Enhanced natural attenuation of CAHs contaminated groundwater

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As the enhanced natural attenuation (ENA) technique classified into semi-passive remediation method, a permeable bio-barrier was installed in aquifer by injecting the hydrogen release compound in order to prevent further spreading of the chlorinated aromatic hydrocarbons (CAHs) contaminated groundwater. Long-term monitoring of groundwater quality was conducted for 3 years to evaluate the effectiveness of the technology, and biological tests have been continuously conducted to measure the subsurface biological environment change. In this paper, remediation effect of CAHs and the dechlorination mechanism were reported.

The aquifer of the site is located 3m to 6m below the ground surface, and it is composed of sand and gravels with boulder mixed. The average thickness of the aquifer is about 2.1m. From the monitoring well W2, which is located near to the groundwater downgradient boundary of the plant, tetrachloroethylene (PCE) and its daughter products trichloroethylene (TCE), cis-dichloroethylene (cis-DCE) were detected exceeding environment standard values. In order to prevent the further spreading of the contaminated groundwater out of the plant, HRC (produced by Regenesis) mainly composed of polylactate ester was injected into the aquifer to form a bio-barrier. With the injection of HRC into the aquifer, it was expected to enhance the degradation rates of the CAHs around the HRC barrier zone. The width of the target area is 8m and 7 HRC injection wells (2 rows, 4 for one row and other 3 for another row) were installed. At the beginning, 272kg of HRC was injected, 423 days late second injection with 189kg HRC was conducted, and the third injection was conducted on day 821 with 272kg of HRC again. On day 723, because high concentration of nitrate was detected from up-gradient well, 94.5kg of HRC was additionally injected.

According to groundwater monitoring, it is confirmed when groundwater flowed through the bio-barrier, total molar concentration of CAHs had been reduced, and part of the contaminants had been completely degraded to ethylene. Regarding on the effect of the enhanced natural attenuation, first-order degradation rates of CAHs showed stable trend along time. Comparing with the original natural degradation rates, the estimated first-order degradation rates after third HRC injection (monitoring data from day 821 to day1198 were used) are 170 to 190 times for PCE, 38 to 51 times for TCE and 20 to 45 times for DCE.

Biological environment monitoring results showed that, after HRC injection, the number of beta-subclass and gamma-subclass Proteobacteria in groundwater took priority of increasing, and the ratio of beta-subclass to gamma-subclass Proteobacteria and preferential species substantially changed along time. Detected preferential species after day 946 is the bacteria which belongs to beta-subclass Proteobacteria and is extremely near to the Psudomonas spinosa. It is considered that this preferential species used the hydrogen from HRC as the electron donor, and was related to the anaerobic degradation process except anaerobic dechlorination.

Regarding on Dehalococcoides sp., which is the bacteria that can degrade the chlorinated contaminants completely to ethylene, it was temporarily detected from the down-gradient water samples using the special PCR method. However, even at seasons when Dehalococcoides sp. was not detected, monitored results showed a stable enhanced natural degradation of contaminants. The results show that Dehalococcoides sp. is not the unique bacteria that can degrade CAHs completely, there are several other bacteria species that have same living environment as Dehalococcoides sp. and have abilities of degrading CAHs completely.