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A Sustainable Bioremediation Approach for BTEX-Contaminated Groundwater under Methanogenic and Sulfate-Reducing Conditions

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Background/Objectives. Engineered anaerobic bioreactors (ABR) constructed from mixtures of peat and sand can biodegrade high concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX) from contaminated groundwater. The objective of this research is to design an ABR system with varying terminal electron acceptors and a versatile platform for BTEX biodegradation in groundwater. In this study, a laboratory-scale ABR was constructed to treat 10 mg/L of BTEX compounds while simultaneously adjusting the terminal electron accepting processes in the bed. These changes were confirmed by using a metagenomics assessment of microbial populations within each ABR bed.

Approach/Activities. This study was conducted using ABR systems constructed from triplicate glass columns (4.0” diameter and 27.6” length) packed with a peat-sand mixture (50/50 by weight proportion). The ABR system was operated in a growth chamber with regulated temperature (20 to 30°C), light and humidity (35-55%). Aerobic synthetic groundwater was deoxygenated by passing through a separate oxygen scavenging, peat bed operated by gravity and the effluent water was dosed with 10 mg/L of BTEX using water saturated solutions. The ABR system was operated for 90 days without addition of any electron acceptor and then sulfate was added at 500 mg/L and the system operated for another phase. Anaerobic synthetic groundwater with BTEX was pumped (1.1 mL/min) through the ABR system in up-flow mode. Groundwater and sediments were collected from multiple ports along the length of the reactor. Concentrations of BTEX in synthetic groundwater was measured using a gas chromatograph fitted with a flame ionization detector. Genomic DNA from the sediment samples sequenced using the Miseq Illumina platform and the changes in bacterial population was characterized over the operation period of the ABR system.

Results/Lessons Learned. At a loading rate of 1.96 g BTEX/m2?day, near complete biodegradation of BTEX was observed in a residence time of the column of 1.3 days. During the first 90 days of operation, a 94±0.02% decrease in BTEX was observed. After 90 days with the addition of sulfate, a 96±0.027% decrease in BTEX compounds were observed. The removal percentage was not statistically significant ($p = 0.343$) between the two redox conditions. The majority of the decrease (9.94±0.94 g/m3?day, $p = 0.966$) in BTEX was observed in the lowermost zone (from 0-6” from inlet). At depths of 6-12” from the inlet, a BTEX decrease of 1.82±0.94 g/m3?day was observed. Within the uppermost part of the column (12-24” from the inlet), only a 0.55±0.14 g/m3?day decrease in BTEX was observed. During the first 90 days of operation with no added electron acceptor, the relative abundance of organisms was similar throughout the sample set; the dominant phyla were Bacteroidetes, Proteobacteria and Verrucomicrobia. The order Cytophagales within the phylum Bacteroidetes was a dominant sub-group found within the cores. The largest percent of abundance of Cytophagales is within Zone 1 at approximately 27%, with Zone 2, Zone 3, and Zone 4 approximately 15% abundance of the total Bacteria. After the addition of sulfate, Proteobacteria and Chloroflexi were the most abundant phylum populations at approximately 28% and 15%. The change in microbial populations is attributed to the electron acceptor available within the reactors. Both redox conditions were effective at treating BTEX under anaerobic conditions.