Complete Dechlorination of Chlorinated Ethenes and Chloroform in a Brackish Environment

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Background/Objectives. An industrial site in the port of Tarragona (Spain) is contaminated with mainly chlorinated ethenes, chlorinated methanes and chlorinated ethanes. The contamination was caused by leakages of the sewer system in the past. High concentrations (DNAPL) of mainly tetrachloroethene (PCE) and chloroform are present as well as the degradation products. The remediation goals are 37 µg/L and 6.5 mg/kg for PCE in groundwater and soil, respectively, and 440 µg/L and 87 µg/L for chloroform and vinyl chloride (VC), respectively.

Approach/Activities. Given the nature of the contamination and aquifer, anaerobic reductive dichlorination was identified as the most promising in situ bioremedation solution. To test the feasibility of enhanced reductive dechlorination (ERD) to remediate the site both laboratory tests and a field test were conducted in the past. Based on the successful results of these tests, a full-scale remediation is being carried out. Since the site is situated close to the sea, the groundwater is brackish to salt with an electrical conductivity (EC) up to 25,000 µS/cm and sulphate concentrations up to 1600 mg/L.

The remediation consists of circulation of groundwater via extraction and infiltration wells, removing DNAPL above ground and adding an electron donor to stimulate the process of ERD. By circulating the groundwater the electron donor and dechlorinating microorganisms will be distributed and the contamination will be mobilized as well. Besides regular monitoring of geochemical parameters and the concentrations of contaminants also molecular analyses (qPCR and sequencing) were performed to have a better understanding of the microorganisms and degradation pathways involved under the specific conditions.

Results/Lessons Learned. Concentrations as high as 100,000 µg/L of PCE, 41,000 µg/L of VC and 340,000 µg/L of chloroform were found on site. Due to the presence of DNAPL there is still no clear decreasing trend in PCE concentrations in most wells. However, degradation products are increasing in concentrations and especially ethene increased dramatically from below detection limit up to 26,000 µg/L.

Molecular analyses of groundwater from several wells were performed and confirmed that there is a strong increase of the amount of bacteria and enzymes involved in dichlorination. For example the VC reductive dehalogenase vcrA increased up to 3.8E+11 copies/l. *Dehalobacter*, *Geobacter* and *Dehalococcoides* were all present in high numbers and increased in time, with the exception of *Geobacter* in some wells. Also the gene encoding for chloroform reductive dehalogenase (cfrA) increased dramatically from below detection limit up to 8.9E+7 copies/l. Quite remarkably, considering the strong reducing conditions, the gene etnE, which is a biomarker for ethenotrophs and the aerobic VC-degrading potential was present in some wells and increased up to 4.9E+04 copies in one well.

The DNA from the well with the highest number of both vcrA and etnE was partially sequenced (ORVIdecode). It appeared that the dominant genus of the bacterial community consisted of *Dehalococcoides (27%)* of which 70% was closely related to *Dehalococcoides mccartyi*.

These results so far demonstrated the enhanced biological degradation capacity on site and the complete dichlorination of the various contaminants, despite the high concentrations of chloroform and the brackish to salt environment.