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Estimating Rates of TCE Degradation and Other Processes Affecting the Fate of TCE in a Fractured Sedimentary Rock Using Compound Specific Isotope Analysis

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Chlorinated solvents, such as trichloroethene (TCE) are common contaminants of groundwater in industrial and urban settings. Physical, chemical, and biological processes affect the concentration of these compounds as they are transported in groundwater. The isotopic ratio ($^{13}C/^{12}C$) of carbon in TCE and its degradation products is altered by microbial degradation, whereas, the isotopic ratio remains unchanged for other processes, such as adsorption, dispersion, volatilization, and diffusion. Different microorganisms can yield different kinetic isotopic fractionation factors (α); consequently, field evaluation of α is essential in evaluating the impact of microbial degradation.

Water samples were collected from a borehole (25BR) completed in a section of rock that had minimal permeability. The concentration and isotopic ratio ($^{13}C/^{12}C$) of TCE in the water of this borehole was assumed to be affected mainly by microbial degradation, since groundwater fluxes into and out of the borehole were assumed to be negligible. Monitoring the changes in isotopic ratio ($^{13}C/^{12}C$) and concentration of TCE in 25BR with time provided an in situ estimate of α=0.99345 and an in situ estimate of the first-order degradation rate constant (k). Differences in the α values estimated from 25BR for TCE compared to α values estimated in other boreholes located in more permeable sections of the same aquifer provide indications of geochemical heterogeneity; it could indicate the location of un-degraded, free-phase TCE in the aquifer. Furthermore, the original concentration of TCE that was biodegraded in the aquifer could be estimated from the Raleigh equation using the established kinetic fractionation factor.

The analysis of the isotopic ratio ($^{13}C/^{12}C$) of dissolved inorganic carbon (DIC) and dissolved organic carbon (DOC) may prove to be useful in studying a TCE-contaminated aquifer. The relationship of the carbon isotopic ratio of DIC and DOC could differentiate between the organic carbon in different groundwaters, which might also help indicate varying levels of bioavailability for microbes in the process of degrading chlorinated ethene contaminants.