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Successful Bioremediation of 1,4-Dioxane and 1,2-Dichloroethane in a Dilute Plume

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Background/Objectives. The Air Force Civil Engineer Center supported a field demonstration project to test the effectiveness of in-situ aerobic cometabolic biodegradation (ACB) of 1,4-dioxane (1,4-D) and co-contaminants, including 1,2-dichlorothane (1,2-DCA) and trichloroethene (TCE) at the former McClellan Air Force Base. The groundwater in the test area is aerobic and contains 1,4-D (~50 mg/L), 1,2-DCA (~10 mg/L), and TCE (~4 mg/L). The site-specific cleanup goals for these constituents are 6.1, 0.5, and 5 mg/L, respectively.

Approach/Activities. The field testing consists of two stages: bromide tracer testing and biostimulation. During the biostimulation stage, the In-situ ACB activity was established using groundwater recirculation together with propane and oxygen addition. Two monitoring wells in the recirculation zone were used for performance monitoring. Propane and oxygen was added to the recirculated groundwater at various concentration levels, durations, and frequencies in order to assess the effectiveness and robustness of the biostimulated in-situ ACB bioreactor. Hydrogen peroxide was used for bioclogging control and also served as a secondary source of oxygen. Beside regular monitoring of chemical concentrations, samples were also collected for the microbial functional genes analysis and the next generation sequencing analysis in order to assess 1,4-D metabolic and cometabolic biodegradation activities and the microbial community evolution in the bioreactor.

Results/Lessons Learned. The bromide tracer test shows that the travel times from the injection well to two nearby monitoring wells are approximately 1.5 and 2 days. 1,4-D and 1,2-DCA in groundwater were treated to the levels below their respective cleanup goals. The in-situ ACB bioreactor achieved a stable treatment efficiency of more than 98% for 1,4-D and 1,2-DCA and more than 90% for TCE. Injection of concentrated propane pulses (twice weekly and 6 hours each time at about 15 to 20 mg/L), together with an oxygen loading rate that could maintain oxygenic conditions in the recirculation zone, was sufficient to sustain the stimulated ACB activity. The starvation test results showed that propane addition was important to maintain ACB for TCE and 1,4-D. Without adding propane, TCE and 1,4-D biodegradation gradually disappeared; however, 1,2-DCA and 1,1-DCE biodegradation remained very strong in spite of no propane addition for a month. After one month of starvation, the ACB of 1,4-D and TCE could be quickly re-established with propane and oxygen addition. The first-order 1,4-D degradation rate for the established bioreactor was 1.5 day^{-1}, which is equivalent to a degradation half-life of 0.45 day. The rate is comparable to other ACB field studies on TCE degradation. The results of the microbial functional genes analysis indicate that the propane monooxygenase activity correlated well with the performance of the bioreactor. Metabolic 1,4-D biodegradation by CB1190-like bacteria was not responsible for the observed 1,4-D biodegradation. The next generation sequencing results show that Mycobacterium was likely the primary bacterial genus responsible for the observed ACB activity.