An innovative Biocirculation®-System for Chlorinated Aliphatic Hydrocarbon (CAH) Degradation with Groundwater Circulation Well (IEG-GCW®)

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Background/Objectives. The remediation of chlorinated solvents polluting groundwater demands a thorough understanding of the hydrogeological context, pollution scenario, and the transformations these compounds experience once embedded in the hydrogeological and biochemical framework. At an industrial area in Barcelona (Spain), trichloroethylene (TCE) and degradation products such as 1,2-dichloroethylene (1,2-DCE) and vinyl chloride (VC) have been detected at concentrations up to 170 mg/L. An innovative Groundwater Circulation Well (IEG-GCW®) technique was tested to improve the distribution of a biostimulant in a heterogeneous aquifer for reductive dehalogenation and create an in situ bioreactor for the enhanced treatment of chlorinated aliphatic hydrocarbons (CAHs). This work aims to evaluate the impacts of the strategy for enhancing in situ bioremediation and delineate the mechanisms and dynamics of decontamination in the hydrogeological and biochemical environment.

Approach/Activities. An IEG-GCW system has been combined with a reagent/biostimulant metering system to mix and directly infiltrate an electron donor releasing amendment (C-MIX®), for reductive degradation, into different screened intervals of a GCW and four peripheral multilevel injection wells (IEG-MIWs®). The GCW induced flow moves the groundwater in an ellipsoidal recirculation cell to spread the supplements from the central GCW and the peripheral MIWs in the aquifer body. Two multilevel sampling wells (IEG-MLSWs®) in the radius of influence (ROI) are used to collect multiple, undisturbed groundwater samples for hydrochemical and compound-specific isotope analysis (CSIA), monitoring the remediation process along the vertical aquifer sections. A 3-D data-driven, multi-source model harmonizes geological and hydrochemical information during different remediation stages, supporting the remedial design to suit the physicochemical conditions and unmasking the decontamination mechanics induced by the remedial actions.

Results/Lessons Learned. Multi-source modeling, hydrochemical monitoring, and the stable carbon isotopic signature of cis-1,2-DCE and VC show the mobilization of secondary contamination sources triggered by recirculation during remediation, the stimulation of microbiological activity following nutrient supplement via GCW and MIWs, and the substantial decrease of CAH concentrations at different aquifer levels. Evidence from the first application at the field scale reveals the significant increase in the chloroethane biodegradation rate, the short-term effectiveness of the innovative remediation strategy, and the persistence of dechlorinating microbiological activity. GCW-MIWs synergy increases the extension of bioactive surface in the circulation area through enhanced three-dimensional mixing of groundwater, contaminants, microorganisms, and biostimulants. Injection of C-MIX through the MIWs in combination with GCW-induced recirculation generates a hydro-bio-geo-chemical reactor and offers a novel and promising strategy to remove CAHs and other contaminants.