Integrated Assessment of Anaerobic Reductive Dechlorination of Chlorinated Ethenes by Stable Isotope Analysis and Microbial Techniques

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Background/Objectives: Natural degradation is a cost-effective alternative to traditional remediation methods for chlorinated solvents. However, the degradation products formed through natural degradation processes are also hazardous, and complete dechlorination is necessary to reduce the risk. Documentation of the occurrence, extent and rate of the complete dechlorination process is therefore vital in producing reliable risk assessments. At the current knowledge level, no stand-alone method can provide this necessary information. The scope of this project was therefore to document and quantify the natural reductive dechlorination of chlorinated ethenes at a contaminated site by an integrated approach based on a variety of analytical and conceptual tools. Field investigations were carried out at a site in Denmark, were degradation occurs in the source zone and plume in a geologically complex and strongly reduced subsurface.

Approach/Activities: An extensive integrated approach including traditional methods as hydrogeological, geochemical and chemical measurements as well as the new promising techniques, microarrays e.g., QuantArray-Chlor (specific degraders and functional genes) and compound specific isotope analysis (CSIA) was applied at field scale, where 21 boreholes (several with two screens) were sampled.

Results/Lessons Learned: Measurements of specific degradation products can provide documentation for the occurrence of the natural degradation. However, as the contaminant distribution is affected by transport processes (cis-DCE and VC migrate further than PCE and TCE), it cannot alone be used to determine where the biodegradation occurs, for this advanced techniques can be integrated. The biodegradation potential, determined by the abundance of specific degraders and functional genes, was highest near the source zone and less abundant down-gradient. Carbon isotope results further revealed the highest enrichment in the $\delta^{13}C$ value for both cis-DCE and VC near the source zone, indicating currently higher degradation near the source zone than in the past and less potential for further degradation down-gradient. At sites, where there is a temporal and spatial variation in the conditions and degradation, a combination of microbial analysis and CSIA thus provide a more robust characterization of the biodegradation (areas, extent and rate). Application of isotope mass balances and a lumped variable enrichment factor further facilitate the quantification of biodegradation, even at sites where the initial isotopic signature is uncertain. The integrated approach provided essential information for the evaluation of the occurrence, extent and rate of the natural biodegradation at the complex site. This is promising for the future evaluation of natural biodegradation in site risk assessment, and for this specific project, the results have influenced the Regions prioritizing of the site.