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Influence of microbial uranium reduction processes on the final disposal of radioactive waste

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Abstract. The safe disposal of high-level radioactive waste represents a major scientific and societal challenge. In addition to geological, geochemical and geophysical properties of such a repository, the influence of naturally occurring microorganisms from deep geological layers has to be taken into account for a comprehensive safeguard concept. Various sulfate- and iron-reducing bacteria are present in different clay formations, which can serve as a potential host rock for the long-term disposal of the waste, as well as in the backfill material bentonite. In the event of a worst-case scenario, if water enters the repository, those microorganisms can interact with the waste and change, for example, the oxidation state or the chemical speciation, which can influence the mobility of the radionuclides.

In this study, the reduction of highly mobile, water-soluble U(VI) to less mobile U(IV) by the iron-reducing microorganism *Desulfitobacterium* sp. G1-2 and the sulfate reducer *Desulfosporosinus hippei* DSM 8344^T were investigated. *Desulfitobacterium* sp. G1-2 has been isolated from a bentonite sample, and *Desulfosporosinus hippei* DSM 8344^T represents a genus of sulfate-reducing bacteria present in clay rock and bentonite.

During time-dependent experiments in a bicarbonate buffer (30 mM, 100/550 µM U(VI)), *Desulfitobacterium* sp. G1-2 showed a removal of up to 80 % of U within 5 d, whereas samples of *Desulfosporosinus hippei* DSM 8344^T showed no decrease in U concentrations over time. Therefore, experiments were carried out in artificial Opalinus Clay pore water with this bacterium (100 µM U(VI), pH 5.5). In this case, the U concentration showed a decrease of up to 80 % of the radionuclide from the supernatants within 48 h. UV–Vis studies of dissolved cell pellets of both bacteria after U incubation showed an almost complete reduction to U(IV) for *Desulfitobacterium* sp. G1-2. On the other hand, samples of *Desulfosporosinus hippei* DSM 8344^T exhibited only a partial reduction. Transmission electron microscopy (TEM) imaging combined with energy-dispersive X-ray spectroscopy analysis revealed the release of membrane vesicles from cells of *Desulfosporosinus hippei* DSM 8344^T as a possible defense reaction against cell incrustation. Furthermore, TEM images of *Desulfitobacterium* sp. G1-2 cells showed the presence of two different U-containing aggregates inside the cells.

These investigations showed clear differences in the reduction behavior of sulfate- and iron-reducing bacteria relevant to nuclear waste disposal. This highlights the importance of studies on the U(VI) interactions of different microorganisms present in deep geological layers. Moreover, new aspects for a safety concept for a nuclear repository in clay formations and for final disposal sites using bentonite as backfill material could be revealed.

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