Specifically Configured Groundwater Circulation (GCW) System for Accelerated Biodegradation of CAHs under Anaerobic Conditions

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Background/Objectives. Enhanced natural attenuation (ENA) via direct injection of agents tends to suffer from restricted mixing in heterogeneous, anisotropic and low permeable systems. Standard injection, even conducted at short horizontal distances and vertical depth levels, frequently leads to preferential transport pathways within the slightly higher permeability zones thus bypassing the lesser, often highly contaminated, low permeability zones. Those obstacles can be overcome by the installation of a specially designed groundwater circulation well (GCW) system that creates effective mixing cells bringing contaminants and reactants together via forced vertical flow paths and higher vertical velocities and thus increases the in situ degradation rates. The same delivery mechanisms are also applicable for many other agents suitable for in-situ applications (e.g., ISCO).

At the impacted industrial pilot test site in Hungary, several confined, heterogeneous sandy to silty aquifer units are developed down to a depth of 70 m, which are separated by discontinuous clay layers. The horizontal to vertical anisotropy shows a ratio of 1:100 (k_H = 10^{-5} m/s and k_V = 10^{-7} m/s). Chlorinated aliphatic hydrocarbon (CAH) concentrations reach up to 1.5 g/l. Primary substances of concern are trichloroethene (TCE), 1,1,2,2-Tetrachloroethane (TeCA), 1,2-dichloroethene (DCE), and chloroethene (VC), indicating an ongoing degradation process.

Approach/Activities. For the remediation of two subsequent aquifers, a large diameter GCW remediation well was designed and drilled by a pile drilling machine (protective casing 1000 mm) down to a depth of 37 m. GCW casing and equipment was installed for the circulation of two separately-held circulation cells. Into each aquifer, C-Mix a mixture of molasses, sugar alcohol components and vitamins was continuously admixed into the aquifer to stimulate indigenous microbes for enhanced reductive dehalogenation. Full-scale pilot testing for more than one year was performed in both aquifers.

Results/Lessons Learned. The effective delivery and distribution of C-Mix, either via the vertical circulation or directly via peripheral wells in the circulation cell was confirmed. The distribution and fermentation of the electron donor throughout the circulation cell was proven by DOC and SCFAs (especially acetic acid) measurements. Due to the strong vertical hydraulic gradients by their operation, GCW systems force the groundwater to flow through heterogeneous anisotropic aquifer layers. After 12 months of continuous operation, the numerical calculated radius of influence (ROI) has been verified in the field via acetic acid, anion measurements and significantly enhanced degradation of CAHs. The forced flow also enhanced the DNAPL dissolution by increasing the liquid-phase mass transfer coefficient. This presentation will outline the remediation performance within the two separated aquifers and will draw conclusions on the feasibility of GCW circulation systems as highly effective delivery systems for ENA remediation technologies.