Uranium sequestration during and after bio-remediation in shallow aquifer sediments

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Long-term column experiments are being conducted to examine the effect of iron sulfide precipitates on limiting the remobilization of uranium (IV) formed during bioremediation processes. Increasing iron sulfide precipitation is intended to help maintain reducing conditions by providing a redox buffer and to 'armor' the bio-reduced U (IV), and therefore limit re-oxidation. The columns contain sediments collected beneath a former mill tailings site in Rifle, CO. During the bio-reduction phase the influent groundwater was anoxic and amended with 10 mM acetate and 10 μM U (VI), throughout this phase, uranium removal from the influent groundwater was observed with U (VI) concentrations decreasing from an average of 10 μM to 3.5 μM through 110 days. At this time uptake of 50 μg U/g sediment had occurred in the column. Rapid removal of uranium from the groundwater was observed for the first 20 days of bio-reduction, with concurrent increase in Fe (II) in the effluent groundwater and increased activity of iron-reducing bacteria. Subsequently, a decrease in the uranium removal rate and an increase sulfide production due to the increasing activity of sulfate-reducing bacteria were observed. The U (VI) and acetate amendments to the groundwater were halted prior to introducing oxygenated groundwater into the columns, however, we continued to observe a release of U (VI) (1-1.5μM) in the effluent, and once oxygenated groundwater was introduced, we continued to see a similar concentration released. Parallel columns that have additional ferrous iron added initially, or subsequent to the onset of sulfate reduction are currently being studied to test the effect of iron sulfide precipitation on release of U (VI) upon return to oxidizing conditions.

Electrical geophysical and geochemical monitoring of *in situ* enhanced bioremediation

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In many situations *in situ* enhanced bioremediation is a cost-effective and efficient method of remediating contaminated groundwater when compared to traditional pump-and-treat approaches. Although understanding of the complex biogeochemistry associated with bioremediation has advanced rapidly, there often is substantial uncertainty concerning the effectiveness of enhanced bioremediation because of uncertainty in the delivery and distribution of biostimulants and the lack of data concerning remedial progress at locations away from sampling wells. Uncertainty in the spatio-temporal distribution of biostimulants and the evolution of biogeochemical processes can be significantly reduced through time-lapse electrical or electromagnetic geophysical imaging/monitoring. The basic premise supporting the approach is that biostimulants and the associated remediation byproducts modify the electrical properties of the subsurface, which can be monitored in 4D using time-lapse electrical resistivity tomography (ERT), induced polarization (IP), and radar velocity/attenuation difference tomography.

We demonstrate the applicability of an autonomous time-lapse ERT and IP monitoring system for monitoring the distribution and evolution of *in situ* bioremediation processes in near real time during a remediation campaign at a Superfund site in Brandywine MD. Beginning in March 2008, the system has been used to monitor subsurface alterations in electrical conductivity and chargeability driven by bioremedial processes, with 3D difference inversions acquired every 2 days. When calibrated with periodic chemical analysis of field chemistry, changes in bulk conductivity and chargeability are diagnostic of the distribution and progress of remedial geochemical processes with high resolution in space and time.