Biotransformations Involved in Sustained Reductive Removal of Uranium in Contaminated Aquifers

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Previous field studies on in situ uranium bioremediation have focused on the addition of organic electron donors to stimulate the activity of dissimilatory metal reducers. A field study at the NABIR study site in Rifle, CO, further confirmed that this approach can successfully precipitate uranium from contaminated groundwater and that this process can result in long-term immobilization of uranium. However, when acetate is added as the electron donor, a substantial portion of the acetate is wasted as Fe(III) becomes depleted near the injection gallery. This is because sulfate reducers can then compete for the electron donor and, unlike *Geobacter* species, acetate-oxidizing sulfate reducers are ineffective in reducing U(VI). In an effort to overcome this limitation, additional laboratory studies were conducted with sediments from the Rifle site. Previous studies have demonstrated that these laboratory studies, which are carried out under in situ conditions, can accurately predict the outcome of field experiments. Lactate was added as an electron donor with the idea that this might stimulate the growth of lactate-oxidizing, sulfate reducers such as *Desulfovibrio* species, which our previous studies have shown are effective U(VI) reducers. However, the addition of lactate was a less effective stimulant of U(VI) reduction than acetate during the Fe(III) reduction phase of the experiment when *Geobacter* species were prevalent, and no *Desulfovibrio* could be detected during the sulfate reduction phase when there was little or no U(VI) reduction. These results suggest that, although *Desulfovibrio* species can readily reduce U(VI) in laboratory cultures, it is difficult to enrich for *Desulfovibrio* in field experiments. Thus, the potential for using *Desulfovibrio* species as an agent for in situ uranium bioremediation seems limited.

In order to alleviate the waste of electron donor consumption by sulfate reducers and possibly avoid other potential problems, such as sulfide production associated with sulfate reduction, a search was undertaken for an electron donor that might be exclusively used by *Geobacter* species but not sulfate reducers. Our previous studies have demonstrated that *Geobacter* species can accept electrons from electrodes poised at the appropriate potential, but it is unlikely that sulfate reducers can use an electrode as an electron donor. In sterile systems, electrodes poised at –500 mV (vs. Ag/AgCl reference) rapidly removed U(VI) from solution. However, when these poised electrodes were removed, all U(VI) returned to solution, demonstrating that the electrodes did not reduce the uranium. However, if *G. sulfurreducens* was present on the electrodes, U(VI) did not return to solution until the uranium was oxidized by bubbling with air. This finding suggests that *G. sulfurreducens* respiring at the electrode surface reduced the U(VI). Batch studies with contaminated sediment and groundwater demonstrated that poised electrodes removed U(VI) from solution and that the removal was dependent on the poised potential at the working electrode. Column studies demonstrated that electrodes placed in a reactive barrier setting removed uranium from contaminated groundwater and this uranium could be recovered by extracting the electrodes. These results suggest an alternative strategy for providing an electron donor for in situ uranium bioremediation, which will be evaluated in the field in 2005.