Evidence of Biodegradation at a DNAPL Contaminated Fractured Bedrock Field Site Using Stable Carbon Isotopes

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Stable carbon isotope analysis of chlorinated ethenes and ethene was performed at a site where the TCE DNAPL source and dissolved plume are located in fractured bedrock. Previous attempts to biostimulate the pilot test area (PTA) at the site resulted in the accumulation of cis-1,2-dichloroethene (cis-DCE). Since there was no appreciable production of vinyl chloride (VC) or ethene (ETH), there was no evidence for further reductive dechlorination beyond cis-DCE. Subsequently, the PTA was bioaugmented with KB-1, a natural microbial consortium shown in laboratory experiments to completely reduce TCE to non-toxic ETH. While the appearance of breakdown products (VC, ETH) suggested that bioaugmentation was successful to some extent, due to the continuous source of TCE from the DNAPL in the fractured bedrock and variability in the hydraulic gradient, concentration profiles of TCE and degradation products cis-DCE, VC and ETH were unable to unambiguously verify bioaugmentation.

Compound specific carbon isotope analysis of the chlorinated ethenes was able to confirm biodegradation. At any given sampling well, the isotopic signature of the breakdown products were more depleted than that of their parent compound. For instance, for one well during the September sampling event, the isotopic signatures of cis-DCE, VC and ETH were -17.6, -22.5 and -43.7 ‰, respectively. In addition, the isotopic signatures of cis-DCE and VC became increasingly enriched over the four sampling events (from -18.9 to -12.8 ‰, and from -21.6 to -18.2 ‰ for cis-DCE and VC, respectively) consistent with the effects of biodegradation. The isotopic profile of TCE remained relatively consistent (range -22.4 to -25.8 ‰) due to the continuous input of undegraded TCE from DNAPL dissolution. Stable carbon isotope measurements can provide an important line of evidence for biodegradation in hydrogeologically-complex systems.
Biographical Sketches

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Michelle Chartrand (University of Western Ontario; MSc University of Guelph) is a PhD student in environmental chemistry in the Stable Isotope Laboratory at the University of Toronto with Prof. Barbara Sherwood Lollar. She is a recipient of an NSERC graduate scholarship. Her current research focuses on isotopic fractionation of VC during aerobic and anaerobic microbial degradation.
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