

## THREE DECADES OF DEEP GEOLOGICAL DISPOSAL RESEARCH IN GERMANY - THE WAY AHEAD

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### ABSTRACT

Deep geological disposal of long-lived, high-level radioactive waste (HLW) is worldwide still an open issue. Until present, only three deep geological disposal facilities have been operated: the Asse experimental repository (1967-1978) and the Morsleben repository (1971-1998) in Germany as well as the Waste Isolation Pilot Plant (WIPP) in the USA (1999 to present). In 2002 the license for the fourth such facility, the German Konrad repository, ended with a positive "Planfeststellung" (plan approval). The license for the Konrad repository is the outcome of twenty years of repository development and licensing and more than 30 years of geological disposal research. In regard to HLW, all knowledge and technology needed for implementing its final disposal is completely available in Germany, most of the required facilities are already there. Nevertheless, repository construction is now at a standstill, with little chances of real change without a drastic improvement in the political environment. Several different ways ahead appears currently possible, with distinct advantages and disadvantages. But willingness to take action in the political arena is faint, if at all existing. Meanwhile, waste continues accumulating and risk increases that it will come to a decades-long delay in HLW repository construction.

### INTRODUCTION

Research and development (R&D) work on the peaceful uses of nuclear power started in Germany in the mid-fifties. The need to manage and dispose of the resulting radioactive waste was given due attention from the very beginning. As early as 1957 the German Atomic Energy Commission stated that: "*development work must in particular incorporate the safe disposal of radioactive contaminants*". There was also already then general consensus that all radioactive waste was to be disposed of in deep geological repositories.

Back in 1963 geoscientists of the "Bundesanstalt für Bodenforschung", the predecessor organization of today's German Geological Survey (BGR), began investigating rock formations as to their suitability to host a repository for radioactive waste disposal. Based on a first survey of available geological information for Western Germany, a recommendation was made in favor of rock salt formations of in the deep geological underground. Salt was favored from the very beginning due to the fact that there are plenty of large salt domes under the plains in Northern Germany in an old, geologically very stable environment. Such salt formations are essentially water-free, and salt has very favorable properties for waste isolation: very low permeability, high thermal conductivity, and pronounced creeping that renders waste packages some time after disposal completely embedded in a dry, impermeable rock.

## LILW DISPOSAL RESEARCH AT THE ASSE EXPERIMENTAL REPOSITORY

In 1964, Germany launched an extensive R&D program for low and intermediate level (LILW) radioactive waste disposal. In this context, the “Gesellschaft für Strahlen und Umweltforschung” (GSF) acquired on behalf of the Federal Government the Asse salt mine on March 12, 1965 [1] [2]. Previous studies had confirmed its suitability to host an experimental repository. At this early time only a first unit, the Kahl Experimental Nuclear Power Plant (VAK) was supplying electricity to the public in Germany. Almost six decades of mining had left in the Asse 131 large chambers open, with typical dimensions of 60 m length, 40 m width, and 15 m height, at 13 levels between 490 m and 750 m below surface, with 3.35 millions m<sup>3</sup> open volume. Figure 1 shows a view of the Asse mine.

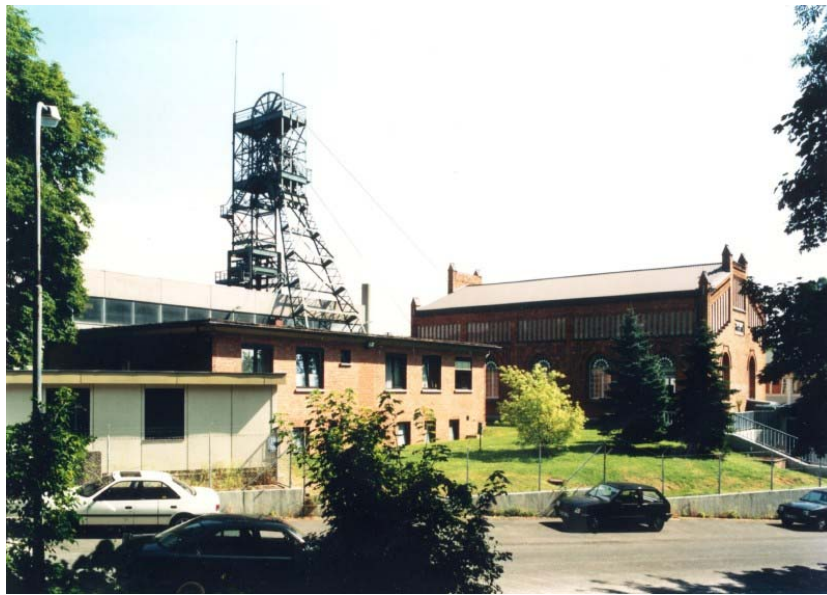


Fig.1 Surface facilities of the Asse experimental repository

On April 4, 1967 a first campaign of low-level waste (LLW) geological disposal began. Figure 2 shows the unloading of the second 200-liter waste drum delivered to the Asse. With this pioneer waste disposal, R&D work in the first European Underground Research Laboratory (URL) began.

Waste disposal was carried out at the Asse in six disposal phases. During the first four years (1967 to 1971) disposal took place in short campaigns of a few months each, involving a limited waste volume. Waste drums were piled standing up upon each other in chambers 750 m below surface, leaving a pathway for monitoring open between four drum rows.



Fig. 2 First delivery of LLW to the Asse URL for experimental disposal

After filling a first chamber, this disposal technique was changed for improving disposal space use. Drums were then disposed lying on their sides, in up to 10 layers using a forklift and a disposal machine with telescopic grabber. In a further improvement for minimizing workers' radiation exposure introduced 1974, chambers were filled from an opening near the ceiling. Waste drums were discharged by a shovel loader at the opening and tumbled down a slope of salt previously dumped from the chamber opening (Figure 3). From time to time crushed salt was dumped onto the drums, thus gradually filling the chamber from the entrance to its rear end.



Fig. 3 LLW disposal by drop-down technique

A first load of Intermediate-level waste (ILW) was delivered to the Asse on August 1972 in 200 1 drums packed into reusable shielding containers. Due to the high activity inventory of up to 10 TBq per drum and the high surface dose rate of up to 100 Gy/h such wastes required remote handling. Moreover, the ILW disposal chamber was excluded area, which required developing a new

remote disposal technique. Figure 4 shows the technology used to dispose of such waste in a chamber at the 511 m level.

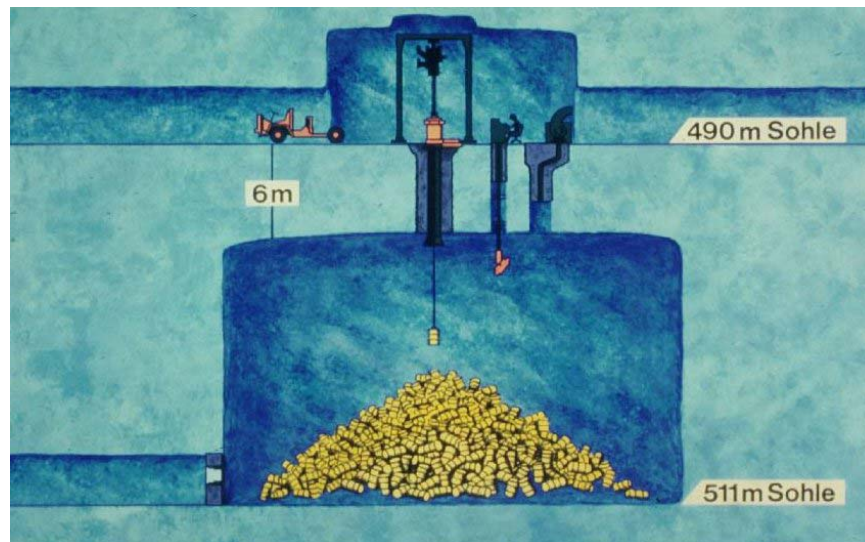


Fig. 4 Asse experimental repository, ILW disposal technique

In a transfer chamber at the 490 m level shielding overpacks were unloaded from the transport cart by a crane and lowered down and locked onto a shielding airlock on the transfer chamber floor. After opening a sliding door on the disposal chamber shielding airlock and a second one at the bottom of the shielding overpack the waste drum was lowered down into the disposal chamber by a drum grabber.

On August 31, 1976 the 4<sup>th</sup> amendment to the Atomic Energy Act introduced a series of important changes. Among others, it prescribed a new, complex plan approval procedure as the licensing procedure for radioactive waste repositories. With the end of the existing disposal permit for disposal research waste disposal at the Asse was therefore permanently discontinued on December 31, 1978. In the six disposal phases carried out until then, almost all LILW at that time arising in Germany was disposed of at the Asse experimental repository: 124,497 drums with LLW (hands-on disposal) and 1,293 drums containing ILW (remote operation). The total activity amounted to some 7600 TBq at the time of disposal.

### **HLW DISPOSAL RESEARCH AT THE ASSE EXPERIMENTAL REPOSITORY**

After discontinuing waste emplacement, the Asse mine served until recently as a large-scale underground research laboratory only. Research focused on development, testing, and demonstration of disposal technology for heat-generating HLW as well as basic and applied research on the safety of HLW disposal for performance assessment. The research work included a series of heater tests, in which first the technology for carrying out such tests (electrical heaters, measuring instruments, data acquisition systems for underground use) was developed during the seventies. The know-how obtained with these first series of test was then used to plan and carry out several large-scale test with electrical heaters and with radiation sources, to study among others the response of the salt to the combined effect of heat and radiation as in case of HLW disposal.

One important result obtained from the first heater tests with significant impact onto the German repository program for the Gorleben site, was the insight that the evaporite mineral older halite (older rock salt) is more suitable for the disposal of heat generating waste than the halite deposited at a later geological time. In view of this it was decided to build at the planned Gorleben repository the shafts and the underground infrastructure areas, which shall remain stable for several decades, in the more stable younger halite. This allows minimizing maintenance of underground rooms, drifts and chambers to counteract the effects of rock convergence. In contrast with this, heat-generating waste disposal will be done in the older rock salt. There, the higher creep rate in connection with the waste decay heat that will heat up the salt up to 200 °C will provide for a rapid closing of disposal drifts and boreholes by enhanced convergence. This self-sealing effect is a unique characteristic of rock salt and one of the main reasons for Germany to originally select salt as the preferred formation for heat-generating waste disposal.

International co-operation in HLW disposal was an important goal for the German R&D in the Asse URL. From 1981 to 1986, The "Brine Migration Test" (BMT) was jointly performed with the US Department of Energy (DOE). This large-scale test aimed at studying the combined influence of radiation and heat on the host rock, and used strong  $^{60}\text{Co}$  sources and electrical heaters. The test provided valuable insight on waste package interaction with rock salt, data on the salt response to the combined effect of radiation and heat, to evaluate the data acquired in terms of model and parameter validation, and to qualify methods, equipment, and monitoring devices for such in situ testing. The results were very encouraging and proved the suitability of rock salt as host rock for disposal of HLW and spent nuclear fuel.

A further large-scale in situ test aimed at demonstrating disposal of heat-generating HLW, the HAW-Project (after the German acronym for HLW). In this test, carried out between 1982 and 1994, the equipment for shaft transportation, underground handling, and disposal of canisters containing vitrified HLW was developed and tested, and a comprehensive in situ and laboratory experimental program performed. The test set up included six disposal boreholes in two parallel galleries at 800 m below the surface. The initial planning anticipated using 30 actual vitrified waste canisters containing large amounts of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  to simulate the decay heat and the radiation field of real HLW from reprocessing. But the residual content of fissile material (mainly  $^{239}\text{Pu}$ ) of the US-made glass logs rendered impossible for regulatory reasons to bring the vitrified waste into the Asse URL.

The test was therefore carried out using electric heaters only. Since some of the objectives could not be attained under these new circumstances the test plan was changed and the test terminated in form of a controlled shutdown during the year 1993. The laboratory program was continued as foreseen until the end of 1994. A view of the test set up during the preparation phase is shown in Fig. 5.



Fig. 5 HAW-Project test site during construction

A further large-scale in situ test was aimed at demonstrating the feasibility of constructing an underground sealing dam as needed to tightly seal and isolate disposal areas from the rest of the mine. In spite of budgetary restrictions in the wake of German reunification that rendered impossible to reach the final demonstration phase, this test provided and it is still providing valuable insight and experience for the closure of repositories in salt, as the Morsleben repository and the Asse URL.

The “Active Handling Experiment with Neutron Sources” project (AHE), which ran from 1991 to 1995, was devoted to study the effects of neutron and gamma radiation backscattering from the underground vault walls. A simulated HLW disposal cask containing a strong  $^{252}\text{Cf}$  radiation source was used. The AHE-Project included participants from several countries. A main objective was to verify by means of in situ measurement the forecasts of occupational gamma and neutron radiation dose to repository operators during underground waste disposal. As neutron radiation is very important in case of spent fuel disposal, and since for many reasons it is intended to keep drift dimensions as narrow as possible, neutron backscattering from the drift walls was expected to significantly contribute to the dose received by the repository personnel. A first series of tests was performed on the surface to measure neutron radiation fields and spectra without backscattering. Thereafter, such measurements were repeated in the Asse URL at a large variety of configuration and drift dimensions. While neutron backscattering by air proved to be minimal, as expected, neutron backscattering by salt underground resulted to be quite significant.

The longest running in situ test at the Asse URL was the “Thermal Simulation of Drift Emplacement” project (TSS-project). In this large-scale heater test cask mock-ups containing electric heaters simulating the decay heat of spent fuel were used to study the interaction of waste packages with the salt in the waste near field, with a special focus on consolidation of the crushed salt backfill. The heaters were switched on in September 1990 and kept heating until February 1999 with a total power exceeding 36 kW, corresponding to the decay heat of about 24 t of fuel. The set up consisted of two parallel drifts with a length of 70 m each, a height of 3.5 m, and a width of 4.5 m with a 10 m wide pillar between them, with three casks mock-ups in each

drift. The dimensions, weight and heat output of the cask mock-ups correspond to those of the German Pollux cask reference concept: 6 m length, 1.6 m diameter and a weight of 65 t. The test set up is schematically shown in figure 6.

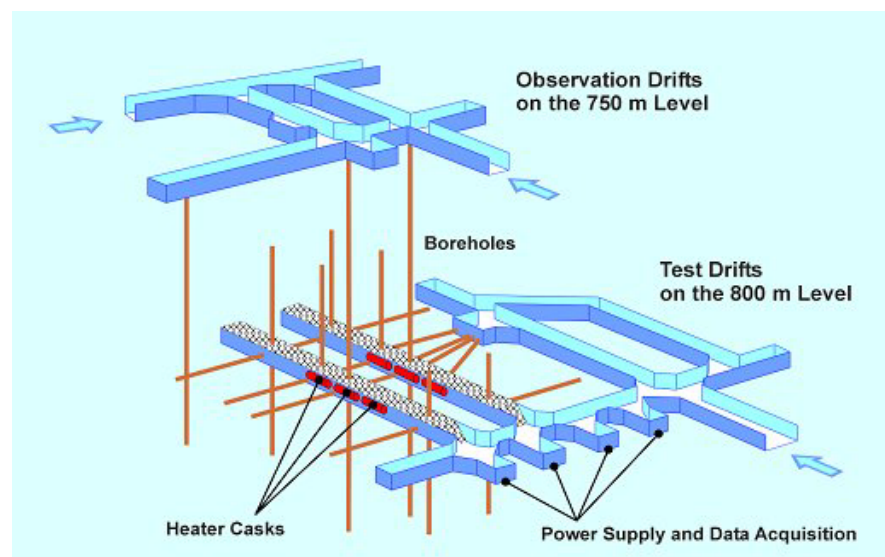


Fig. 6 Scheme of the TSS test layout

Re-excavation of one drift to study the now compacted backfill material, obtaining material samples for laboratory tests with consolidated salt and recovering corrosion specimens was recently carried out. Among others, retrieval of several of the installed monitoring devices will allow analyzing their current state and in some cases also assessing the causes of their failure. This very successful test rendered a large amount of data and information for validating numerical models needed to demonstrate HLW and spent fuel disposal long-term safety.

## OUTLOOK

These very few examples of experimental large-scale work in an underground research laboratory, together with a large, decades long research effort at universities and other research institutions; the demonstration of all needed equipment under real and/or simulated repository conditions; the construction of the encapsulation plant needed to manufacture the waste packages for disposal; all them substantiate the initially made statement about the availability of the knowledge and experience needed for implementing disposal. Furthermore, actual realization is well underway at Gorleben, with the exploration mine, designed to become a part of the repository if the site is finally confirmed suitable, quite close to reaching the originally intended site suitability statement.

Obviously, all involved parties have failed in separating the waste management issue from the continuation or not of the use of nuclear power. This is particularly obvious in Germany, where progress in the realization of waste final disposal was during twenty years a regulatory condition for nuclear plant operation. In fact one of two, the only other one being plant safety. Furthermore, the fact that an agreement about phasing out nuclear power use was signed in 2000 has not eased

the pressure on waste disposal project. Just the opposite happened. The Federal Government set up a commission to develop a procedure and criteria for selecting a new, single repository site starting from scratch, which would delay the availability of a repository for several decades. Interestingly, the next steps of the procedure suggested by the AkEnd commission would have been a wide public discussion with stakeholders on the proposed procedure. And exactly this will not take place due to the decision of most concerned stakeholders, from the waste producers to environmental NGOs, not to participate in the discussion, mostly because the room for negotiations is considered inadequate. The Government has therefore announced it would issue a law to implement the new site selection procedure. With this move, the perspectives for a negotiated solution to the long-lasting repository site conflict remain rather dim.

## REFERENCES

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