Thermally-Enhanced Bioremediation and Desorption of Chlorinated Ethenes Using Groundwater Circulation

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Background/Objective. An in situ thermal treatment system using circulating groundwater was developed to be an effective remedial approach to clean up sites contaminated with volatile organic compounds (VOCs). This system is designed to stimulate anaerobic dechlorination and desorption of VOCs from soil particles by water treatment including raising the groundwater temperature and injecting organic substrates. Since anaerobic dechlorination and desorption are greatly influenced by temperature, it is important to keep target areas at an appropriate temperature without bias for long periods. The objectives of this study were to: (1) evaluate the effect of temperature on the anaerobic dechlorination and desorption of VOCs in the laboratory experiments; and (2) confirm uniform low-level heating of target ground areas by groundwater circulation system in the field experiment.

Approach/Activities. Dechlorination experiments were performed in 120-mL serum bottles kept at 15, 20, 25, 30, 35, 40 and 45°C. 96 mL of medium, which included electron donor compounds (EDC®), 4 mL of dechlorinating consortium obtained from contaminated sites, 1 mg/L of one of tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (DCE) or vinyl chloride (VC), and 1 mL of hydrogen gas were anaerobically set up in the bottles. VOCs were measured from the samples to obtain the first-order degradation rate constant. Adsorption experiments were performed in a column filled with 3 to 5 g of uncontaminated soil. One of PCE, TCE, DCE or VC gas was humidified and passed through the column kept at 15, 30, 35 and 40°C. VOCs were measured from soil samples to obtain the equilibrium of adsorption between soils and water. The field experiment was carried out in uncontaminated fine silty sand in Chiba, Japan. The aquifer at the test site extended from 6 m below ground level and was surrounded by sheet piling to a length of 20 m, a width of 13 m, and a depth of 19 m. The water circulation was controlled by two injection wells and two pumping wells. The target values of the groundwater temperature and EDC concentration were 30°C ±10 % and above 100 mg/L, respectively. Groundwater was collected to determine the EDC concentration from total organic carbon, while the temperature of the aquifer was recorded continuously using a thermocouple.

Results/Lessons Learned. In the dechlorination experiments, DCE and VC were completely degraded within 16 days at 25°C, although it took 47 days at 15°C. Compared to the rate at 15°C, the first-order degradation rate constant of DCE was 6.8 and 8.4 times higher at 25 and 30°C, respectively. On the other hand, degradation of any contaminants was not observed above 40°C. In the adsorption experiments, the equilibrium of adsorption between soils and water was reduced by 8 to 32 percent at 30°C compared to that at 15°C. In the field experiment, groundwater at depths of 10 m to 13 m below ground level reached the target temperature of close to 30°C in about 2 months and were mostly successfully controlled within the target range of 27 to 33°C over 4 months. The EDC concentration was above 100 mg/L over the entire target area after 9 months of continuous operation. The results of this study concluded that elevating groundwater temperature could enhance both anaerobic dechlorination and desorption of VOCs and the groundwater circulation system was useful to achieve uniform heating of the remediation area.