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Investigation of In Situ Bioremediation of Chlorofluorocarbons at a Contaminated Field Site via Compound Specific Isotope Analysis (CSIA)

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Background/Objectives. Chlorofluorocarbons (CFCs) are anthropogenically produced stable organic compounds that have been widely used as refrigerants, propellants, foaming agents and intermediates for synthesis of other fluorinated compounds. Although banned in 1987 under the Montreal Protocol due to their contribution to stratospheric ozone destruction, a legacy source of contamination remains in the subsurface and continues to impact groundwater. Groundwater contaminated with CFCs due to improper disposal, spills and leakage from underground tanks remains a challenge for control and remediation. Originally, due to their chemical stability CFCs were expected to be biologically inert, however in last two decades studies investigating biodegradation potential via dechlorination under anaerobic conditions have been published.

Approach/Activities. When the compounds are degraded in the environment, the ratio of stable isotopes change due to differences in bond strength and consequently reaction rate between molecules containing lighter isotope (e.g.^{12}C) and molecules containing heavy isotope (e.g.^{13}C). Typically, molecules containing lighter isotopes are degraded faster, which leads to an enrichment for the degraded molecule in ^{13}C relative to its initial composition, as the reaction proceeds. From this information the extent of degradation can be assessed if the appropriate fractionation factor associated with the transformation step is known. Compound Specific Isotope Analysis (CSIA) has been applied to monitor biodegradation for many aliphatic and aromatic chlorinated compounds in groundwater but has not to date been tested for the CFCs. In this study we apply CSIA for the first time to assess the natural attenuation of trichlorofluoromethane (CFC-11) and trichlorotrifluoroethane (CFC-113) at a historically contaminated site (Chemours' Chambers Works Facility) in New Jersey, USA. Groundwater samples were collected from 9 sampling wells (including one seven port continuous multichannel tube (CMT) well) and analyzed for both concentrations and carbon isotopes signatures of CFC-11 and CFC-113.

Results/Lessons Learned. Carbon isotope values for CFC-113 remained quite uniform within each sampling well, but differed considerably (from -31.7±0.5‰ to -24.8±0.5‰) from one well location to another. It is unclear whether the observed variations were caused by differences in source signatures or are related to in situ biodegradation. In contrast, for CFC-11, significant variability in carbon isotope values was observed within each sampling well location. CFC-11 values ranged from a δ^{13}C value of -46.9±0.5‰ to values as enriched as -23.4±0.5‰, a large enrichment in carbon isotope signature is consistent with the effect of in situ degradation. To our knowledge this is the first study to use CSIA to assess in situ degradation of the chlorofluorocarbons at a field site and suggests that natural attenuation of CFCs possibly via biodegradation may be more important than previously recognized.