Bentonite colloid studies

Pirkko Hölttä
Suvi Niemiahho
Outi Elo

University of Helsinki (UH)
Department of Chemistry
Laboratory of Radiochemistry
Colloid projects

Finnish Research Programme on Nuclear Waste Management (KYT2014/BOA/KOLORA)
- Formation and stability of colloids
- Radionuclide sorption

EU FP7 BELBaR WP3
- Colloid/radionuclide and host rock interaction

Grimsel Test Site Phase VI,
Colloid formation and migration (CFM)
Objectives

- To determine the release and stability of inorganic colloids in different groundwater conditions
- To study bentonite erosion
- To determine radionuclide sorption ($K_d$) on MX-80 bentonite powder and bentonite colloids as a function of ionic strength, pH and particle size
- To study colloid/radionuclide and host rock interaction in dynamic conditions
- To test and apply colloid characterization methods
Characterization methods

- Dynamic light scattering (DLS: Malvern Zetasizer Nano ZS)
- Asymmetrical flow field-flow fractionation (AsFIFFF)
- ICP- MS, ICP-OES
- Field emission scanning electron microscopy (FESEM/EDX)
- DualBeam focused ion beam/scanning electron microscope with EDS
- Atomic force microscopy (MultiMode V scanning probe microscope)
- X-ray diffraction (XRD), small-angle X-ray scattering (SAXS)
Formation and stability of bentonite colloids

- The release and stability of bentonite colloids have been followed in diluted OLSO reference groundwater, sodium chloride and calcium chloride solutions (I = 0.001 – 0.1 M)
- Colloidal particle size distribution and zeta potential has been determined applying the dynamic light scattering (DLS) method.
- Colloid concentration determination:
  - A standard series made from MX-80 bentonite applying the DLS measurement count rate.
  - Al determination (ICP-MS)
NaCl
0.001- 0.1 M

CaCl₂
0.001- 0.1 M

OLSO
0.001- 0.03 M
Stability of bentonite colloids

Zeta potential as a function of ionic strength in sodium chloride, calcium chloride and OLSO solutions after 2.5 years.
Stability of bentonite colloids

Mean zeta potential of bentonite colloids in diluted OLSO reference groundwater.
Estimated particle concentration of bentonite colloids in diluted OLSO reference groundwater.

Bentonite colloid concentration

- Estimated particle concentration of bentonite colloids in diluted OLSO reference groundwater.
Radionuclide sorption

- Determinations as a function of ionic strength, a batch method, 4 parallel samples.
- $^{85}$Sr and $^{152}$Eu sorption onto bentonite powder (MX-80)
  - NaCl and CaCl$_2$ solutions ($I = 0.001 – 0.1$ M)
- $^{152}$Eu sorption on bentonite colloids, separated from MX-80.
  - NaCl and CaCl$_2$ solutions and diluted OLSO ($I = 0.5$ M)
  - Solutions of 10 ionic strengths ($I = 0.001 – 0.1$ M)
- $^{85}$Sr sorption determination on bentonite colloids is under way.
- Radionuclide sorption reversibility in static and dynamic conditions.
  - method development under way

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Sorption onto powdered bentonite

20 mL NaCl/CaCl₂-solution
Sr-85 or 120 µl Eu-152 tracer
1 g Bentonite powder
pH ~ 8 (Adjusted)

Shaking (1h/1-2 d/7 d)
Sentrifugation (7500 rpm/30 min)

10 mL aliquot
Radioactivity measurement (5 min)
(Wizard® 3" gamma counter)
Particle size and zeta potential determination

Filtration 1.2 µm (Isopore polycarbonate filter)
Radioactivity measurement (5 min)
Particle size and zeta potential determination (Zetasizer)

Filtration 0.05 µm (Isopore polycarbonate filter)
Radioactivity measurement (5 min)
Particle size and zeta potential determination (Zetasizer)

Drying and weighing of the filters

Desorption experiments
Sorption onto colloids

90 mL OLSO/NaCl/CaCl$_2$-solution
Sr-85 or Eu-152 tracer
Bentonite colloids solution

4.5 mL aliquot after 1h/1-2 d/7 d
Ultracentrifugation (90000 rpm/60 min)

Solution:
Radioactivity measurement (10 min)
(Wizard® 3" gamma counter)
Particle size determination
(Zetasizer)

Solid phase:
Drying and weighing

Desorption experiments
Eu-152 sorption

Bentonite powder in NaCl

Colloid concentration
Eu-152 sorption on colloids

![Graph showing the sorption of Eu-152 on colloids as a function of ionic strength. The graph plots K_d (m^3/kg) on the y-axis against ionic strength (M) on the x-axis. The data points are represented for different time periods: 1d, 3d, and 7d.]
Colloid/radionuclide and host rock interaction

- Old fracture columns from Olkiluoto tonalite
- New crushed rock columns from Kuru Grey granite and strongly altered tonalite and.
  - The hydraulic properties have been determined using non-sorbing tracers ($^{36}$Cl, $^{125}$I) without colloids
  - Experiments $^{85}$Sr and $^{152}$Eu with and without colloids are under way
- Natural fracture (0.9 m x 0.9 m) in Kuru Grey granite block
  - Experiments will start in the near future
Sievi crushed rock column
Sr-85 with and without colloids
Conclusions

- The formation and stability of bentonite colloids depends strongly on the ionic strength of the medium and the valence of the cations.
- In NaCl (0.001-0.1 M), CaCl$_2$ and OLSO (0.001-0.01 M) zeta potential was lower than -30 mV indicating stable colloids.
- Colloids were smaller and more stable in monovalent (Na$^+$) than in divalent (Ca$^{2+}$) dominated solutions.
- The colloid concentration increased only in 0.001-0.01 M solutions.
Thank you and welcome to laboratory of radiochemistry!