Selenium speciation in diverse microorganisms used in bioremediation
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A) Overview

Due to the tendency to bioaccumulate, trace concentrations of selenium in surface waters have led to disastrous toxicity effects on ecosystems in the past. Current remediation approaches try to use microorganisms that are highly efficient in reducing toxic, water soluble selenium oxyanions to insoluble selenium phases, which are considered non toxic [1]. Amongst the microorganisms studied, so called dissimilatory selenium reducers (DSeR), appear promising for such applications, since they can respire selenium oxyanions to elemental selenium while conserving energy for growth. Previous studies have observed large differences in the optical properties (UV-visible absorption and Raman spectra) between single dissimilatory selenium reducers and in contrast to chemically formed selenium phases [2]. However, to date there is still discussion as to the definitive assignment of selenium allotropes. At the DUBBLE beamline at ESRF, we studied for the first time these phases systematically by XAFS at the selenium K-edge.

B) Quality of measurement/data

The runs have been successful. A variety of Se K-edge spectra were collected for previously not studied model compounds and solid phases formed by different pure microbial strains. Figure 1A-C shows the quality of the spectra collected at DUBBLE, whereas one should note that the samples were fairly diluted in selenium. We collected data at low temperatures (20, 50, 70 K) as the ionic bonds of Se within its allotropes makes it sensitive to thermal-induced Debye-Waller-type attenuations. Comparing different pure microbial strains, by now one can already claim that variations in selenium solid phases exist. We want to take the opportunity to state that the support by the beamline staff (Sergey Nikitenko, Miguel Silveira) was excellent in every aspect.

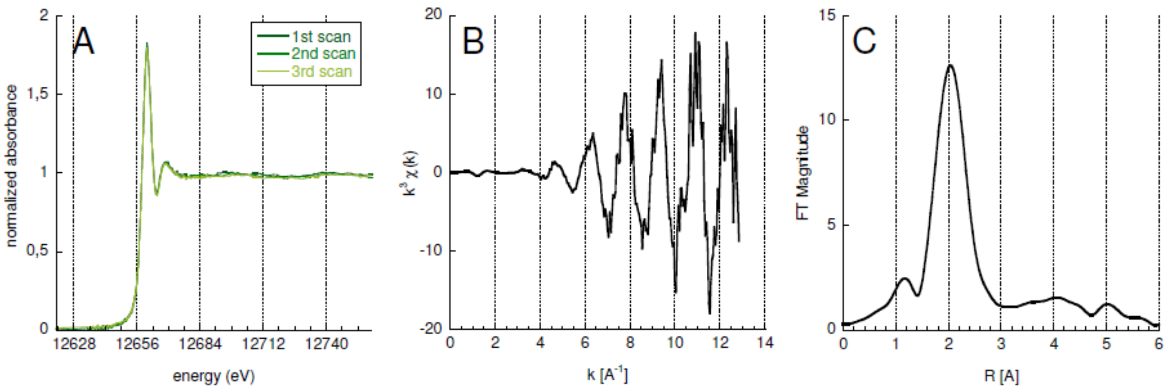

Figure 1. Selenium K-edge spectra collected at DUBBLE on a sample diluted in selenium with 3 consecutive XANES scans (A), the normalized k^3-weighted EXAFS spectra (B) and Fourier Transforms of the EXAFS spectra (C).

C) Status and progress of evaluation

Data reduction and analysis is underway, using a variety of methods. However, it is too early to provide any definitive result at this time, because XAFS requires months of careful analysis. Furthermore, one has to note that all selenium solid phases studied here differed significantly in their XAFS at the selenium K-edge, underlining the difficulty to definitively assign the difference in mechanism of microbially induced selenium precipitation (e.g. differences in incubation conditions, different enzymatic systems involved).

D) Results

As stated above, it is too early to provide any definitive result at this time. However, based on XANES / EXAFS, we can already safely state that different microorganisms indeed form different insoluble selenium phases - which are all commonly simply referred to as "elemental selenium". The results gained at DUBBLE will thus provide a detailed understanding of selenium phases formed by microbial processes. This will help to better control solid phases formed in bioremediation applications, enhancing the efficiency of these systems. On a longer scale, the microbial strains studied here can be applied in bio(nano)technology to synthesize defined selenium phases, replacing currently used chemical synthesis relying on energy intensive processes and toxic chemicals.

1. Lenz, M., and P. N. L. Lens. (2009). The essential toxin: the changing perception of selenium in environmental sciences. Science of the total Environment 407:3620-3633.
2. Oremland, R. S., M. J. Herbel, J. S. Blum, S. Langley, T. J. Beveridge, P. M. Ajayan, T. Sutto, A. V. Ellis, and S. Curran. (2004). Structural and spectral features of selenium nanospheres produced by Se respiring bacteria. Appl. Environ. Microbiol. 70:52-60.