

Compound-specific isotope analysis (CSIA) – A reliable method to assess chlorinated solvent degradation in groundwater systems

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The long-term persistence of chlorinated solvents poses a major challenge for the remediation of contaminated sites. To determine the best remediation strategy for sites contaminated by chlorinated solvents, it is of major importance to determine whether chlorinated solvents are subject to degradation. If degradation is absent the sites need to be remediated by active remedial measures such as excavation, which is time-consuming and often related to high costs. In contrast, if chlorinated solvents degradation occurs such that the contamination concentrations are expected to decrease below the remediation goal within reasonable time frames, a monitored natural attenuation approach (MNA) can be applied. MNA is a much cheaper remediation option compared to more active remedial approaches. Thus, the costs of a site remediation heavily depend on whether chlorinated solvents are subject to degradation.

Despite its high importance for applying the best remediation strategy and for its costs, determination of chlorinated solvent degradation is challenging based on concentration measurements only. Often, it remains unclear if chlorinated solvent concentrations decrease due to dilution or degradation. To overcome the shortcoming of concentration analysis only, compound-specific isotope analysis (CSIA) has emerged in the last two decades as an effective tool to determine chlorinated solvent degradation. The method makes use of the preferential cleavage of bonds between light compared to heavy isotopes during degradation, leading to a progressive enrichment of heavy isotopes in the parent compared to the daughter compound. Hence, an enrichment of heavy carbon isotopes in the parent compound over time provides unequivocal evidence for chlorinated solvent degradation.

This study aimed to assess the degradation of chlorinated solvents in the groundwater at the Råven site in Helsingborg, Sweden using CSIA. The Råven site was contaminated by chlorinated solvents, predominately tetrachloroethene (PCE), during dry cleaner activities between 1929 and the end of the 1970's. To obtain detailed insight into the degradation of the chlorinated solvents and its implications for remediating the site, high-resolution carbon CSIA profiles were determined from 9 multilevel wells located in the contamination source zone and farther downstream. In the source zone, the CSIA profiles revealed that the degradation activities are generally low and that trichloroethene (TCE), previously considered as a degradation product of PCE, likely originates from the contamination source. Moreover, the CSIA combined with the concentration profiles in the source zone showed that chlorinated solvent degradation stalled at cis-dichloroethene (cDCE) and did not proceed further to vinyl chloride (VC). In the downstream multilevel wells, the chlorinated solvent concentrations decreased by more than two orders of magnitude, and the degradation activities were higher as opposed to the source zone, which also proceeded to some extent to VC. However, despite the higher degradation activities in the downstream wells, the concentration decrease compared to the source zone could be attributed to a higher extent to dilution in comparison to degradation. This demonstrates that MNA might be not a suitable remediation approach for the Råven site and that other remedial measures might be more effective for fulfilling the site remediation goals.