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Long-term lab-scale microbial bentonite storage experiment

Hanna Miettinen, Minna Vikman, Michał Matusewicz, Markus Olin & Merja Itävaara
VTT Technical Research Centre of Finland Ltd

Introduction

The final disposal of high-level radioactive waste in Finland is planned to start in 2020s. The waste will be encapsulated in copper canisters and be surrounded by compacted bentonite barrier in the geological repository at the depth of 400 m, in Olkiluoto, Finland. The relationship between microbes and minerals like clay, and the complex nature of reactions occurring between them are not well characterised at present. The possible deterioration of bentonite structure due to microbial activity is a risk that needs to be studied to ensure the bentonite ability to function as planned in long-term.

The aim of this laboratory scale bentonite storage experiment was to simulate worst case scenario conditions that could happen in real life at least in some parts of the repository. In the experiment bentonite was not compacted, water, gases, nutrients and microorganisms were able to move along easily at temperature hospitable for microorganisms. The objective was to find out if microorganisms and the produced metabolites were able to change the bentonite structure in favourable conditions and if these changes are significant for the bentonite stability in long-term scale.

Storage experiment conditions

The experiment was initiated both in aerobic and in anaerobic conditions in spring 2016. In Table 1 the experiment parameters are summarized. The bentonite used was MX-80 (CETCO).

Figure 1. Sample bottles of long-term bentonite storage experiment. On the left anaerobic and on the right aerobic 120 ml headspace bottles.

Methods

Microbial cell numbers (microscopy with DAPI, 4',6-diamidino-2-phenylindole) and microbial activity (ATP, Adenosine triphosphate) were measured and DNA of water-bentonite mixture was extracted at the beginning and later at least once a year. After one month of incubation, bentonite was studied with atomic force microscopy (AFM). In addition the gas composition was followed with the gas chromatography.

Table 1. Long-term bentonite storage experiment parameters.

	Anaerobic	Aerobic
Water mixture (together 80 ml)	3 anaerobic groundwaters and 1 surface water from Olkiluoto (25:25:25:5)	Surface water and 3 anaerobic groundwater from Olkiluoto (65:5:5:5)
Gas mixture	N_2:CO_2:H_2 80:10:10 + CH_4 15 ml	Air
Temperature	30 °C	37 °C
Nutrients	Na-acetate and Na-formate 0.1 mM, methanol 0.05 mM	
Other additions	Olkiluoto graphite containing rock crush (2-6 mm)	
Controls	1) Heat sterilized bentonite (180°C, 16 h), sterile filtered water, autoclaved rock "Sterile" 2) Only the water mixture sterilized, no nutrients "Half sterile" 3) Heat sterilized bentonite, sterile filtered water, no rock	

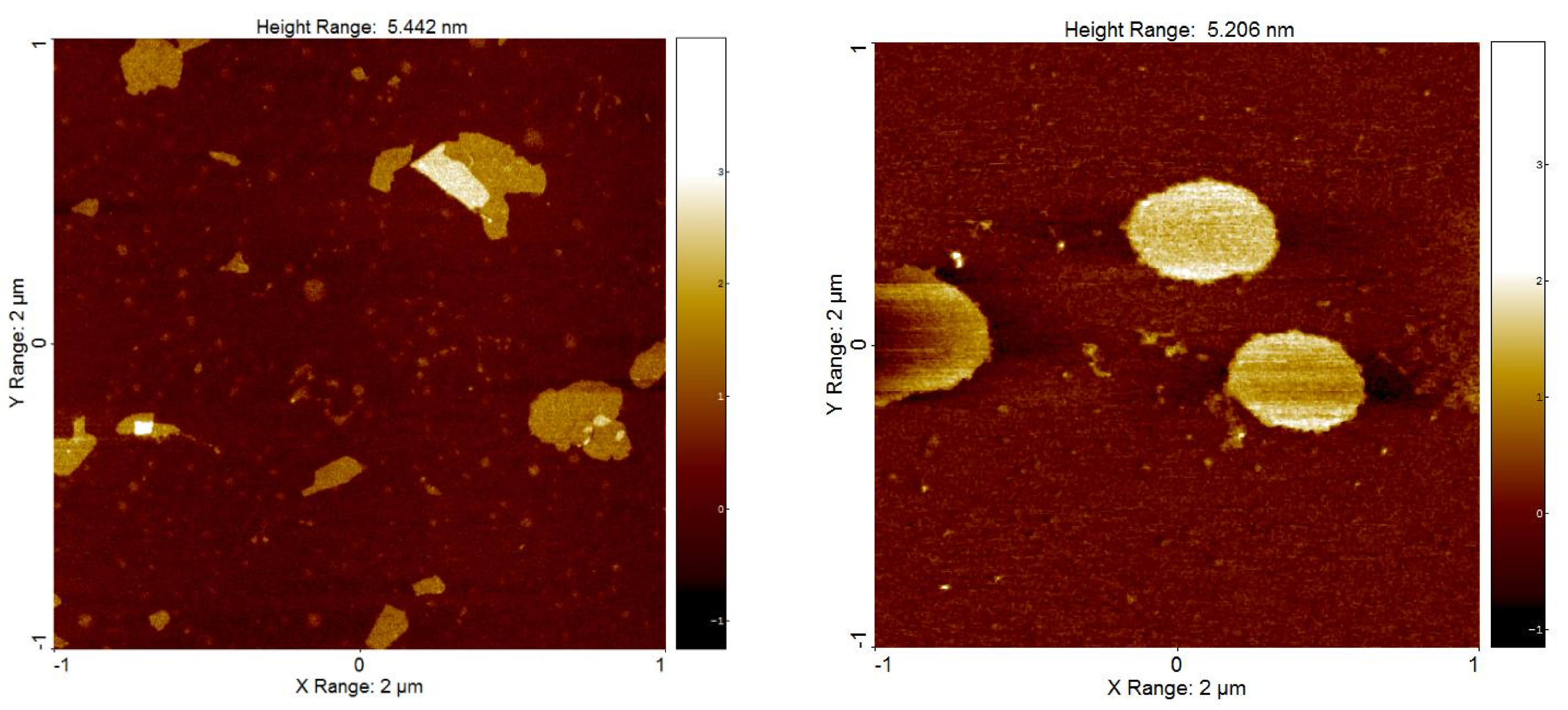

Figure 2. Atomic force microscopy (AFM) image of one month old bentonite. On the left bentonite single layers visible, on the right possible microbes (dried).

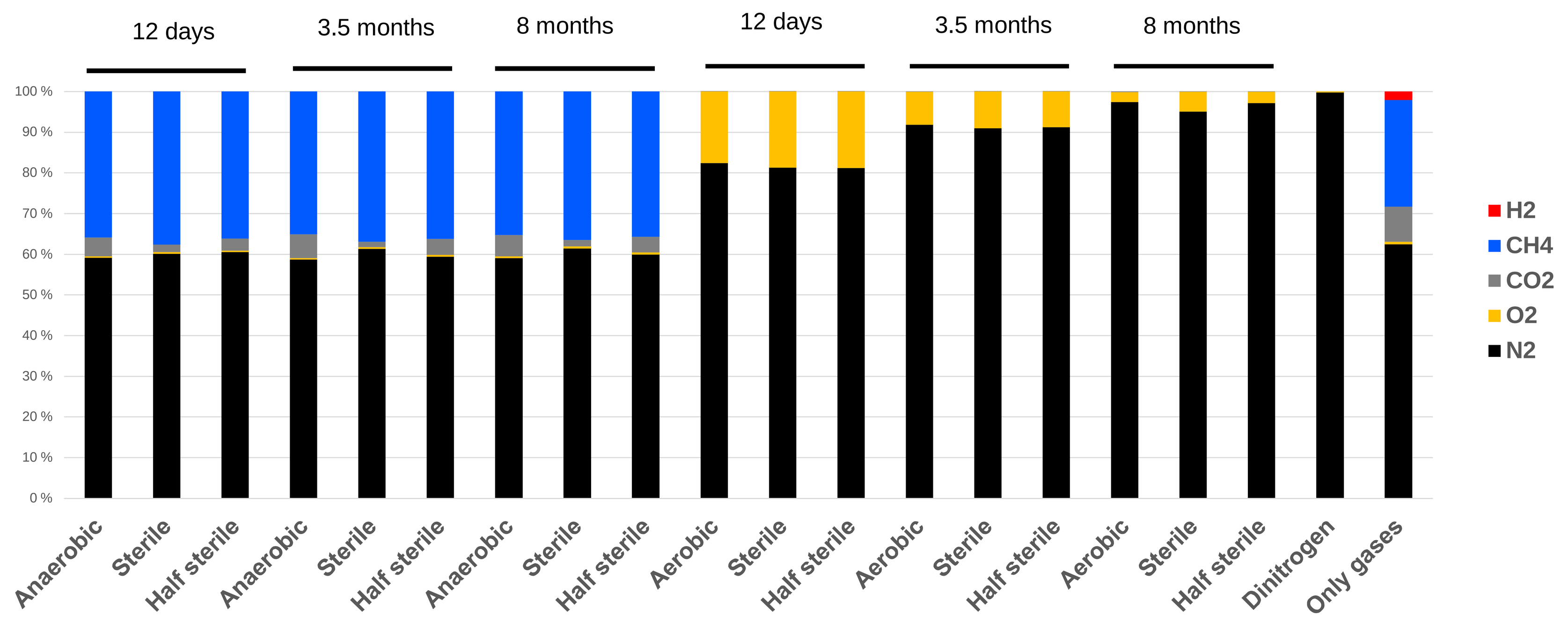

Figure 3. Development of gas composition in anaerobic and aerobic samples and two control types (look Table 1 for "Sterile" and "Half sterile") as a function of time.

Results and conclusions

- AFM showed size distribution of clay layers (Figure 2)
  - Other methods to study bentonite structure later on
- Oxygen portion steadily declined during the first 8 months in aerobic experiment (Figure 3)
- Hydrogen was used rapidly or it permeated through the rubber stoppers in anaerobic experiment (Figure 3)
- Microbial activity in water-bentonite mixture was difficult to measure due to bentonite particles
  - ATP amounts and cell counts were relatively low at the beginning
- Storage experiment continues several years

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Contacts

Hanna Miettinen
Tel. +358 20 722 5150
hanna.miettinen@vtt.fi

Minna Vikman
Tel. +358 20 722 7155
minna.vikman@vtt.fi