In Situ Bioremediation of Aged Low-K DNAPL Source Zone in Complex Geological Settings by Groundwater Circulation Wells for Efficient Amendment Delivery and Contaminant Mobilization

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Background/Objectives. Aged low-k DNAPL source zones represent a substantial challenge for aquifer remediation. The effective delivery and distribution of electron donors and amendement is often limited in complex geological settings. Traditional injection methods usually result in a preferential horizontal migration of injected fluids through higher permeable aquifer zones whereas less permeable and higher contaminated area are often not properly affected. Moreover, contaminants are often strongly sorbed and trapped in the low permeable matrix and thus not available for biological processes thus acting as persistent long-term contamination source. This presentation will describe a complete pilot study conducted at an important operating industrial site in Northern Italy strongly impacted by chlorinated aliphatic hydrocarbons (CAHs) with aquifer concentrations up to 100 mg/l. Most of the residual contaminant mass was retained by low permeable aquifer layers with the prevalence of the lower chlorinated 1,2-DCE and VC. A three-screened 30 meters Groundwater Circulation Well (IEG-GCW) was installed to allow a vertical flux through highly contaminated low-k zones. The extracted water was passed through an “external treatment unit” and reinjected in the aquifer thus creating two recirculation cells. The external unit included an easy fermentable polymer, PHB (Poly-Hydroxy-Butyrrate), containing reactor operating as a continuous carbon source to enhance the mobilization of contaminants by cosolvent effect and to support the in situ reductive dechlorination. Moreover, a ZVI reactor allowed the mobilized CAH to be removed before groundwater reinjection.

Approach/Activities. The double cell GCW system has been operated and investigated under different hydraulic and process arrangements for around one year. The hydraulics of the GCW system (ROI, etc.), polymer fermentation kinetics, mobilization of residual CAHs, removal efficiency, vertical CAHs distribution and degradation processes in the treatment zone have been thoroughly investigated also by microbiological tools.

Results/Lessons Learned. GCW allows to extract water at a flow rate up to 0.35 $m^3\ h^{-1}$ from the intermediate low k layer (around 10^{-7} $m\ s^{-1}$) whereas around 2 $m^3\ h^{-1}$ were extracted from the deeper high k zone (around 10^{-4} $m\ s^{-1}$). Extracted groundwater was reinjected after flowing through the treatment unit. The mass of chlorinated solvents extracted from the low k layer was significantly higher than from the high k zone. Fermentation of the biodegradable polymer was still active and efficient after 10 months of operation and after few months of operation the PHB reactor behaved as an “external incubator” of *Dehalococcoides mccartyi* where *cis*-DCE and VC were fully converted to ethene. Combination of recirculation and injection of electron donor significantly improved CAH mobilization. Dechlorinating microbial population in the less permeable layer was conclusively enhanced by the vertical flushing as revealed by microbiological analyses. Full-scale implementation started in August 2018.