Microbial reduction of uranium(VI) by anaerobic microorganisms isolated from a former uranium mine

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The former uranium mine Königstein (Germany) is currently in the process of controlled flooding by reason of remediation purposes. However, the flooding water still contains high concentrations of uranium and other heavy metals. For that reason the water has to be cleaned up by a conventional waste water treatment plant. The aim of this study was to investigate the interactions between anaerobic microorganisms and uranium for possible bioremediation approaches, which could be an great alternative for the intensive and expensive waste water treatment. EXAFS (extended X-ray absorption fine structure) and XANES (X-ray absorption near edge structure) measurements were performed and revealed a complete reduction of U(VI) to U(IV) only by adding 10 mM glycerol.

Despite high uranium concentrations up to 13 mg/L and a low pH of 2.9, the flooding water of the former uranium mine Königstein (Saxony, Germany) contains a high microbial diversity as detected by culture-independent methods.[1] Microorganisms are known to interact with metals and radionuclides in different ways.[2] Therefore, they can change the chemical behavior of metals and radionuclides. Anaerobic bacteria which are able to gain energy from the reduction of several metals are known to change the redox state of radionuclides as well. For instance, anaerobic sulfate-reducing bacteria (SRB) are known to reduce U(VI) to U(IV) and, thus, change the migration behavior from the highly soluble U(VI) into the less soluble U(IV).[3] To investigate the possible reduction of U(VI) within the flooding water by anaerobic microorganisms EXAFS and XANES measurements were performed.

EXPERIMENTAL. Flooding water was sampled and directly gas-flushed with N_2. 10 mM glycerol was sterile added as carbon source. The approaches (triplicates) were incubated for six weeks at 30 °C under anaerobic conditions. Samples were taken three times a week for measuring the redox potential (InLab® Redox Micro, Mettler-Toledo). Additionally, every week samples were taken to investigate the redox state of uranium. Therefore, cells were harvested by centrifugation and afterwards analyzed by U-L_{III} edge EXAFS and XANES measurements at the ROBL beamline in Grenoble. By Iterative Target-Factor Analysis (ITFA) the percentage distribution of U(VI) and U(IV) was calculated.[4]

RESULTS. During an incubation time of six weeks, the redox potential decreased from 660 mV to 300 mV. Thermodynamic calculations revealed the presence of reduced uranium at the measured redox potential (data not shown). To confirm the calculated findings EXAFS/XANES measurements were performed. The results show a change in the oxidation state of uranium after five weeks (Fig. 1). ITFA was used to calculate the percentage distribution of U(VI) and U(IV) during the six weeks of incubation (Tab. 1). After six weeks at 30 °C and under anaerobic conditions, the microorganisms were able to reduce U(VI) completely to U(IV) only in the presence of 10 mM glycerol as carbon source.

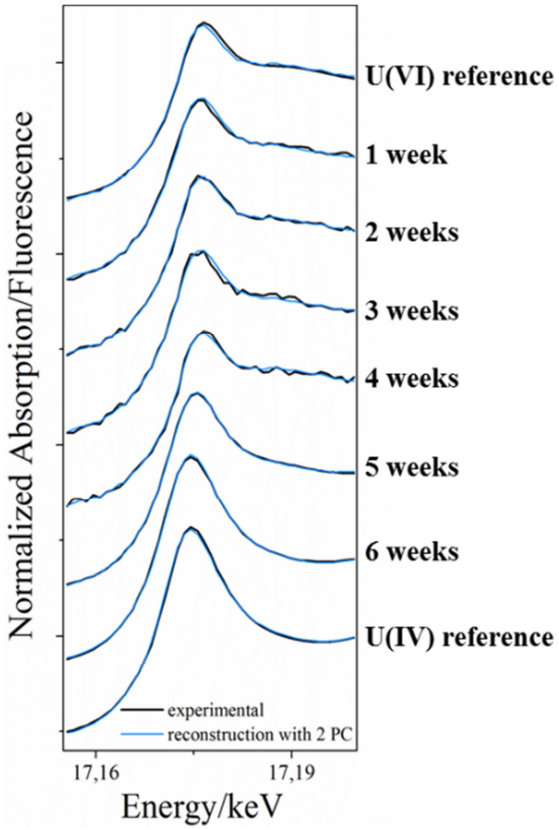

Fig. 1: EXAFS/XANES spectra of the two references and six samples.

Tab. 1: Relative uranium concentrations (in %) after XANES measurements. Calculation with ITFA.

Sample	U(VI) (%)	U(IV) (%)
U(VI) reference	100	0
1 week	100	0
2 weeks	88	12
3 weeks	97	3
4 weeks	100	0
5 weeks	48	52
6 weeks	8	92
U(IV) reference	0	100

OUTLOOK. In conclusion, the results display that anaerobic microorganisms within the flooding water are suitable for on-site bioremediation approaches which could be realized directly in the underground. Further investigations with industrial-scale setups are planned.

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