Natural Analogues for containment providing barriers in rock salt: results from the German research project ISIBEL

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ISIBEL project: Status of Safety Assessment of Final Repositories for HLW in Salt

Status of Safety Assessment of Final Repositories for H

ISIBEL-I (2006-2010):

- Safety concept and safety demonstration strategy for HLW/SF repository
- In compliance with the German Safety Requirements
- Financed by Federal Ministry of Economics and Technology (BMWi)
- BGR, DBE Technology, GRS
- Identification of existing deficits

→ ISIBEL-II (2010-2013):

• (...)

Applicability of Natural Analogues for a Safety Case in salt



Objectives

Start of a systematic compilation and evaluation of how analogues can be used for the safety case of a HLW/SF repository in salt

Focus on the safety concept, i.e. the long-term safe containment by the assessment of the geological and geotechnical barriers

Safety Analysis \rightarrow Natural Analogues



Step 1: Identification of NA

For which aspects can analogues contribute to the assessment of safety?



Step 2: Assessment of NA

What is the status of the identified aspects / analogues?



Step 3: Future Work

Identification of future work on aspects / analogues



General safety concept in Germany (Safety Requirements)





General safety concept for salt (ISIBEL)





General safety concept for salt (ISIBEL)

= Avoid contact from water outside the CRZ with waste packages



compaction

= containment providing barriers





Site-specific safety concept (Salt dome Gorleben)





How to demonstrate safety?



STEP 1/2



Types of Analogues for the Safety Case

Safety function: containment
Integrity of the geological barrier
Integrity of geotechnical barriers

Safety function: retardation / containment

Natural analogues for release scenarios



STEP 1/2

Analogues for the integrity of the geological barrier



Aspect Application	S	Α	С
Existence of salt domes in Northern Germany Long-term stability of salt domes	++	+	фф
++ Natural Analogue identified and well documented	++		¢φ
+ Natural Analogue identified but documentation insufficient	++	+	Φ¢
Matural Analogue identified but no documentation	++	+	ф.
- Natural Analogue is not identified	+	Ø	Φ¢
Natural Analogue is (probably) not identifiable	++	++	¢
Chemical composition of fluid inclusions in salt formations Interaction between salt formation and external solutions	++	++	¢
Chemical and isotope composition of gas Migration of gases in a salt dome inclusions in salt formations	++	++	¢
Investigation of openings from salt mining Behaviour of rock salt in the depth	Ø	+	ф¢
Basalt intrusions in Fulda-Werra Series of Sealing of fissures (Self sealing)		++	¢φ
		++	-17-
など rather appropriate for communication with experts が な			~
The second secon	-	+	¢
Step 1	S ¹	tep 2	

Analogues for the integrity of geotechnical barriers

Aspect	Application	Α	С
Bulkhead drift in the Asse mine	Reduction of the permeability of an EDZ around drift sealings	+	ţ.
Basalt intrusions in salt formations (e.g. Fulda-Werra series of Zechstein)	Long-term behaviour of basaltic gravel as part of the shaft in rock salt	++	Φ¢
Chemical and mineralogical composition of natural clays	Impact of high temperatures on clay minerals	++	×
Properties of natural salt clays in salt deposits of the Zechstein	Long-term behaviour of clays/bentonite as sealing material in rock salt	+	¢
Corrosion of historical concrete buildings	Long-term behaviour of cementitious materials in rock salt	++	☆
Bentonites in saline environment	Long-term stability of bentonite as sealing element in rock salt	+	¢
Chemical and mineralogical composition of natural bitumen	Long-term behaviour of bitumen as material in sealing elements	+	ţ.
Degradation of organic material	Limits for microbial gas formation from organic material in geological time frames	+	ţ.
Compacted backfill material from old drifts and shafts in salt mines	Compaction of Salt grit over long time scales	Ø	☼

Analogues for release scenarios

Analogue	Application	Α	С
Stability of natural Basaltic glass	Corrosion of borosilicate glass	+	ф.
Uraninite deposits	Corrosion of spent fuel	+	ф¢
Basaltic glass in saline environment	Formation of secondary phases during glass corrosion and retardation of radionuclides	+	¢
Co-precipitation and sorption of radionuclides	Retardation of radionuclides on corrosion products from metal corrosion	+	×
Lanthanide distributions in low soluble mineral fractions of marine evaporites	Mobility of lanthanides (as chemical homologue for actinides) in salt formations	+	×
Precipitation of natural elements during formation and recrystallisation of salt deposits	Retardation of radionuclides in the salt dome by co-precipitation with salts	-	\
Behaviour of radionuclides in highly saline systems, e.g. sole of geothermic deep drillings, California	Radionuclide retardation under high saline conditions	+	¢
In-situ K _d values in sedimentary formations (Morsleben, Gorleben)	Confirmation of K _d values for the overburden from batch experiments	+	×
Uranium migration at Ruprechtov site	Behaviour of uranium and thorium in tertiary sediments of the overburden	+	×



Important Aspects for the Safety Case

	geological barrier					
designed lifetim	e geotechnical barriers					
	compa	acted cru	ished salt			
compaction						

Aspect	Application	S	А	С
Existence of salt domes in Northern Germany	Long-term stability of salt domes	++	+	ΦΦ
Stability of neotectonic conditions	Occurrence of earthquakes and magmatic events	++		ΦΦ
Thickness and composition of the cap rock	Subrosion rates	++	+	Φ¢
Analysis of the salt flow	Uplift rates	++	+	¢
Behaviour of competent salt formations in a salt dome	No continuous water pathway e.g. through anhydrite	+	ø	ά¢
Br- (and Rb)-distribution in minerals or rocks	Interaction of external solutions with the salt dome	++	++	¢
Chemical composition of fluid inclusions in salt formations	Interaction between salt formation and external solutions	++	++	¢
Chemical and isotope composition of gas inclusions in salt formations	Migration of gases in a salt dome	++	++	¢
Investigation of openings from salt mining	Behaviour of rock salt in the depth	ø	+	ΦΦ
Basalt intrusions in Fulda-Werra Series of Zechstein	Sealing of fissures (Self sealing)		++	ά¢
Basalt intrusions in Fulda-Werra Series of Zechstein	Behaviour of salt at high temperatures		++	¢
Kryogenic fractures in northern German salt diapirs	Formation and behaviour of fractures formed by salt contraction during cooling	-	+	¢

Aspect	Application	Α	С
Bulkhead drift in the Asse mine	Reduction of the permeability of an EDZ around drift sealings	+	¢
Basalt intrusions in salt formations (e.g. Fulda-Werra series of Zechstein)	Long-term behaviour of basaltic gravel as part of the shaft in rock salt	++	ΦΦ
Chemical and mineralogical composition of natural clays	Impact of high temperatures on clay minerals	++	¢
Properties of natural salt clays in salt deposits of the Zechstein	Long-term behaviour of clays/bentonite as sealing material in rock salt	+	¢
Corrosion of historical concrete buildings	Long-term behaviour of cementitious materials in rock salt	++	☆
Bentonites in saline environment	Long-term stability of bentonite as sealing element in rock salt	+	¢
Chemical and mineralogical composition of natural bitumen	Long-term behaviour of bitumen as material in sealing elements	+	¢
Degradation of organic material	Limits for microbial gas formation from organic material in geological time frames	+	¢
Compacted backfill material from old drifts and shafts in salt mines	Compaction of Salt grit over long time scales	Ø	₽



Important Aspects for the Safety Case

Mechanical behaviour of salt rock, e.g.	
 Earthquakes 	
 Competent salt rock (anhydrite) 	
 Composition of fluid inclusions \rightarrow U.Noseck 	
Thermal behaviour of salt rock	Geological barrier
Seals (permeability, long-term behavior)	
Compaction of crushed salt	Geotechnical barriers

• Microbial processes \rightarrow U.Noseck



Behaviour of competent formations (2011)









The repository system in Gorleben: Competent formations SE NN Quartär Tertiär -1000 m Oberkreide Unterkreide lura bis Wealden Keuper

-2000 m -21 Werra-Folge Rotliegend



Lab experiments / in-situ observations in the Gorleben salt dome



Source: Zulauf et al. 2010, Journal of Structural Geology 32



Source: BGR



In-situ observations in the Morsleben salt dome Anhydritmittelsalz (z3AM), -231m level, Marie shaft, Morsleben







Source: BGR



Behaviour of competent formations (2013)



- Competent layers embedded in incompetent material break under mechanical stress
- Several lab investigations
- Results from Gorleben exploration area

(but anhydrite is not always competent material $\rightarrow f(p,T)$)

Evaluation of literature / Investigation of other sites

- Morsleben (BGR)
- there are more!

Good example how Natural Analogues support a Safety Case! Can be communicated to the public!



Compaction behaviour of crushed salt (2011)

Ø

- Samples with significant reduction of porosity
- Geotechnical requirements: representative material, knowledge about initial state and history
- Suitable objects to be identified
- Example: Compacted rock salt from abandoned salt mine "Riedel" (about 20 years old)



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Crushed salt as long-term barrier: long-term compaction



Sample 3 (1% Moisture)

13th Natural Analogue Working Group Workshop, 13th to 16th May 2013, Nagoya



Possible objects for Natural Analogue investigations

Location	Ressource	Mining from	to	Remarks	Geology	Priority	contact
Bergwerk	Rock salt	1883	aktiv				Südwestdeutsche Salzwerke AG
Heilbronn							
							Salzgrund 67
							74076 Heilbronn
							Telefon: +49 7131 959-0
							Telefax: +49 7131 959-2270
							E-Mail: <u>info@salzwerke.de</u>
							Bereichsleiter:
							Dr. Gerd Bohnenberger
							Bereich: Bergbau und Salz
Salzbergwerk	Rock salt	1899	1994				Südwestdeutsche Salzwerke AG
Bad							Bergrat-Bilfinger Str.1
Friedrichshall-							74177 Bad Friedrichshall
Kochendorf							Telefon: +49 7136 271-3400
							Telefax: +49 7136 271-3405
							E-Mail: info@uev.de
Salzbergwerk	Rock salt	1854	aktiv				Wacker Chemie AG
Stetten							Salzbergwerk Stetten
							Salinenstrasse 49
							72401 Haigerloch-Stetten
							Deutschland
							Tel: +49 74 74694-0
							Fax: +49 74 74694-160
							E-Mail: info.stetten@wacker.com



Compaction behaviour of crushed salt (2013)



- Obseravtions in "nature" can never directly support safety case
- Samples with reduction of porosity exist
 - What conclusions may be drawn from real systems?
 - Requirements: representative material, knowledge about initial state and history (p,T,w)
- Suitable objects are identified / Clarification of boundary condition necessary
- Try to describe compaction state with models used in the safety case

Could be a good example how Natural Analogues support confidence in models! Process of high complexity \rightarrow Only for discussion with experts!

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Summary

- Safety Analysis \rightarrow Natural Analogues
- Mechanical behaviour of salt rock, e.g.
 - Earthquakes
 - Competent salt rock (anhydrite)
- Composition of fluid inclusions \rightarrow U.Noseck
- Thermal behaviour of salt rock
- Seals (permeability, long-term behavior)
- Compaction of crushed salt
- Microbial processes \rightarrow U.Noseck
- Communication of NA!!

Geological barrier

Geotechnical barriers

Thank you very much for your attention!

