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Complete Degradation of Chlorinated Ethanes in Sequential Bioreactors Operated under Varying Redox Conditions

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Background/Objectives. An anaerobic bioreactor (ABR) designed from engineered mixtures of peat and sand can provide an environment to foster the use of microbial degradation processes for treatment of chlorinated ethenes and ethanes from groundwater. Chlorinated ethenes can be readily dechlorinated to ethene, while reductive dechlorination processes for chlorinated ethanes, such as 1,1,1-TCA, do not typically progress beyond chloroethane under anaerobic conditions. The objective of this study is to develop a design approach for a bioremediation system that completely degrades aqueous concentrations of chlorinated ethanes via a combination of anaerobic and aerobic processes. The selected method for testing using an anaerobic process in the peat:sand bed for reductive dechlorination of 1,1,1-TCA and 1,1-DCA to chloroethane, followed by the addition of oxygen via diffusion to stimulate chloroethane mineralization.

Approach/Activities. A two-phase pilot-scale ABR system was operated in series inside a greenhouse to evaluate the anaerobic dechlorination of 1,1,1-TCA to chloroethane, followed by aerobic oxidation of chloroethane. Two ABR systems, constructed from a peat:sand mixture were used in te study: the first operated in a downflow mode under anaerobic conditions with feed water 1,1,1-TCA concentration of 4 mg/L. The effluent from the first reactor was pumped to the second reactor operated in an upflow mode. The second phase reactor was divided into a bottom anaerobic zone (approximately 9.5”) to complete dechlorination and an upper aerobic zone for aerobic oxidation of chloroethane. The lower anaerobic and aerobic zones were separated by a 2-inch sand layer. The upper aerobic zone was created by pumping pressurized oxygen (at 45 PSI) via 50 feet of porous Silastic tubing into the 2-inch sand layer. Aqueous samples were collected from intermediate ports and analyzed for chlorinated ethanes using gas chromatography with a flame ionization detector. Genomic DNA in the peat-sand bed mixture were extracted from various depths in the second-phase reactors and 16S rRNA in V4 region was sequenced using Miseq Illumina platform. A batch study was also conducted in serum bottles with media from the aerated zone.

Results/Lessons Learned. Complete mineralization of chloroethane was observed in the effluents from the aerobic zone of the ABR system at a 1,1,1-TCA loading rate 0.36 ± 0.02 g/m^2*day. Complete dechlorination of 4,300 mg/L 1,1,1-TCA resulted in an influent concentration of approximately 380 ± 45 mg/L of chloroethane and 650 ± 54 mg/L of 1,1-DCA to the second-phase bioreactors. Dechlorination of 1,1-DCA continued in the anaerobic zone of the second reactor with an increase in chloroethane to a concentration entering the aerobic zone at 540 ± 56 mg/L. Approximately 98.5 ± 0.01% decrease in chloroethane was observed in the aerobic zone of the second phase reactor. Dissolved oxygen levels in the aerobic zone ranged from 3 to 7 mg/L and the anaerobic zone dissolved oxygen was less than 1 mg/L. In the batch study with serum bottles, decreases in chloroethane (94.01 ± 0.04%) was only observed in the aerobic treatment with no apparent losses in anaerobic treatments and control bottles. The analysis of the DNA extractions will be completed well before the May 2017 conference date.