Hydrogen as an Indicator to Assess Biological Activity during Trace-Metal Bioremediation

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The design and operation of a trace-metal or radionuclide bioremediation scheme requires that specific redox conditions be achieved at given zones of an aquifer for a predetermined duration. Tools are therefore needed to identify and quantify the terminal electron acceptor processes (TEAPs) that are being achieved during bioremediation in an aquifer, and to ensure that this is done at a high spatial resolution. Dissolved hydrogen concentrations have been shown to correlate with specific TEAPs during bioremediation in an aquifer. Theoretical analysis has shown that these steady-state hydrogen levels are solely dependent upon the physiological parameters of the hydrogen-consuming microorganisms, with hydrogen concentrations increasing as each successive TEAP yields less energy for bacterial growth. The assumptions for this statement may not hold during a bioremediation scheme in which an organic substrate is injected into the subsurface and where organisms may consume hydrogen and carbon simultaneously.

A series of batch experiments were conducted to study the utilization of acetate and hydrogen by *Geobacter sulfurreducens* under iron-reducing conditions. Microcosms were set up to investigate the utilization of hydrogen and acetate when either of them is the sole electron donor and when both are present and utilized simultaneously as an electron donor. These experiments were conducted for varying initial conditions of the hydrogen and acetate concentration, and the disappearance of these compounds plus the evolution of Fe^{2+}, as well as biomass, were monitored over time. The results of these studies indicate that the biokinetic coefficients describing the rate of hydrogen utilization are not affected by the simultaneous utilization of acetate, and that the biokinetic coefficients describing the rate of acetate utilization are not affected by the simultaneous utilization of hydrogen.

A model was developed using the batch dual-donor experiments, which indicate that the steady-state hydrogen concentration in the presence of an organic as electron donor is not only dependent on the biokinetic coefficients of the TEAP, but also the concentration of the organic substrate. Column experiments performed to measure steady-state H_2 concentrations under dual electron-donor conditions were compared to the model formulation. Steady-state H_2 concentrations in a flow-through column using NABIR Field Research Site (Oak Ridge, TN) soil were higher than observed for iron-reducing conditions in the field even though evidence suggests that iron reduction was the only active TEAP in the column. These dual-donor steady-state H_2 concentrations correlated with the dual-donor model formulation. Additional column experiments are currently being performed under iron-reducing conditions to further characterize the effect of dual electron-donor utilization on steady-state dissolved hydrogen concentrations. This includes an additional column experiment similar to that described above (Field Research Site soil, indigenous organisms) as well as a more controlled column experiment using glass beads, synthetic iron (ferric citrate), and the iron-reducing, H_2 and acetate-oxidizing bacteria (*Geobacter sulfurreducens*) used in the batch experiments.