Quantification of biodegradation for various organic compounds using first-order, Michaelis-Menten kinetics and stable carbon isotopes

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Quantification of biodegradation in contaminated aquifers has become an increasingly important issue. This is closely related to the acceptance of monitored natural attenuation (MNA) as a means to manage contaminated sites. The site of this study was a former wood preservation plant where the impact of coal tar oil resulted in a severe NAPL contamination of the sandy aquifer down to a depth of 50 m. Qualitative evidence for substantial biodegradation was demonstrated before using (1) signature metabolite analysis (SMA), (2) redox-sensitive tapes (RST), and (3) compound-specific isotope analysis (CSIA) and consequently MNA is evaluated as alternative remediation strategy. However, in order to predict future contaminant migration, in situ biodegradation rates are required. Hence, in situ biodegradation rates for mono- and polyaromatic hydrocarbons and for heterocyclic compounds were determined using (1) first-order and (2) Michaelis-Menten (MM) degradation kinetics, as well as (3) stable carbon isotopes. The center line method (CLM), restricted to contaminant plumes in steady state, was applied to evaluate the obtained biodegradation rates. In case of naphthalene, the best-fit, i.e. the best description of in situ biodegradation along the center line of the plume, was achieved by MM kinetics. The second best-fit was obtained based on stable carbon isotopes when the isotope fractionation factors were chosen according to the observed dominant redox conditions in the aquifer. Finally, the most commonly-applied first-order kinetics degradation models were afflicted with the highest uncertainties and should therefore only be used with great caution.