Integrated Anaerobic-Aerobic Biodegradation of Mixed Chlorinated Solvents by Electrolysis Coupled with Groundwater Circulation in a Simulated Aquifer

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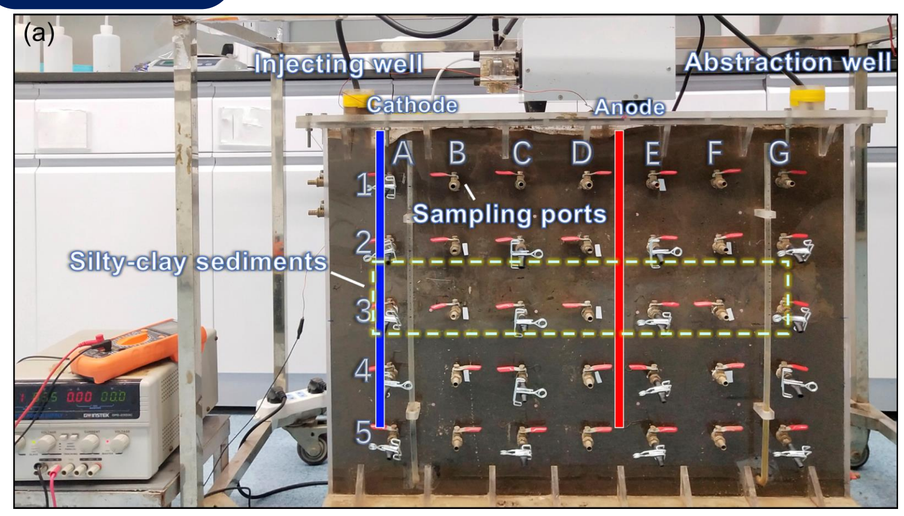
MOTIVATION

Chlorinated solvents are often present as complex mixtures in subsurface environments. Their complete biodegradation remains challenging because the optimal redox conditions for biodegradation of different chlorinated solvents differ significantly. Electrochemical process may provide solutions to in situ supplements of electron acceptors/donors and the creation of well-controlled multiple redox conditions in aquifers. However, it is still unclear whether this treatment is effective in the simultaneous removal of different chlorinated solvents which require different redox conditions for efficient removal.

METHODS



Two-dimensional acrylic tank

- 80 cm length × 6 cm thickness × 60 cm height
- Simulated heterogeneous aquifer filled with sandy and clayed sediments
- MMO electrodes inserted into the sediments
- Water circulation to enhance water flow in high-permeability (sandy) sediments
- Chloroform (CF), trichloroethylene (TCE), and 1,2-dichloroethane (DCA) were selected as target contaminants.

Analysis

- Contaminants and their products
- DO and DH diffusion
- Microbial community compositions
- $\delta^{13}C$ values of the chlorinated solvents

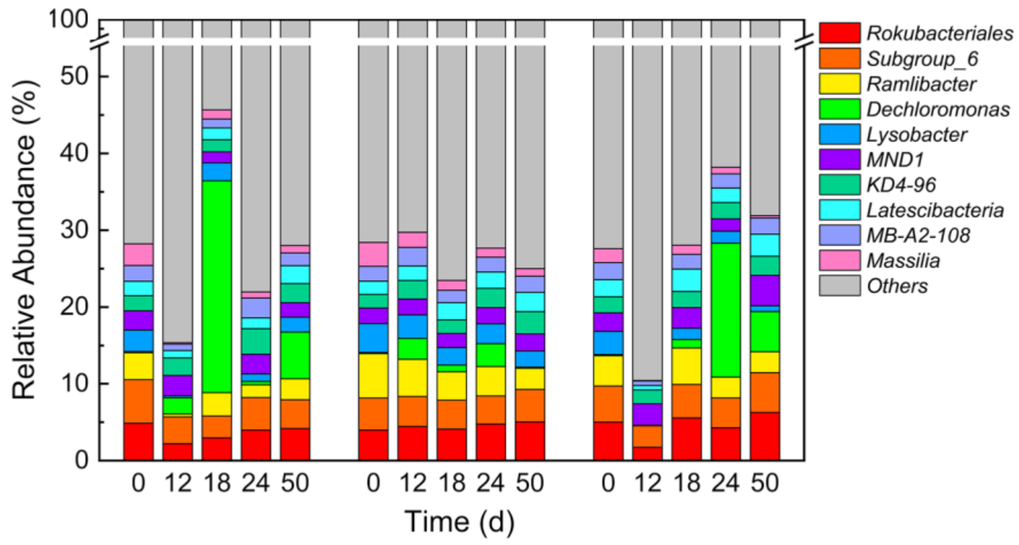
RESULTS

Variations of groundwater chemistry during treatment

- The treatment posed negligible influence on pH in the simulated aquifer
- Variations of DH, DO, and ORP show that anaerobic and aerobic conditions could be integrated in the system and the aquifer environment could be artificially manipulated by changing the electrolysis mode, adjusting the current intensity, and adding carbon sources.

Variations of microbial community during treatment

- Chao1 and Shannon indices of microbial community after 50 days of treatment were similar to or slightly higher than the initial value
- The total relative abundance of the top 10 microorganisms at ports close to electrodes (B2 and F2) firstly decreased during the first 12 days and increased afterward.
- A dechlorinating bacteria, *Dechloromonas*, that has electrochemical activity, was enriched at port B2 during days 12~18.
- Both aerobic and anaerobic microbes could survive in multiple redox conditions.

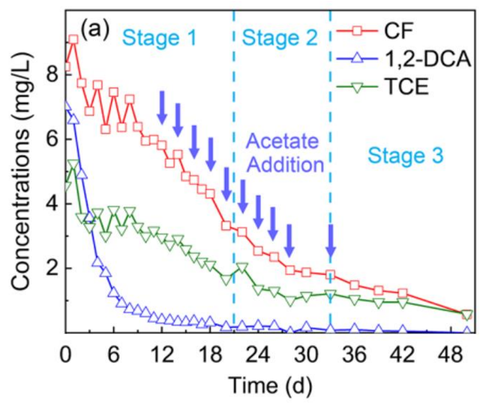


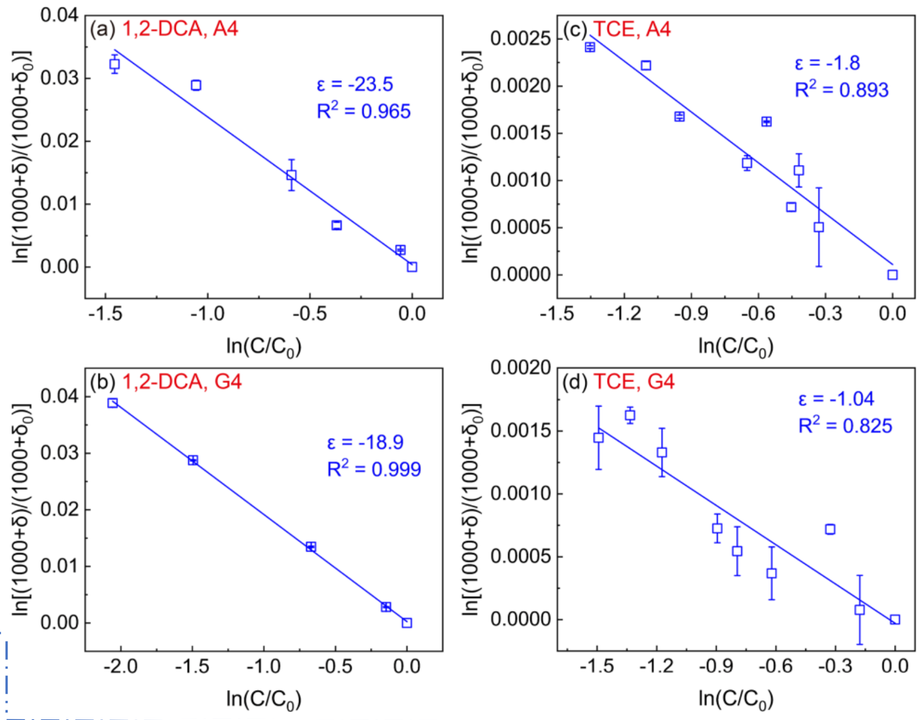
Biodegradation of mixed chlorinated solvents in the treatment

- After 50 days of treatment, 93.1%, 100%, and 87.3% of CF (8.25 mg/L), 1,2-DCA (7.01 mg/L), and TCE (4.56 mg/L) were removed.
- DCM (below 1 mg/L) was constantly detected along with the degradation of CF.
- 1,2-DCA was rapidly degraded during the first 11 days and was completely removed at the end of the experiment.
- For all of the chlorinated solvents, no residual dechlorination intermediates were detected by GC–MS at the end of the experiment.

Biodegradation pathways of different chlorinated solvents during the treatment

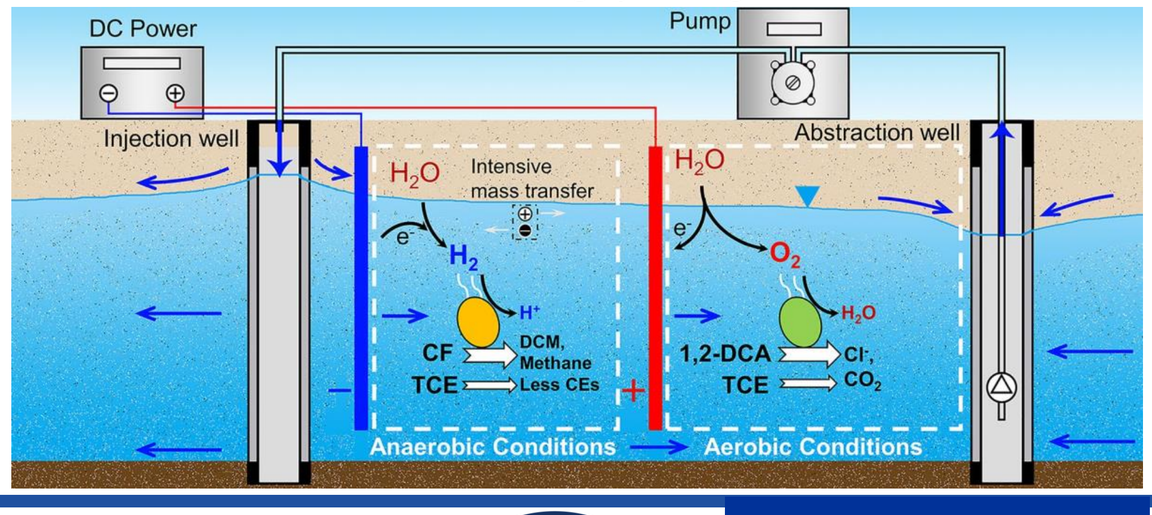
- Distinct degrading efficiencies of CF in different ports and the detection of DCM implies the reductive dechlorination of CF.
- Comparing the δ13C enrichment factors of 1,2-DCA and TCE in this study with those from previous research indicates that the removal of 1,2-DCA was predominantly due to aerobic oxidation, whereas TCE elimination was facilitated by both aerobic and anaerobic biodegradation processes.





CONCLUSIONS

- Electrolysis coupled with groundwater circulation integrated Anaerobic and aerobic conditions in a heterogenous aquifer
- The system constructed habitats suitable for both aerobic and anaerobic microbes
- Mixed chlorinated solvents were thoroughly biodegraded without intermediates



Acknowledgement:

This project has received funding from the National Natural Science Foundation of China (32061133002) and the European Union's Horizon 2020 research under grant agreement N°965945.

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