Institut für Werkstoffkunde

Leibniz Universität Hannover

TRANSENS

TRANSDISZIPLINÄRE FORSCHUNG ZUR ENTSORGUNG HOCHRADIOAKTIVER ABFÄLLE IN DEUTSCHLAND

Uncertainties on the disposal path with regard to the technical barrier - the container system

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safeND - Interdisziplinary research symposium on the safety of nuclear disposal practices
Berlin, Westhafen Event & Convention Center – 10.-12.November 2021

Bundesamt für die Sicherheit der nuklearen Entsorgung

safeND

Uncertainties in the ongoing process – container issues.

- Which host rock will be selected in Germany?
- How should the repository system look like?
  - Longitudinal storage or borehole storage (horizontal or vertical)
  - Containers with self-shielding or without self-shielding
- How and where will the final repository containers be conditioned?
- What is the time period between the end of the site selection procedure and the decommissioning of the repository?
- Which cask materials are available and on what reasons are they selected?
  - Steel or cast iron
  - Corrosion-resistant cladding to fulfil the long-term safety verification (e.g. copper)
- In what manner can knowledge of the international state of the art be used in the national procedure?
  - Is copper really the best material or can modern alloys be better?
  - Which steels should really be selected (manufacturability, weldability, corrosion resistance)
  - Which environmental influences are relevant for the sites to be selected in Germany (corrosion rate)
- …

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Time periods of unknown duration?

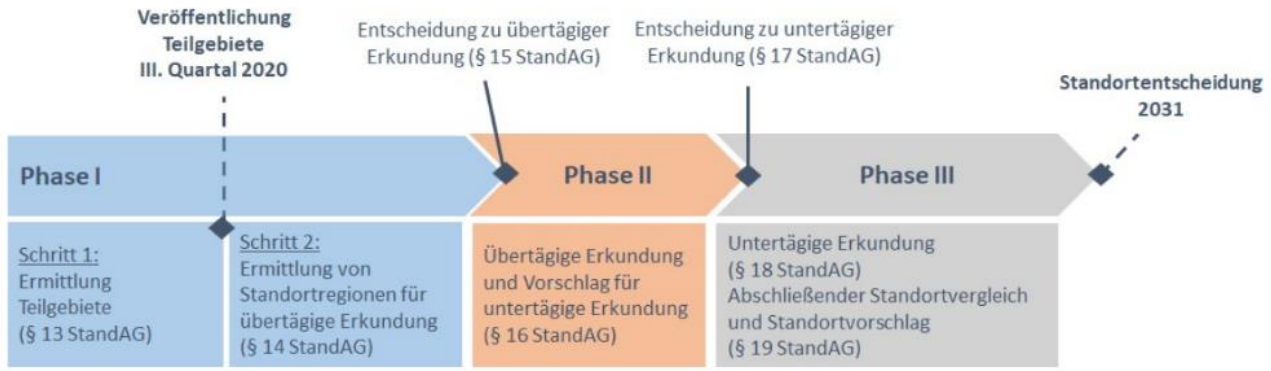


Abbildung 1: Schematische Darstellung der Phasen des Standortauswahlverfahrens.

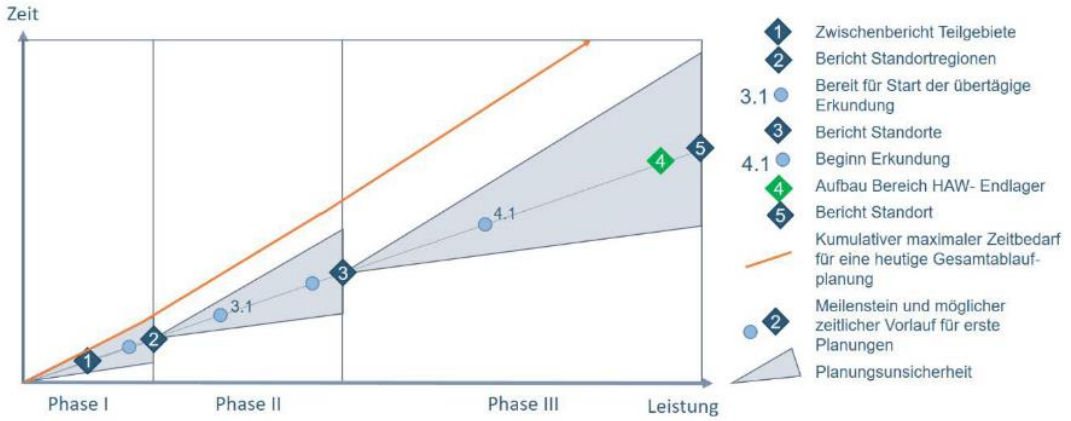


Abbildung 2: Ablaufplanung unter vorheriger Ausweisung von phasenübergreifenden Planaktualisierungen.

Source: BGE - Bundesgesellschaft für Endlagerung mbH (2019): Standortauswahlverfahren: Ablaufplanung bis hin zur Standortentscheidung. (Gesamtzeitplanung). www.bge.de - download vom 07.06.2021.

No.	Uncertainties regarding the timeline of the site selection process	Known?
1	Date of the location decision and duration of the preparatory periods	no
2	Exploration mine concept depending on host rock formation and repository concept	no
3	Number of sites to be explored underground and time required for exploration	no
4	Date of the end of Phase III site selection process	no
5	Estimation of the time required for the preparation of the decision and the decision by the Bundestag and the Bundesrat.	no

Time periods of unknown duration?

No.	Uncertainties regarding the timeline of the site selection process	Known?
6	Start of planning and construction of the repository	no
7	Date of approval of the repository	no
8	Duration of the storage phase	no
9	Duration of the closure phase	no
10	Duration of the retrievability phase and the decommissioning phase	no
11	Time of decommissioning of the repository and start of the recoverability phase	no
12	Recoverability period of 500 years after decommissioning	yes
13	Definition of the assessment period of 1,000,000 years	yes

Sources:

1. Deutscher Bundestag (2020): Gesetz zur Suche und Auswahl eines Standortes für ein Endlager für hochradioaktive Abfälle. (**Standortauswahlgesetz - StandAG**), vom 05.05.2017, zuletzt geändert durch Art. 1 G v. 07.12.2020 I 2760. Online verfügbar unter www.gesetze-im-internet.de.

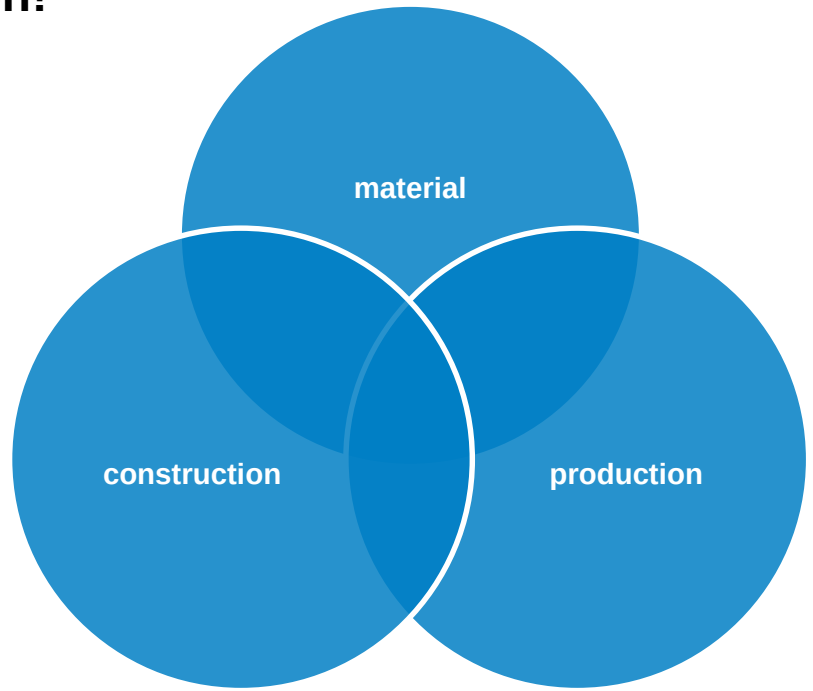
2. Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU) (Mai 2020): Verordnung über Sicherheitsanforderungen und vorläufige Sicherheitsuntersuchungen für die Endlagerung hochradioaktiver Abfälle. **EndlaSiAnfV**, vom 19/19291.

3. Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU) (Mai 2020): Verordnung über Sicherheitsanforderungen und vorläufige Sicherheitsuntersuchungen für die Endlagerung hochradioaktiver Abfälle. **EndlaSiUntV**, vom 19/19291.

What challenge do the engineers face?

First and foremost, a repository must remain sealed for a very long time in order to prevent the radioactive inventory from escaping into its environment.

➔ **The most important function is therefore the barrier function!**



1. Repository container materials offer safety against rust-through
   ➔ Corrosion resistance for t > 1,000,000 years
   (e.g. as an essential barrier in crystalline rock)
   Without an effective containment zone

2. Repository container design hermetically encloses the inventory
   ➔ Corrosion resistance as good as possible
   (z.B. as a further barrier in the salt or clay rock)
   With an effective containment zone

3. Repository container design delivers defined functionality
   ➔ Container can be produced on a large scale and cost effectively
   Container is hermetically sealable
   Container is retrievable and recoverable
   Container fulfils the safety criteria in the assessment period
   Container fits into the repository system (technical, geotechnical and geological barriers)

How are material decisions realised?

data basis
(Model materials for repository containers)

physico-chemical material behaviour general and under repository conditions

- anerobic, aerobic corrosion
- pitting corrosion
- stress corrosion cracking
- microbial corrosion
- local element corrosion
- contact corrosion
- sulphur-induced corrosion
- gas formation processes

Determination of the corrosion rate as a usable calculatory factor

ca. 50 years

data basis
(archaeological analogon)

archaeological investigation programme on material behaviour

- Place of discovery and age
- Material composition
- Corrosion products
- Environmental conditions
- Manufacturing process
- Theories and hypotheses on corrosion
- Theses and theories on coating formation
- Relation to the environment

Determination of the corrosion rate as a usable calculatory factor

200 – 1300 years

data basis
(natural analogon)

archaeological investigation programme on material behaviour

- Place of discovery and age
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Determination of the corrosion rate as a usable calculatory factor

> 500.000 years

10^0 10^1 10^2 10^3 10^4 10^5 10^6

Time scale in the context of final disposal [years]

Example Schweden.

data basis
(Model materials for repository containers)

Source: SKB (2006):
Long-term safety for KBS-3 repositories at Forsmark and Laxemar – a first evaluation.
Technical Report. TR-06-09.
In: Svensk Kärnbränslehantering AB.

pure oxygen-free copper
(Copper 99,999%)
(Oxygen-Content <0,001%)

Use as a container material

data basis
(archaeological analogon)

Source: King, Fraser (1995):
A natural analogue for the long-term corrosion of copper nuclear waste containers—reanalysis of a study of a bronze cannon.
In: Applied Geochemistry 10 (4), S. 477–487.

Brass:
96.3 wt% Copper,
3.3 wt% Tin, 0.5 wt% Zinc, Iron

200 – 1300 years

data basis
(natural analogon)

Source: Milodowski et. al (2000):
A natural analogue for copper waste canisters: The copper-uranium mineralised concretions in the Permian mudrocks of south Devon, United Kingdom
(Swedish Nuclear Fuel and Waste Management Co, SKB-TR--00-11UR)

Copper ca. 99,4%
but with a lot of Copper ore in the surroundings

> 500.000 years

10^0 10^1 10^2 10^3 10^4 10^5 10^6

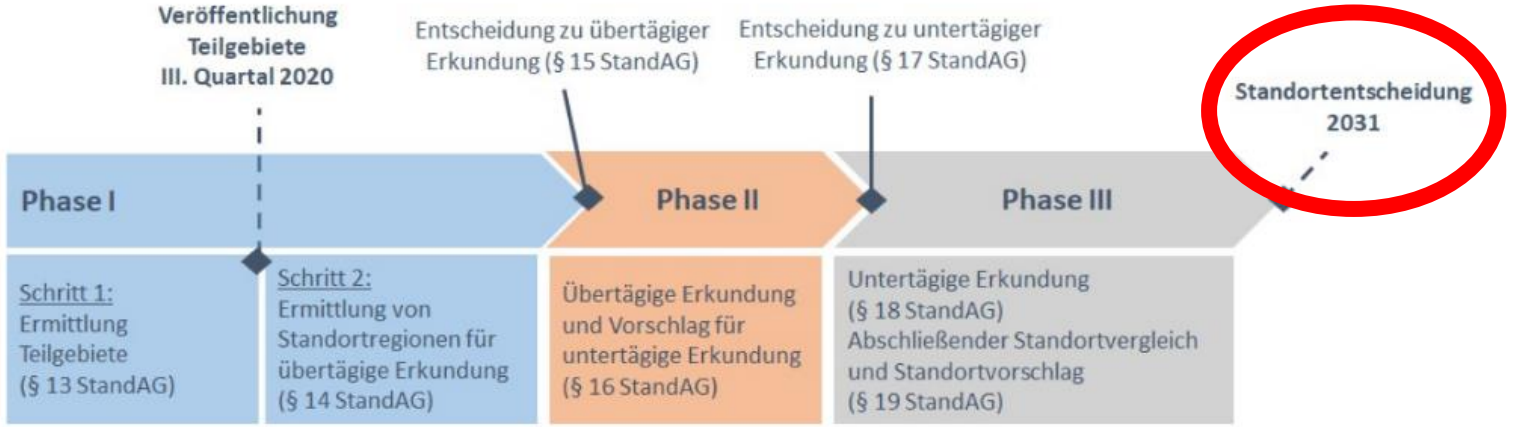
Time scale in the context of final disposal [years]

- Research into the use of copper has been going on in Sweden since about 1978

  Source:
  Scully, J. R.; Feron, D.; Hanninen, H. (2016): Review of the NWMO copper corrosion program
  (Nuclear Waste Mangement Organization (NWMO), NWMO-TR--2016-11UR

- Research into the use of steel has been going on in Switzerland since about 1989

  Source:
  Simpson, J. P.; Vallotton, P.-H. (1989):
  Experiments on container materials for Swiss high-level waste disposal projects Part III. Technical Report 86-25



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(Gesamtzeitplanung).
www.bge.de - download vom 07.06.2021.

Where we are in Germany?

➢ Research into the use of cast iron and steel as container material in the 1980ies

Included in the Preliminary safety analysis for the Gorleben site (VSG)

- **Bollingerfehr, Wilhelm (2011):** Endlagerkonzepte. Bericht zum Arbeitspaket 5 ; vorläufige Sicherheitsanalyse für den Standort Gorleben. Köln (GRS, GRS-272). Online verfügbar unter https://www.grs.de/sites/default/files/pdf/GRS-272_neu.pdf, zuletzt geprüft am 27.01.2021.
- **Wolf, Jens; Behlau, Joachim (BGR); Beuth, Thomas; Bracke, Guido; Bube, Christiane (KIT/INE)., Buhmann, Dieter; Dresbach, Christian (BGR) et al.**: FEP-Katalog für die VSG. Dokumentation. Bericht zum Arbeitspaket 7 - Vorläufige Sicherheitsanalyse für den Standort Gorleben. Online verfügbar unter https://www.grs.de/sites/default/files/pdf/GRS-283.pdf, zuletzt geprüft am 27.01.2021.
- **Beuth, Thomas (2012)**: Szenarienentwicklung - Methodik und Anwendung. Bericht zum Arbeitspaket 8 ; vorläufige Sicherheitsanalyse für den Standort Gorleben. Gesellschaft für Anlagen- und Reaktorsicherheit. Köln (GRS, GRS-284). Online verfügbar unter http://www.grs.de/sites/default/files/pdf/GRS-284_inkl_Anhaenge.pdf, zuletzt geprüft am 10.02.2021.
- **Kock, Ingo (2012)**: Integritätsanalyse der geologischen Barriere. Bericht zum Arbeitspaket 9.1 ; vorläufige Sicherheitsanalyse für den Standort Gorleben. Köln (GRS, GRS-286). Online verfügbar unter https://www.grs.de/sites/default/files/pdf/GRS-286_cor2_web.pdf, zuletzt geprüft am 27.01.2021.
- **Laure, J.; Baltes, B.; Fischer, H.; Frieling, G.; Kock, I.; Navarro, M.; Seher, H. (2013)**: Radiologische Konsequenzenanalyse. Bericht zum Arbeitspaket 10. Vorläufige Sicherheitsanalyse für den Standort Gorleben (GRS-289). Online verfügbar unter https://www.grs.de/sites/default/files/pdf/GRS-289_corr%20_0.pdf, zuletzt geprüft am 10.02.2021.
- **Peiffer, Frank; McStocker, Brigitta (2012)**: Einschätzung betrieblicher Machbarkeit von Endlagerkonzepten. Bericht zum Arbeitspaket 12 ; vorläufige Sicherheitsanalyse für den Standort Gorleben. Köln (GRS, GRS-279). Online verfügbar unter https://www.grs.de/sites/default/files/pdf/GRS-279_neu.pdf, zuletzt geprüft am 27.01.2021.

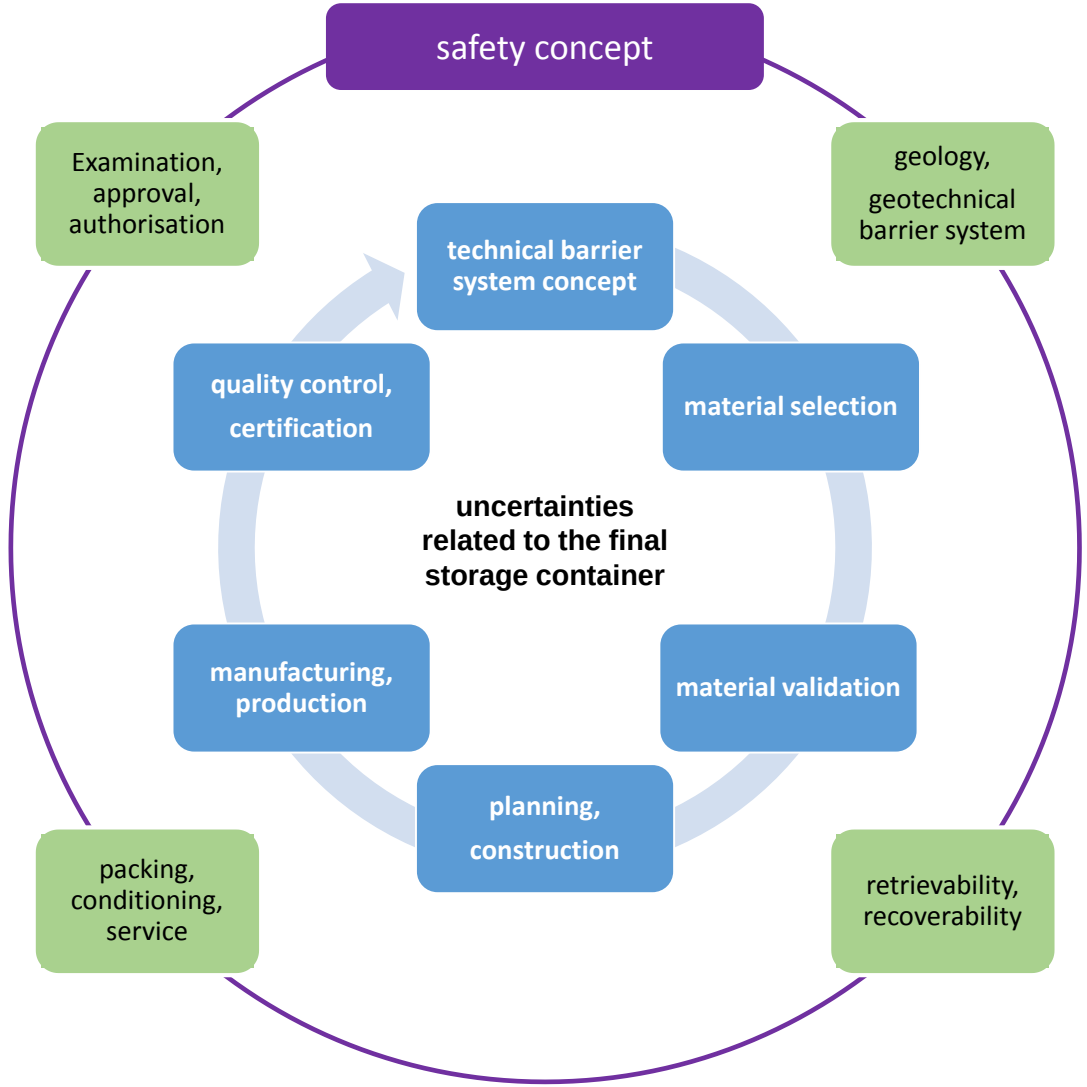
Where we are in Germany?

➢ Research into the use of cast iron and steel as container material in the 1980ies

Results of the Preliminary safety analysis for the Gorleben site (VSG)

Storage option B1	Storage option B2	Storage option C
POLLUX®-9 und 10 CASTOR® THTR/AVR und KNK CASTOR® MTR2	CASTOR® V/19; CASTOR® V/52 CASTOR® 440/84; CASTOR® HAW 20/28 CG und TS28V; TN85 und TGC 36 CASTOR® HAW 28 M	Brennstabkokillen (BSK) Triple-Pack modifizierte BSK
Self-shielding containers in line storage	Use of the TLB self-shielding in horizontal wellbore storage	Deep, vertical borehole storage
Requirements for the containers according to VSG		
• Stability, tightness, transportability, handling, corrosion	• Stability, tightness, transportability, handling, corrosion	• Stability, tightness, transportability, handling, corrosion
Proof not provided	Proof not provided	Proof not provided

How do we achive at a best possible repository container?



- The final storage container is an important component in the disposal path.
- The disposal path begins far before the site selection, namely during interim storage.
- A clear temporal context is important for cask development.
- Concept and material selection are by far not all that needs to be done for container development.
- Uncertainties must be resolved in parallel with the site selection process so that the container does not become the "bottle neck" of final disposal.
- Everything that is conceptually possible must be started now in order to be able to be implemented concretely after the site selection.

The report will be available shortly! ➔

Many thanks for your attention!

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