Biogeochemical and mineralogical aspects of sustaining low concentrations of uranium in groundwater at nuclear sites

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Microbial metabolism can alter the solubility of priority radionuclides including uranium. Here, we explore the potential for biostimulation to accomplish the long-term removal of U(VI) from groundwater by: adding an electron donor to stimulate U(VI) reduction by the natural microbial community present in different sediments obtained from a nuclear licensed site; investigating the role played by residual electron donor in buffering oxidative remobilisation of U(IV); and by stimulating an environmental isolate of *Serratia* to reduce U(VI) and/or precipitate uranium-phosphate minerals under anaerobic conditions.

The natural microbial community in a variety of different soils was able to remove 0.05 mM U(VI) from solution when supplied with acetate and lactate as electron donors, including at 10°C, representative of UK groundwater temperatures.

Microbially-reduced U(IV) was fully remobilised after exposure to oxygen in batch experiments, while around 60% was remobilised by exposure to nitrate. The presence of residual electron donor controlled U(IV) remobilisation kinetics. X-ray absorption spectroscopy results suggested that microbially-reduced U(IV) did not become more crystalline (and therefore recalcitrant) after 4 months of ageing.

Finally, a *Serratia* species was used in pure culture experiments to explore the range of end-member biominerals that could be precipitated via biostimulation processes. Cells in an anaerobic minimal medium supplemented with glycerol phosphate removed 1 mM U(VI) from solution, precipitated as uranyl phosphate (autunite) minerals. A black nanocrystalline mineral, likely uraninite, was precipitated by washed cell suspensions containing 0.5 mM U(VI) as the sole electron acceptor and glycerol as an electron donor. The stability of these biomineral phases is now being studied.

Collectively, this work demonstrates the potential for biostimulation to control aqueous uranium solubility in groundwater / sediment systems from a nuclear site, and highlights the complex interplay between uranium solubility and electron donor and phosphate concentrations.