Phytoremediation of PAHs-TCE co-contamination

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Motivation

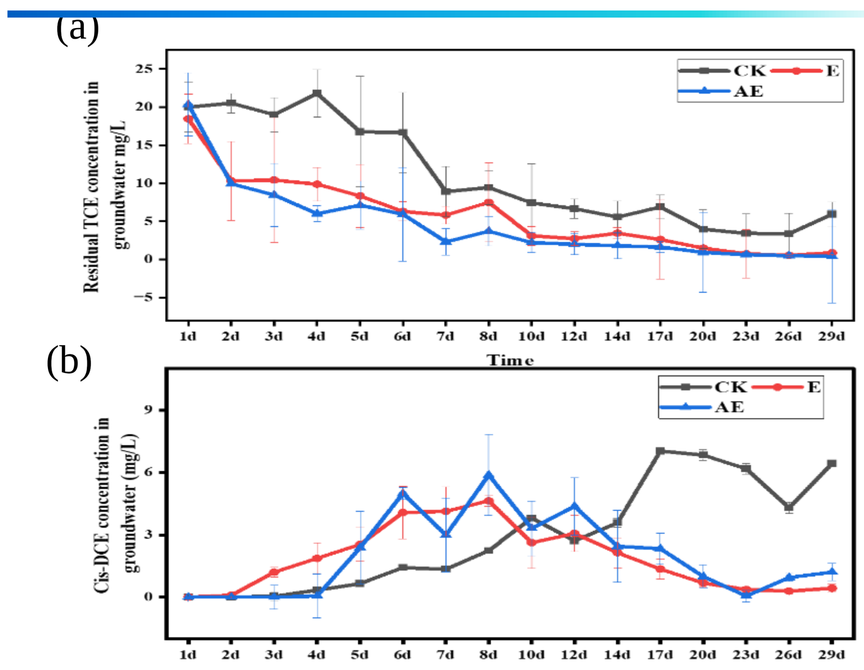
Chlorinated hydrocarbons and polycyclic aromatic hydrocarbons (PAHs) are prevalent organic pollutants commonly found together at contaminated sites. Plants have demonstrated significant potential for in situ bioremediation of such pollutants through uptake, metabolism, volatilization, and the stimulation of microbial degradation in the rhizosphere. This study investigates the roles of alfalfa and eucalyptus in remediating co-contamination by PAHs and trichloroethylene (TCE), explores the underlying mechanisms, and highlights the enhanced degradation of PAHs through microbial community construction. These findings offer new insights and strategies for the ecological remediation of organic contaminants.

Methods

This study established four experimental groups: a plant-free control (CK), an alfalfa treatment group (A), a eucalyptus treatment group (E), and an alfalfa-eucalyptus intercropping group (AE) to evaluate alfalfa's effectiveness in degrading PAHs and eucalyptus's role in removing trichloroethylene (TCE) from groundwater. Additionally, the study also evaluated the degradation of PAHs by synthesized microbial communities.

Eucalyptus tree restoration of TCE in groundwater

TCE and its metabolites



- **The planting of eucalyptus trees reduces the accumulation of TCE and cis DCE in groundwater;**
- **The planting of eucalyptus trees has increased the relative abundance of aerobic reducing microorganisms**

Figure 1 (a) The residual TCE concentration (mg/L); (b) Concentrations of anaerobic metabolites cis-DCE.

Flux of TCE

	AE(%)	AE (mol as Cl)	E(%)	E (mol as Cl)	CK(%)	CK (mol as Cl)
Inputs Cl	/	0.0138	/	0.0127	/	0.0133
Residual TCE in groundwater	8.71%± 4.66%	0.0012± 6.5*10-4	9.03%± 1.24%	0.00123± 2.6*10-4	12.02%±0.98%	0.0016± 0.00013
Cis-DCE in groundwater	4.69%± 2.43%	0.00064± 3.4*10-4	4.36%± 2.93%	0.00055± 3.0*10-4	37.0%± 6.73%	0.0047± 0.00085
Trans-DCE in groundwater	ND	ND	ND	ND	ND	ND
VC in groundwater	ND	ND	0.10%± 0.018%	1.33*10-5± 2.22*10-6	0.18%± 0.027%	2.36*10-5± 3.52*10-6
Cl^- in groundwater	22.7%± 4.25%	0.00313 ± 5.87*10-4	27.2%± 5.82%	0.0035 ± 7.37*10-4	28.8%± 10.1%	0.0037 ± 0.0012
TCA in groundwater	1.71%±0.59%	7.40*10-4± 1.92*10-4	4.47%±1.51%	5.66*10-4± 1.92*10-4	ND	ND
TCE volatilized from plants	22.2%± 10.7%	0.0031 ± 0.0015	19.7%± 3.73%	0.0025 ± 4.71*10-4	NA	NA
TCE volatilized from soil	3.21%± 2.34%	4.01*10-4± 2.97*10-4	6.93%± 1.74%	8.81*10-4± 2.20*10-4	1.73%± 0.97%	2.29*10-4± 1.3*10-4
TCE in soil	3.04%± 2.48%	4.22*10-4± 3.45*10-5	1.69%± 0.52%	2.13*10-4± 6.56*10-5	4.28%± 2.04%	5.67*10-4± 2.70*10-4
Cis-DCE/trans-DCE/VC in soil	ND	ND	ND	ND	ND	ND
TCE in plants	0.0046%± 0.00034%	6.31*10-7± 4.54*10-8	0.0040%± 0.00030%	4.86*10-7± 3.82*10-8	NA	NA
Plant metabolism TCE	ND	ND	ND	ND	NA	NA
Recover	70.2%	/	73.5%± 7.83%	/	84.4% ± 9.11%	/

- **Plant volatilization played an important role in TCE removal;**
- **Plants promoted microbial anaerobic dechlorination and improved aerobic degradation.**

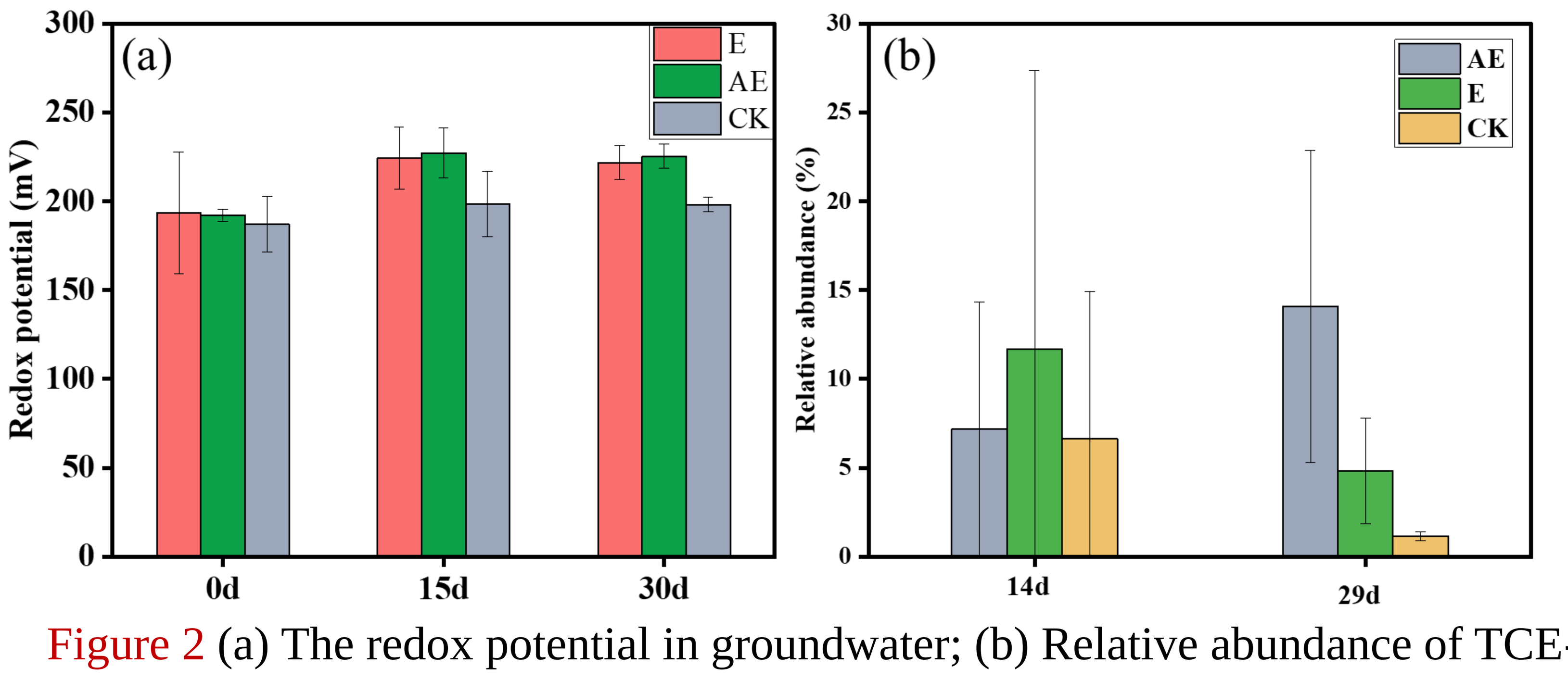


Figure 2 (a) The redox potential in groundwater; (b) Relative abundance of TCE-degraders identified by SIP.

- **The oxidation-reduction potential and relative abundance of aerobic degradation bacteria in groundwater were significantly higher in A and AE treatments than in CK treatment, indicating a significant enhancement of TCE aerobic degradation in eucalyptus rhizosphere.**

Alfalfa remediation of PAHs in soil

Alfalfa promotes the degradation of PAHs

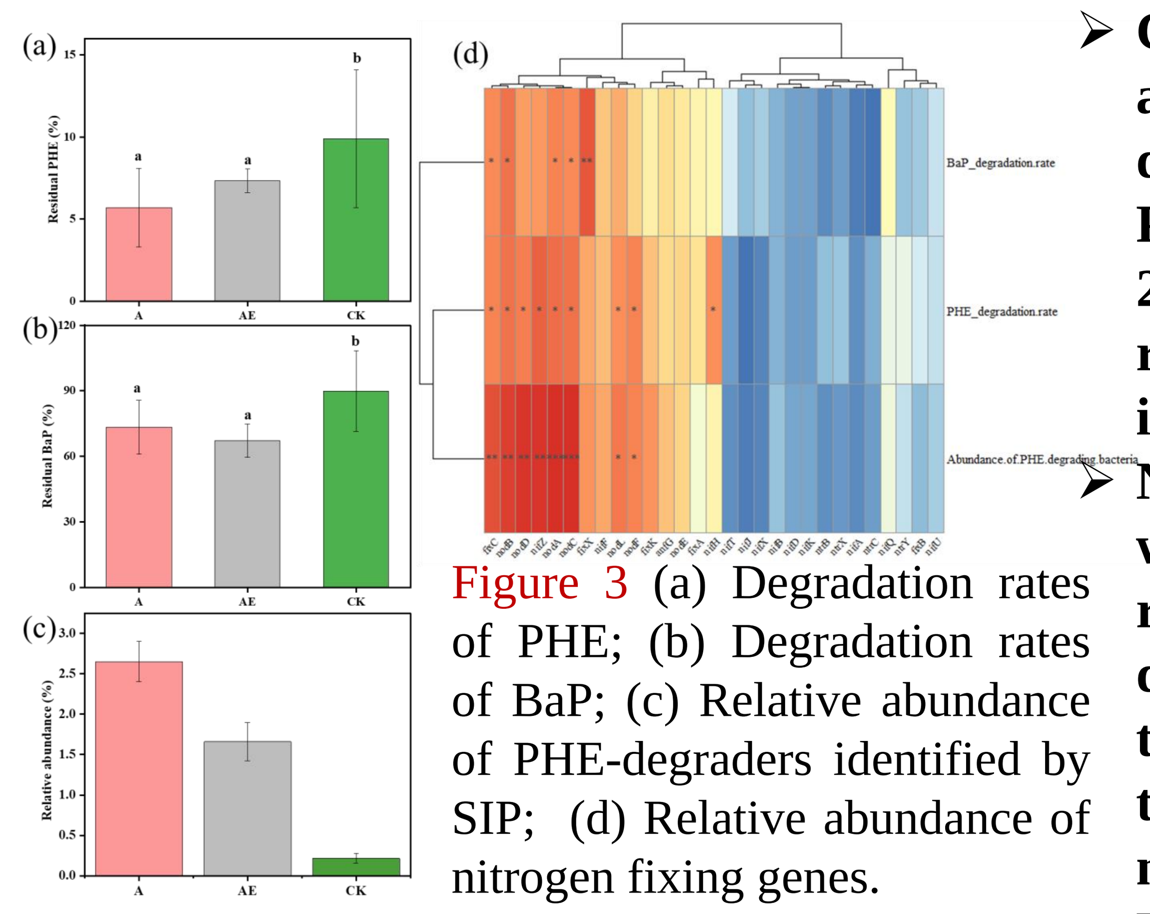


Figure 3 (a) Degradation rates of PHE; (b) Degradation rates of BaP; (c) Relative abundance of PHE-degraders identified by SIP; (d) Relative abundance of nitrogen fixing genes.

- **Compared with CK and E treatments, the degradation rates of PAHs increased by 25.3% and 4.6% respectively in the intercropping mode.**
- **Nitrogen related genes were significantly related to PAHs degradation in alfalfa treatment suggested the important role of nitrogen nutrition in PAHs reduction.**

Microbial community construction

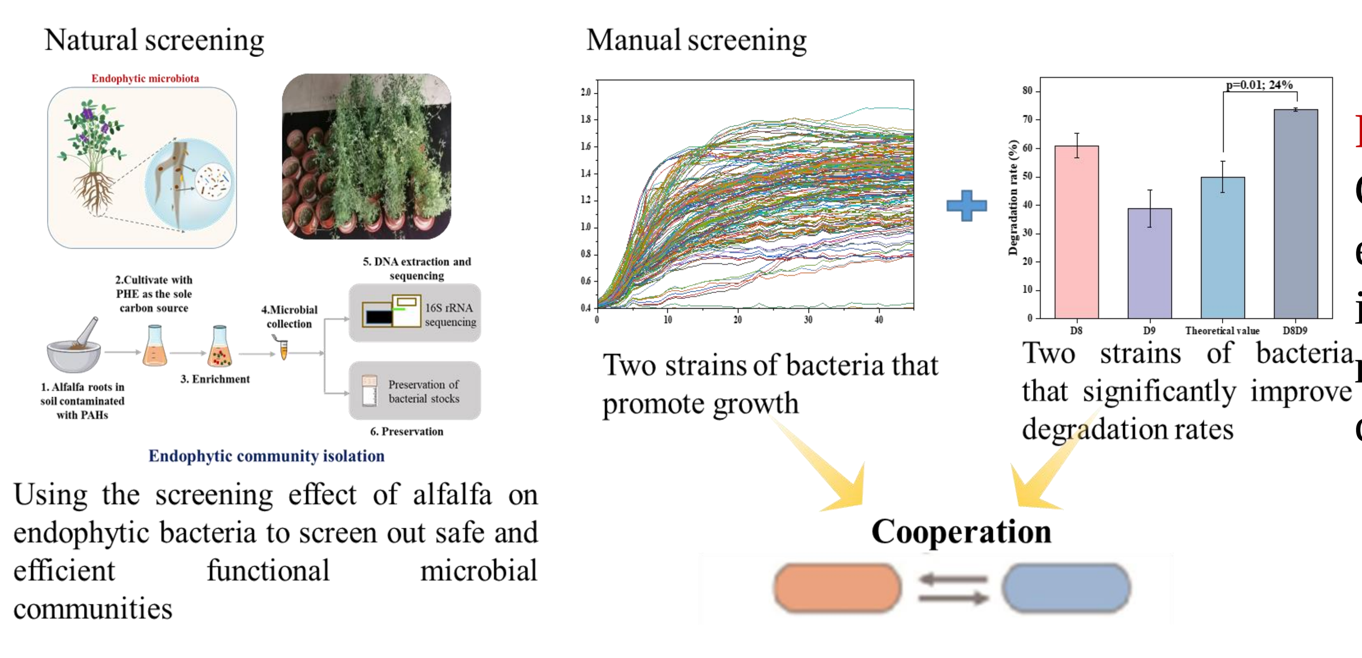


Figure 4 Construction of endophytic and interacting microbial communities

- **Constructed a stable and efficient microbial community with colonization and degradation capabilities**

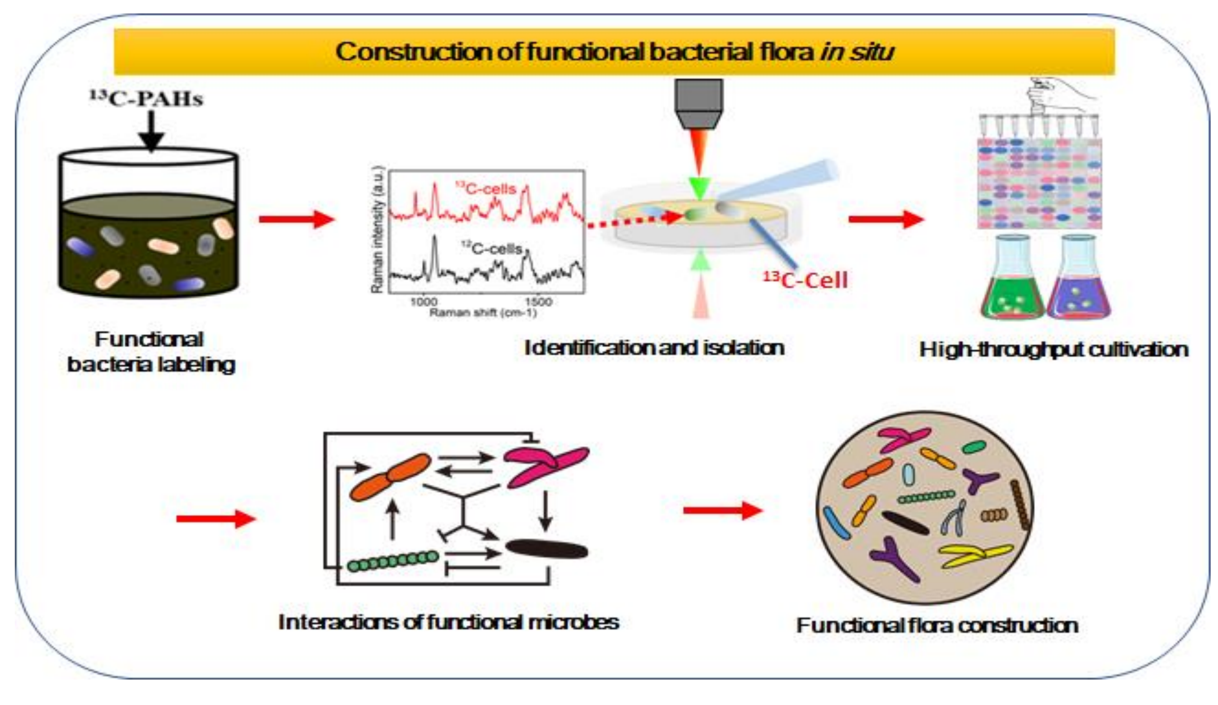


Figure 5 Microbial consortium assembly and functional analysis via isotope labelling and single-cell manipulation of PAH degraders

- **This study innovatively constructed Functional Microbial Consortia (FMCs), using single-cell identification, sorting, and cultivation techniques, with phenanthrene as a model compound, to reveal its in situ biodegradation mechanisms in actual soil and demonstrate its high efficiency in environmental pollution control.**

Conclusions

- Eucalyptus effectively removes TCE and, through volatilization and aerobic conditions, reduces the formation of toxic anaerobic byproducts of TCE degradation.
- Eucalyptus and alfalfa intercropping can effectively remove PAHs and TCE, and is a promising co pollution remediation strategy.
- Synthetic microbial communities can effectively promote pollutant degradation

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