How much homogeneity can we expect? How much heterogeneity can we afford?

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Rationales

Safety assessments assumes a **homogeneous bentonite material density distribution** with a minimum dry density of 1.45 gcm^{-3} at full saturation.

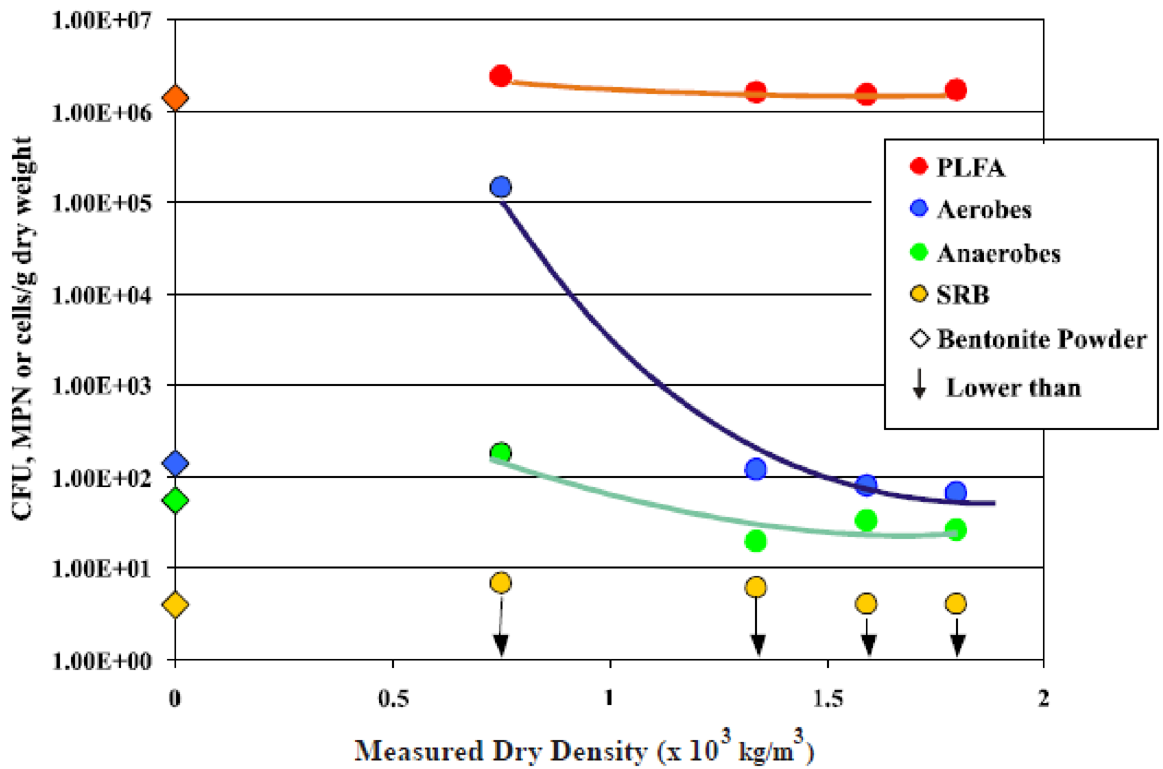
To fulfill this requirement, **it is assumed** that:

1. **Initial material property** differences vanish through resaturation (e.g. blocks and pellets)
2. **Backfill process** induced heterogeneities vanish with resaturation (including technical gaps)
3. **Heterogeneities induced through the nearfield evolution** disappear with resaturation (including chemical interactions at all interfaces)

But based on **experimental evidences homogeneity is never fully achieved**, thus following questions become pertinent for safety assessment:

1. What **phenomena and processes** are expected in backfilled repository sections that could be **detrimental to safety** and that are caused by a heterogeneous backfill?
2. What **degree of backfill/buffer homogeneity** is needed to ensure long term **safety?**
3. If **heterogeneities** are detrimental to the long term safety, how can these be **limited or avoided?**

Why do we care about heterogeneities? E.g. Microorganism could take advantage of low buffer density zones.



- Comparison of culturable and PLFA-indicated viable biomass in saturated Wyoming MX-80 bentonite compacted to target dry densities ranging from 800 to 1800 kg/m^3 and in as-received bentonite powder (Stroes-Gascoyne et al. 2010).

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Processes that potentially lead to heterogeneities and processes that promote homogenization

Identified processes potentially **leading to heterogeneities** are:

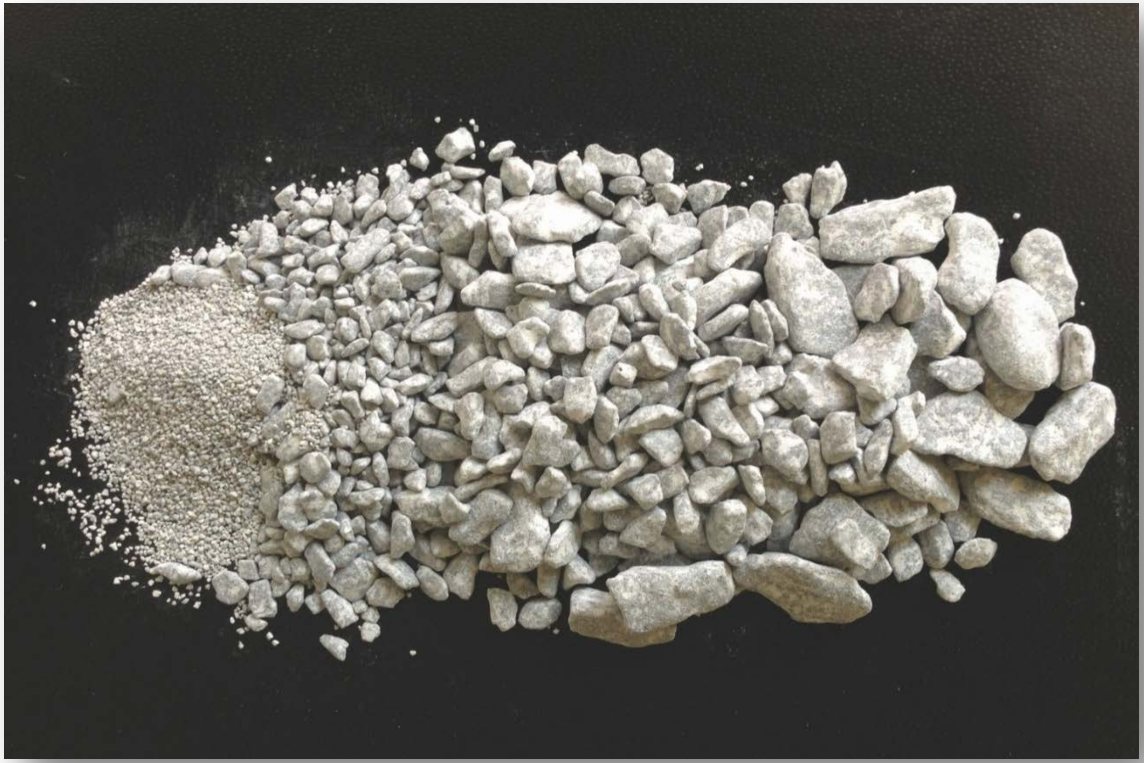
1. Choice of **material**
2. The production and use of different **forms** (blocks/pellets)
3. Material production and **emplacement techniques**
4. Potential settlement /**segregation** of the backfilled material prior to resaturation
5. Localized or heterogeneous **re-saturation**
6. **Thermal-resaturation history/path**
7. Chemical evolution of the **interfaces**
8. Long-term **equilibration processes** in the nearfield

It was acknowledged that processes **promoting homogenization** are:

1. **Swelling** of the bentonite minerals
2. **Plasticity** of the backfill materials
3. **Creep** of the backfill materials

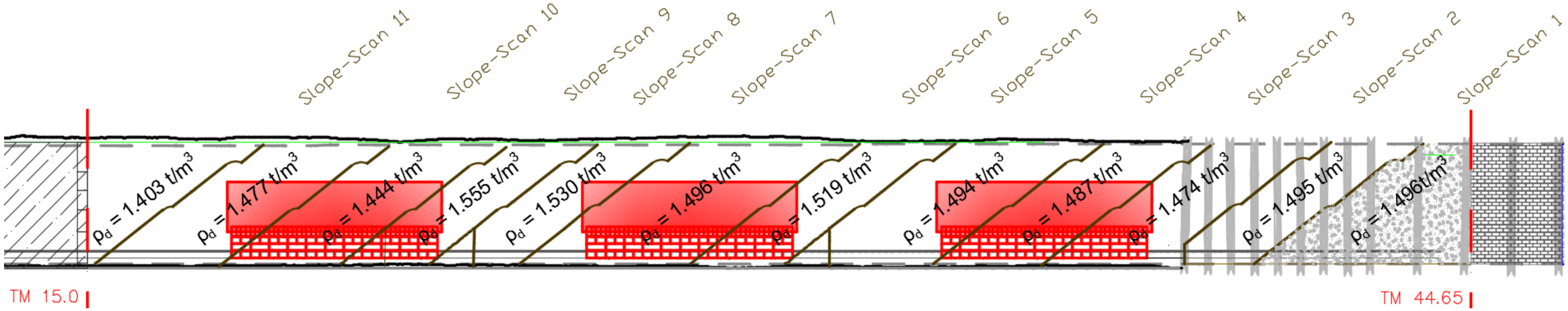
Example: Pelletized material – heterogeneous material for higher dry densities

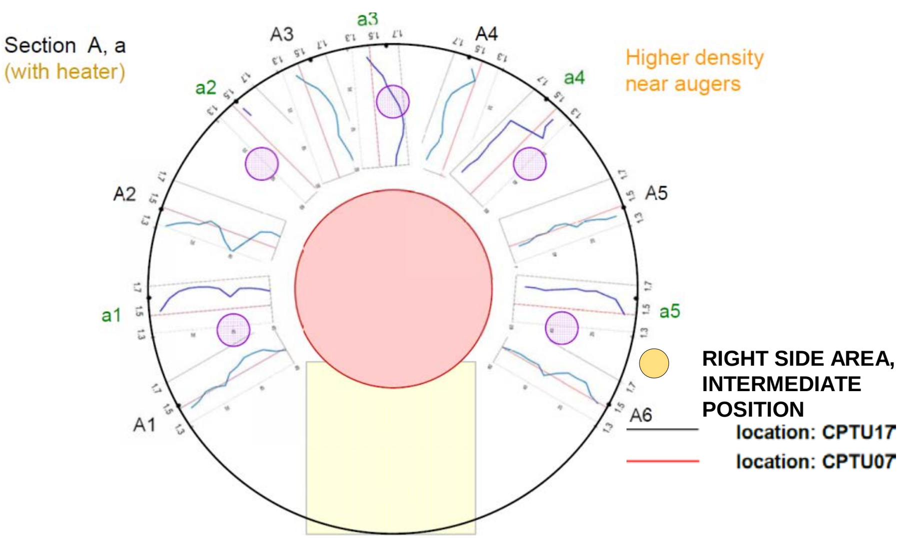
To maximize the packing density of granulated bentonite material a Fuller curve was approximated by grain size fractions. But the choice of material, the production and use of different forms (blocks/pellets) and emplacement techniques may promote the degree of heterogeneity

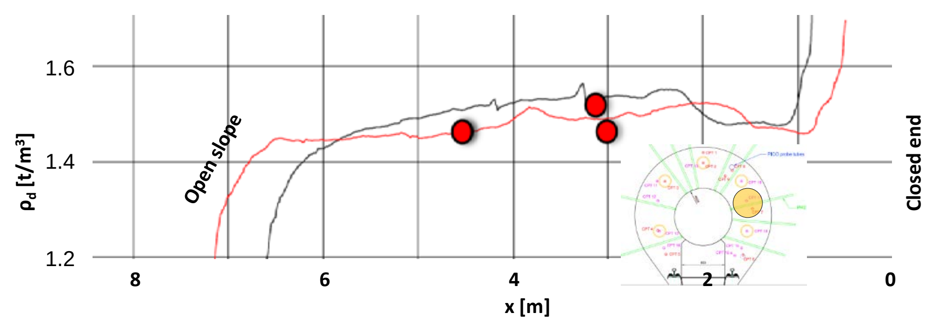


Example: Average dry density results in [t/m³] per section calculated from mass-volume measurements

Section	Wall TM 15	Slope 11	Slope 10	Slope 9	Slope 8	Slope 7	Slope 6	Slope 5	Slope 4	Slope 3	Slope 2	Slope 1
Local dry density [t/m³]	1.403	1.477	1.444	1.555	1.530	1.496	1.519	1.494	1.487	1.474	1.495	1.496







Example: Segregation effects during backfilling

- Visualisation of segregation effects depending on various measures during backfilling.
- Top pictures: $\rho_d \approx 1.43$ t/m^3 and no counter measures. Lower pictures: $\rho_d \approx 1.46$ t/m^3, flexible slope coverage and broader grain size distribution

Example: Thermal-resaturation path defines where bentonite is swelling and thus increasing homogeneity.

- At both ends of the FEBEX liner where temperature is lower bentonite has swollen through the perforations, whereas in the hotter central part bentonite did not swell into the interspace between canister and liner.

Example: Evolution at interfaces

- Near field evolution may also impact the homogeneity of the buffer properties (picture Aitemin FEBEX-DP).

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Example: Block material – homogeneous in principle

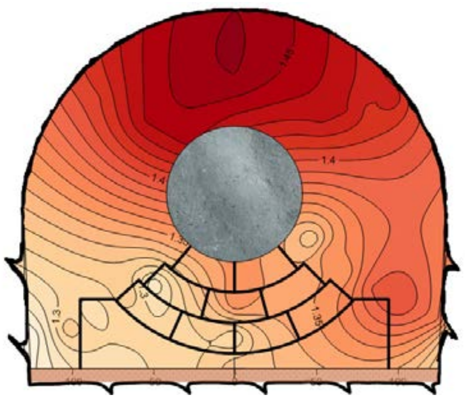
- How do the properties of bentonite blocks evolve during saturation at the block interfaces: below an example from the FEBEX-DP

Persisting uncertainties in the performance of the bentonite buffer

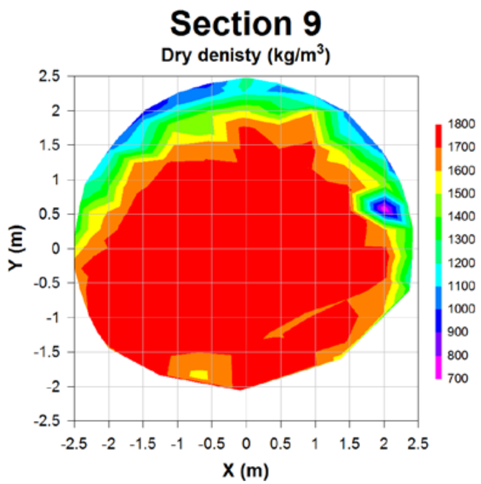
- **Uncertainties** are not limited to single parameters but rather to the understanding of system components, their evolution and interactions

- What heterogeneity in respect to emplaced density (due to the procedure and also to the presence of open spaces and transients) can we afford/allow in order to fulfil the requirements with respect to the emplacement of the granular bentonite and blocks

- This question implies a better understanding of:
  - Resaturation processes and mass redistribution in the nearfield
  - Impact of the heat gradient on the resaturation process and mass redistribution
  - Interfaces evolution and its impact on material density and porosity (on larger scale)



Fair homogenization: ”reasonable” dry density gradients, EB experiment, Mont Terri URL



Poor homogenization: ”unacceptable” dry density gradients (Prototype Repository, Äspö HRL)

SAVE THE DATE – Clay Conference 2017, Davos