The Fifth International Symposium on Bioremediation and Sustainable Environmental Technologies

Removal of Tetrachloroethylene (PCE) from Groundwater by Coupled nZVI-LDH Composite and PCE-Degrading Microbial Consortium

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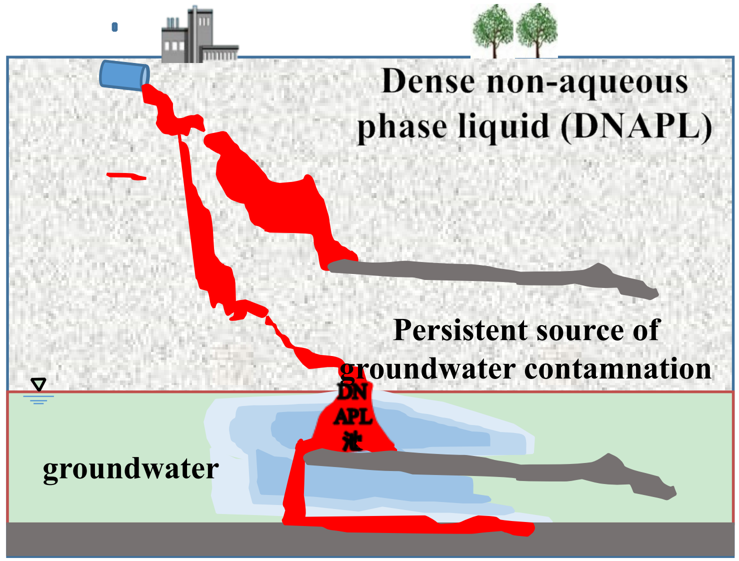
1. Introduction

◻ The exposure of chlorinated organic can cause threats to human beings

- Carcinogenic and cytotoxic effects that can cause severe damage to central nervous system, endocrine system and immune system
- Listed as one of the priority pollutants by the US Environmental Protection Agency

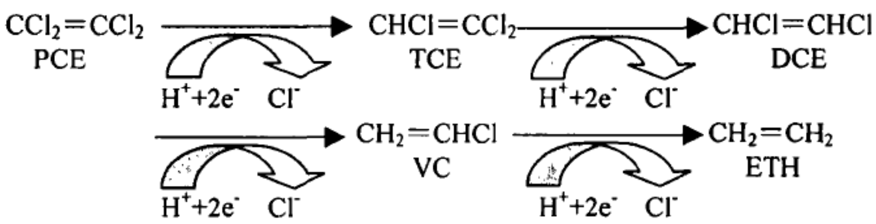


◻ Soil Pollution Prevention and Control

1. Introduction

☐ Remediation technology

■ Bioremediation



Many anaerobic bacteria reductively dechlorinate PCE or TCE to vinyl chloride and ethene (e.g., *Desulfuromonas*, *Sulfurospirillum multivorans*, and *Dehalobacter*).

The challenges of bioremediation:

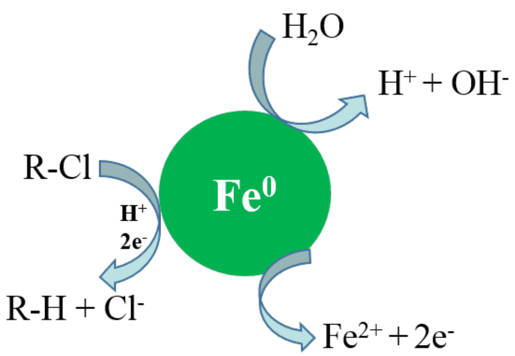
- Low dechlorination rates and long clean up times;
- Inefficient supply of suitable electron donors to the dechlorinating bacteria;
- Toxicity of high PCE orTCE concentrations to dechlorinating bacteria.

Need to combine other technology with various bacteria to improve the removal efficiency of chlorinated-solvent contaminated groundwater

1. Introduction

Remediation technology

Nanoscale zero-valent iron (nZVI)

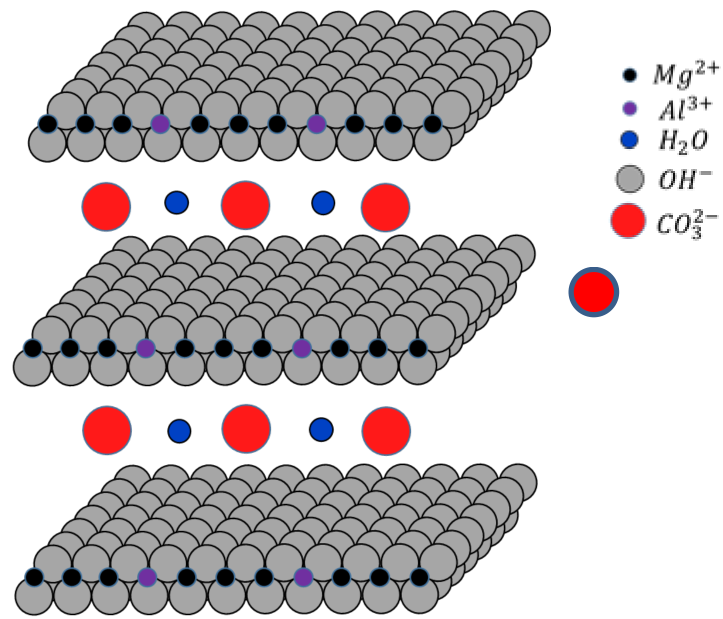


The challenges for field applications of nZVI:

- The agglomeration of nZVI particles;
- nZVI particles are oxidized spontaneously;
- nZVI particles exhibited severe toxicity on cell growth;

Modified

Layered double hydroxides (LDHs)

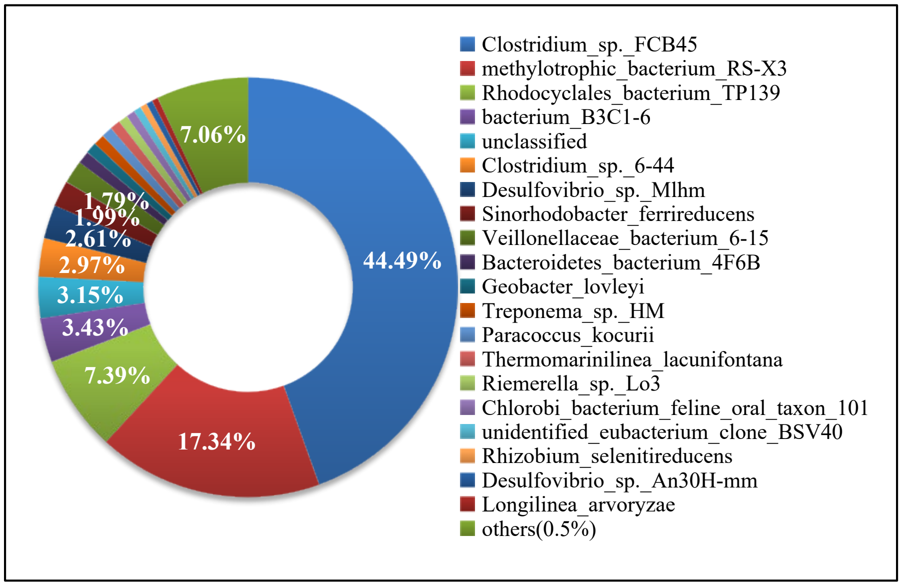


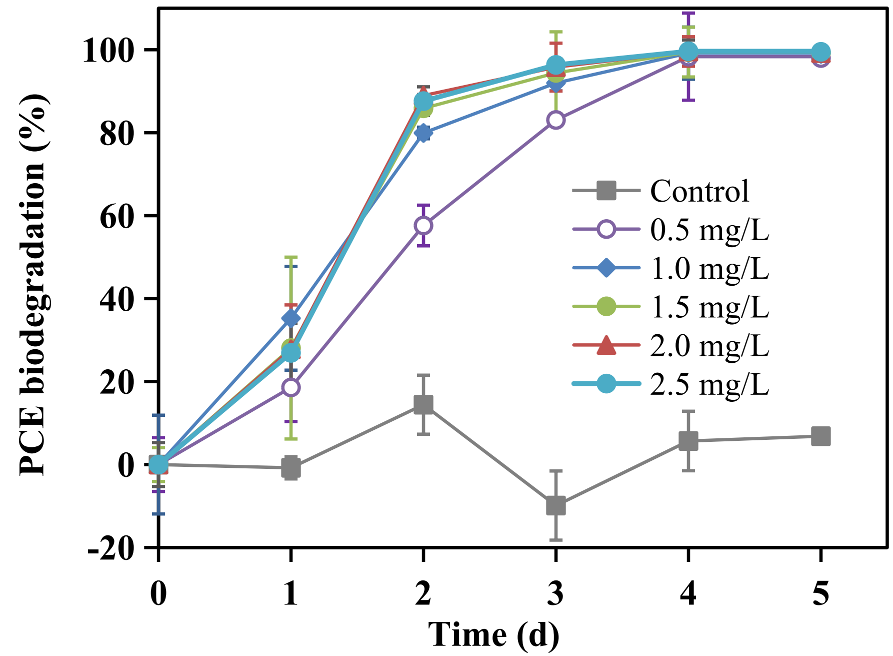
LDHs are widely used as catalysts, sorbents, due to the layered structure, high anionic exchange capability, large surface area, high porosity and thermal stability

- A combined nZVI-LDH+bacteria system for PCE remediation will result in more removal efficiency and benign end products because of microbial actions.
- The degradation kinetics and efficiency of PCE by nZVI-LDH and acclimated microbial consortium were investigated

2. PCE biodegradation by microbial consortium

Composition of the acclimated microbial consortium

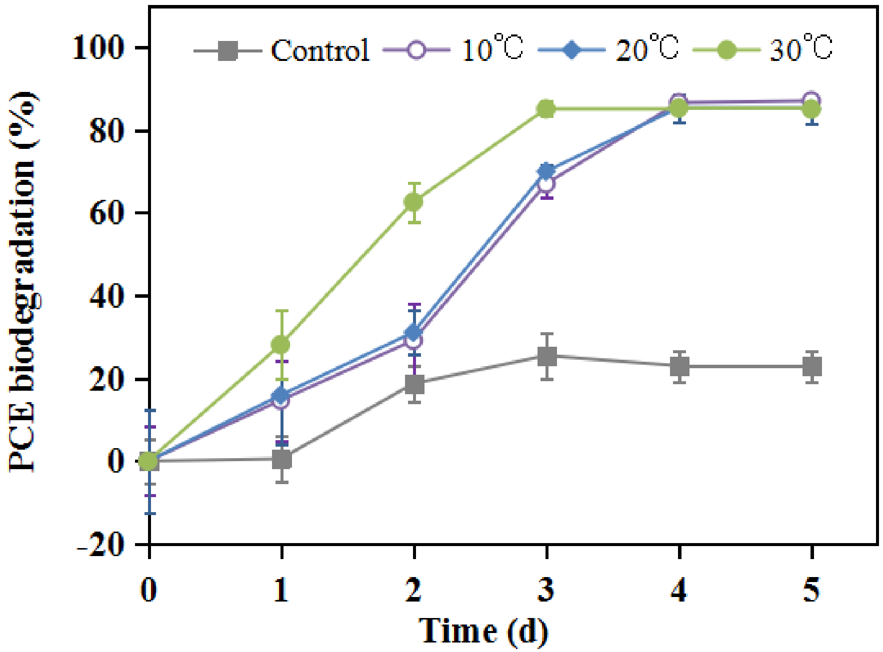


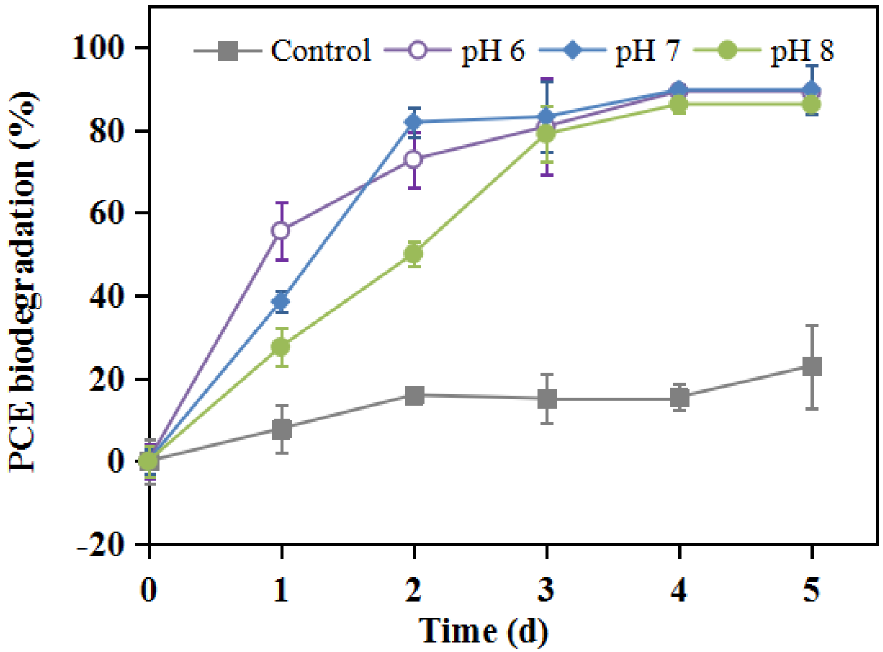


- the acclimated microbial consortium mainly consisting of *Clostridium sp.* FCB45 (44.49%), *Methylotrophic bacterium* RS X3 (17.34%), *Rhodocyclales bacterium* TP139 (7.39%), *Desulfovibrio* (2.61%), and *Treponema* (0.85%) at species level;
- 0.5-2.5 mg/L PCE could be completely biodegradation within four days.

2. PCE biodegradation by microbial consortium

Effect of pH and temperature on PCE biodegradation

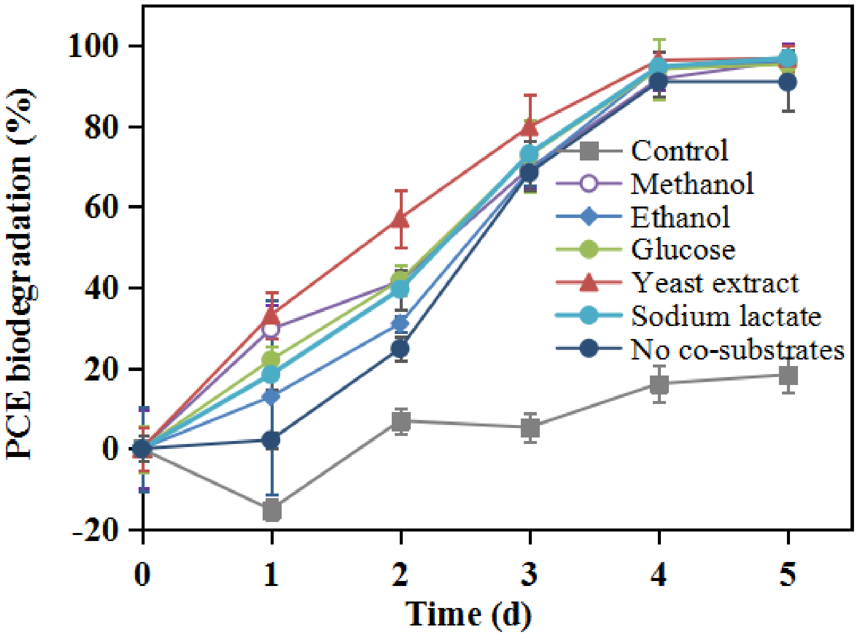




- The highest PCE biodegradation rate was observed at temperature of 30°C, in neutral pH.
- The acclimated microbial consortium had a potential for in situ PCE bioremediation.

2. PCE biodegradation by microbial consortium

Effect of co-substrate on PCE biodegradation

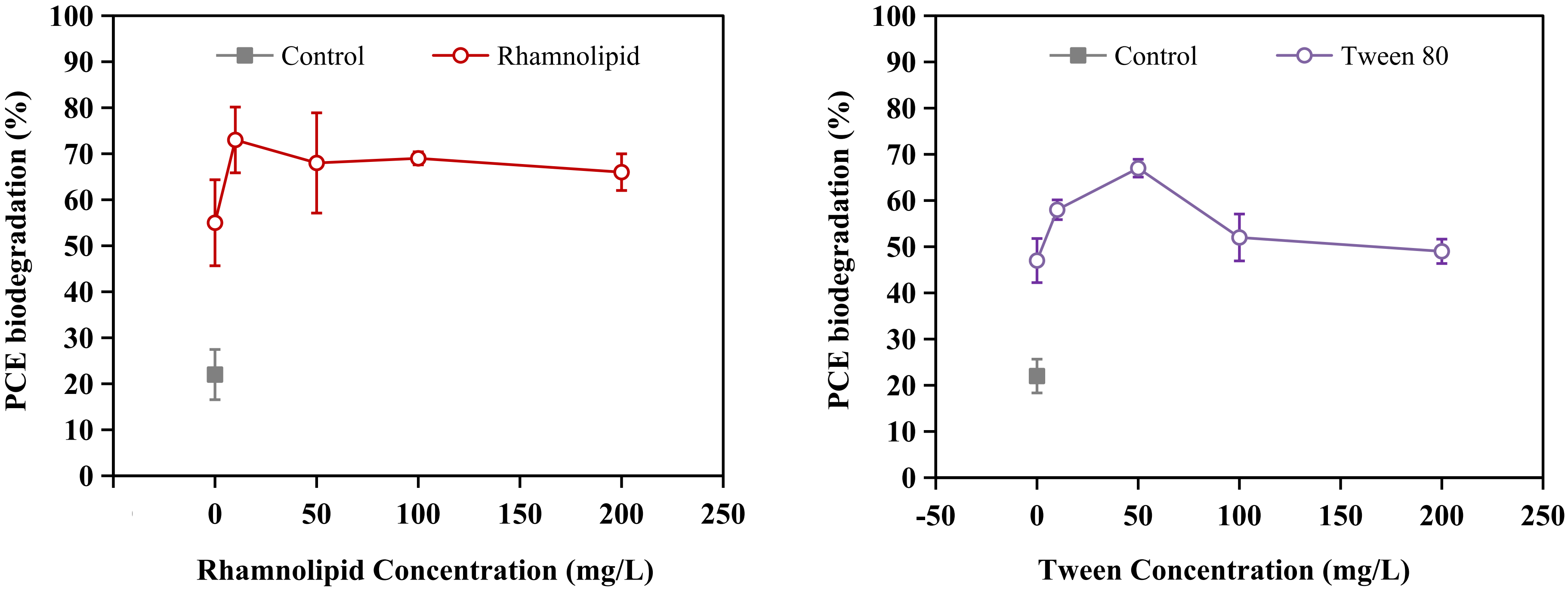


- The biodegradation rate: Yeast extract>Glucose≈Methanol>Sodium lactate>No co-substrates>Ethanol;
- The enhanced biodegradation process followed the first-order reaction kinetics.

Co-substrates	First order kinetic model	R^2	K	$T_{1/2}$ (d)
Methanol	$y = 1.39 * e^{-\frac{x}{7.02}} - 0.682$	0.972	0.142	1.138
Ethanol	$y = 4.38 * e^{-\frac{x}{27.23}} - 3.67$	0.928	0.037	1.338
Glucose	$y = 1.62 * e^{-\frac{x}{6.875}} - 0.792$	0.963	0.145	1.555
Yeast extract	$y = 1.11 * e^{-\frac{x}{3.055}} - 0.223$	0.988	0.327	1.309
Sodium lactate	$y = 1.895 * e^{-\frac{x}{8.906}} - 1.106$	0.955	0.112	1.474
No co-substrates	$y = 1.746 * e^{-\frac{x}{10.155}} - 1.061$	0.884	0.098	1.137

2. PCE biodegradation by microbial consortium

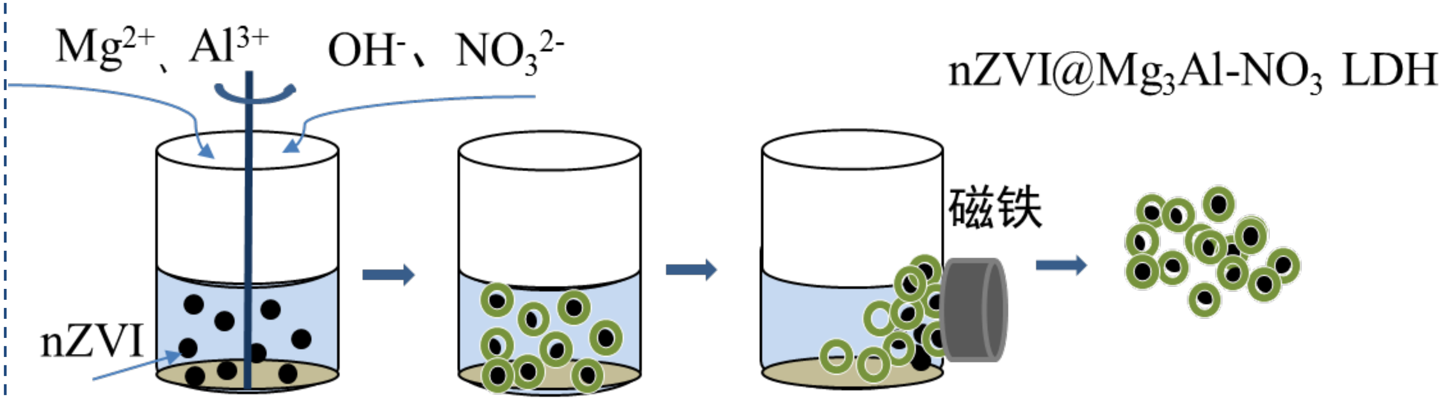
Effect of rhamnolipid and tween 80 on PCE biodegradation

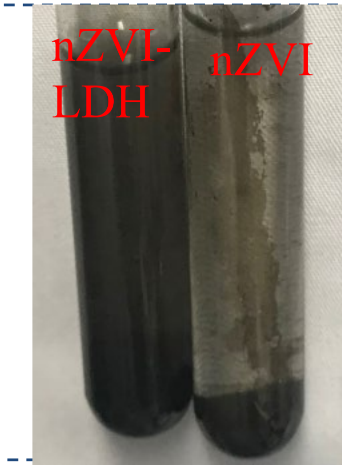


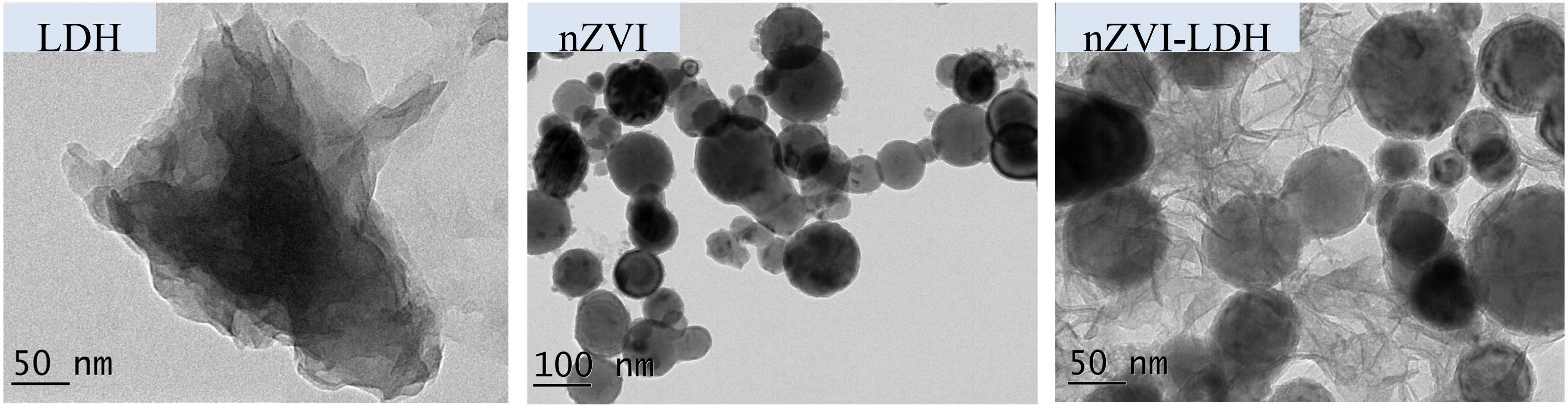
- When the rhamnolipid and tween 80 were at 10 mg/L and 50 mg/L, the PCE biodegradation efficiency was enhanced to 73% and 67%, respectively.

3. Degradation of PCE by nZVI-LDH

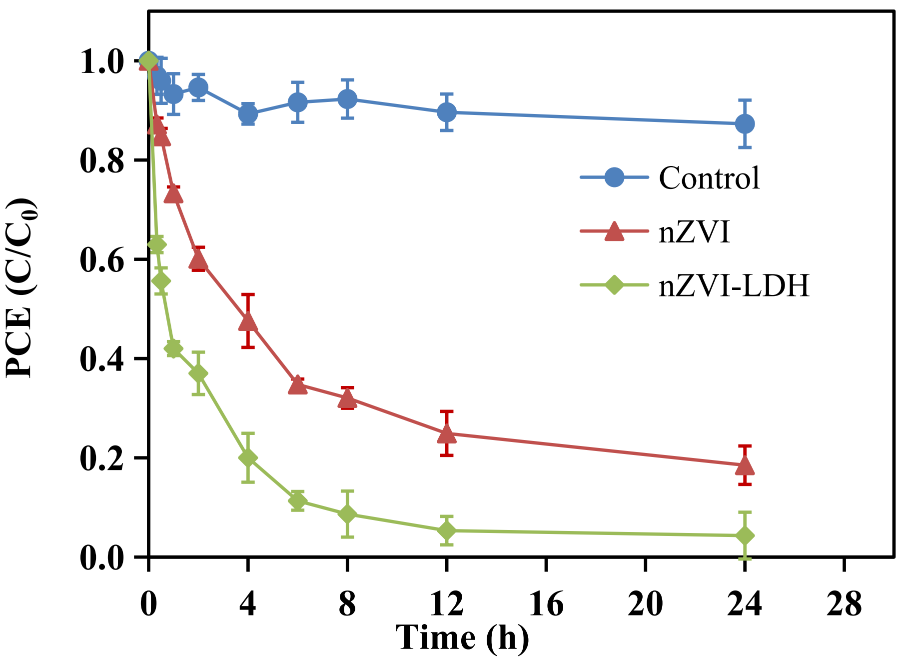
Layered double hydroxide (LDH) modified nanoscale zero-valent iron (nZVI-LDH) was prepared by co-precipitation method with nZVI as the core and LDH as the shell.

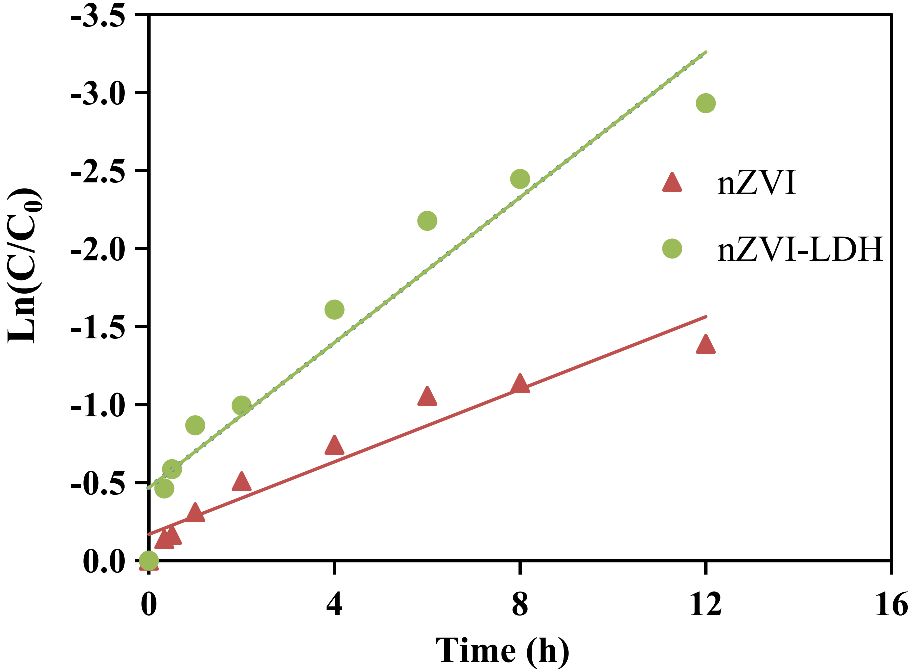






3. Degradation of PCE by nZVI-LDH

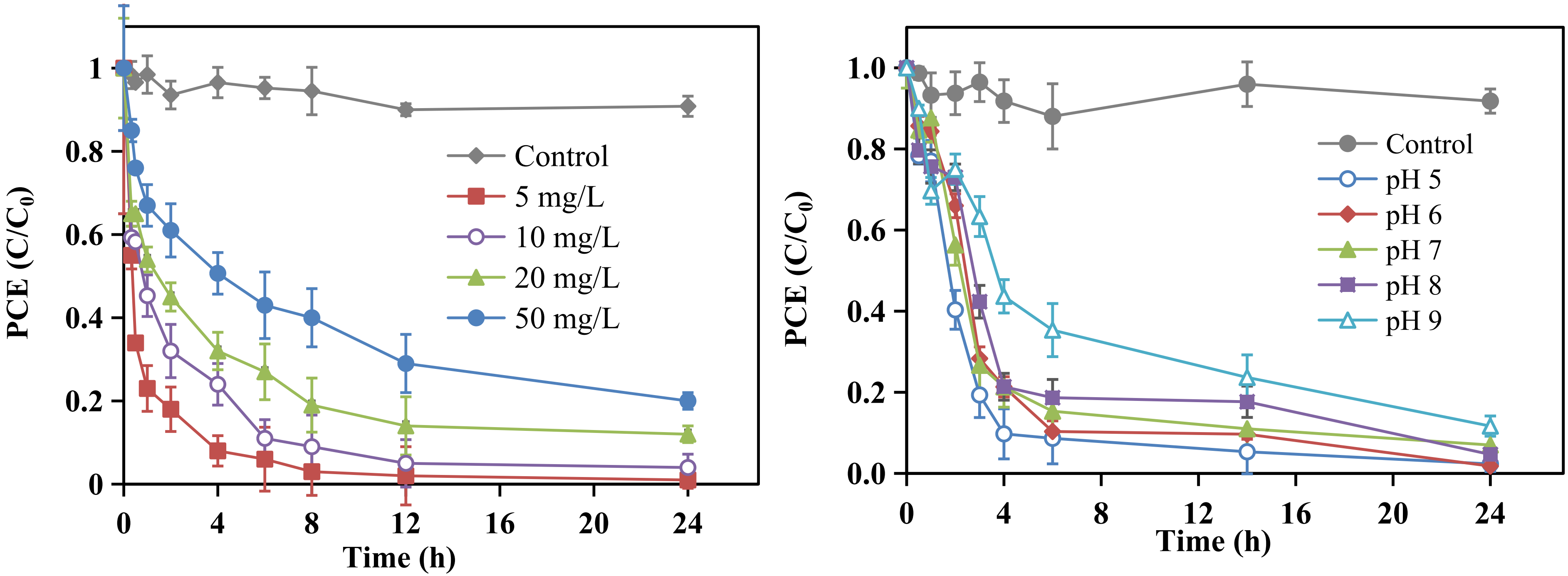




	The removal rate constant（h^{-1}）	R^2
nZVI	0.12	0.935
nZVI-LDH	0.23	0.924

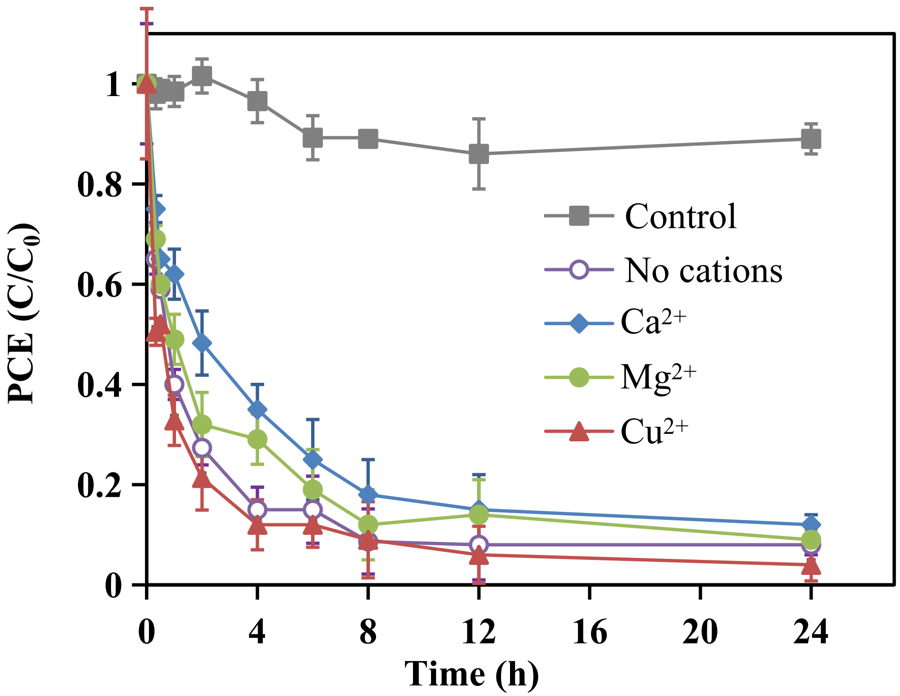
- The removal efficiency of PCE by nZVI and nZVI-LDH were 81.5% and 96.3% respectively after 24 h.
- The kinetic analysis demonstrated that PCE degradation follows pseudo first order kinetic behavior.

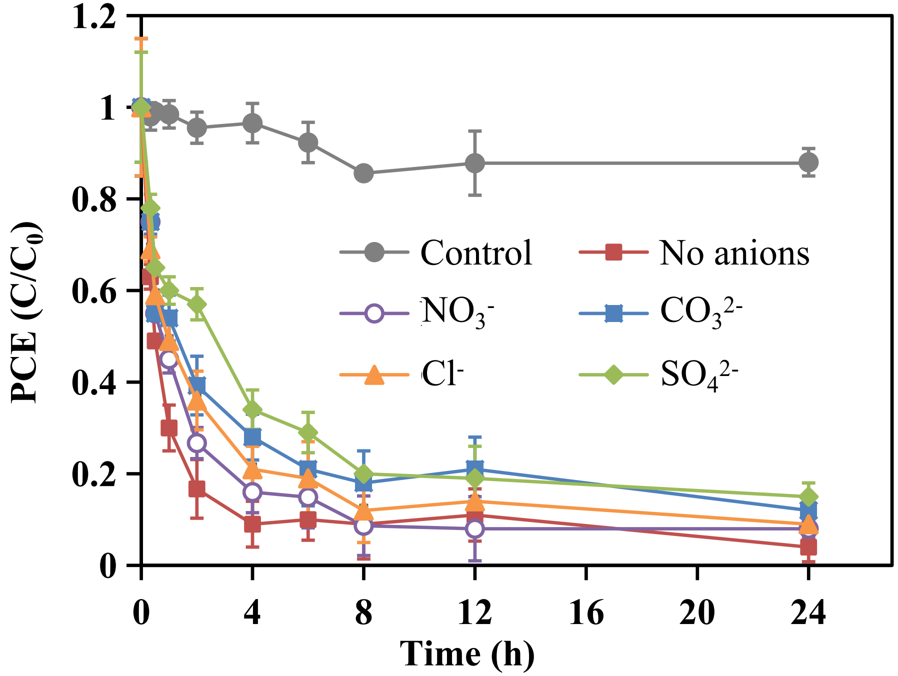
3. Degradation of PCE by nZVI-LDH



- When the initial PCE concentrations increased, more Fe^0 would be oxidized and would lose its activity leading to a decrease in the removal rate;
- The efficiency of PCE degradation decreased with the increase in pH, indicating that nZVI-LDH could remove PCE in groundwater more effectively at acidic pH values than alkali pH values.

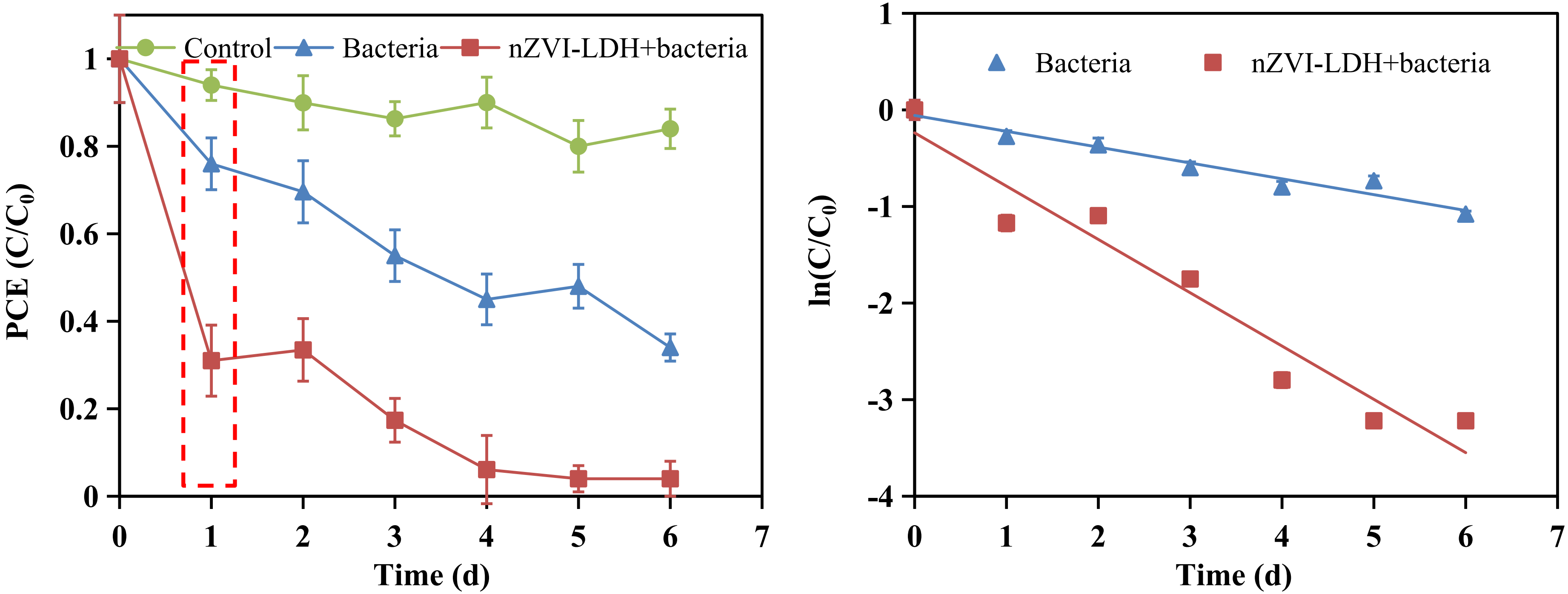
3. Degradation of PCE by nZVI-LDH





- PCE removal as obviously promoted in the presence of co-existing Cu^{2+} ions, while inhibited in the presence of co-existing Ca^{2+} and Mg^{2+} ions.
- The performance of PCE degradation was inhibited slightly by the common groundwater anions;

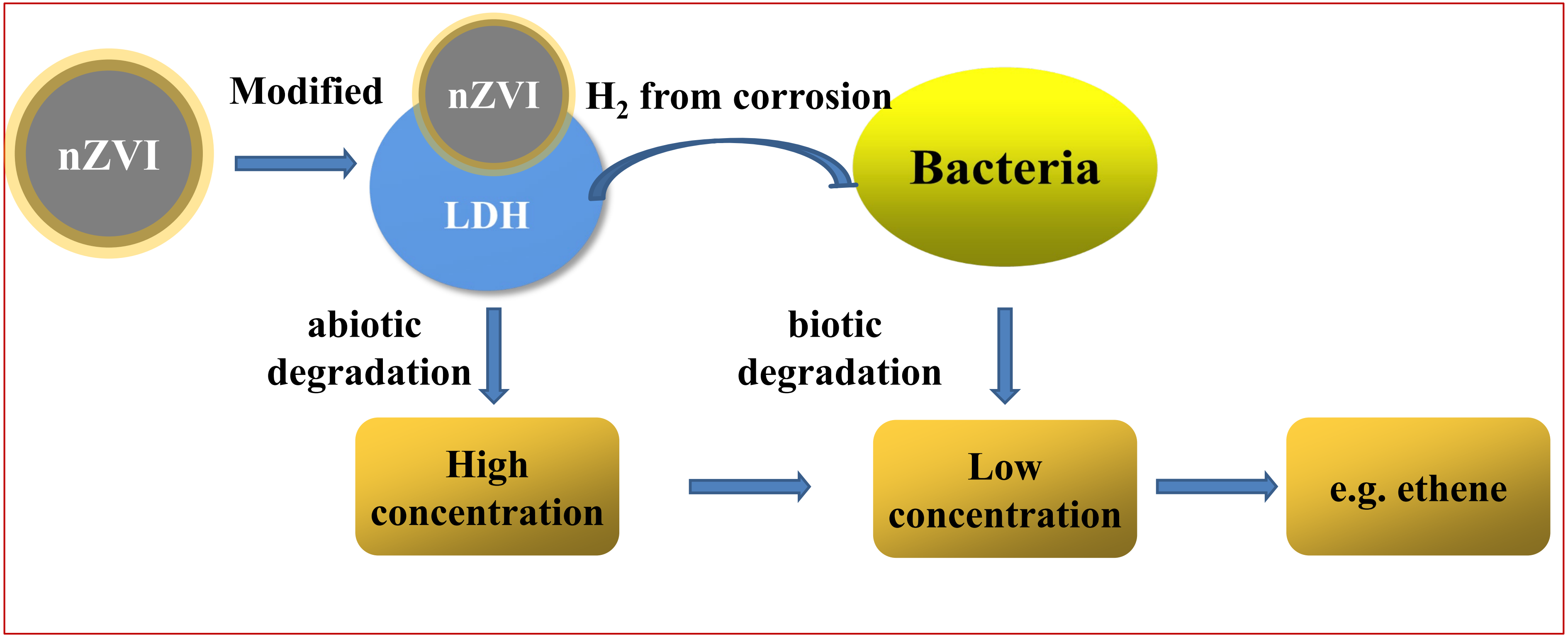
4 Coupled degradation of PCE by bacteria and nZVI-LDH



- For the combined nZVI-LDH+bacteria system, the removal rate of PCE was higher than that of PCE-degrading consortium;
- The degradation of PCE followed the pseudo-first order reaction kinetics, the degradation rate constant was 0.16 and 0.55 d^{-1} , respectively.

4 Coupled degradation of PCE by bacteria and nZVI-LDH

- **nZVI-LDH+microorganism**



PCE was degraded by nZVI-LDH to lower concentration at the initial stage, which was conducive to the growth of microorganisms. In addition, the addition of nZVI-LDH can create reducing conditions and produce hydrogen as electron donor, enhancing the PCE biodegradation efficiency.

5. Conclusions

- The enriched PCE-degrading consortium consisted of 44.49% *Clostridium* and other potential PCE degraders; 0.5-2.5 mg/L PCE could be completely biodegradation within four days.
- The optimal temperature and pH for PCE biodegradation were 30°C and pH 7; When the rhamnolipid and tween 80 were at 10 mg/L and 50 mg/L, the PCE biodegradation efficiency was enhanced to 73% and 67%, respectively.
- The PCE degradation by nZVI-LDH could be well described by pseudo first order model; The degradation efficiency of PCE decreased with the initial pH increased;
- The presence of Cu^{2+} improved degradation efficiency of PCE by nZVI-LDH due to its role as a catalyst or medium of charge transfer during reduction;
- Enhanced biodegradation of PCE by coupling nZVI-LDH and PCE-degrading consortium was observed.

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Thanks for your attention !