GROUNDWATER CIRCULATION WELL TECHNOLOGY (IEG-GCW®) FOR ENHANCED NATURAL ATTENUATION OF TCE AND PCE

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ABSTRACT

Background and 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 overcame by the installation of a specially designed Groundwater Circulation Well (GCW) system.

Figure 1 shows the installation layout of a standard GCW system. Pumping groundwater out of the aquifer formation through one screen section in a double-screened well and discharging it through the other screen section induces a three-dimensional circulation cell in groundwater. The flow direction in the circulation cell can be adjusted. In standard mode the groundwater is flowing downwards, in the reverse mode it is in opposite direction. No groundwater is removed from the aquifer. High potentiometric head differences forces groundwater to circulate within the entire radius of influence (ROI) of the IEG-GCW® circulation zone.

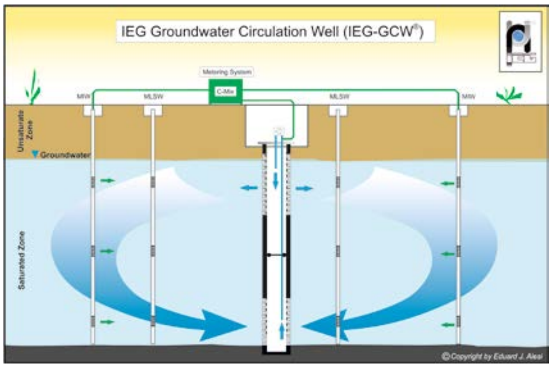

Fig. 1: IEG-GCW®Full scale pilot test assembly

Microbial degradation of chlorinated aliphatic hydrocarbons (CAHs) in an aquifer occurs by means of anaerobic reductive dehalogenation. However, those reactions are usually slow and require the addition of organic matter (Pierro et al., 2017; Dolinová et al., 2017). Here we present a novel approach for an effective microbial degradation applying a groundwater circulation flow to provide optimal conditions for a better contact between microbes, contaminants, amendments and nutrients.

Site and pilot plant

The site is located in the Llobregat delta, at the industrial area of Zona Franca in Barcelona (Spain). Despite the close proximity to the coast (3 km), no influence of tide activity or salt water detection is detected on the site. The groundwater level fluctuates around 4.2 to 4.5 m. The 8 m thick aquifer is formed of heterogeneous sand layers containing fine, coarse and silty grains. The k-values of the permeabilities vary between $1.44x10^{-4}$ m/s and $8x10^{-5}$ m/s with Kh/Kv ratios greater than 10. During the site assessment, the maximal CAH concentration detected was 170 mg/l. The contaminants comprise of tetrachloroethylene (PCE), trichloroethylene (TCE) and their degradation products cis-1,2-dichloroethylene (cDCE), trans-1,2-dichloroethylene (tDCE), 1,1-dichloroethylene (1,1-DCE) and vinyl chloride (VC).

A full-scale pilot test for anaerobic reductive dehalogenation of CAHs in combination with vertical groundwater circulation has been conducted. Therefore, a 12 m deep dual screened GCW well for standard and reverse mode operation, two MultiLevel Sampling Wells (MLSW) screened at different vertical sections to obtain contamination profiles and analyzing the remediation process, and four MultiInjection Wells (MIW) in different aquifer horizons were designed, drilled and constructed. The GCW system was also equipped with a metering device for admix an organic carbon solution (C-MIX) directly into the groundwater circulation and/or into MIW.

Results

Before the start of GCW operation, microcosm experiments with original contaminated soil and groundwater and different percentage compositions of C-MIX were performed with the objective to determine the halorespiring activity at the site. Results show that microorganisms can degrade PCE, TCE, cDCE and 1,1-DCE. Next generation sequencing (NGS) results of bacterial 16S rDNA confirmed the presence of different dehalorespiring bacteria.

After 124 days GCW field operation, a strong decrease of TCE and an increase of degradation compounds under standard groundwater circulation mode was observed (Fig. 2). For enhancing the degradation in the upper part of the aquifer, the circulation was switched into a reverse mode. In this way, contaminants are hydraulically forced directly through the upper bioactive area, previously generated in the standard flow. Finally, C-MIX was also injected through MIW in order to increase the area of bioremediation from the day 200 onwards. Results for more than 1 year of operation will be presented as well as CAHs isotopic fractionation evolution and assessment of the microbial community diversity during the bioremediation.

Fig 2: Molar CAHs concentration at different vertical sampling levels of MLSW1. Flow operation mode periods (standard, reverse) and C-MIX injection in the MIW is indicated in the graphs.

To better understand the hydraulic flow regime in the circulation zone, a new particle generating algorithm was created to reconstruct realistic porous structures. The objective was also to gain a better understanding of the flow behaviour and velocities through different heterogeneous layers in groundwater recirculation cell. In nine different layers, the grain shapes, grain size distribution and the permeabilities were modelled and calculated. The flow resistance produces different hydraulic conductivities (kf) for each flow direction. By solving the equation $kf = kg\rho/\mu$ in PACE3D, a flow dependent pressure gradient can be calculated. For flow simulations, an in-house PACE3D solver has been used to solve the full Navier-Stokes equation.

Conclusions

Microcosm experiments determined the feasibility of C-MIX for bioremediation. In field test, the coupling of C-MIX and the GCW system showed a rapid decline of CAHs concentrations at different aquifer levels (Fig. 2). Flow simulations provide valuable predictions of the groundwater circulation flow.

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References:

Dolinová, I., Strojsová, M., Cernik, M., Nemecek, J., Machacková, J. and Sevcu, A. “Microbial degradation of chloroethenes: a review”, *Environ. Sci. Pollut. Res.*, 24: 13262–13283 (2017).

Pierro, L., Matturro, B., Rossetti, S., Sagliaschi, M., Sucato, S., Alesi, E.J., Bartsch, E., Arjmand, F., Petrangeli Papini, M. “Polyhydroxyalkanoate as a slow-release carbon source for in-situ bioremediation of contaminated aquifers: From laboratory investigation to pilot-scale testing in the field”, *New Biotechnology*, 37: 60-68 (2017).