INTEGRATED PLUME TREATMENT WITH PERSULFATE ISCO AND MICROBIALLY MEDIATED SULFATE REDUCTION (IBR): A FIELD EXPERIMENT

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Introduction

The coupling or sequential use of two or more treatment technologies is believed to provide more efficient and extensive removal of a range of environmentally relevant contaminants including petroleum hydrocarbons (PHCs) [1]. Coupling of different remediation technologies combines the strengths of each individual technology to improve treatment performance. The sequential use of in situ chemical oxidation (ISCO) and intrinsic bioremediation (IBR) is an example of a treatment train approach. The notion behind a persulfate ISCO/IBR treatment train is that it could potentially combine the aggressive nature of persulfate ISCO in the source zone with the long-term efficiency of subsequently enhanced sulfate reduction in both the source zone and downgradient plume [2]. To design an effective and efficient persulfate treatment train, it is necessary to have a comprehensive understanding of all the relevant physical, chemical and biological processes occurring in the subsurface system. The primary objective of this research is to develop a better understanding of the characteristics of a coupled persulfate ISCO/IBR treatment train by executing a carefully monitored pilot-scale field experiment. Additionally, novels site characterization tools were used to assess the performance of the treatment system.

Methods

The pilot-scale field experiment was conducted at the University of Waterloo Groundwater Research Facility at the Canadian Forces Base (CFB) Borden, ON, Canada. A dissolved BTX plume over 170 days with maximum concentrations of approx. 15 mg/L was created using a diffusive source. An anaerobic aquifer system was fully developed prior to persulfate injection. The anaerobic aquifer is intended to provide a favorable condition for the acclimation and growth of indigenous sulfate reducing bacteria (SRB). A persulfate solution was injected at day 170 and 180, and the plume monitored during 391 days in total. Numerical modelling has been used to optimize the design of the persulfate injection system.

BTX concentrations, compound specific isotope and microbiological analysis were conducted to investigate the performance of the treatment train, the effect of the injected persulfate on the population and activity of sulfate reducing bacteria indigenous to the Borden aquifer and finally to differentiate concentration reduction processes (e.g., biodegradation vs chemical oxidation).

Results

The BTX plume was partially remediated. An average degradation of 50% because of the ISCO was estimated using BTX concentration and $\delta\ ^{13}C$ and $\delta\ ^{2}H$ results. The remaining fraction was degraded because of the mediated sulfate reduction processes for most part of the plume (Fig. 1). A detectable growth of indigenous sulfate reducing bacteria was shown by qPCR r and key metabolites concentration results. The coupling $\delta\ ^{13}C$ and $\delta\ ^{2}H$ indicated a different and specific trend for chemical oxidation and biodegradation processes for benzene only (Fig. 2).

Conclusions

Induced biodegradation under stimulated sulfate reduction condition following a persulfate ISCO treatment was successfully demonstrated. Compound specific isotope analysis and molecular biology methods are powerful tools in evaluating the performance of these type of combined remediation techniques like persulfate ISCO/IBR treatment trains.

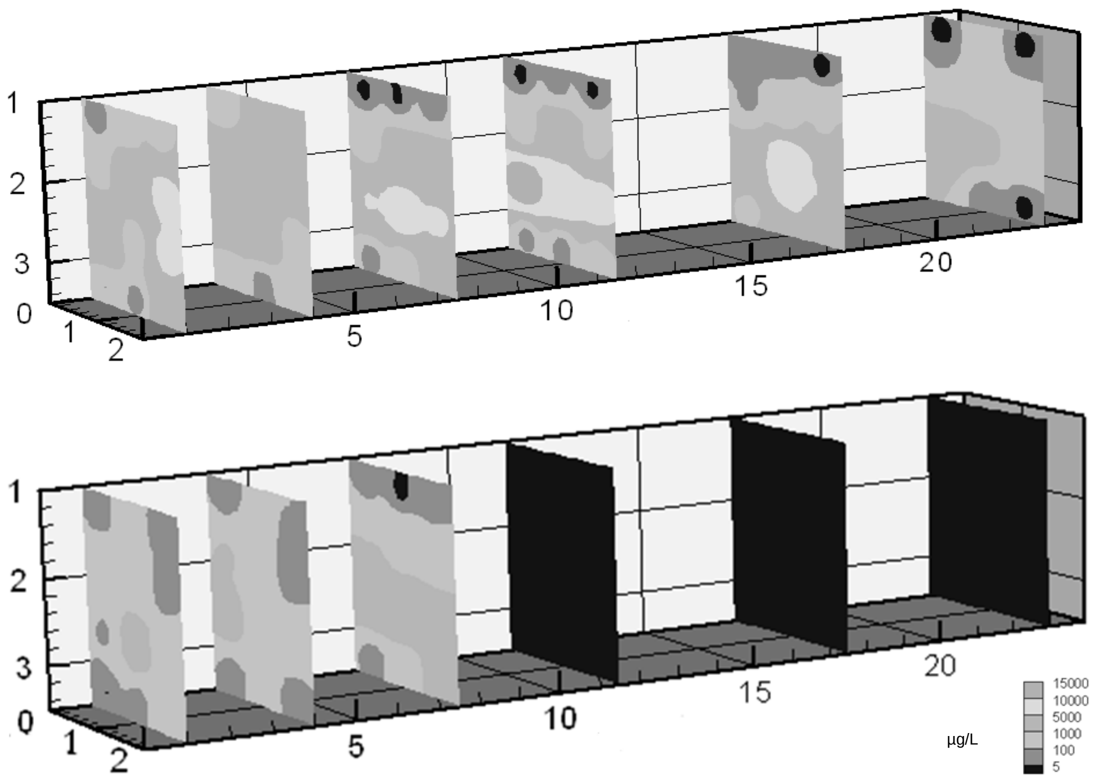

Fig. 1 – Benzene concentration in µg/L at day 170 (on top, before the injection) and day 391(below); the plume is moving from left to right. The persulfate was injected in between Row 1 and Row 2 (located at the left side)

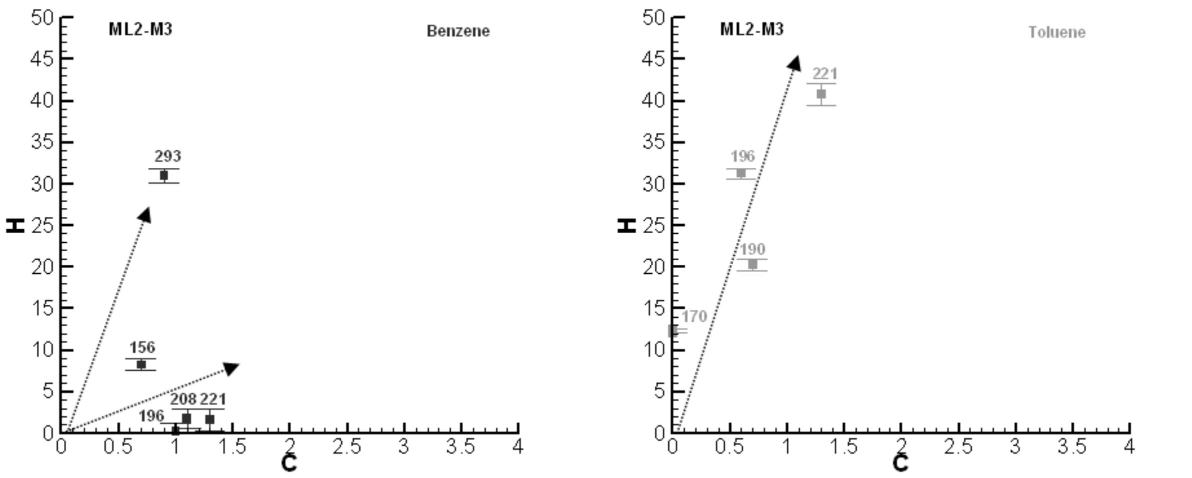

Fig. 2 – Δ δ ^{13}C & δ ^{2}H (‰) for Benzene (left) and Toluene (right) at Row 2 multilevel M3; the numbers at the top refers to the sampling date

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