Enhanced removal of BTEX/TCE/cis-DCE mixture using waste scrap tires immobilized with indigenous *Pseudomonas* sp.

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INTRODUCTION

Waste Tires Recycling

✓ 3 billion car and truck tires are discarded

- Fuel (54%)
- Recycled or used in civil engineering projects (23%)
- Converted into ground rubber and recycled into products (9%)
- Converted into ground rubber and used as asphalt (5%)
- Exported (4%)
- Recycled into cut/stamped/punched products (3%)
- Used in agricultural and miscellaneous uses (2%)
INTRODUCTION

Two-Phase Partitioning Bioreactor (TPPB) with 10% and 15% (v/v) tires*

Waste tires: sorption phase

2,4-dichlorophenol (83% removal)
4-nitrophenol (~100% removal)

BTEX: Benzene, Toluene, Ethylbenzene, and Xylenes (ortho-, meta-, and para-)

- Major monoaromatic components in petroleum products
- Industrial solvents and equipment cleansing
- Among priority pollutants (US EPA)
- Benzene (carcinogen)

Common source of BTEX contamination:

- Spills from leaking oil tanks
BACKGROUND

✓ Chlorinated Aliphatic Hydrocarbons (CAHs):
  
  • Most widespread contaminants in subsurface
  • Cleaning and degreasing solvents

✓ Perchloroethylene (PCE), trichloroethylene (TCE), dichloroethylenes (DCEs), vinyl chloride (VC).

✓ TCE: the most frequently found contaminant in groundwater (US)
✓ Carcinogen
Microbial degradation of CAHs:

- anaerobic reductive dechlorination (*Dehalococcoides*)

- Aerobic cometabolism
BTEX and CAHs:

- Soil
- Water

BTEX/CAHs mixture: biological

Further improvements: CAHs removal

Hybrid technology (biological + physical)
OBJECTIVES

✓ To remove BTEX/cis-DCE/TCE mixture from artificially contaminated water using indigenous bacterial isolate, *Pseudomonas plecoglossicida*

✓ To utilize scrap tires (waste) for hybrid/enhanced removal of mixture; physical/adsorption and biological/immobilization
MATERIALS AND METHODS

Experimental setup

Microcosms: suspended and immobilized systems

**Serum bottle:** MSM (mineral salts medium) solution (45 mL)

Contaminants

Inoculum (5 mL)

Scrap tires (1.3, 2.8, and 4.0 g).

Incubation: 150 rpm, 25°C, pH 7, 5 days.

**Contaminants concentrations:**

- **BTEX (300 mg L⁻¹):** based on mass fractions in crude oil (benzene: toluene: ethylbenzene: o-xylene: m-xylene: p-xylene at 22.7%: 48.3%: 4.6%: 6.3%: 6.9%: 11.1%)

- **TCE (10 mg L⁻¹) and cis-DCE (5 mg L⁻¹)**
MATERIALS AND METHODS

Adsorption kinetics of BTEX onto tire surface

✓ Concentrations used in bioremoval experiments
  
  BTEX: 300 mg L\(^{-1}\)
  
  TCE: 10 mg L\(^{-1}\)
  
  \(cis\)-DCE: 5 mg L\(^{-1}\)

✓ Sampling: 0.25, 0.5, 1, 1.5, 24, 48, and 72 h

✓ Sorption capacity (\(q_e\)) of adsorbent calculated by:

\[
q_e = \frac{V(C_0 - C_e)}{m}
\]

\(C_0\) and \(C_e\), initial and equilibrium concentrations (mg L\(^{-1}\));

\(m\), mass of adsorbent (g);

\(V\), solution volume (L).
MATERIALS AND METHODS

Scrap tires

✓ Bridgestone (BATTLAX BT-39 tubeless)
✓ Cut into small pieces (0.2 cm x 0.2 cm x 0.2 cm)
✓ Weighed and autoclaved for 1 h (121°C, 103.5 kPa)

Microbial culture

✓ Pure culture of *Pseudomonas plecoglossicida*
✓ Isolated from a heavily petroleum-contaminated site (Xiamen, China)
Adsorption studies

Adsorption kinetics of individual BTEX compounds (total concentration, 300 mg L\(^{-1}\)), TCE (10 mg L\(^{-1}\)), and cis-DCE (5 mg L\(^{-1}\)).

Mass of tire: 26 mg/mg.
RESULTS

Adsorption studies (each BTEX, 100 mg L\(^{-1}\))

(a) Adsorption kinetics of individual BTEX (100 mg L\(^{-1}\)).

Mass of tire: 26 mg/mg.

(b) Removal efficiencies for individual BTEX in multi and single solution.
# RESULTS

Bioremoval by immobilized (attached) microorganisms

Removal efficiency (%) for each compound in mixture under different conditions after 5 days of incubation

<table>
<thead>
<tr>
<th>Surface area (cm²)</th>
<th>Benzene</th>
<th>Toluene</th>
<th>Ethylbenzene</th>
<th>m,p-Xylene</th>
<th>o-Xylene</th>
<th>cis-DCE</th>
<th>TCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T</strong> 1.5, 7.2</td>
<td>70.6 ± 3.2</td>
<td>75.4 ± 2.3</td>
<td>92.8 ± 1.4</td>
<td>92.0 ± 1.1</td>
<td>92.1 ± 0.9</td>
<td>47.0 ± 3.4</td>
<td>54.1 ± 3.4</td>
</tr>
<tr>
<td><strong>T</strong> 3.0, 14.4</td>
<td>84.2 ± 2.1</td>
<td>82.4 ± 1.2</td>
<td>95.6 ± 1.8</td>
<td>96.8 ± 0.4</td>
<td>97.2 ± 0.3</td>
<td>53.7 ± 3.1</td>
<td>64.0 ± 2.8</td>
</tr>
<tr>
<td><strong>T</strong> 4.0, 19.2</td>
<td>88.6 ± 1.3</td>
<td>82.8 ± 2.2</td>
<td>98.3 ± 0.3</td>
<td>97.6 ± 0.2</td>
<td>97.9 ± 0.4</td>
<td>64.6 ± 2.2</td>
<td>62.5 ± 2.5</td>
</tr>
<tr>
<td><strong>MT</strong> 1.5, 7.2</td>
<td>99.6 ± 0.2</td>
<td>100</td>
<td>95.5 ± 0.7</td>
<td>96.5 ± 0.3</td>
<td>98.2 ± 0.2</td>
<td>60.0 ± 1.7</td>
<td>70.3 ± 1.7</td>
</tr>
<tr>
<td><strong>MT</strong> 3.0, 14.4</td>
<td>100</td>
<td>100</td>
<td>97.8 ± 0.4</td>
<td>96.3 ± 0.4</td>
<td>98.5 ± 0.3</td>
<td>60.8 ± 2.4</td>
<td>71.6 ± 2.5</td>
</tr>
<tr>
<td><strong>MT</strong> 4.0, 19.2</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>96.8 ± 0.3</td>
<td>99.0 ± 0.1</td>
<td>61.6 ± 0.9</td>
<td>73.0 ± 2.8</td>
</tr>
<tr>
<td><strong>BM</strong></td>
<td>99.5 ± 0.2</td>
<td>97.6 ± 0.1</td>
<td>88.0 ± 0.4</td>
<td>64.5 ± 3.3</td>
<td>56.0 ± 2.7</td>
<td>20.4 ± 1.2</td>
<td>36.3 ± 2.0</td>
</tr>
</tbody>
</table>

- **T**: Tire in the absence of microorganisms
- **MT**: Tire with microorganisms
- **BM**: Microorganisms only
- **1.5, 3.0, 4.0**: Different mass of tires
RESULTS

Contact angle (93.4±4.1°)

Measurement of contact angle for tire sample over time. Drop volume: 5 μL. a) Water drop before experiment; b) Water drop after experiment.
CONCLUSION

✓ Scrap tire (waste) is considered a good candidate to enhance removal of VOCs such as BTEX, cis-DCE, and TCE from liquid phase, due to remarkable adsorption properties as well as capability to immobilize (attach/entrap) microorganisms.

✓ Further studies are in progress to evaluate whether the immobilized microorganism possess the same initial removal efficiency after the reutilization cycles, including whether higher concentrations of contaminants can also be applied.
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