

Microbiological-enhanced mixing by long-range extracellular electron transfer during in-situ bioreduction of uranium

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ABSTRACT

Bioreduction is a promising strategy for the long-term management of groundwater contaminated by metals and radionuclides, for which conventional treatments may be ineffective, ecologically damaging, or prohibitively expensive to implement at larger scales. For example, it is a suitable remediation technique for the immobilization of hexavalent uranium, which is difficult to treat by conventional means due to the large area of contamination that currently exceeds 2 million acres. By amending the affected areas with an electron donor such as acetate or ethanol, native bacteria capable of dissimilatory metal reduction are able to grow by coupling the oxidation of donor with the reduction of uranium. The reduced product is insoluble, immobile, and less toxic than the reactant.

Physical models have accounted for various aspects of hydrology, geochemistry, and microbiology to predict the extent of bioreduction, but all to date have excluded the potential contribution of long-range extracellular electron transfer (EET) by bacteria that may exceed the zone of physical mixing between electron donor and acceptor. Long-range EET by metal-reducing bacteria is a recently discovered phenomenon that occurs via electron shuttling, or along the length of conductive pili called 'nanowires'. Nanowires are known to extend tens of micrometers from the cell and form conductive biofilms, but their contribution to metal reduction has not been adequately tested under field conditions using chemicals and concentrations representative of the groundwater environment.

Using a novel microfluidic reactor that I designed and fabricated in my lab, and manganese dioxide as a surrogate for uranium, I am investigating the role of long-range EET in bioremediation. In particular, I hope to determine 1) the distance of nanowire penetration of nanopores 2) the concentration threshold below which nanowires and electron shuttles are produced, and 3) the relative contribution of each under different flow regimes. Preliminary results from the first task indicate that reduction of metals and radionuclides may be underestimated due to the neglect of long-range EET in field models. I am actively working on the remaining tasks to gain insight into the chemical triggers that promote EET and the role that groundwater flow has in selecting between different EET mechanisms. Greater understanding of long-range EET phenomena as a result of my experiments has the potential to improve the predictive power of field models, reduce the cost of bioreduction, and lead to engineered strategies that are more efficient than the current standard.