In-situ tracer tests and models developed to understand flow paths in a shear zone at the Grimsel Test Site, Switzerland

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1. The Grimsel Test Site

The Grimsel Test Site (GTS) is an international underground research laboratory excavated at a depth of 450 m below the surface in the granitic rock formations of the Aare Massif in southern Switzerland. In 1990 a radiation controlled zone was set up in one of the tunnels to study in-situ migration of radionuclides (Fig. 1).

2. The Colloid Formation and Migration Test

The Colloid Formation and Migration project (CFM) was set up in the controlled zone in 2004 to study colloid facilitated transport of radionuclides in a well characterised shear zone under repository relevant boundary conditions.

3. Target shear zone

Large-scale shear zone transmissivity of $5 \times 10^{-6}$ m$^2$/s (Fig. 3). Locally, transmissivity may vary from $10^{-10}$ to $10^{-6}$ m/s.

Flow through the shear zone appears to be channelled.

Geostatistical inverse model using well test and tracers.

4. Migration Tracer Tests using conservative tracers and homologues

Migration tracer tests carried out between the emplacement borehole (CFM 06.002) and the extraction point (‘Pinkel’ surface packer).

Initial tests were carried out with conservative tracers: Uranine & Amino-G with online detection.

Additional tests were performed with bentonite colloids and homologues (Th, Hf, Tb, Eu) at a range of extraction rates (travel times) prior to carrying out tests with radionuclides.

Conclusions and Outlook

• A unique setup has been established which allows migration tests to be carried out in a well characterised flow field using colloids and radionuclides under repository relevant conditions.

• A long-term (2-3 years) emplacement and migration test will be carried out using a bentonite block spiked with radionuclides and installed into the emplacement borehole in 2013.

• Modelling of this long-term test requires integration of colloid formation and migration models.

5. Migration Tracer Test using Radionuclides

A migration test using Amino-G, bentonite colloids, Na, Ba, Cs, Np, Am, Pu, Th was successfully initiated on 26th February 2012.

Conclusions and Outlook

Homologue tests

• Tests repeated in same geometry but with reducing extraction (Fig. 4).

• Decreasing extraction slowed transport velocity by a factor of 10 (breakthrough time).

• Increasing travel times allowed investigation of in situ colloid sorption reversibility.

Radionuclide Activity (Bq)

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Activity (Bq)</th>
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<tbody>
<tr>
<td>Cs</td>
<td>2.40E+04</td>
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<tr>
<td>Sr</td>
<td>1.10E+05</td>
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<tr>
<td>U</td>
<td>9.8E+03</td>
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<tr>
<td>Np</td>
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<tr>
<td>Pu</td>
<td>3.6E+02</td>
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<tr>
<td>Th</td>
<td>4.0E+01</td>
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</tbody>
</table>

7. Migration tracer using radionuclides (LIBD visible in foreground)

8. Comparison of colloid breakthrough curves from the LIBD system and the PSI single particle counter

9. Breakthrough curve of Amino-G, Na, Ba and Cs

Fig. 5: Recovery curves for colloids, homologues and conservative tracer for test 10-01. 

Fig. 6: Tracer test 12-02

Fig. 7: Migration test using radionuclides (LIBD visible in foreground)

Fig. 8: Colloid number density measured by LIBD

Fig. 9: Comparison of colloid breakthrough curves from the LIBD system and the PSI single particle counter

Fig. 10: Breakthrough curves of Amino-G, Na, Ba and Cs