Electrochemical and Corrosion-Induced Hydrogen Generation to Stimulate Bioremediation of Perchlorate in Groundwater

Christopher J. Ritchie and Scott Warner (Ramboll, Emeryville, CA, USA)

Background/Objectives. The widespread use of perchlorate as an oxidizer in solid propellants has led to subsurface contamination at numerous sites. Perchlorate's properties make it difficult to remove physically and destroy chemically once released to groundwater. However, enzymes produced by bacteria can overcome the kinetic barrier to perchlorate reduction making in situ bioremediation of perchlorate an effective remedial alternative. While organic carbon substrates can enhance bacterial perchlorate reduction, they require frequent reapplication and can result in growth of other, non-target heterotrophic bacteria competing for electron donors. In contrast, dissolved hydrogen specifically enhances the activity of autotrophic perchlorate-reducing bacteria that can use hydrogen as an electron donor and inorganic carbon, like carbon dioxide (typically present and measured as alkalinity in groundwater), as a carbon source. If applied electrochemically via low-voltage direct current generated from solar arrays or via the sustained slow release from zero valent iron (ZVI) corrosion, hydrogen may be a long-term sustainable alternative for in situ bioremediation of perchlorate and other contaminants. Here, we investigate the viability of bioelectrochemical reduction and the use of ZVI for the sustainable bioremediation of perchlorate-contaminated groundwater at a site in the Western United States.

Approach/Activities. Two approaches for the in situ generation of hydrogen are being evaluated. Currently, bench-scale testing of each of the two approaches is underway with subsequent field testing planned for early 2019. In the bioelectrochemical process, both hydrogen from water electrolysis and organic carbon from carbon dioxide reduction are generated at the cathode, serving as electron donors for downgradient microbial perchlorate reduction. Different electrode materials and membranes were tested in a divided electrochemical reactor to evaluate electron donor generation. Subsequently, flow-through column tests were employed to determine microbial perchlorate reduction kinetics and elucidate the impacts of competing electron acceptors. In the ZVI corrosion process, hydrogen is released from the iron particles as ZVI is reduced to ferrous iron. The resulting reaction provides dissolved hydrogen to the aqueous system and increases the pH locally. The dissolved hydrogen can be used as an electron donor to support biological reduction of perchlorate. Batch tests evaluated ZVI grain size on various abiotic factors such as hydrogen generation rate and direct reduction of competing electron acceptors. Subsequently, flow-through column tests were employed to evaluate perchlorate reduction rates and potential for biofouling and/or mineral precipitation effects.

Results/Lessons Learned. Preliminary data from the bench-scale testing indicate that both the bioelectrochemical and ZVI processes warrant further testing at this site; however, high total dissolved solids (TDS) concentrations may inhibit the performance of biological perchlorate reduction. Results of the batch and flow-through column tests will be presented along with site characterization data for a potential field test location. Conceptual designs for field implementation of these approaches will also be presented.