Effect of Electron Acceptors on the Stimulation of Anaerobic Benzene Degradation Using Passive Anode-Cathode Technology (PACT)

Samantha Chomyshen (scc118@mail.usask.ca), Kathlyne Hyde, and
Steven D. Siciliano (University of Saskatchewan, Saskatoon, SK, Canada)
Scott R. Burge (Burge Environmental Inc., Tempe, AZ, USA)
Kris Bradshaw (Federated Cooperatives Limited, Saskatoon, SK, Canada)

Background/Objectives. Benzene, a known carcinogen, is a highly mobile and recalcitrant petroleum hydrocarbon found in the groundwater and soil at contaminated sites. In-situ biodegradation of benzene is a cost-effective method of removing the risk from the soil, but under anaerobic conditions, benzene degradation is slow. As part of the Sustainable In Situ Remediation Cooperative Alliance (SIRCA), an in-situ sensor for measuring microbial activity consisting of a graphite anode and platinum catalyst cathode, termed passive anode-cathode technology (PACT), may enhance anaerobic degradation via two methods. One is to introduce a surface for the microbial community to adsorb to and deposit electrons onto, allowing for biofilm formation with a unique biodegradative community. The second is to allow molecular diffusion of oxygen into the community to assist in the removal of benzene by allowing an aerobic pathway to occur under anaerobic conditions. Anaerobic benzene degradation can occur under nitrate, iron(III) or sulfate reducing conditions. Here we evaluated two hypotheses: (i) PACT can stimulate anaerobic benzene degradation and (ii) PACT's stimulation would differ between electron acceptors.

Approach/Activities. Cultures were prepared anaerobically under fiveconditions: 1) no electron acceptors, 2) nitrate-reducing, 3) sulfate-reducing, 4) iron(III)-reducing, and 5) all electron acceptors. Various cultures contained a PACT and inoculant at 2% v/v using an enrichment culture from oil sands process affected water provided by Dr. Ania Ulrich (University of Alberta). The inoculum was taken from an enrichment culture kept under nitrate reducing and benzene degrading conditions. The cultures were measured weekly for benzene, nutrients, metabolites, cDNA, rRNA, and iron concentrations. After six weeks of readings, cultures were sampled for DNA sequencing in the following locations: 1) the FeS mineral resting at the bottom, 2) the suspended media, 3) the surface of the graphite, 4) and the membrane.

Results/Lessons Learned. Electron acceptors had a strong effect on the degradation rate of benzene when paired with PACT. Benzene degradation (0.059 ± 0.007 day^{-1}) was the highest with the sulfate treatment. Surprisingly, the next most effective treatment (0.032 ± 0.006 day^{-1}) was all electron acceptors combined. In addition, visual observations confirmed the importance of iron and sulfate reduction as the combined treatment cycled through nitrate reducers, iron reducers, and sulfate reducers over the six weeks. The presence of PACT significantly increased degradation rates for the combined electron acceptors, 0.032 ± 0.006 day^{-1} with no probe compared to 0.058 ± 0.004 day^{-1} with probe, as well as for sulfate reduction, 0.059 ± 0.007 day^{-1} with no probe compared to 0.066 ± 0.006 day^{-1} with probe. There was minor degradation under nitrate or iron reducing conditions. Further work will determine if the community on the probes versus the mineral-associated community is responsible for the enhanced anaerobic degradation.