Thermally-Enhanced Bioremediation of TCE Contaminated Groundwater

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Background. Worldwide industrial use of chlorinated solvents has resulted in an extensive groundwater contamination by compounds such as the suspected human carcinogen, trichloroethene (TCE). In situ bioremediation using reductive dechlorination is a widely accepted and commercially used technology for groundwater treatment. In comparison to physical or chemical technologies however, it is a lengthy slow approach. As increased temperature has a positive effect on microbial metabolism, thermal enhancement may prove a feasible means of in situ bioremediation acceleration.

Activities. The temperature dependence (in the range of 10 to 40 °C) of TCE dechlorination was observed within the lab experiments in TCE contaminated groundwater and soil. The degradation process was monitored using numerous techniques, including physical-chemical analyses and molecular biological analyses. The abundance changes of organohalide-respiring bacteria were studied using quantitative PCR. Based on promising results of laboratory tests the thermally enhanced reductive dechlorination was tested on site where the total concentration of chlorinated ethenes (cVOCs) ranged from 249 to 14, 539 µg/L. The aquifer at this site was situated in shallow sandy saprolite underlined by irregularly fractured granite. A circulation system comprising of pumping and injection wells was used to heat the aquifer. A layout of the circulation system was designed using a heat transfer mathematical model.

Results. Biotic reduction was significantly supported by whey addition as an organic substrate for indigenous bacteria. The temperature increase and whey addition had the most positive effect on TCE dechlorination at the temperature 22 °C. The chlorine number (average number of chlorine atoms per ethene in the groundwater sample) dropped after 9 week from 2.5 to 0.1 at 22 °C, to 1.1 at 17 °C and to 1.7 at 12 °C. The result indicates, that complete reductive dechlorination at 22 °C was achieved. The outcome of the chemical analyses was in congruence with vinyl chloride reductase genes (bvcA and vcrA) and *Dehalococcoides* spp. rapid increase after 9 weeks at 17 and 22 °C. *Dehalobacter* spp. and *Desulfitobacterium* spp. increase was observed earlier (after 6 weeks) with the maximum at 22 °C. Based on the lab test results the optimal temperature range from 20 °C to 25 °C was set for reductive dechlorination by indigenous dechlorinating microorganisms.

The temperature of the extracted groundwater on site was raised to 35 to 45°C with solar and electricity heaters then injected back into the aquifer, the temperature being adjusted in order to maintain a temperature in the aquifer ranging from 20 to 25°C. Fermentable substrate (whey) was injected in three batches into the injection well. The test was monitored using hydrochemical and molecular biological tools. The addition of a substrate and increasing the temperature resulted in a rapid increase in total biomass, sulphate reducing bacteria (functional gene apsA), and reductive dechlorinators (especially *Dehalococcoides* sp. and vinyl chloride reductase genes vcrA and bvcA), along with a strong increase in cVOC dechlorination. After just one month, total cVOC concentration had decreased by 54% to 94% in effectively influenced neighbouring wells. At the same time, the chlorine number decreased from an initial 1.1–1.6 to 0.1–0.8, indicating significant reductive dechlorination. In a reference well where the reductive dechlorination was enhanced with substrate only, the degradation process was significantly slower. In conclusion, results of the pilot tests indicate that thermally enhanced in situ bioremediation is a promising remedial approach for the treatment of chlorinated ethenes.