

## Integrated Characterization of NA of PCE Plume after Thermal Source Zone Remediation: Microbial Techniques and Dual Isotope Analysis

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**Background/Objectives.** PCE DNAPL contamination at the former central dry cleaning facility in Røddekro, Denmark, was subject to thermal (steam) source zone remediation in late 2006. A > 2 km long plume of chlorinated ethenes (PCE and chlorinated degradation products) which has migrated downgradient from the source zone has not undergone active remediation. A study of the natural degradation within the plume prior to source treatment conducted in 2006-2007 by Hunkeler et al. (2011) documented degradation of PCE via TCE to cDCE by reductive dechlorination 1-1.5 km downstream the source area that further downgradient cDCE and VC were degraded. Detection of specific degraders (*Dehalococcoides*) indicated that cDCE degradation was (partially) biotic. The understanding of the degradation within the plume, not least the documentation of VC degradation, was essential in the risk evaluation of the plume. The objective of the new (2014) study (Badin et al., 2016) is to evaluate how the source remediation has impacted the plume and in particular the natural attenuation within the plume. This project is unique in the integrated characterization approach for line of evidence evaluation of the natural attenuation of cDCE and VC in the cDCE dominated plume and the monitoring of the effects of source remediation on plume natural attenuation.

**Approach/Activities.** The evolution in plume composition and attenuation has been monitored by the Region of Southern Denmark on an annual basis since the source remediation, and in 2014 a large monitoring campaign including redox, chlorinated ethenes, non-chlorinated degradation products, carbon and chlorine stable isotope composition, specific degraders and their activity and next generation sequencing (454 pyrotag) for bacterial composition was conducted.

**Results/Lessons Learned.** The source remediation has, in addition to direct reduction of the concentration level in and flux from the source area, resulted in the release of dissolved organic matter (DOC) and some geochemical changes. This has had an effect on redox conditions and biodegradation by reductive dechlorination in both the near source area and further downstream in the plume suggesting enhancement of the natural attenuation over a significant extent of the plume. Stable carbon and chlorine isotopic fractionation revealed significant increase in the degree of degradation of cDCE in particular - both near the source area and > 1 km down-gradient - which co-occurs with the transition to more reducing conditions caused by the DOC release. Chlorine - carbon isotope correlations strongly indicated abiotic degradation of cDCE to play an important role. *Dehalococcoides* presence and activity was observed in areas in the plume documenting biotic degradation of chloroethenes. Whereas *vcrA* and *bvcA* and hence evidence of VC biodegradation was not detected. Pyrotag sequencing revealed the presence of both anaerobic and aerobic potential chloroethene degraders in the plume, including a wide presence of *Dehalogenimonas*, which may also completely dechlorinate chloroethenes. The findings document a significant increase in cDCE degradation without accumulation of VC. This reduces the risk posed by the contaminant plume to the drinking water resource. Analysis for microbial composition and specific degraders and their activity as well as dual stable isotopes has revealed high complexity in degradation processes and played an important role to substantiate the natural attenuation of the plume.

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**References:**

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