Investigating In Situ Bioremediation Approaches for Sustained Uranium Immobilization Independent of Nitrate Reduction

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Uranium and radionuclide contamination at DOE facilities frequently occurs with nitrate. Current bioremediation strategies reduce nitrate/nitrite before reducing U and metals. While consistent with traditional thinking, this approach is problematic within the geochemical environment of DOE wastes, where nitrate may persist for centuries. The goal of this research is to investigate bioremediation strategies involving the addition of specific energy sources and nutrients, such as propane, hydrogen, methanol and triethylphosphate, that can effectively immobilize metals and radionuclides without requiring complete nitrate removal. Such strategies would be compatible with the current FRC Area 1 environmental constraints of high nitrate, low permeability, and low pH. We hypothesize that if even a fraction of the microbial reducing potential can be directed towards the reduction of U and metals, the reduced species can be stable in anaerobic waters, making nitrate/nitrite removal unnecessary. Our initial objective is to demonstrate that the stringent removal of oxygen from groundwater is a key for U(IV) stability rather than removal of nitrate/nitrite. Experiments to date suggest that stringently deoxygenated waters containing uranium plus mM concentrations of nitrate are stable for a month or longer, whereas aerobic or moderately anaerobic suspensions of nitrate result in uranium oxidation within hours to days. Accordingly, transient influxes of nitrate may exhibit little change in the status of reduced metals so long as oxygen is rapidly eliminated and metal-reducing conditions reestablished. A second objective is to stimulate extant microorganisms to reduce metals in microcosm experiments with high nitrate and low pH. Enrichments are in progress, and growth is evidenced. Our final objective is to develop supporting approaches minimizing impacts of nitrate reduction that might facilitate U(IV) reoxidation and mobilization. Evidence that a small percentage of the potential bioreduction capacity within microcosms can be directed toward U reduction and its sustained immobilization would constitute success. Through this microcosm-based laboratory research, we will investigate innovative biotransformation strategies that can provide long-term stability of immobilized metals and radionuclides without requiring nitrate removal. This research will also enhance our understanding of interrelationships between biological nitrate and metal reduction in low pH environments.