Long Term Safety of the Asse Salt Mine

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Abstract. The strategy for performance assessment of the long term safety of a salt mine with radioactive waste is complex. It must include various aspects of geochemistry, fluid flows, geomechanics, geology, hydrology and radiation protection. The concept of geochemical engineering to ensure low radionuclide solubilities and enhance sorption as well as program tools to model fluid flows in the galleries and shafts with and without technical barriers have to be developed and fine tuned for selecting technical measures to enhance the long term safety. These results have to be combined with the hydrogeological model and the geologic long term prediction. The radiological exposition of man has to comply with the limits given by the federal laws for radiation protection to prove the long term safety. The current status of assessment of long term safety of the Research Mine Asse is presented here.

Introduction

The Asse salt mine operated from 1909 to 1964. In this period chambers were excavated with a total volume of more than 4 million m^3. The salt mine was acquired by the GSF as a research and development site for nuclear waste disposal in 1965 in contract with the federal government. The mine was used subsequently as a test site for low-level nuclear waste disposal from 1967 to 1978. The salt mine was used thereafter as a research and development site for high level waste disposal. Since termination of research in 1995 the mine is backfilled and prepared for closure. A prerequisite for the mine closure in 2013 is an assessment of the long term safety in order to comply with federal laws.

Important boundary conditions for the long term safety of the Asse salt mine are:

1. A site-specific property of the Asse Salt Mine is large excavated volumes and a network of galleries and shafts.
2. Brine (saturated with halite) is leaking into the Asse Salt Mine for several years now. The origin of the brine is not exactly known. There are indications of a supply with groundwater.

Brine will corrode the disposed waste containers. Radionuclide from the waste will disperse in the salt solution and will be transported to the biosphere finally. In addition the brine alters carnallitite rock leading to geomechanical instabilities.

Therefore, a series of technical measures are considered to ensure as low as reasonably possible potential radiological consequences in future times. This is called the Asse closure concept.

Calculations did show the necessity of technical measures to achieve a lower level of radiological exposition.

Multi Barrier System and Technical Measures

The multi-barrier system for an underground waste repository is illustrated in Fig. 1. Neither can the disposed radioactive material, its cemented or bituminized waste matrix and waste container be strengthened as a barrier nor the host rock, geosphere and biosphere. The remaining technical barriers include emplacement chamber, disposal level and the mine. They can be enhanced by technical measures.

Radioactive Material (RM)	
Technical Barrier (TB)	Waste Matrix (WM)
	Waste Container
	Waste Chamber
	Disposal Level
	Mine Building
Host Rock (HR)	
Geosphere (G)	
Biosphere (B)	
Man (M)	

Fig. 1. Multi Barrier System.

The closure concept aims to lower the release of radionuclides and to limit and hinder their transportation to the geo- and biosphere. Technical measures are possibly applied to the emplacement rooms, disposal level (near field), the mine and shafts. The various aspects of technical measures are:

Waste chamber

1. Minimizing the fluid volume in the chamber (backfilling)

2. Hindering fluid inflow into the chamber (barriers, plugs)
3. Lowering the solubility of radionuclides (geochemical buffer)

Disposal level

1. Hindering fluid flows in the mine (barriers)
2. Hindering fluid flow through the chambers (barriers, plugs)
3. Avoidance accumulation of gas in the chambers (buffer, transport)
4. Avoidance of brines of different densities

Mine

1. Minimizing the convergence rate (backfilling)
2. Avoidance of brines with different densities (backfilling)
3. Stabilizing the mine and minimizing host rock deformations (backfilling)
4. Minimizing carnallitite alteration (backfilling)

Shafts

1. Sealing the shafts

Closure Concept

1. The present closure concept includes the option to lower the solubility of radionuclides using a geochemical buffer.
2. Barriers and plugs are build at various places to hinder fluid flows in chambers and galleries (disposal level).
3. Backfilling of the salt mine with crushed salt provides stability of the mine.
4. Backfilling of the remaining pore volume with $MgCl_2$-rich brine lowers the convergence rate significantly and reduces alteration of carnallitite significantly.

Long Term Safety

The performance assessment of the long term safety comprises several steps:

Scenario Development

The basis for an assessment of long term safety of the Asse salt mine is a site-specific scenario analysis, which identifies a number of potential evolutions –

called scenarios. They should be assessed for their potential consequences. The scenario analysis includes the Multi Barrier System along with site-specific screening of catalogues of features, events and processes (FEP). This, for the Asse salt mine, led to two main scenarios, which are fluid mediated:

1. "Asse Closure Scenario" implying technical measures as outlined in the closure concept
   and
2. "Asse Natural Filling Scenario" implying natural filling of the mine with saturated NaCl-brine.

Transport of radionuclides in the mine

The inventory of the disposed radioactive waste is documented. Using the inventory, a source term is calculated applying a geochemical speciation code (EQ3/6). This assumes a quasi-closed system in the emplacement chamber as depicted in Fig. 2 (Schuessler et al. 2001a, b). After equilibration the fluid may be squeezed out (small arrows) by the convergence of the surrounding host rock (thick arrows).

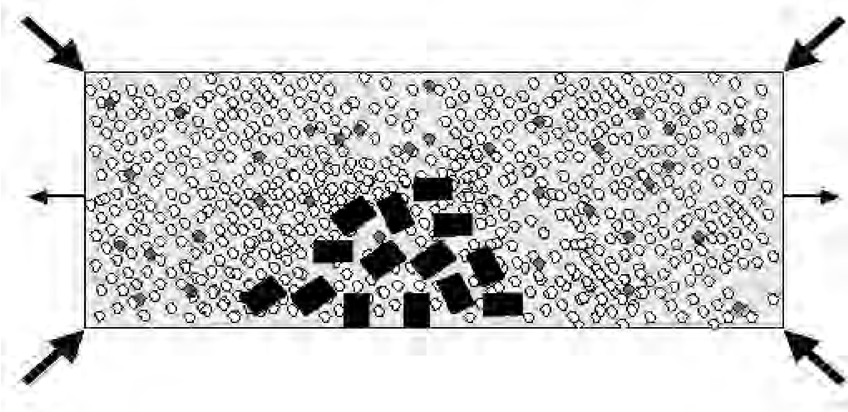

Fig. 2. Quasi-closed system and convergence.

Applying the source term to a model of the mine the pathways and dilution processes of the nuclides are calculated. The main driving force for squeezing out the fluid is the convergence. Minor driving forces are gas accumulation, temperature and density changes of the brine, which can cause additional fluid flows in the mine.

A sketch of the mine and its first model representation is given in Fig. 3. This simplified model showed that technical measures at the disposal level are sufficient to hinder fluid flows in the mine. A more detailed version of this model will be used to calculate the distribution, dilution and transport of radionuclides in the mine.

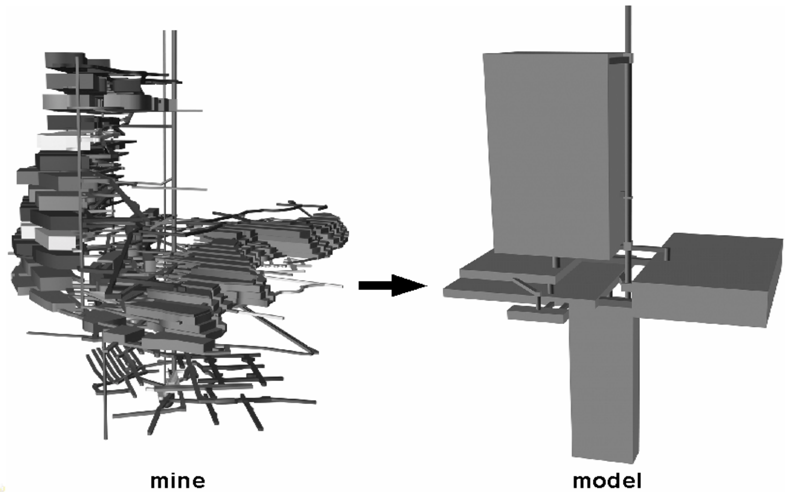

Fig. 3. Derivation of a simplified model of the mine

Transport of radionuclides in the overlying rock

According to analytical data (groundwater and brine chemistry, isotopic data) it is likely that the brine entering the mine contains meteoric water. The precise location of the brine leakage into the Permian salt formation is still unknown despite hydrogeologic and geophysical research (seismic, tracer experiments). A possible source and pathway of the brine entering the mine can be described as follows:

1. Groundwater penetrates through the overlying rocks of the Asse salt ridge
2. The underground passage leads to an increase of salinity of groundwater due to rock / water interaction
3. The brine is saturated (halite) by passing outer salt rock areas
4. Deformation processes resulting from the mining activities and long-term convergence caused cracks and fractures in the host rock of the salt ridge thus opening pathways for brines
5. The brine enters the mine at the weakest Permian salt rock zones.

The present leakage of brine into the mine is assumed to be the leakage for the contaminated fluid squeezed out to the geosphere. Using a hydrogeological model, the pathway of contaminated fluid into the biosphere is modelled through the overlying rock. Dilution, sorption and precipitation may reduce the amount of radionuclide reaching the biosphere.

Transport of radionuclides into the biosphere

Transport into the biosphere occurs by direct uptake of contaminated groundwater via plants and animals. Transfer coefficients are applied.

Potential Exposition

Combining all models yields the potential radiological exposition of man by the disposed radioactive waste for the given scenarios.

Summary and Conclusion

Two fluid mediated scenarios are the basis for performance assessment of the long term safety of the Asse salt mine.

The radionuclide inventory and its composition are documented.

Using this data gas generation is calculated.

The source term with application of a buffer is modeled using a geochemical code. The economic efficiency of its application still has to be proved.

A simple model of the mine showed that technical measures at the disposal level are sufficient to hinder fluid flows in the mine. Nevertheless a more detailed model is necessary to simulate the transport of radionuclides in the mine to the geosphere.

The discussion of the hydrogeological model of the brine leakage into the mine rsp. transport of brine in the geosphere is still in progress since various pathways are possible.

Up to date, only a normalized radiological exposition of man via the biosphere is available.

Combining all parts of the performance assessment of long term safety of the Asse salt mine is scheduled for 2004.

The outlined methodology has been proven to be successful at other sites to assess the consequences. The final performance assessment has to comply with the federal law for radiation protection in order to prove the long term safety and allow closure of the Asse salt mine.

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