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Handout – Quality Assurance of Bentonite: Foundations and Perspectives

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1. Introduction

Bentonite is a critical component in the engineered barrier system of geological repositories due to its swelling capacity, low permeability, and chemical buffering function. According to §§5(4) and 6(4) of the German EndlSiAnfV regulation [1], its quality assurance (QA) must meet the *state of the art in science and technology*. QA does not regulate production methods directly, but it must ensure material performance, consistent quality, and reliable availability from mining to emplacement.

2. QA Triangle – Core Elements of Quality Assurance

- A robust QA framework is based on three interdependent pillars: **Safety-Relevant Properties**
  (e.g. swelling pressure, redox potential, corrosion resistance)
- **Process Integrity**
  (from raw material extraction to emplacement)
- **Regulatory Alignment**
  (compliance with safety concepts and legal standards)

3. Challenge: Natural Variability

Bentonite is a natural material with significant variability in its mineralogical composition — especially in smectite, iron, and sulphur content [2]. To ensure functional suitability as a geotechnical barrier, quality control must begin at the mining site and be maintained throughout the supply and processing chain.

4. Proxy Strategy for Parameter Monitoring

Direct measurement of multiple safety-relevant properties can be complex or time-consuming. Therefore, QA can rely on standardised proxy parameters [3] (e.g.):

Function	Target Parameter	Proxy / Method
Corrosion protection	Redox potential (Eh)	Eh in eluate – DIN ISO 11271
Sorption capacity	CEC, smectite content	ISO 11260, XRD (Rietveld analysis)

This approach enables more efficient and reproducible QA, especially during large-scale implementation.

5. Tiered QA Concept

Different repository zones require different material specifications. A tiered approach allows efficient use of resources without compromising safety:

Tier	Repository Zone	Requirements
Q1	Near waste canister	>80% smectite, high swelling, low Fe/S
Q2	Buffer/backfill areas	60–80% smectite, stable pH, medium CEC
Q3	Seals/far field	≥50% smectite, basic swelling and compactability

Benefits: Material flexibility, cost efficiency, functional safety.

6. Regulatory Coordination & Future Outlook

Early and continuous coordination with regulatory authorities is essential for building a robust QA framework — particularly when applying proxy parameters or tiered material concepts.

Looking ahead, the following developments are expected to shape future QA systems:

- **Digital QA platforms** for traceability and documentation
- **AI tools** for real-time material classification and anomaly detection
- **European collaboration** to harmonise QA standards and methods

References

1. EndlSiAnfV (2020): Ordinance on Repository Safety Requirements
2. Svensson et al. (2017): Strategies for the acquisition and control of bentonite, SKB TR-16-14
3. DIN ISO 11271, ISO 11260

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