Use of Compound-Specific Isotope Analysis (CSIA) to Assess the Efficiency of Soil Vapor Extraction Applied to a Petroleum Hydrocarbon Source Zone

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Background/Objectives. Engineered in situ remediation methods usually aim at promoting a specific mass removal process. However, it can be challenging to demonstrate that the intended process has successfully been initiated as contaminant concentrations are often also modified by other co-occurring processes. Furthermore, conventional tools to evaluate remediation performance often provide bulk removal rates but are not compound-specific. The aim of this study was to evaluate if compound-specific isotope analysis (CSIA) can be used to demonstrate that an intended mass removal process acts on specific contaminants, using soil vapor extraction (SVE) as an example. A main question was if physical removal of the compounds of concern, benzene and toluene, is complemented by biodegradation, which is difficult to demonstrate by classical indicators such as O_2 and CO_2 concentrations.

Approach/Activities. An SVE treatment system was implemented at a petroleum hydrocarbon contaminated site. CSIA was applied to effluent gas samples. Effluent gas samples were collected over a 12 month period and were analyzed for conventional parameters (O_2, CO_2) and for CSIA ($\delta^{13}C$ and δ^2H) on benzene and toluene. To distinguish physical removal processes from biodegradation, the dual element isotope approach was applied by plotting δ^2H values as function of $\delta^{13}C$. Previous laboratory studies have demonstrated that physical contaminant removal processes (e.g., volatilization) lead to carbon and hydrogen isotope patterns that are distinctly different from those for biodegradation.

Results/Lessons Learned. Dual hydrogen and carbon isotope plots ($\delta^{13}C$ vs δ^2H) for benzene and toluene in effluent gas indicated minimal biodegradation. Hence the high CO_2 concentrations were likely due to biodegradation of other compounds such as aliphatic hydrocarbon. Thus, contaminants of concern were mainly removed by volatilization, which proceeded at a low rate. At some locations, a trend towards depletion of heavy isotopes was observed, i.e. opposite to what is expected for biodegradation. This shift could result from diffusion-limited mass removal, consistent with the low mass removal rates. Accordingly, such results would indicate limitations of the SVE system to sustainably remove the remaining contaminant, and supporting the decision to shut down the SVE system and rely on a monitored natural attenuation approach. In conclusion, this study demonstrates that CSIA can provide insight into dominant mass removal processes impacting targeted compounds during SVE treatment and illustrates how these results can support remediation system optimization/shut down decisions by field practitioners.