Konrad Repository Facing its Construction - 8229

V. Kunze
Bundesamt für Strahlenschutz (BfS)
Postfach 10 01 49, 38201 Salzgitter, Germany

ABSTRACT

According to the German Atomic Energy Act the Federation is responsible for the construction and operation of installations for the safekeeping and disposal of radioactive waste. This duty was assigned to the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz – BfS) .

In 1982, the Federal Institute of Physics and Metrology (Physikalisch Technische Bundesanstalt – PTB) as the precursor of BfS applied for a license for the disposal of radioactive waste with negligible heat generation in the Konrad iron ore mine near Salzgitter at the Ministry for Environment of Lower Saxony. After 25 years of plan approval procedure and subsequent lawsuits the license is now valid and Konrad is waiting for construction.

Facing this challenge BfS has established a project team to supervise the in-house and external activities to be done. It is intended to construct the Konrad repository within a preparation period of two years and a subsequent erection phase of four years. Thus, Konrad is planned to come into operation in 2013.

In this paper the development of the plan approval procedure, the technical design of the planned repository, especially with regard to safety-related aspects, and the planning for the construction will be discussed.

INTRODUCTION

In Germany it is intended to dispose of all types of radioactive waste in deep geological formations. The current situation is characterized as follows.

In the Asse salt mine techniques for the emplacement of low and intermediate level radioactive waste (LLW/ILW) were developed and tested from 1967 to 1978. Within this period of time about 125,000 m^3 LLW and about 1,300 m^3 ILW with a total activity of about 10^{15} Bq were disposed of. Not far away in the former German Democratic Republic the Morsleben repository came into operation a few years later. After German reunification BfS also got the responsibility for the Morsleben site, the so-called ERAM. From 1971 to 1998, 36,754 m^3 LLW and ILW and 6,623 spent sealed radiation sources with a total activity of $5.2 \cdot 10^{14}$ Bq (reference date end of 2005) were disposed of in the ERAM. It is now planned to decommission both sites and the licensing procedures are in progress. Both sites suffer from the fact that already existing mine openings from the extraction of rock salt and potash were used for the disposal of radioactive waste and that the final closure was not included in the operating license and, thus, the necessary safety assessments for the post-closure phase had not been done prior to any waste disposal.

In 1982, the abandoned Konrad iron ore mine situated near the town of Salzgitter (Federal State of Lower Saxony) was proposed as a repository for low and intermediate level radioactive waste with negligible heat generation. After 20 years of plan approval procedure, the license was granted by the Lower Saxonian Ministry for the Environment in May 2002. This decision was subject to several cases at the Lower Saxonian Higher Administrative Court in February/March 2006 where the legality of the license was confirmed. The Court denied a revision of the trial. This dismissal was brought to the Federal Administrative Court which finally confirmed the previous decision in March 2007. That means that from the legal point of view there is no breakpoint for the construction and operation of the Konrad mine as a repository for radioactive waste.

DEVELOPMENT OF THE PLAN APPROVAL PROCEDURE

Konrad is an abandoned iron ore mine located in Salzgitter in the Federal State of Lower Saxony. Two shafts were sunk from 1957 to 1962 and the extraction of iron ore started in 1960. Only 16 years later, in 1976, mining was stopped for economical reasons after 7 million tons of iron ore had been extracted. This was because the iron ore had only a Fe-content of about 27 to 33 % which could not compete with deposits in other countries. Furthermore, the percentage of phosphate was comparatively high.

Due to the fact that the Konrad mine is extremely dry a preliminary geological investigation program was already launched in 1975. Since this program revealed encouraging results for the suitability of Konrad, the PTB as the precursor of BfS applied for a license for the disposal of radioactive waste with negligible heat generation in 1982. In 1992 and 1993, a public hearing took place which, having lasted 75 days, was the longest one ever performed in Germany. Within this public participation about 200,000 objections were raised. In May 2002, the license was granted by the Lower Saxonian Ministry for the Environment . Then, it took another four years until the four cases filed by three municipalities and one local farmer were dismissed by the Lower Saxonian Higher Administrative Court in March 2006 and one more year until the Federal Administrative Court confirmed this decision in March 2007. That means that now , from the legal point of view, the way is free for Konrad to become a repository for 303,000 m^3 of LLW and ILW with a total beta/gamma emitter activity of $5 \cdot 10^{18}$ Bq and an alpha emitter activity of $1.5 \cdot 10^{17}$ Bq. The history of the Konrad mine is summarized in Table I.

So far, the costs for the whole plan approval procedure and scientific investigations including safety assessments have summed up to 916 million € (approximately 1.3 billion $). Another 900 million € are estimated to be necessary for the construction of the repository. This includes both, investment for new buildings and machinery as well as maintenance of the existing facility.

Table I. Konrad timetable

1933	Discovery of the iron-ore-deposit on the occasion of oil exploration.
1937-1943	First geological exploration via drilling.
1957-1960	Sinking of shaft 1.
1960-1962	Sinking of shaft 2.
1960	Start of extraction of the ore from tunneling.
1965	Start of extraction of the ore from room caving.
Since 1971	Conversion to trackless vehicles.
1975	Preliminary geological investigation
1976	Stopping of extraction.
1982	Application for a license
1992/1993	Public hearing (75 days)
2002	Licensed
2006	Cases dismissed by the Lower Saxonian Higher Administrative Court , revision denied
2007	Claim against court judgment dismissed by Federal Court, license valid

TECHNICAL DESIGN OF THE KONRAD REPOSITORY

Presently the Konrad mine consists of two shafts and galleries of about 40 km in length. The mine openings comprise 6 levels ranging from 800 m to 1,300 m depth. Shaft 1 is the intake air shaft. The return air is completely released via shaft 2. In contrast to Asse and Morsleben, no existing mine openings will be used for the emplacement of radioactive waste. For this reason, the ventilation conditions will be well defined. It is intended to dispose of the waste in galleries of about 400 m to 1,000 m length. The return air from the waste galleries will be conducted separately from any working places via ventilation boreholes, return air drifts, and shaft 2 and will be released into the environment through a diffuser of 45 m height.

Whereas the emplacement of 650,000 m^3 of radioactive waste was applied for in 1982, the waste volume was restricted to 303,000 m^3 in the license from 2002 due to the actual amount of waste with negligible heat generation being expected until the year 2080. This was done because Germany had decided to phase out the use of nuclear power for electricity production. The emplacement of gaseous and liquid wastes is excluded. The term “negligible heat generation” means that the temperature on the edge of the emplacement chambers will not rise by more than 3 K on average due to the decay heat of the radioactive waste. Table II shows the division of the existing amount of radioactive waste in Germany of 115,053 m^3 into different categories (reference date end of 2006). The origin of the existing conditioned waste of 88,515 m^3 from various fields of applications is given in Table III.

Table II. Current inventory of radioactive waste in Germany

Type of residue	Waste volume
Unconditioned residues (recyclable residues and primary waste) Inventory at the end of 2006	17,035 m³
Interim products Inventory at the end of 2006	9,503 m³
Conditioned waste Inventory at the end of 2006 Arising in 2006	 88,515 m^3 3,983 m^3
Prognosis for 2007	~ 5,500 m^3

Table III. Origin of conditioned waste in Germany (88,515 m^3)

Origin of radioactive waste	Relative portion
Research facilities (incl. clients)	44 %
Nuclear power plants in operation	17 %
Decommissioning or dismantling of nuclear facilities	12 %
Reprocessing facilities	16 %
Nuclear industry	7 %
Federal state collecting depots (incl. military)	4 %

Figure 1 shows an aerial view of the above ground installations at shafts Konrad 1 and 2 as it appeared in October 2007. The two shafts are about 1.5 km apart. Shaft Konrad 1 is in the background of the figure and serves for personnel and material transports. Shaft Konrad 2 was part of the Salzgitter steelwork and is thus directly connected to an industrial site. Later on, shaft 2 will serve as emplacement shaft. In between the two shafts the village of Salzgitter Bleckenstedt and the Salzgitter channel, serving as transport route to the steelwork for various goods, are visible.

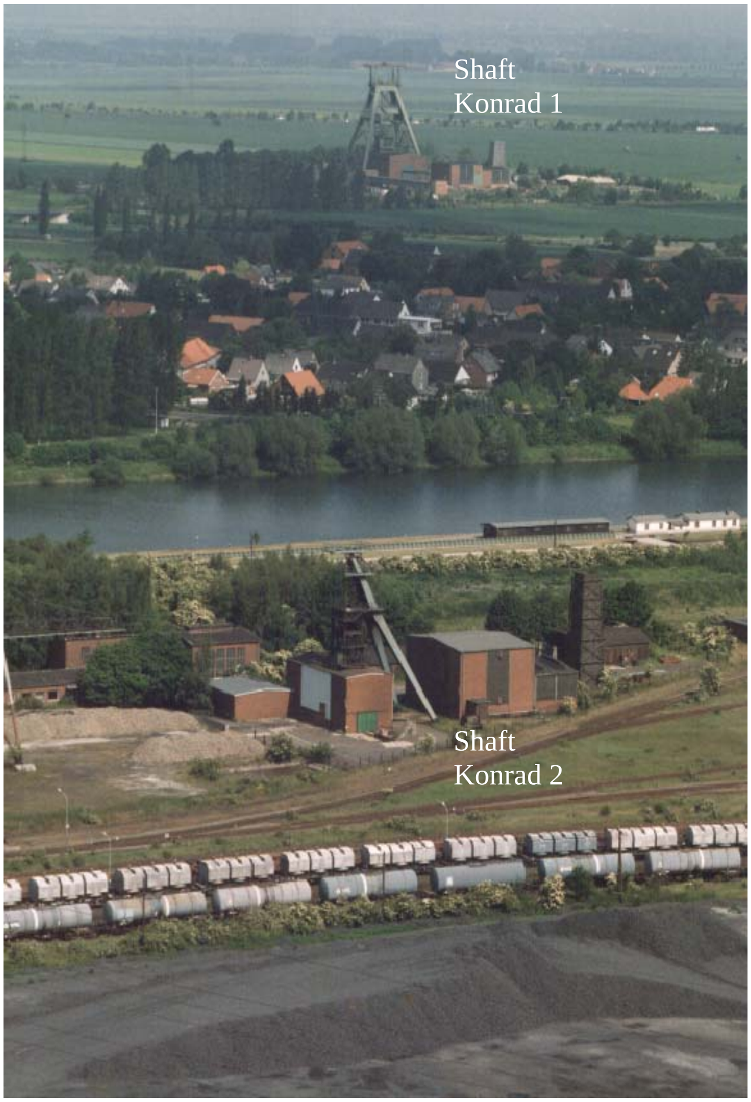

Fig. 1. Aerial view of the two Konrad mine shafts (October 2007)

A perspective of the buildings and installations to be erected at shaft 2 is given in Figure 2. The waste will either be delivered by train or truck. Main components are the reloading and transfer building (1) with a drying plant being connected upstream., the new hoisting tower and shaft hall (2), the ventilator building with diffuser (3) and the storage building for the buffering of radioactive waste (18).

Six types of cubic and four types of cylindrical containers will be accepted in the Konrad repository, the latter being delivered on pool pallets with up to two cylindrical units in horizontal position. The container gross volume ranges from 0.7 m^3 to 10.9 m^3 with a maximum mass of 20 Mg. Konrad is designed for the acceptance of 6,800 transport units per year (cubic containers or pool pallets) within a two-shift operation. In this respect, an average shaft transport frequency of 17 per shift and 200 days of emplacement per year were adopted. Since up to 40 transport units can be accepted per shift and, due to possible disturbances in operation, the storage building is designed for buffering up to 258 waste containers.

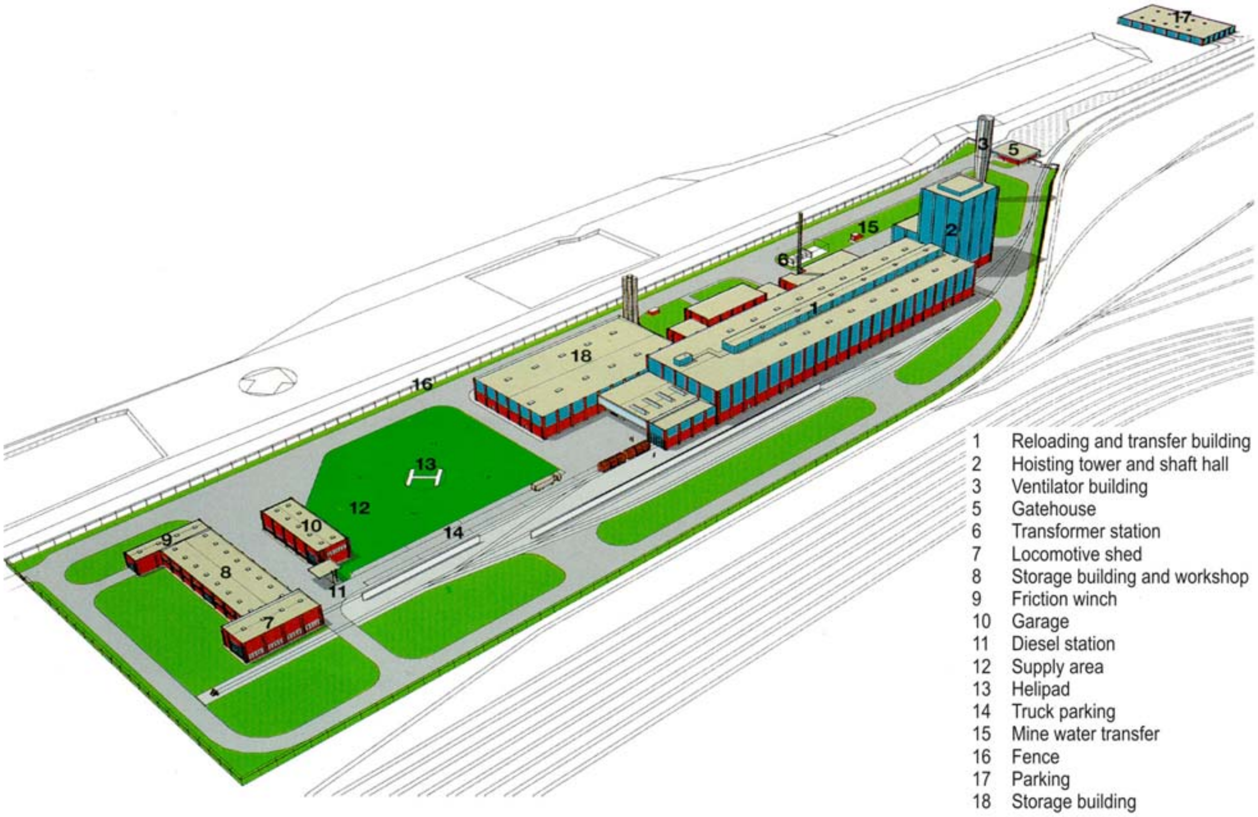

Fig. 2. Perspective of planned shaft 2

Inside the reloading hall the containers are unloaded from the respective vehicles and then placed on an internal flatcar conducted by railways. The transportation of these flatcars is remote controlled. After an automated contamination control and local dose rate measurements the waste containers are either fed to the shaft transport system or buffered inside the storage building with the help of a special forklift truck. Below ground at the 850 m level the containers are taken from the flatcar with a portal crane and then placed on an electric driven truck. After transportation below ground to the emplacement drifts a fork lift truck picks up the containers and stores them inside the stack.

Emplacement takes place in drifts 7 m wide and 6 m high. After a drift length of about 50 m is filled with waste a shotcrete wall is erected and the residual cavities behind the wall are backfilled. This is done with a mixture of about 70 % of Konrad debris (Ø ≤ 5 mm), 20 % of water and 10 % of cement plus retarder. The purpose is to ensure a tight enclosure of the waste packages, to minimize residual voids and to prevent any accumulation of explosive gas mixtures.

The emplacement of radioactive waste is illustrated in Figure 3, where the three different stages “emplacement”, “sealing” with shotcrete wall and “backfilling” are visible. Once an emplacement drift is filled it will again be equipped with a sealing and then be backfilled from the exhaust air drift via the respective borehole.

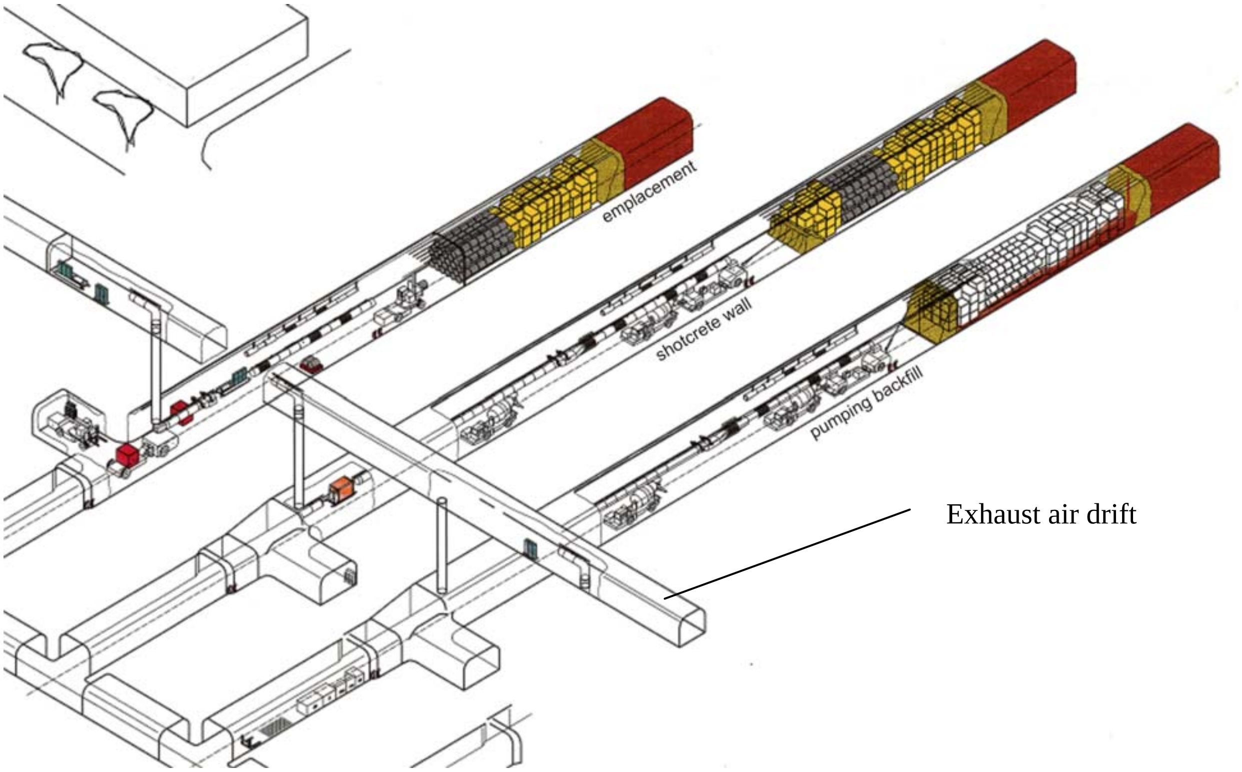

Fig. 3. Planned emplacement of radioactive waste at Konrad

GEOLOGY AND LONG-TERM SAFETY

The initiative to investigate Konrad as a potential site for a repository was given by the staff themselves in the middle of the 1970ies because Konrad was known to be extremely dry as compared to other mines. Konrad is located in the south of a large iron ore formation. The sediment was deposited about 150 million years ago during the Upper Jurassic (Malm). The iron ore horizon has a maximum dip of 22 degrees in a westward direction. The overlying cretaceous strata mainly consist of clayish rock with a total thickness of several hundreds of meters and completely cover the iron ore sediment. For this reason, there is no connection to groundwater leading horizons above the clayish rock. The small amounts of water found in the mine (so-called formation water) have proven to be at least 10 million years old and are possibly as old as the Jurassic ocean (150 million years). Furthermore, no hints of groundwater movement in horizontal direction have been found. As an upper limit for groundwater movements 1 cm per 1,000 years could be derived. Another important fact is that the salinity of the Konrad groundwater increases with depth. This indicates that the potential vertical transport of radioactive substances is only diffusion-dominated.

Despite this scientific evidence, potential pathways for a release of radionuclides in the post-operational phase were investigated. The result was that the time span from the closure of the repository until the first radionuclides may reach the biosphere under conservative assumptions is at least 300,000 years. Due to the model calculations, the bandwidth of groundwater flow times varied from 330,000 years up to 38.8 million years. For the long-term safety assessment and the derivation of activity limits per waste package (see below) a freshwater model was used in order to minimize the calculation effort. In a conservative manner, this yields rather short flow times. However, this model assumption is not realistic. If the salinity is taken into account there is almost no water movement and, thus, a zero release of radionuclides.

OTHER SAFETY ASSESSMENTS AND WASTE ACCEPTACE REQUIREMENTS

Safety assessments were performed for normal operation, assumed incidents, the thermal influence on the host rock, the criticality safety and the long-term safety in the post-operational phase. From all these analyses nuclide-specific activity limits were derived in such a way that the corresponding limits of the Radiation Protection Ordinance or the self-given design data were kept. These derived limits for the disposable activities per waste package were laid down in the waste acceptance requirements.

Some safety aspects regarding the host rock temperature and the long-term safety have already been briefly discussed above. In the following the focus is laid on some important safety aspects for the operational phase.

Normal Operation

For normal operation the radiation exposure to the staff and the environment was assessed. Direct and scattered radiation from the waste packages give rise to external exposure to the personnel and the members of the public. The possible release and discharge of volatile radioactive substances via the diffuser may cause an inhalation of radionuclides by the workers and the public. Furthermore, for the public, the deposition of radionuclides in the environment via the air and water path and the resulting ingestion doses were calculated. In accordance with the values applied for the release rate limits given in Table IV were licensed.

The calculation was done assuming a total length of open emplacement drifts (filled with waste but not yet backfilled) of 400 m. From such wastes a release of the volatile radionuclides as given in Table IV may occur. After backfilling there is no release of radioactive aerosols, iodine and radon which will be completely captured in the backfill due to its short half-life of 3.8 days. According to the safety assessments performed only tritium (H-3) in the chemical form of HT or C-14 in other forms than CO_2 (e.g. CH_4) may be released from backfilled emplacement drifts.

A possible contamination of the waste water is only expected from naturally occurring radionuclides or the species mentioned above due to the condensation in the mine and the diffuser building.

An important feature of the Konrad repository is the parallel ventilation of emplacement and excavation areas. This ensures that in normal operation and in the case of incidents the activity released is limited to a small region of the mine where no permanent workplaces are located. It is also noteworthy that in contrast to Asse and ERAM no existing mine openings will be used for disposal such that the ventilation conditions are well defined.

Table IV. Release rate limits and corresponding calculated annual doses for the public

Radionuclide/ Path of release	Release rate limit of the license (Bq/a)	Maximum potential radiation exposure (µSv/a)
Return air		
• H-3	$1.5 \cdot 10^{13}$	2
• C-14	$3.7 \cdot 10^{11}$	31
• I-129	$7.4 \cdot 10^{6}$	0.6
• Rn-222	$7.4 \cdot 10^{11}$	5
• β/γ-aerosols	$7.4 \cdot 10^{7}$	0.5
• α-aerosols	$3.7 \cdot 10^{6}$	< 0.8
Total		40
Waste water		
• H-3	$7.4 \cdot 10^{12}$	20
• Other radionuclides	$7.4 \cdot 10^{8}$	24
Total		44

Incidents

Possible incidents which may occur during the operational phase due to events inside the plant and as a result of external events have been systematically analyzed. According to the “Incident Guideline for Pressurized Water Reactors” these incidents have been assigned to the following categories:

Category 1:	Incidents whose radiological effects are limited by the design of the plant and/or waste packages (design basis incidents).
Category 2:	Incidents which are excluded by the design of the plant and/or waste packages.

After the assessment of mechanical and/or thermal loads on the waste packages the following radiological representative incidents have been derived:

1. Dropping of waste packages during handling from a height of 3 m onto the floor of the reloading hall (above ground)
2. Dropping of waste packages during emplacement in the disposal room from a height of 5 m (below ground)
3. Burning of an underground vehicle during waste transportation in a transport gallery with a temperature of 800 °C for one hour.

As a result of the incident analysis six different waste form groups and two waste classes were introduced according to the different release behavior of the waste forms and waste containers. These waste form groups were used without any changes in the assessments for normal operation and the long-term safety.

The derivation of activity limits for the different types of waste packages was done in such a way that for each radiologically important radionuclide the resulting doses were still below the limits of the Radiation Protection Ordinance (effective dose and dose for the critical organ). For a mixture of radionuclides a sum rule has to be applied ensuring that for all relevant radionuclides the sum over the nuclide-specific activity in relation to the respective activity limit for the waste package is below one ($S < 1$).

Criticality Safety

There are also requirements regarding criticality safety. When fissile material is delivered to the repository the transport regulations will ensure criticality safety. Thus, it must be analyzed whether in the course of handling or storing the waste either in the storage building above ground or in the emplacement drifts below ground a critical arrangement is possible. The same applies to the post-operational phase in case there may be a water intrusion into the repository. As a result, limitations for waste packages were also derived from the criticality safety point of view.

Optimization of Radiation Protection

Already in the course of the involvement of the public and the public hearing in 1992/1993 is was argued that the so-called backward calculation method by deriving disposable activities under the assumption that the dose limits of the Radiation Protection Ordinance (RPO) are almost reached does not comply with the optimization principle. In Germany, the optimization principle is stated in § 6 RPO with the duty

- to avoid any unnecessary radiation exposure or contamination of man and environment, and
- to keep every radiation exposure or contamination of man and environment as low as possible below the limits taking into account the state-of-the-art of science and technology and the circumstances of the single case.

The objection is, in principle, true. It must be noticed, however, that for every licensing procedure there is a need to demonstrate safety with conservative assumptions that need to cover the whole range of possible operational states and in the special case of a repository need to cover all possible types of waste. For this reason and due to lack of information regarding future wastes, it was necessary to chose a rather conservative approach for the safety assessment. It is obvious that, among others, assumptions such as

- all waste packages have the maximum admissible local dose rate of the transport regulations (2 mSv/h on the surface, 0.1 mSv/h in 2 m distance) and
- all waste packages have the highest possible inventory according to the waste acceptance requirements

are quite unrealistic as it is the case for many other licensing procedures in the nuclear sector. For instance, recent data investigations of BfS have shown that instead of the licensed β/γ-activity of $5 \cdot 10^{18}$ Bq only about $8 \cdot 10^{16}$ Bq are expected until the year 2040. Such comparisons may yield confidence that real doses for the personnel and the public will be far below the calculated ones.

Apart from that, the optimization principle will be obeyed in the operational phase by carefully evaluating all radiological parameters and looking for improvements for public and worker protection in order to ensure that real doses will be far below the limits.

CONSTRUCTION OF THE REPOSITORY

After the legal basis for the construction of the repository has been established by the decision of the Federal Administrative Court in March 2007 BfS is now facing the challenge to further plan and construct the repository within a preparation period of 2 years and a subsequent erection phase of 4 years.

Since now the boundary conditions for planning have been fixed the preparatory work as well as the implementation planning can be performed. There are also some necessary sanitation measures which, due to the lack of boundary conditions, have been delayed so far. At shaft Konrad 1 (see figure 1) only some replacements and sanitation measures are necessary. In contrast to that, at shaft 2 the buildings will be completely dismounted (compare Figures 1 and 2) and the pit frame of shaft 2 was already removed due to necessary rehabilitation measures at the shaft transport system.

As a matter of fact most of the documents and planning originate from the 1990ies and need to be revised because from that time on until now no adaptation was appropriate. The last revision of some documents was necessary after the implementation of the new Radiation Protection Ordinance in 2001.

Since it has been known from World War II that there might be some unexploded ordnance devices at shaft Konrad 2 a corresponding remediation of explosive ordnance is necessary before the new buildings for the repository can be built. For nature conservation reasons and in order to stick to the envisaged time schedule this must be done before the incubation of birds in spring 2008.

The license also includes a lot of collateral clauses that need to be fulfilled before radioactive waste will be emplaced. This is especially the case for the waste acceptance requirements which are, so far, preliminary. This special topic is discussed in another contribution to this conference [1]. With all this in mind, the aim for the Konrad repository to come into operation at the end of 2013 is ambitious but realistic.

REFERENCES

1. G. BANDT, G. SPICHER, S. STEYER, and P. BRENNECKE, “Disposal of LLW and ILW in Germany – Characterisation and Documentation of Waste Packages with respect to the Change of Requirements - 8363”, contribution to this conference