topic of future political discussions.

For the Konrad mine, planned to be used as a repository for intermediate and low-level waste, the licensing procedure is completed after more than two decades. However, the license has not become effective immediately. Further on-site construction is delayed due to appeals in court. The court decision is expected at the end of February 2006.

In Morsleben the stop of short-lived long- and intermediate-level waste emplacement was decreed. At present, among others things, the main activities still comprise works necessary for licensing and closure of the mine and the repository areas.

RESPONSIBILITIES FOR R&D

The German Federal Government has to ensure the safe disposal of radioactive waste by providing repositories (Atomic Energy Act, 2002). All R&D activities are embedded in the Government's precautionary research activities based upon the Federal Energy Research Program.[10]

The general aim of this R&D is to provide the scientific and technical basis to help protect man and the environment against hazards originating from disposal facilities.

R&D activities that are related to HLW disposal are basically in the responsibility of three departments: the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the Federal Ministry of Economics and Technology (BMWt) and Federal Ministry of Education and Research (BMBF).

Site-independent generic R&D projects are funded by BMWt (Fig. 1, below) managed and supervised by the Project Management Agency Forschungszentrum Karlsruhe (PTKA). Basis is the Research concept of BMWt. [11] The concept has two main research areas: research for the ad-

vancement of repository concepts, and research to develop, to improve both basic knowledge and the tools and instruments for long-term safety demands. BMWi is the supervising and funding department for the BGR (Federal Institute for Geosciences and Natural Resources) the German Geological Survey, a counselling organization, which, among other things, performs R&D focusing on geological issues.

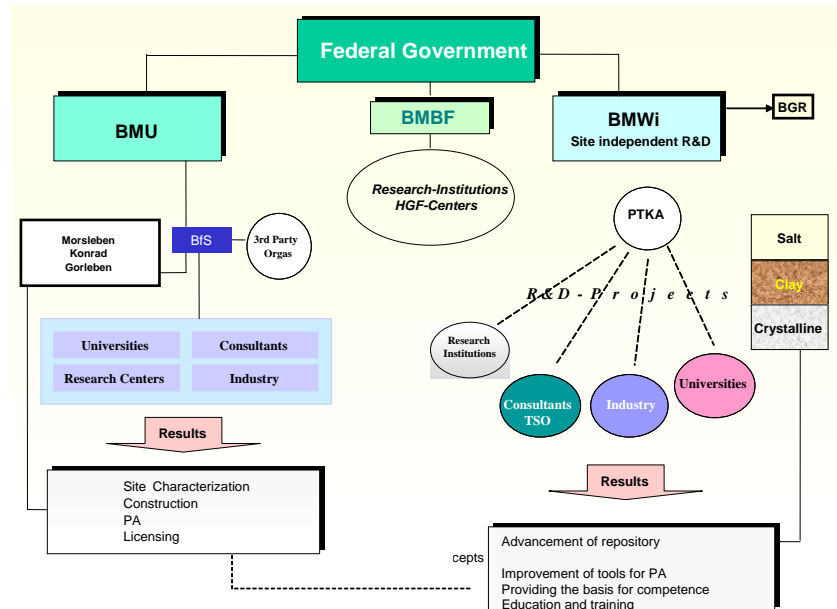


Fig. 1. Responsibilities for R&D on HLW disposal

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R&D projects are carried out by industrial companies, consultants, technical support organizations (TSO), universities, and research institutions. Principally, any legal bodies, authorities, reviewers, operators, private industry, and other stakeholders can use the results.

BMU is the regulatory department for disposal projects and is responsible for the related site-specific R&D, e.g., the Gorleben site.

On behalf of BMU, the Federal Office for Radiation Protection (BfS) initiates and coordinates site specific R&D. BfS is responsible for construction and operation of plants and installations for disposing of radioactive waste. The expertise of third-party organizations is used to fulfill this task. Special R&D tasks are carried out mainly by research centers, consultants, universities, and industrial companies. The results are directly used by BfS for site characterization, performance assessment, and license application. By law, the costs for the site-specific R&D are paid by the electric utility industry according to the “polluter-pays-principle“. The future procedure is still under discussion.

BMBF is the responsible department for funding primarily basic research. BMBF is responsible for the national research centers —members of the Helmholtz-Gemeinschaft— that host some of the institutes involved in the research on radwaste disposal.

INTERNATIONAL COOPERATION

International cooperation has been and will be an indispensable part in R&D on radioactive waste disposal. International cooperation is mainly based on agreements between Governments, scientific institutes, universities or national research centers, and on agreements with the European Commission. A lot of fruitful and successful cooperative work was and is being performed in the frame of these areas. Moreover, very positive consequences arise by the overlapping of these areas, which results in starting and building up multidisciplinary and multinational networks. Beyond that, it becomes increasingly acknowledged that it is valuable and practical to cooperate in joint international projects, not only to distribute the financial burden, i.e. by operating URLs, but to use the distributed and sound expertise for solving common national and international problems. Furthermore, it is a great chance to show the public that there is a serious common understanding in the scientific community to solve the problem of waste disposal together in a multinational effort and safety-oriented in due time.

A lot of the international activities is funded or co-funded by the German government, esp. the BMWi, on the one hand because of its responsibility for this research, but, on the other hand, as a sign for the importance attached to international cooperation.

In the past when rock salt was the favorite host rock in Germany, a series of projects were carried out in cooperation with institutions from countries which then had also interest in rock salt (France, the Netherlands, Spain, US). It was a great advantage not only to have the Asse salt mine available as an URL of the first generation to host in situ experiments, but it also showed the importance of having a national URL. The experiments were designed both for development, test, and demonstration of emplacement and disposal technologies, as well as for the development of methods and procedures to study fundamental processes. Complementing these experiments adequate laboratory and modeling work was performed. Even though there were drawbacks, the lessons learnt from all these experiments contributed substantially to the sound basis of knowledge on rock salt as a suitable and favorable geological formation to host a repository. The first repository worldwide in salt, the WIPP, is the “living” proof.

Beyond that, the experiments and their results were one of the cornerstones to develop and support the German disposal concept as the basically feasible way to dispose of spent fuel and vitrified HLW.

Selected examples for experiments conducted in the Asse that were carried out in cooperation with international researchers: The “Brine Migration Test”, then performed in cooperation with the US Department of Energy (WIPP) investigated the behavior of saline solutions in the temperature field of HLW. The “HAW-project” had the objective to develop and test the technology for vitrified high-level waste canister transportation and emplacement and got substantial input from scientists from Spain, the Netherlands, and France. Alas, the active in-situ test was not carried out because problems with licensing and funding. Finally, in the two DEBORA- (Development of Borehole Seals for Radioactive Waste)-experiments the borehole emplacement of steel canisters containing vitrified waste from reprocessed spent fuel was tested.[14] Most of these experiments were also co-funded by the European Commission in the respective Framework Programs.[12, 13, 14]

Although R&D mainly concerned rock salt, German institutions always have participated in foreign projects and programs related to other host rock formations. There was always the opinion, that information on and knowledge of different host rocks and concepts is necessary, and only international co-operation, especially in URLs, could provide this information.

Not at last, it was also important to better understand and evaluate the pros and cons of possible other candidate formations than rock salt. Furthermore, the fact that large-scale or full-scale in situ demonstration experiments are essential for any disposal program was a crucial aspect. Therefore, German institutions always considered the participation in experiments designed in URLs in crystalline rock and argillaceous rocks to be necessary.

Cooperation in Foreign URLs

For decades German scientists have participated actively in R&D projects performed in foreign URLs or cooperated in the framework of foreign research programs. The main goal valid for all collaborative activities was and still is to gain experience and expertise in techniques and technologies relevant for site characterization, for repository construction and operation, and performance assessment. Because Germany has no underground laboratory, neither in hard rock nor in argillaceous media, participation in R&D projects in foreign URLs is even more of importance. In the case that there will be a move on to continue with the activities in waste disposal, it is important for German scientist to be prepared and to have know-how and tools available. Co-operation in foreign URLs in other host rock formations is therefore the only way for German scientists to gain the necessary experience.

The R&D activities concerning crystalline rock are both focused on experiments performed in the URLs in the Grimsel Test Site (GTS) in Switzerland and in the HRL Äspö in Sweden, and cooperation with Russian institutions.

The R&D activities in the GTS reach back to the nineteen eighties and are based upon mutual agreements between NAGRA, the Swiss Waste Management Organization that operates the GTS, and collaborating organizations. Since this time close collaboration with international partners

from any country involved in radwaste R&D activities took place in a series of projects during the six investigations phases of the GTS.[15]

The investigations in granitic rock being performed by German institution started with the goal to characterize the host rock with regard to its hydrogeological, petrophysical, and mechanical behavior. During the experimental phases of the GTS collaboration took place in projects focusing on studying the EBS behavior (FEBEX, GMT) and questions related to geochemistry (colloid and radionuclide migration). Besides acquiring basic knowledge and detailed system understanding, sophisticated computer codes measuring devices and methods, and state-of-the-art analytical tools, were developed and could therefore be considered as extremely valuable spin-off results from these collaborative efforts.[16, 17]

In 1995 the cooperation with Sweden in the HRL Äspö started. There was the opinion that a fair amount of knowledge was gained on the Grimsel granite. As a consequence it was felt to extend the knowledge to a crystalline host rock that differs from the Grimsel granite and also had a surrounding that diverges remarkably. Whereas the GTS granite is relatively dry and low fractured, the Äspö granite is relatively high fractured with water-bearing features, and, the water is of relatively high salinity. Within several projects work was performed on issues dealing with developing and testing of instrumentation and methods for underground rock characterization, behavior of the engineered barrier system and the Prototype Repository project, the development of numerical models for the calculation of flow and transport processes in natural and technical barriers as well as on studies of radionuclide migration (in particular actinides) and impacts of colloids and microbes. Tools, measuring devices, sophisticated analytical instruments [18] and method used in GTS were also very successively used in the HRL Äspö.

In 2002, cooperation has been started with Russia. Based upon a bilateral agreement signed in 2001 between BMWi and the then MINATOM, now ROSATOM, a series of projects were defined by Russian and German experts. The first project aimed at developing an approach for a site investigation and selection program. The activities were mainly focused at the Nishnikansk massif in granite at Krasnoyarsk. A generic repository concept for borehole disposal of HLW was developed. Construction of a geological model (using a sophisticated geological information system) and the development of a sound technological repository concept was part of the task.

Another task was to accompany this work by modeling and to do performance assessment calculations. Beyond that, certain quality standards for all project phases should be transferred. The chosen approach was very successful and led to recommendations for future site investigation.

The project was a good example for activities with mutual benefit: German scientist had the unique possibility to perform site-specific work, to test their tools and to enlarge their knowledge. Russian specialists and institution got the chance of being integrated into the international disposal community.[19] The activities will be continued.

In Germany R&D concerning argillaceous rocks started relatively late and was performed on a much smaller scale compared to research activities in crystalline rock. The work on argillaceous rocks was intensified after the political decisions to phase-out nuclear energy and to investigate other potential rock formations hosting a repository because of the doubts concerning the salt option. Because there is no URL in this formation in Germany it seemed appropriate to collabo-

rate in foreign URLs as a preparatory measure. Therefore, since some years collaboration in several experiments in the Swiss Mont Terri rock laboratory and in the French Bure URL is ongoing.

The Mt. Terri URL is constructed in opalinus clay. A consortium of international organizations - among others, from Switzerland, Germany, France, Belgium, Japan, and Spain - has been carrying out several projects related to issues like characterization of the Opalinus rock, the development of instruments for rock characterization, the study of the THMC- behavior, modeling of processes that are expected to occur in the rock as a consequence of the storage of radioactive waste, etc. Moreover, an accompanying performance assessment modeling exercise is being performed.

German research institutions participate in the experimental R&D-program of the French ANDRA at the Underground rock laboratory at Bure. Issues addressed are comparable and complementing the Mt. Terri activities. Topics are the study of thermo-hydraulic-mechanical properties of the callovo-oxfordian clay, the characterization of this material, and participation in selected in-situ tests. Of course, these work is accompanied by laboratory experiments and modeling. This collaboration will be a unique opportunity to be involved in a URL construction project from its very beginning and therefore is an extremely valuable source of information.

Details and a comprehensive collection of publications can be found at the web pages of the German principal investigators BGR, and GRS.[20, 21]

EC-Framework Programs

The second important area of international cooperation which becomes of increasing importance is the participation in the Framework programs of the European Commission. Participation has been and will be an essential part of a national research policy. The participation is indispensable and necessary to gain expertise and to transfer experience, to exchange knowledge and to increase excellence, support mobility and scientific exchange. Not to forget: Framework programs are a valuable source for funding.

For thirty years, German scientists have actively participated in EC-Framework Programs based on the EURATOM agreement in different fields of research (in-situ experiments, modeling and performance assessment exercises)

An outstanding example for international cooperation was the EC co-funded BAMBUS-project, which was chosen as one of 36 examples for successful research.[22] Collaborators from European countries and the US participated in these so called BAMBUS I and II-experiments within the 4th and 5th Framework Program of the EC. This project owed its success not at least the efficient international cooperation between participants from Spain, the Netherlands, US, and Germany.

It bases at the then TSDE experiment (Thermal Simulation of Drift Emplacement) simulating the drift emplacement of heavy self-shielding casks for spent fuel. The experiment was designed in 1985 as a full-scale experiment to be performed later in the Asse mine. Six dummy casks were emplaced in two drifts and instrumented with measuring devices. After backfilling with crushed salt heating started in 1990 and was finished in 2003 including a post-test evaluation phase. Excellent data concerning the mechanical behavior of the surrounding rock salt, the crushed salt

backfill, the EDZ behavior, the corrosion behavior of container materials, and instrument performance were collected. Modeling tools to be used for describing the THM-behavior were further developed substantially during the experiment.[23]

German research institutions currently participate in or coordinate projects within the European Atomic Energy Community (Euratom) 6th Framework Programme for Research and Training (6th FP). Projects concerned in the thematic area “Management of radioactive waste” are the Integrated Projects (IP) NF-PRO (Near field processes), ESDRED (Engineering Studies and Demonstration of Repository Designs) and FUNMIG (Fundamental Processes of Radionuclide Migration), one Network of Excellence (ACTINET) and some minor projects not addressed in detail. Integrated Projects are instruments to “support objective-driven research, where the primary deliverable is new knowledge”. Moreover, training, the support of mobility, and dissemination of results became key points for all these projects in order to make a contribution to the European added value. Dissemination of results by state-of-the-art media is not only important in the scientific community but even more important for attracting the interest and building trust of the public concerning safe disposal in deep geological repositories.

Main objective of the IP NF-PRO is to extend the understanding of the processes occurring in the near field of a repository. All host rock formations are subject of investigation, because they determine the disposal concept, which also determine the near-field. This undertaking is done by 40 partners. The aim is to investigate all safety-related topics concerning the near field. Laboratory and in situ experiments are accompanied by modeling and performance assessment exercises. Key points are to study dominant processes and process couplings in the near field (THMC-modeling), the behavior of EDZ and the EBS. Esp. for Germany there is the possibility to clarify and answer still open questions concerning the EDZ in a salt repository, and to test and validate constitutive models.[24]

ESDRED is an ambitious joint research project of thirteen organizations (waste management organizations and technical support organizations). General goal is to demonstrate on an industrial scale the technical feasibility of measures and technologies for construction, operation and closure of a deep geological repository for HLW in all geological formations. The results will be strongly communicated to the public and stakeholders. They must serve to underpin the advancements in disposal technology and the feasibility of HLW disposal deep underground.

German Scientists cooperate in the module that is connected with “canister transfer and emplacement techniques”. The participation in this project can be regarded as important step towards completing the German disposal concept of Direct disposal. The emplacement concept (drift emplacement for SF, borehole emplacement for vitrified waste) will be completed by demonstrating not only the feasibility of SF emplacement in vertical boreholes but to demonstrate it on a real industrial scale.[25]

The aim of the Integrated Project FUNMIG is to study fundamental processes determining and influencing radionuclide migration from the near-field to the biosphere for all relevant host rock types. By a well chosen approach the completeness of processes and their importance will be tested. Transport studies relevant for all host rocks will be performed, and tools to be used in performance assessment will be provided. This cooperation project, involving 51 partners from 15 European countries, is coordinated by the Institute for Nuclear Waste Disposal at the For-

schungszentrum Karlsruhe. It is a real multinational-multidisciplinary approach to tackle these outstanding geochemically oriented questions of waste disposal. Besides the important work to investigate and understand the fundamental processes by laboratory, in situ experiments, and field experiments, emphasis is also put on modeling and to satisfy performance assessment demands. In addition to the R&D activities, an important part of the project concerns the training to apply the tools and methods used to deal with the migration processes during workshops and meetings. The approach to offer the training also for implementers and regulators is remarkable. A further important point is to spread all results and information of the project to anybody who is interested in, such as e.g., end users, broader public or scientific community.[26]

Participating in EC-Framework Programs has been very successful for German researchers. Despite drawbacks and problems the general benefit resulting from all the activities justifies the participation - also in the 7th EC-Framework Program.

CONCLUSION

Contrary to expectations, the decisions of the former Federal Government concerning the nuclear phase-out and the related consequences are still binding. Among other things, the investigation of other rock types than rock salt to host a deep geological repository will be continued. This is a challenging task, because a lot of effort is necessary to reach a level of knowledge comparable to rock salt. Having no underground laboratory in Germany the focus must lay on international co-operation and participation to improve knowledge on these formations. For German scientists this co-operation was and still is of great importance and therefore is a driving force to become engaged in several international projects. If one takes stock of many years of international cooperation the outcome was extremely positive. This encourages future common R&D undertakings on an international level.

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