Main findings from CRR experiment

Under the given boundary conditions of the CRR experimental set-up:

- The tri- and tetravalent actinides (Am, Th and Pu) form radio-colloids in the Grimsel groundwater, even in the absence of bentonite colloids.
- Retardation of Am and Pu in the shear zone was greatly reduced in the presence of bentonite colloids.
- The caesium (Cs) data indicated that a certain fraction was transported as colloids and another fraction was retarded in the rock (via sorption and matrix diffusion).
- More than 80% of the injected bentonite colloids passed through the flow field without retardation or filtration of larger colloids.

Colloids, the next steps...

Bentonite colloids, together with actinides, were successfully handled in an in situ dipole experiment under the experimental boundary conditions. Although this experiment was carried out in situ at the GTS, certain conditions applied in this experiment were not the same as those expected in a real underground repository.

- The time schedule of the project meant that the flow rates applied were around one million times faster than the flow rates typical of a real repository.
- The water chemistry of the shear zone was a much more dilute system than that expected in a real repository and therefore colloid stability was enhanced.
- The current techniques used world-wide for studies of this kind are carried out under similar experimental conditions because of factors of time, limitations of current technologies and financial reasons. However, we are now at a stage where such experiments will provide no new information.

Therefore, the next steps are experiments that look at the behaviour of bentonite colloids under more repository-relevant conditions. A new experiment is planned for the next phase of the GTS which builds upon the knowledge gained from the CRR experiment. This multi-decade experiment has the principal aim of investigating the in situ generation and far-field migration of bentonite colloids and associated radionuclides originating from a bentonite barrier under repository relevant conditions.
What do colloids look like close up?

In most HLW (high-level waste) and SF (spent fuel) repository designs, the waste is packed in massive metal canisters, which are surrounded by a large volume of bentonite backfill (which together constitute the EBS). The waste packages are disposed of deep underground (typically between 400 and 1000 metres) in a repository to isolate the waste until it has decayed to safe levels.

These images of bentonite colloids were taken using a Scanning Electron Microscope (SEM).

How can colloids influence radionuclide migration?

If any radionuclides are released from the EBS they will move into the rock surrounding a repository. It is expected that this rock will retard much of the radionuclides by processes of sorption and diffusion within the rock.

CRR is designed to examine whether bentonite colloids produced from degradation of the EBS will enhance the transport of radionuclides through the rock and interfere with sorption and diffusion processes which would otherwise retard these radionuclides.

1. Generation of bentonite colloids.
2. Dissolved radionuclides in groundwater.
3. Sorption/desorption of colloids onto/from the rock surface.
4. Sorption of radionuclides onto bentonite colloids.
5. Filtration of colloids.
6. Colloid size prevents penetration into the pore space of the rock.
7. Diffusion of radionuclides into the pore space of the rock.
8. Sorption of radionuclides onto/into organic colloids.

In situ experiment at the GTS

The main focus of the experiment were two injections of a suite of radionuclides (including actinides) into the experimental shear zone. One injection in the absence of, and one in the presence of, bentonite colloids were carried out at the GTS. All injections were carried out according to the strict guidelines of the Swiss Radiation Protection Regulations.

The output solutions were measured for radionuclides and colloids using state-of-the-art techniques both within the GTS and at external laboratories. The in situ experiments were complemented by studies in the laboratory and computer modelling carried out by project partners from around the world.

Are colloids of significance for repository behaviour?

Five requirements must be fulfilled to allow colloid-facilitated transport of radionuclides in a potential repository host rock to be of significance for the long-term performance of a waste repository. A “no” answer to any of these five questions will allow us to rule out colloidal transport of radionuclides as insignificant.

Therefore, the focus of the CRR experiment is directly related to these five fundamental questions.

1. Generation of bentonite colloids.
2. Dissolved radionuclides in groundwater.
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EBS for high-level waste and spent fuel