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Field Application of Dual-Biofilm Barriers for In Situ Remediation of Chlorobenzenes in Groundwater and Wetland Sediments

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Background/Objectives. Chlorinated benzenes (CBs) can be difficult to treat by bioremediation because complete degradation to CO_2 in many systems cannot be achieved by anaerobic or aerobic processes alone. While tri- and di-CBs can be reductively dechlorinated, monochlorobenzene (MCB) often resists anaerobic degradation; MCB can be treated by aerobic biooxidation, while more highly chlorinated CBs cannot biodegrade aerobically. The National Institute of Environmental Health Sciences and EPA (Region III) have funded a research project to develop aerobic/anaerobic dual-biofilm barriers for treating CBs. As part of the project, a year-long pilot test is being conducted to evaluate the performance of dual-biofilm barriers for treating CBs at a test site – the Standard Chlorine of Delaware Superfund site. At the site, groundwater containing CBs discharges to the adjoining wetland.

Approach/Activities. The biobarrier design involves the use of granular activated carbon (GAC) bioaugmented with a previously developed anaerobic, CB dehalogenating culture (WBC-2) and an aerobic CB oxidizing consortium enriched from the site. The bioaugmented GAC forms a reactive barrier that both reduces CB mobility and promotes transformation into innocuous end products within the barrier. Biobarrier test plots (1 m^2 area each) were constructed at the wetland surface at two hydrologically distinct areas of the wetland (adjacent to the tidal creek and adjacent to the upland boundary). The area adjacent to the creek contained two treatment plots— one with a thin (3-inch) reactive barrier layer placed on the surface and the second with the reactive barrier matrix mixed into the upper 10 inches of wetland sediment— and one control plot with only a thin sand layer on the surface. The second area of the wetland contained one treatment plot with the reactive barrier matrix mixed into the wetland sediment. The reactive barrier matrix consisted of bioaugmented GAC, sand, and chitin. Groundwater (peepers and piezometer nests) and sediment samples were collected from the test plots prior to, and 0.5, 5, and 9 months after installation of the biobarriers. At both areas, samples were also collected outside the plots as wetland controls.

Results/Lessons Learned. Upward flow gradients were measured throughout the test plots, although soil moisture probes also showed short periods of unsaturated conditions in the top of the thin (3-inch) layer treatment plot. The thin layer application was less reliable with periods of freezing and low moisture, although CBs generally were attenuated. In comparison to control samples, the treatment plots demonstrated about 80% to 94% removal in total CB mass in sediment samples and 50% to 99% decline in groundwater concentrations. Substantial increases in chloride concentrations were evident, indicating that decreases in CB concentration were due to biodegradation. Ferrous iron, sulfide, ammonia, and methane concentrations often were higher in the treatment plots than in controls, suggesting dominantly anaerobic conditions. Elevated bicarbonate and volatile organic acid concentrations also indicated enhanced microbial activity in the biobarriers. Microbial analyses of the sediment and GAC by Illumina MiSeq 16S iTag sequencing are being completed and will also be presented. Based on the laboratory and field tests results, the dual-biofilm barrier (mixed into shallow sediments) approach holds considerable promise for full-scale application at the site.