SKB Task Force GWFTS: Task 9 - Increasing the realism of solute transport modelling in fractured media

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Abstract

SKB and several other waste management organizations have established the international SKB Task Force on Modelling of Groundwater Flow and Transport of Solutes (TF GWFTS) to support and interpret field experiments. An important objective of the task force is to develop, test and improve tools for conceptual understanding and simulating groundwater flow and transport of solutes in fractured rocks. Work is organized in collaborative modelling tasks. Task 9 focuses on realistic modelling of coupled matrix diffusion and sorption in heterogeneous crystalline rock matrix at depth. This is done by inverse and predictive modelling of different in-situ transport experiments. The ultimate aim is to develop models that in a more realistic way represent retention in fractured rock. Posiva's REPRO (rock matrix REtention PROperties) experimental campaign has been performed at the ONKALO rock characterization facility in Finland. The two REPRO experiments considered were the Water Phase Diffusion Experiment, addressing matrix diffusion in gneiss around a single borehole interval (modelled in Task 9A), and the Through Diffusion Experiment, which is performed between sections of three boreholes and addressed by modelling in Task 9C. The Long-Term Diffusion and Sorption Experiment (LTDE-SD) was an in-situ radionuclide tracer test performed at the Äspö Hard Rock Laboratory at a depth of about 410 m below sea level. The experimental results indicated a possible deeper penetration of tracers into the rock matrix than expected and the shape of the penetration profiles were not according to theory. This experiment was modelled and interpreted in Task 9B. Task 9D is addressing the possible benefits of the detailed modelling of the experiments in safety assessment calculations. The task is performed by upscaling of Task 9A to conditions applicable for performance assessments of nuclear waste repositories. Of additional interest is the collective work performed by the task force to conceptually understand and interpret the field experiments, and at the same time increase the realism in solute transport modelling. This study would not have been possible without the support from the waste management organizations and the work by the multiple modelling teams.

SKB Task Force GWFTS: Increasing the realism of solute transport modeling in fractured media – Task 9D

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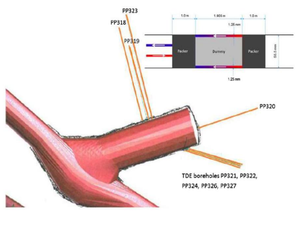
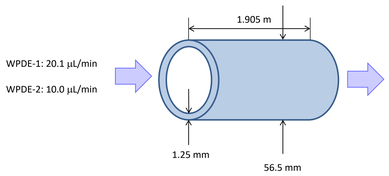
1. Introduction – Task 9D



The REPRO niche



Schematic view of WPDE setup

- The international **SKB Task Force on Modeling of Groundwater Flow and Transport of Solutes (TF GWFTS)** was established to support and interpret field experiments (www.skb.se/taskforce).
- Further objectives: To develop, test and improve tools for conceptual understanding and simulating groundwater flow and transport of solutes in fractured rocks.
- Work is organized in **collaborative modeling tasks**.
- Task 9 focuses on **realistic modeling** of coupled **matrix diffusion** and **sorption** in heterogeneous and fractured crystalline rock at depth.

- Task 9D: **Possible benefits** of **detailed modeling** of experiments in **safety assessment** calculations.
- Done by **upscaling** of Task 9A (Soler et al., 2019. SKB R-17-10) to conditions applicable for SA of nuclear waste repositories.
- Task 9A: Modeling of the **REPRO WPDE** performed at depth in the underground facility **ONKALO in Finland**.
- **WPDE** gave **valuable data for SA**.

2. Objectives and Teams

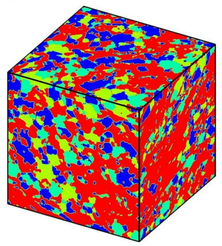
Objectives

- How do we condense complex site characterization models down to something practically useable for Safety Assessment (SA) modeling?
  - Is it possible on much larger spatial & temporal scales?
- How do the more complex behaviors observed in experiments scale to SA conditions & timescales?
  - Do they "vanish" or become less prominent?
- What are the consequences of neglecting microstructural heterogeneity on the Safety Case?
  - Confidence building

Team	Tool/Approach
Amphos21, Spain	MARFA with upscaling methodology
CFE, Sweden	DarcyTools
CTU, Czech Republic	GoldSim, analytical solution
KTH, Sweden	Multi-Channel model
PROGEO, Czech Republic	MODFLOW – MT3DMS/MT3USGS
TUL, Czech Republic	Flow123d
ÚJV, Czech Republic	GoldSim

3. Task description

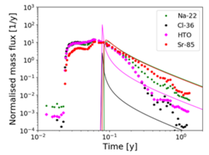
- Flatten the WPDE annulus to a ~**9 cm wide flow channel**
- Make the flowpath 1000 m long, i.e. **plausible SA distance**
- **Hydrodynamic** conditions and **flow-related resistance** (moderate F-factor) **as** SR-Site Central Corrosion Case (in **SA performed by SKB**)
- **Homogeneous** (Task 9D1a-b), & **heterogeneous** (Task 9D1c-d) **matrix properties**
- Modelling teams choose how to implement **hydrodynamic dispersion**
- Modeling teams free to model **matrix heterogeneity** however they see fit
- **Linear sorption**, with K_d proportional to **local mica content of rock**
- Hypothetical **tracers of increasing sorptivity** (& half-life) for Task 9D1
- **U-238 (4*n*+2) series** for Task 9D2



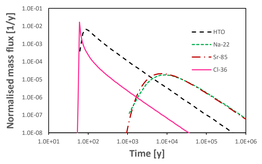
Mineral distribution with mica in red

4. Examples and Summary

Amphos21

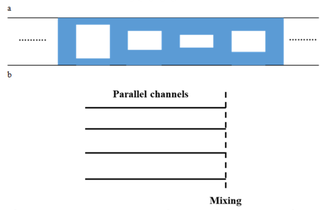


Modeling the experiment

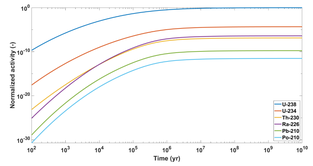


Extrapolating to SA conditions (Trinchero et al., 2020)*

KTH



Schematic, Multi-Channel Model



SA calculations

Summary

- Evaluation is still ongoing
- As predicted, not able to include all the details, but the most important processes
- It is beneficial to have several modeling teams addressing the same topics
- Tools capable of exploring impacts from processes and features of importance for SA
- Task 9D proved to be a useful exercise for SA and confidence building

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