Potential for In Situ Bioremediation of Uranium and Vanadium Contamination in the Subsurface

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A field test was conducted for the first time to further evaluate the potential for in situ bioremediation of uranium-contaminated groundwater. A test plot consisting of a 20-well injection gallery, 15 downgradient monitoring wells, and 3 upgradient control wells was installed at the Old Rifle UMTRA site in Colorado. Acetate (1–3 mM) was injected into the aquifer over a four-month period in order to stimulate the activity of dissimilatory metal-reducing microorganisms. Loss of U(VI) began almost immediately after initiation of acetate injection. This was accompanied by production of Fe(II), resulting from Fe(III) reduction. After 50 days, soluble U(VI) approached or fell below the UMTRA MCL limit (0.18 nM). There was no significant removal of sulfate from the groundwater during this period, and pH remained constant. Loss of U(VI) was coincident with an enrichment of *Geobacteraceae*, with *Geobacteraceae* accounting for over 70% of the microbial community at the height of the Fe(III) and U(VI) reduction phase. These results are consistent with previous laboratory studies with uranium-contaminated subsurface sediments, which demonstrated that the addition of acetate promoted the growth of *Geobacteraceae*, which grew primarily by Fe(III) reduction, but which also reduced U(VI) concurrently. Beyond 50 days of acetate injection in the field experiment, sulfate concentrations started to decrease. This was accompanied by a decrease in *Geobacteraceae* and an increase in sulfate-reducing microorganisms. These results suggest that, as Fe(III) became depleted at the point of injection, Fe(III) reducers could no longer out compete sulfate reducers and thus sulfate reducers began consuming the acetate. As sulfate reducers became predominant, U(VI) concentrations increased, suggesting that sulfate reducers were not as effective in reducing U(VI) as the *Geobacteraceae*. This suggests that it is important to maintain Fe(III)-reducing conditions in order to effectively remove U(VI) from the groundwater. The results demonstrate that promoting the growth and activity of *Geobacteraceae* in the subsurface can be a very effective mechanism for immobilizing uranium in contaminated aquifers.

Although not currently a priority contaminant of focus for the NABIR program, vanadium is a prevalent contaminant in the groundwater at a number of UMTRA sites. Vanadium toxicity and solubility vary considerably with the nature of the compound, but in general, both decrease as the valence state is reduced. Thus, promoting the reduction of V(V) may be a remediation strategy. In order to determine if *Geobacteraceae* microorganisms were capable of reducing V(V), *Geobacter metallireducens* was inoculated into a medium in which acetate was the electron donor and V(V) was the sole electron acceptor. The yellow color of the medium, due to the presence of V(VI), changed to blue, attributable to the presence of V(IV), which subsequently precipitated. Reduction of V(V) was associated with cell growth, and there was no V(V) reduction in heat-killed or abiotic controls. These results demonstrate that *G. metallireducens* has the potential to convert vanadium from a soluble form to an insoluble form and suggest that vanadium may be removed from contaminated waters by stimulating the growth of *Geobacteraceae* in a manner similar to that successfully employed for in situ bioremediation of uranium-contaminated groundwater.