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Forced Convection of Organic Reagent via Groundwater Circulation Well (IEG-GCW®), Analysis of Biostimulation Processes and Innovative PACE 3D Modelling

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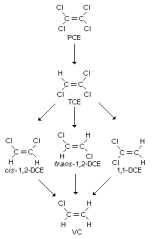
INTRODUCTION

Soil and groundwater pollution by **chlorinated aliphatic hydrocarbons (CAHs)** is a widespread problem in industrialized areas. The chlorinated compounds PCE, TCE and their metabolites cis-DCE, trans-DCE, 1,1-DCE and VC have been detected at an industrial site near Barcelona (Catalonia, Spain) at concentrations up to 170 mg L^{-1} (TCE). **Biodegradation** of PCE and TCE usually occurs through the anaerobic reductive dehalogenation pathways especially performed by bacteria from the genera *Dehalococcoides* and *Dehalogenimonas*. However, those reactions are **usually slow** and require external actions to accelerate the biodegradation, being the most common the addition of organic matter. Many injection points and sometimes reinjection of biostimulants are needed in order to achieve the desired bioremediation. Here we present a **novel approach to improve the distribution of hydrogen releasing amendment (IEG-C-MIX) with peripheral multilevel injection wells (IEG- MIW) and the forced convection of the groundwater circulation well (IEG-GCW®)**



GENERAL OBJECTIVE

Evaluation of a novel technology combining the innovative Groundwater Circulation Well (IEG-GCW®) with Multilevel Injection Wells (IEG-MIW) to increase the **biostimulation** of indigenous microorganisms by **groundwater superimposed recirculation**.

LAB-SCALE MICROCOSMS

OBJECTIVES

- To determine if there was **dehalorespiring activity** in the site
- To establish differences between **different biostimulant** (C-MIX) compositions
- To chose the best **C-MIX composition** for the pilot plant

MATERIALS and METHODS

- **Microcosms** under strict anaerobic conditions were set up (Fig. 1)
- Experiments were performed using **soil and wastewater** from the site spiked with **selected pollutants**
- Three different compositions of **organic amendment** (C-MIX) were tested
- NGS analysis were performed to identify the **microbial community**

Fig. 1 - Microcosms

RESULTS and CONCLUSIONS

- Results showed that microorganisms in the site are **able to degrade** PCE, TCE, cis-DCE and 1,1-DCE (Fig. 2)
- **Mineralization** was suggested because VC was not detected
- No significant differences were found between different **biostimulants**
- Next generation sequencing (NGS) of bacterial 16S rDNA of the site groundwater and at the end of each microcosms experiment showed the **presence of different dehalorespiring bacteria** (*Desulfuromonas* sp., *Desulfovibrio* sp., *Geobacter* sp. and unclassified Dehalococcoidia) additionally to different fermenting bacteria in C-MIX microcosmos (Fig. 3)

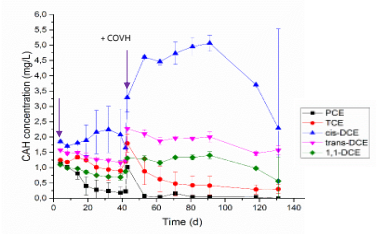


Fig. 2 – CAH concentration evolution in microcosms experiments

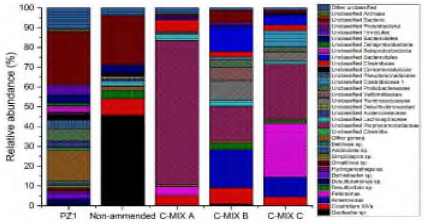


Fig. 3 – Bacterial community in groundwater (PZ1) and each of the microcosms experiments

PILOT PLANT INSTALLATION

OBJECTIVES

- To show the **viability** of the IEG-GCW and IEG-MIW technologies combination
- To optimize the operation to maximize the **biodegradation**

MATERIALS and METHODS

IEG-GCW® (Fig. 4) is an innovative system that allows a more effective distribution of amendments by forced convection to achieve a **faster bioremediation** in the radius of influence (ROI). GCW technology increases the bioavailability of the pollutants even in low permeable zones.

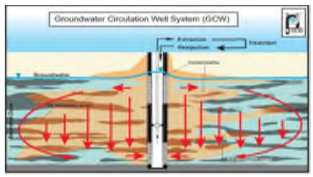


Fig. 4 – General principle of IEG-GCW® technology

Fig. 5 – Remediation equipment

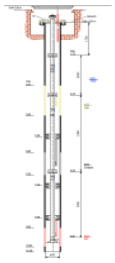


Fig. 6 – Multilevel sampling well (MLSW)

The **IEG-MLWS system** (Fig. 6) is used for obtaining multiple high quality samples of soil gas and groundwater. 2 of these systems are installed at the pilot plant (Fig. 9).

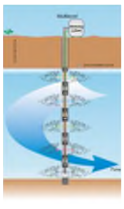


Fig. 7 – Multilevel injection well (IEG-MIW)

The **IEG-MIW system** (Fig. 7) is used to inject amendments in different horizons of the aquifer. It is very flexible in its operation, allowing for simultaneous or single injections. There are 4 IEG-MIW installed on this pilot site (Fig. 9).

RESULTS and CONCLUSIONS

Preliminary results show a **decrease** in TCE and cis-DCE concentrations through biological degradation already during the first days of operation (Fig. 8)

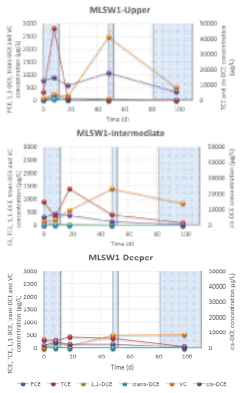


Fig. 8 – CAHs concentration in the different sampling levels of MLSW1. The shaded areas correspond to the periods with active groundwater recirculation during the pilot plant start-up

Fig. 9 – Map of the pilot test area

PACE 3D MODEL

OBJECTIVES

- To **model** the superimposed groundwater recirculation
- To get the essential knowledge of the anisotropy of the different sediment layers in order to get a better understanding of the **influence of forced flow** to microbiological degradation.

MATERIALS and METHODS

Modelling the forced flow through sediments, the **geometrical description of the porosity** is essential. The geometrical description needs information like the grain size distribution, the topology of the grains and the arrangement of the grains inside the sediment.

RESULTS and CONCLUSIONS

- An enhanced **virtual filling algorithm** has been created and applied to selected cores of liner drillings to achieve a better 3-D modelling performance and to get the **flow resistance parameters** of the different layers of the convection cell
- Based on this parameters the phasefield solver Pace3D has been fully coupled with a Navier-Stokes-Solver to be able to model several phases and superimposed flow.
- **Flow behaviour** in the forced convection cell can be analysed and the transport mechanism can be interpreted and simulated (Fig. 10).

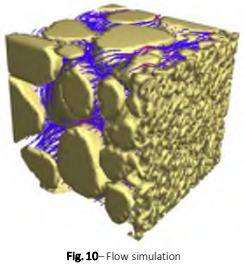


Fig. 10 – Flow simulation

GENERAL CONCLUSION

Preliminar pilot plant results show a **fast degradation** of TCE and cis-DCE at the different groundwater levels.

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