Spectroscopic Study of Uranium (VI) Reduction by Plant Biomass

Margaret Murphy, John R. Bargar, Noémie Janot
Stanford Synchrotron Radiation Lightsource
SLAC National Accelerator Laboratory, Menlo Park, CA 94306

Introduction

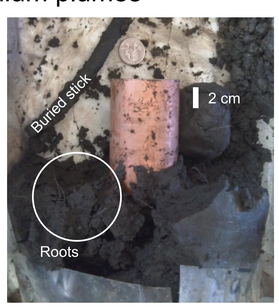
Hypothesis:
- Bacterial cells and extracellular polymeric substances associated with decaying plant biomass will to reduce uranium (VI) bound to its surface functional groups to uranium (IV).

Objectives:
- Determine if decaying plant biomass will reduce uranium
- Measure amount of uranium decaying plant biomass will absorb from solution
- Determine which functional groups of the biomass bind with uranium, in particular if it is the bacteria

Background

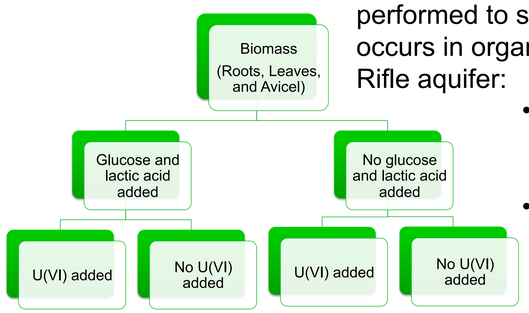
- Uranium is one of the most common and problematic groundwater contaminants at Department of Energy legacy sites
- The oxidation state of uranium helps determine its mobility and behavior in the aquifer:
  - Uranium (VI) dissolves easily and is relatively mobile
  - Uranium (IV) is much less soluble and thus less mobile
- The site of interest in this study is a former uranium ore processing plant at Rifle, Colorado
- Organic rich sediments, decayed plant biomass, have been found to contain the majority of aquifer uranium
- Stream banks in Rifle provide a depositional model to explain the mechanism by which naturally reduced sediment layers formed
- Slow release of uranium from organic rich sediments is believed to be responsible for ground water uranium plumes

- Stream bank in Rifle where naturally reduced sediments are deposited
- Plant roots and leaves can be seen mixed in with the sediments



Naturally reduced sediments collected from well drilling at Rifle

Experimental Set-up

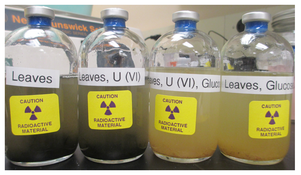


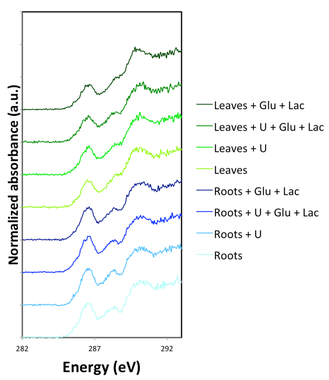
The following experiment was performed to simulate the reaction that occurs in organic rich sediments of the Rifle aquifer:

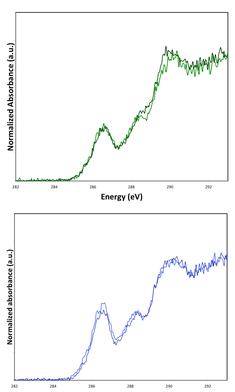
- Ground roots and leaves incubated in Rifle ground water
- Glucose and lactic acid added to some solutions as food for microorganisms
- Uranium (VI) dosed into solutions
- Solid biomass harvested from solution

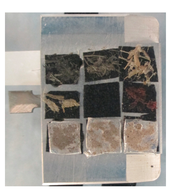
Data & Results

- At the end of the incubation period solutions without added glucose and lactic acid turned black in color, indicating sulfate reduction, while those with remained unchanged
- Carbon X-ray absorption spectroscopy (XAS) was used measure to if uranium was bound to the biomass
- There appears to be a few subtle changes in the C XAS resonances that correlate with the presence of U, particularly in the glucose/lactic acid samples

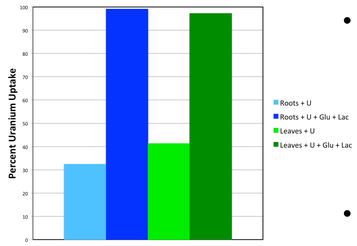






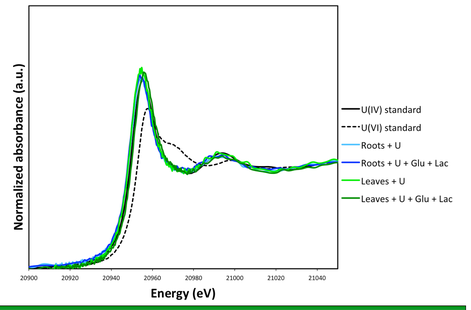


Sample holder for C XAS: Leaf samples mounted on carbon tape



- Uranium inductively coupled plasma mass spectrometry (ICP-MS) was performed to measure uranium concentrations in water samples of each solution before harvesting
- The percentage of uranium uptake was then calculated

- Uranium L_{III}-edge XAS was used to determine the oxidation state of uranium in the solid phase
- The spectra shows that the uranium in the samples is U(IV)



Conclusions

- Biomass promotes the growth of sulfate reducing bacteria
- Glucose/lactic acid promotes the growth of metal reducing bacteria
- Biomass does reduce U(VI) to form U(IV)
- Subtle differences in the C XAS spectra suggest that uranium bound to carbon does affect the carbon speciation
- Less noisy data would improve the spectra comparison, so in future studies more counts should be taken in the 290-295 eV range
- Future measurements should further assess the impact of U on the C spectra by optimizing the experimental and measurement conditions based on the results of this study

Acknowledgements

Special thanks to Morris Jones, Cynthia Patty, Lisa Hammon, Ray Russ, Carol Morris, Darryl Murray, Marcia Torres and the SLAC-SSRL staff for their help and support in this research. I would also like to thank Tom Regier, Jay Dynes, and David Chevrier at the Canadian Light Source for their assistance.

This material is based upon work supported by the S.D. Bechtel, Jr. Foundation, National Marine Sanctuary Foundation, Carnegie Corporation of New York, and/or National Science Foundation under Grant Nos. 0952013 and 0833353. Funding was also provided by the DOE office of Biological and Environmental Research, Climate and Environmental Sciences Division, through the SLAC SFA program (FWP #10094). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funders.
The STAR program is administered by the Cal Poly Center for Excellence in Science and Mathematics Education (CESaME) on behalf of the California State University.