SKB Task Force GWFTS: Lessons Learned from Modeling Field Tracer Experiments in Finland and Sweden

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Abstract

SKB and several other waste management organizations have established the international SKB Task Force on Modeling of Groundwater Flow and Transport of Solutes (TF GWFTS) to support and interpret field experiments. Objectives of the task force are 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 crystalline rock matrix at depth, e.g. by inverse and predictive modeling of in-situ transport experiments. 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 (WPDE), addressing matrix diffusion in gneiss around a single borehole interval (modeled in Task 9A), and the Through Diffusion Experiment, which is performed between sections of three boreholes and addressed by modeling in Task 9C. The Long-Term Diffusion and Sorption Experiment (LTDE-SD) was an in-situ radionuclide tracer test performed at the Swedish Äspö Hard Rock Laboratory at a depth of about 410 m below sea level. The experimental results indicated a possible deeper penetration of sorbing tracers into the rock matrix than expected. The shape of these tracer penetration profiles was difficult to reproduce. This experiment was modeled and interpreted in Task 9B. Task 9D is addressing the possible benefits of detailed models of the in-situ experiments in safety assessment calculations. The task is performed by upscaling of the WPDE models to conditions applicable for nuclear waste repositories. As Task 9 is now in a finalization process, a number of lessons learned from the 4 sub-tasks have been identified. These include: * field tracer experiments can provide surprises even when well designed and executed, * interaction between the experimentalists and modelers is important and mutually beneficial when investigating anomalous results, * differences in conceptual models have the greatest impact on model outcomes, * it is not trivial to go from modeling of field experiments to safety assessment modeling without making substantial simplifications.

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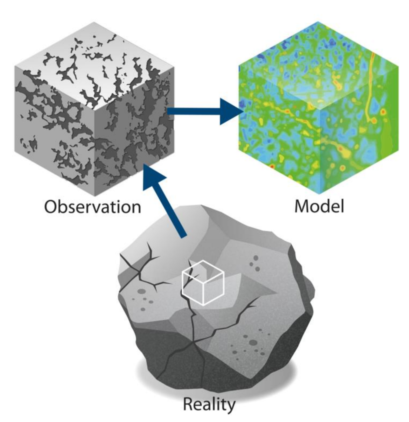
1. Introduction – Task 9

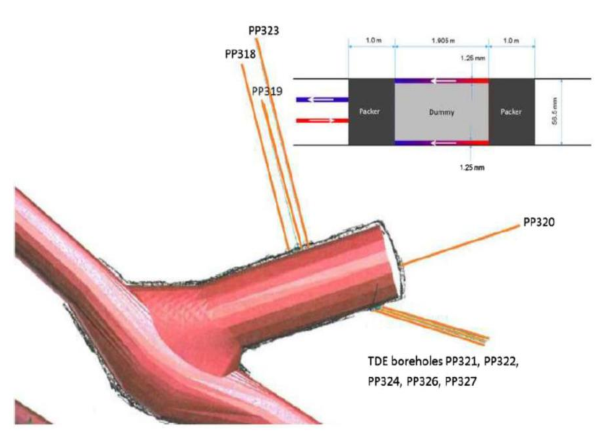
- The international **SKB Task Force on Modeling of Groundwater Flow and Transport of Solutes (TF GWFTS)** was established to support and interpret field experiments (www.skb.se/taskforce).
- Further objectives: To develop, test and improve tools for conceptual understanding and simulating groundwater 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.



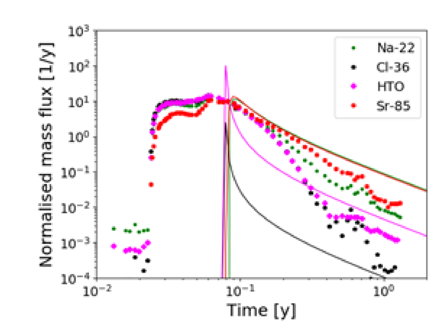
- The participating organizations in Task 9 are:
- **BMWi** (Germany)**, DOE** (USA)**, JAEA/NUMO** (Japan)**, KAERI** (Korea)**, Posiva** (Finland)**, SKB** (Sweden) and **SURAO** (Czech Republic)
- The Modeling Teams are:
- BMWi: **GRS**; DOE: **LANL**; NUMO: **JAEA**; KAERI: **KAERI**; Posiva: **HYRL, VTT**; SKB: **Amphos21, CFE, KTH**; SURAO: **FJFI ČVUT, PROGEO, TUL, ÚJV Řež**

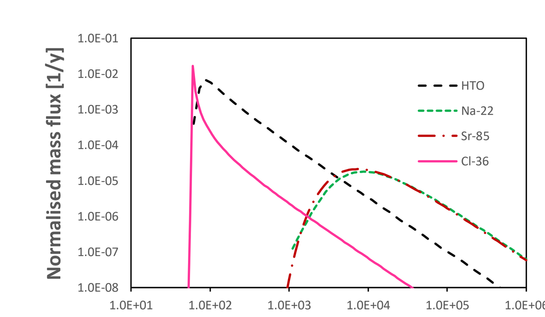
2. Task 9A and 9D

- **Task 9A**: Modeling of the **REPRO WPDE** performed at depth in the underground facility **ONKALO in Finland**.
- The **Water Phase Diffusion Experiment** gave **valuable data** for **modeling** of experiment and **Safety Assessment (SA)**.
- Task 9A was intended to be an easy predictive warm-up exercise, but the experiment gave some unexpected results.
- **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.

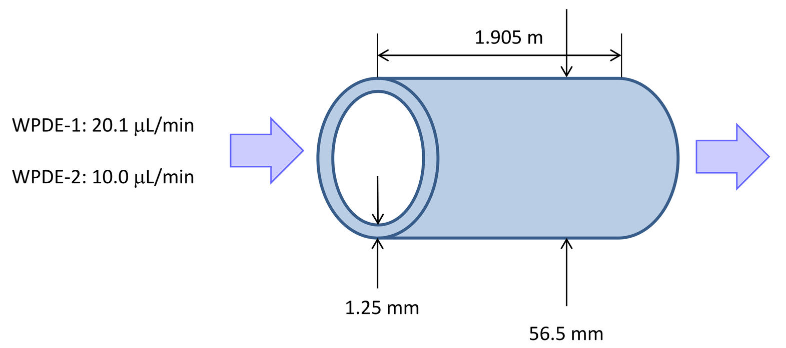


The REPRO niche



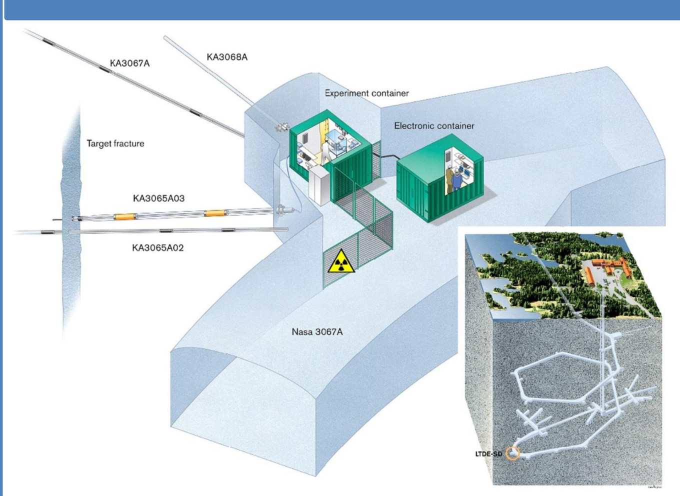


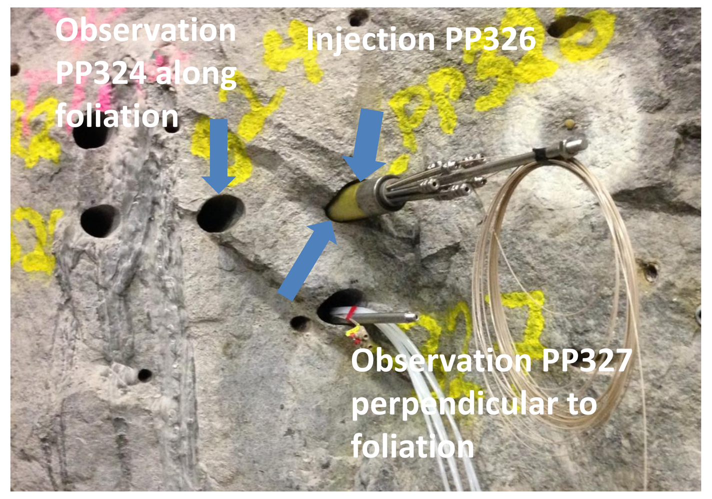
Example: Task 9A (WPDE) upscaled to Task 9D (SA) by Amphos21.



Schematic view of WPDE setup

3. Task 9B and 9C





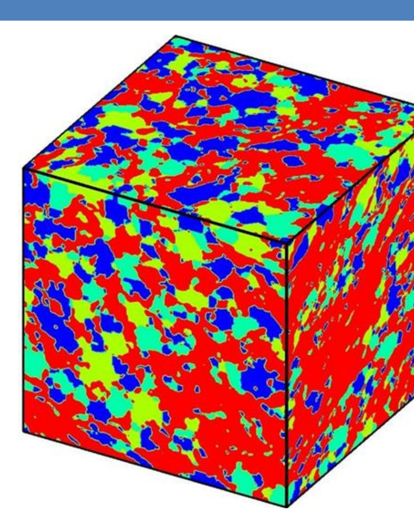
• **Task 9B**: Modeling of LTDE-SD performed at about 410 m depth in the **Äspö HRL**, which is operated by **SKB (Sweden).**

• The in-situ experiment comprised of **injection and seven months monitoring** and sampling of **22 trace elements** representing a variety of **chemical species** and **sorption behavior**. Again, unexpected results. The goal of the modeling was to **interpret** and **explain** the experimental results.

•**Task 9C:** Predictive and inverse modelling of tracer breakthrough curves of the in-situ Through Diffusion Experiment (TDE) performed at about 400 m depth at the ONKALO underground rock characterisation facility in Olkiluoto, Finland, by Posiva.

•TDE was carried out between three parallel boreholes arranged in right-angled triangle. Borehole ONK-PP326 was used for injections and ONK-PP324 and ONK-PP327 as observation boreholes. This facilitated tracer migration along, and across, the rock foliation. The experiment was carried out in 1 m long packed-off intervals, at about 12 m from the tunnel wall.

4. Outcome and Lessons Learned



- **Outcome**: Development of a range of codes and methodologies for modelling diffusion and sorption in the rock matrix
- Development of rich datasets to support modelling (LTDE-SD and REPRO)
- Development of micro-DFN/heterogeneity models
- Better understanding of issues around contamination and anomalous tailing in LTDE-SD
- Useful work on links to SA in Task 9D

- **Conclusions**: In-situ, there will probably be surprises and experimental artefacts.
- Useful with blank samples i.e. not exposed to tracers and radionuclides.
- Predictions can be useful for building conceptual models, aid for planning of experiments, and to create a foundation for further modeling.
- Combined predictive modeling and back-analysis can give clearer identification of uncertainties and gaps in knowledge of processes and importance of various factors and conditions.
- Task 9 pointed out the influence of heterogeneity of crystalline rock e.g., uneven mica distribution.
- Task 9 was a **Team Effort** and all involved learned from each other.

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