SKB Task Force GWFTS: Increasing the Realism of Solute Transport Modelling in Fractured Media

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Abstract

SKB and several other waste management organisations 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 organised in collaborative modelling tasks. This study considers Task 9, which 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. 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. It is one of few recent in-situ studies focusing on tracer transport in the stagnant pore water of the crystalline rock matrix. 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. Posiva's REPRO (rock matrix REtention PROperties) experimental programme has been performed at the ONKALO rock characterisation facility in Finland. The two REPRO experiments considered were the Water Phase Diffusion Experiment, addressing matrix diffusion in gneiss around a single borehole interval, and the Through Diffusion Experiment, which is performed between sections of three boreholes. These three experiments provided an opportunity to improve the conceptual understanding of solute transport in fractured rock and to increase the realism in solute transport modelling, with the ultimate goal of improving safety assessments of deep geological disposal for nuclear waste. 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 organisations and the work by the multiple modelling teams.

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

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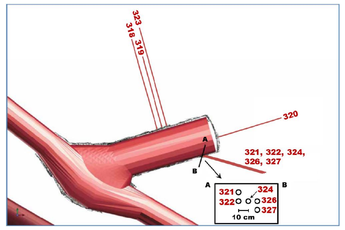
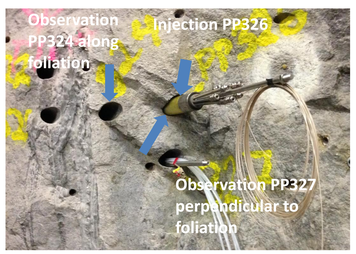
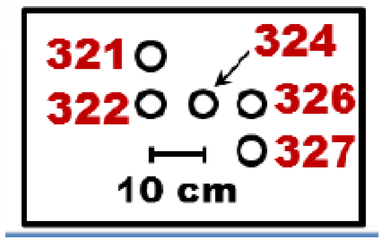
1. The experiment and task description





Task 9C concerns the combined predictive (earlier stage) and inverse (later stage) modelling of tracer breakthrough curves of the Through Diffusion Experiment (TDE). This in-situ tracer test has been carried out within the REPRO programme at about 400 m depth at the ONKALO underground rock characterisation facility in Olkiluoto, Finland, by Posiva.

HTO, ^{22}Na, ^{36}Cl, ^{133}Ba, ^{134}Cs
Start: November 19th, 2015



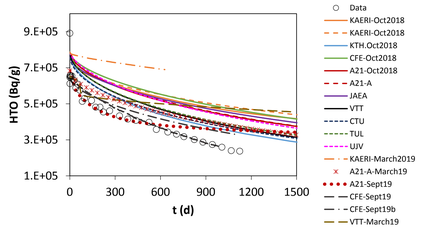
The experiment was initiated in November 2015 and is planned to end December 2019. It is carried out between three parallel drillholes arranged as a right-angled triangle. Drillhole ONK-PP326 is used as the injection hole and drillholes ONK-PP324 and ONK-PP327 as observation holes. This facilitates tracer migration along, and across, the rock foliation. The experiment is carried out in 1 m long packed-off intervals, at about 12 m from the tunnel wall.

2. Modeling

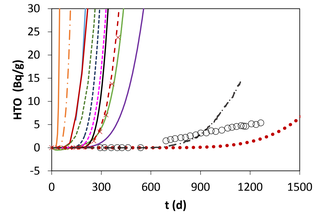
Teams (Predictive modeling)

UJV – GoldSim, 2D
TUL - Flow123D, 2D
CTU – GoldSim, 2D (non-sorbing), 1D-radial (sorbing)
KTH – Comsol, 3D (only non-sorbing) and 2D
KAERI – Comsol, 2D-linear (microstructural model)
A21 – Pflotran, 2D (Effect of foliation)
VTT – Comsol, 3D
JAEA – GoldSim, 2D (Effect of lab to in situ, foliation, BDZ, anion exclusion/cation excess.)
CFE – 2D ADE model, 2D microstructural model. (Anisotropy, foliation).

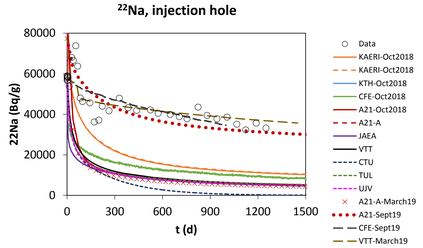
HTO, injection hole



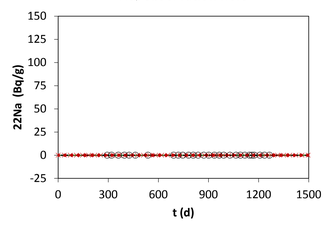
HTO, observation hole



^{22}Na, injection hole



^{22}Na, observation hole



3. Modeling

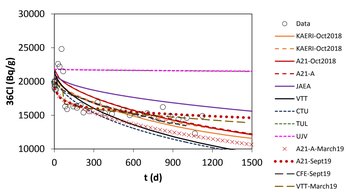
Teams (Back analysis, on-going)

VTT – Comsol, 3D.

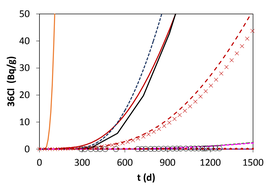
A21 - Pflotran, 2D + BDZ (Borehole Deformation Zone)

CFE – DarcyTools, 2D microDFN model, based on X-ray micro Computed Tomography data

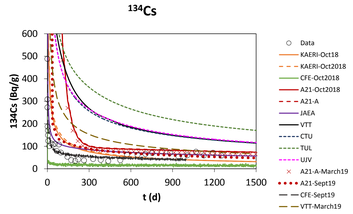
^{36}Cl, injection hole



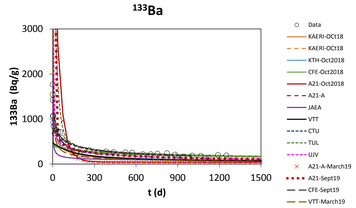
^{36}Cl, observation hole



^{134}Cs



^{133}Ba



4. Conclusions

From predictions:

- Presence of BDZ at observation boreholes?
- Overestimation of calculated activities in the observation boreholes for non-sorbing tracers.
- Pressure anomaly signals visible in the measurements (HTO, ^{36}Cl, ^{22}Na). Advection pulses?

Injection borehole:

- HTO: calculated trends OK (effect of higher C_0 in the calculations).
- ^{36}Cl: Larger spread in the prediction results (probably due to larger spread in D_e values).
- ^{22}Na: Less sorption (or slower diffusion) than expected.
- Already observed in REPRO WPDE.
- ^{134}Cs, ^{133}Ba: Discretization effects?

From back-analysis:

- The presence of BDZs is possibly influencing the results (e.g. modeling results by A21). Could we observe BDZ by over-coring?
- Weak sorption of ^{22}Na (on rock matrix or BDZ) is consistent with observations.
- Strong sorption of ^{134}Cs (on rock matrix or BDZ) is consistent with observations.

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