1. Introduction – Konrad repository and its history

The Konrad mine, an abandoned iron ore mine located in the area of the city of Salzgitter (Federal State of Lower Saxony, Germany) is currently being converted to a repository for radioactive waste with negligible heat generation (Intermediate Level Waste - ILW and Low Level Waste - LLW). The overall responsibility for the construction and operation of the Konrad repository is with the Federal Office for Radiation Protection (BfS).

Two shafts were sunk from 1957 to 1962 and the extraction of iron ore started in 1960. Because of its favourable geology (Figure 1), the mine was investigated for its suitability to host a repository for LLW and ILW as early as in 1976, after iron ore production had stopped as a result of non-profitability. The iron ore deposit located in a depth of 1,300 m to 800 m is 12 to 18 m thick. However, the natural barrier in the form of clay and marl layers lying above the mine is vital; being up to 400 m thick, it seals the mine from groundwater. On account of the clay and marl layers, Konrad is an exceptionally dry mine, compared with other iron ore mines.

In 1982, the Konrad mine was proposed as a repository for LLW and ILW with negligible heat generation. At the beginning of 2007, a definitive plan-approval decision (licence) was granted for the construction and operation of the repository by the Lower Saxon Ministry for the Environment (NMU). Thus, the Konrad repository is the first facility for radioactive waste management in Germany, for which a nuclear plan-approval procedure was conducted prior to taking it into operation. The Konrad repository is permitted to take up max. 303,000 m³ of radioactive waste with a total activity of $\beta$- and $\gamma$-emitters of $5.0 \cdot 10^{18}$ Bq and $\alpha$-emitters of $1.5 \cdot 10^{17}$ Bq.

The two shafts of the Konrad mine are about 1.5 km apart. Shaft Konrad 1 serves for personnel and material transport. Shaft Konrad 2 will serve as emplacement shaft. The underground situation of the Konrad repository below ground is displayed in Figure 2.

2. Safety analyses for the Konrad mine

Comprehensive safety analyses were made in the scope of the plan-approval procedure for the Konrad repository. Five aspects of safety analysis were investigated: 1. “Normal operation”, 2. “Accidents”, 3. “Thermal influence on the host rock”, 4. “Criticality” and, 5. “Long-term safety”. All safety analyses were examined by experts on behalf of the NMU and compliance with specifications is controlled also by the state mining authority.
FIG 1: Geological profile of the region of the Konrad mine showing the iron ore body of a thickness of 12 m to 18 m. The future repository at a depth of 800 m to 1,300 m is covered by thick clay layers of up to 400 m.

FIG 2: Underground situation of the Konrad repository. Excavation of the waste galleries has been completed. Extensive work has been done on the surface facilities of Shaft 1 and the building site equipment at Shaft 2 was set up.

These safety analyses determine requirements for the technical systems and components, the operating procedures and the waste packages to be disposed of. They are binding in order to guarantee safe operation and to minimise possible consequences. Furthermore, it was investigated in long-term safety analyses how the repository could develop after it has been sealed and possible consequences were derived. The long-term development of the Konrad repository was forecast with the help of geo-scientific methods. In model calculations, the dispersion of radionuclides from the repository up into the groundwater near the surface was examined and evaluated. The model calculations show that it would take radionuclides at least 300,000 years to get into the groundwater near the surface. For the transport of long-lived radionuclides with a higher retention level in the geosphere, the model calculations show relevant concentrations only after several million years. The calculated maximum radionuclide concentrations that may occur in the groundwater near the surface have been taken as a basis for the determination of the radiation exposure in the biosphere. For an infant, the effective dose calculated according to the provisions set out in the Radiation Protection...
Ordinance is max. 0.26 millisieverts per year (mSv/a); for an adult it is max. 0.06 mSv/a. It is thus lower than the value of 0.3 mSv/a, this value having been applied for evaluation by the licensing authority. Altogether, the possible impact on the near-surface groundwater through the release of radionuclides and other pollutants from the repository is so low that no adverse effects to man and environment need to be feared.

In addition to the safety analysis of normal operation, accidents were analysed. That means, events in the planned operating procedures which might lead to a release of radioactive substances into the environment were identified and evaluated. Technical or human failure and rock-mechanical causes can be the reason for such accidents. In that context, the NMU stated that the Konrad repository was designed in a manner that is balanced from the safety point of view. Precaution required according to the state of the art of science and technology has been taken against damage.

3. Evaluation of the Safety Requirements according to the state of the art of science and technology

According to the current state of knowledge, there is no information available that is questioning the safety statements given in the application documents. Furthermore, 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. However, the BfS as a responsible owner and operator has still provided for an evaluation of the safety requirements according to the state of the art of science and technology prior to the repository being taken into operation. Here within, the BfS sets a good example to improve safety standards and attempt to contribute to increase trust and confidence into radioactive waste disposal.

The evaluation of the safety requirements according to the state of the art of science and technology of the Konrad repository was initiated in 2014 and was continued with an expert workshop to involve professional audience and stakeholders in April 2016. In the framework of the workshop, safety-related aspects were collected, discussed and prioritised in three working groups. The results of the working groups were published on the website of the BfS and are taken into account in the work of the BfS. Targeted information of professional audience and stakeholders will be continued at workshops and the public will be informed continuously about the progress of the work via the internet.

The planned procedure of the BfS includes a step-by-step approach: 1. “Identification of required updates of the safety analyses” and 2. “Update of safety analyses as required” (Figure 3). The BfS coordinates and controls the entire process. Preparatory work is ongoing and the phase, “Identification of required updates of the safety analyses” will be initiated by a tendering procedure. The BfS will award the contract and the contractor will extensively assess the safety statements given in the application documents. These safety analyses will be compared according to the state of the art of science and technology (delta analysis). Depending on the results, further steps will be conducted. The phase “Update of safety analyses as required” will be executed if the assessment of the current safety analyses show deviations from the state of the art of science and technology.

The work of the contractor will be continuously monitored by external experts via scientific monitoring. The external experts will be installed by the regulatory authority, the Federal Office for the Regulation of Nuclear Waste Management (BfE). The experts will discuss the contractor’s results on a regular basis and advise on the work, if needed and the BfS will coordinate the cooperation of the participants.
To ensure neutrality and to control quality of the evaluation of the safety requirements, the contractor’s work will be reviewed comprehensively (Peer Review) at the end of each phase. The contractor will adapt the work accordingly and the BfS will compile the final results of the work as well as the outcome of the scientific monitoring and the Peer Review to prepare a final judgment about the evaluation of the safety requirements according to the state of the art of science and technology.

In case that evaluation of the safety requirements shows that technical adjustments are required, the BfS will adjust the planning and adapt possible technical changes prior to taking the Konrad repository into operation. A periodic evaluation of the safety requirements according to the state of the art of science and technology will continue after the Konrad repository has been taken into operation (Figure 3). The entire process will be documented carefully to prepare guidelines for future safety assessments.

4. Conclusion

The Konrad mine is the first repository in the Federal Republic of Germany which has been and will be planned, constructed, operated and sealed pursuant to the stringent specifications of nuclear law, from the beginning of filing the application until the sealing of the mine later on.

There is no information available that is questioning the safety statements given in the application documents at this point in time and an evaluation of the safety requirements is not required by law prior to the repository being taken into operation. However, the BfS as a
responsible owner and operator proceeds with the assessing of the safety requirements according to the state of the art of science and technology even now.

Neutrality and transparency need to be ensured throughout the entire procedure and the BfS is monitored by the federal state of Lower Saxony and by the BMUB.

Further on, additional scientific monitoring of external experts, installed by the regulator BfE and Peer Review of the evaluation of the safety requirements according to the state of the art of science and technology is used for the purposes of neutrality. Together with targeted public relations work, transparency of the process will be promoted to improve public acceptability of the repository.

Future periodic evaluation of the safety requirements will be ensured by preparing guidelines based on the current approach. Furthermore, the BfS will continuously monitor the development of the state of the art of science and technology.