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

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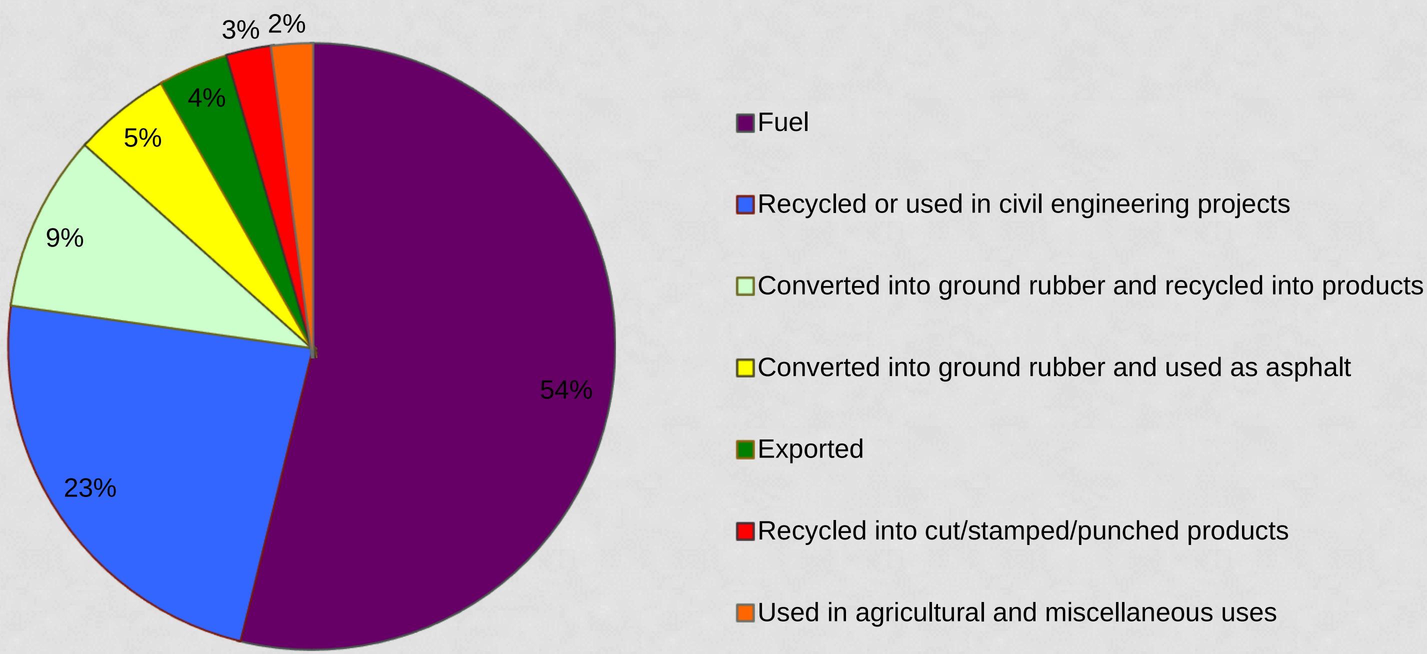
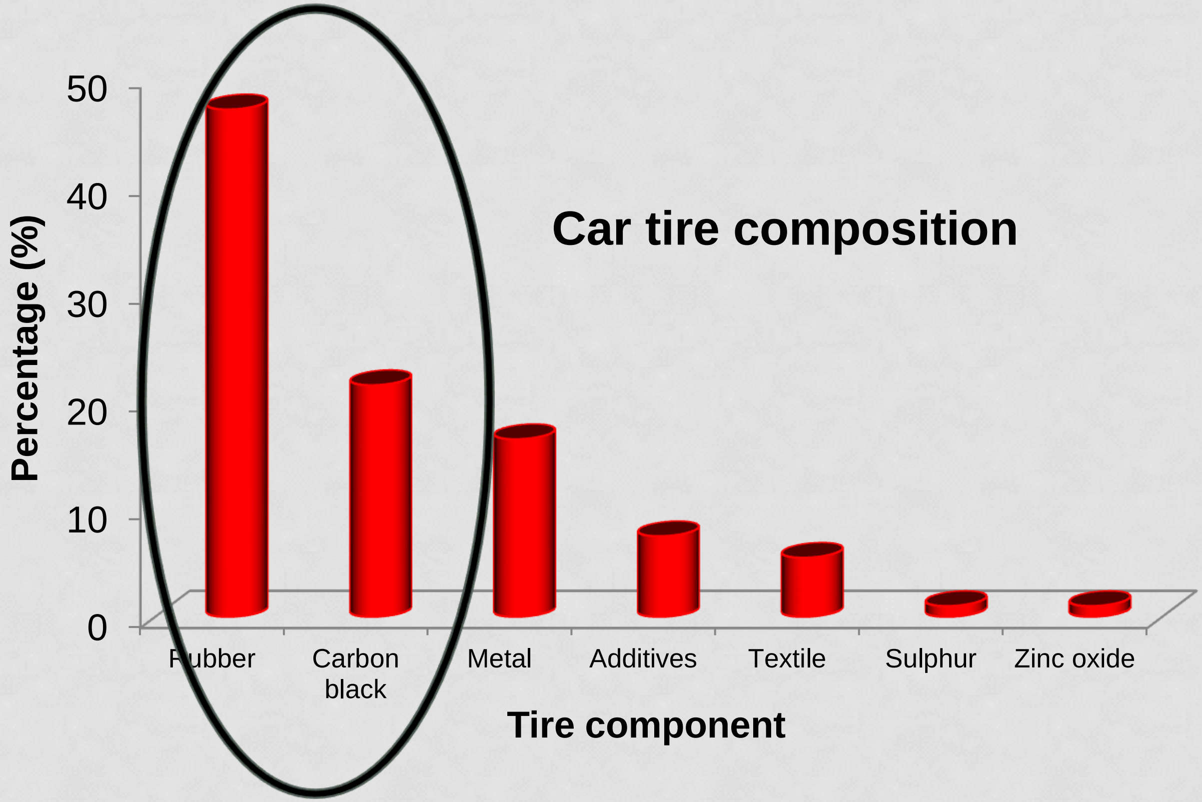
INTRODUCTION

Waste Tires Recycling

- ✓ 3 billion car and truck tires are discarded



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)

* Tomeia MC, Angeluccia DM, Daugulis AJ (2014) Environ Technol 35:75-81

BACKGROUND

✓ 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

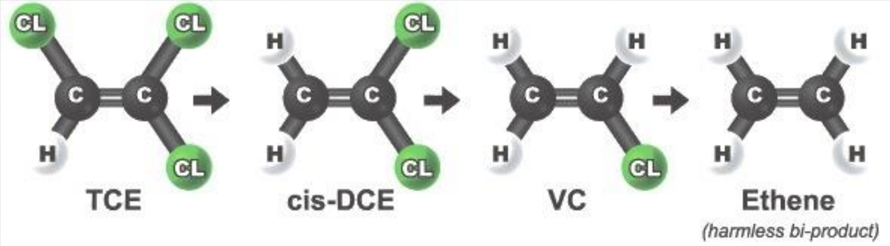
- ✓ Chlorinated Aliphatic Hydrocarbons (CAHs):
    - Most widespread contaminants in subsurface
    - Cleaning and degreasing solvents
- ✓ Perchloroethylene (PCE), trichloroethylene (TCE), dichloroethylenes (DCEs), vinyl chloride (VC).

- ✓ TCE: the most frequently found contaminant in groundwater (US)
- ✓ Carcinogen

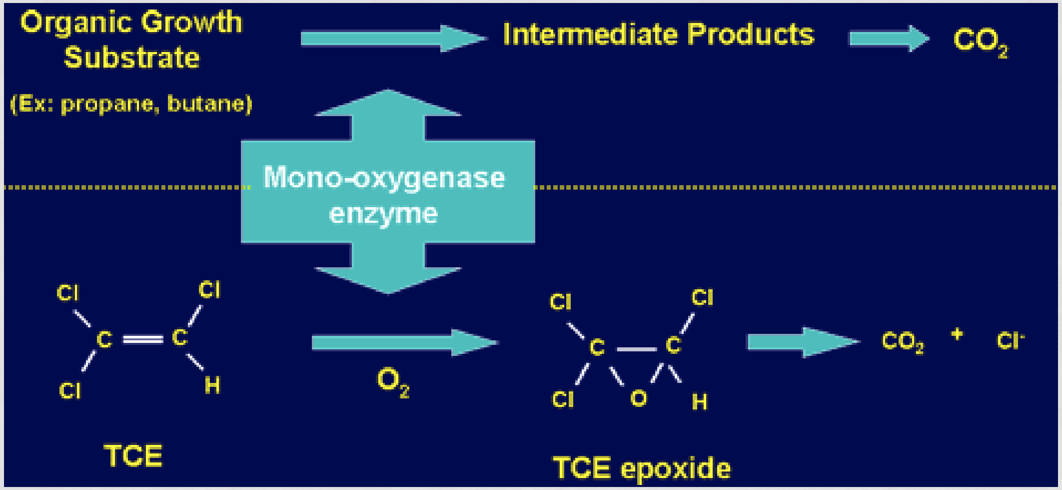
BACKGROUND

Microbial degradation of CAHs:

- anaerobic reductive dechlorination (*Dehalococcoides*)



- Aerobic cometabolism



BACKGROUND

- ✓ BTEX and CAHs: Soil / Water → **Biological**, Chemical, Physical

- ✓ BTEX/CAHs mixture: **biological** → Cost-effective, Environmental-friendly, Contaminant mineralization

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:

$$q_e = V(C_0 - C_e)/m$$

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

m, mass of adsorbent (g);

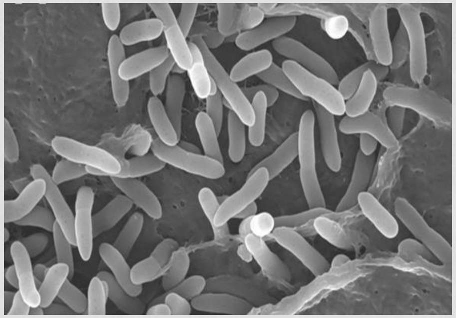
V, solution volume (L)

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)

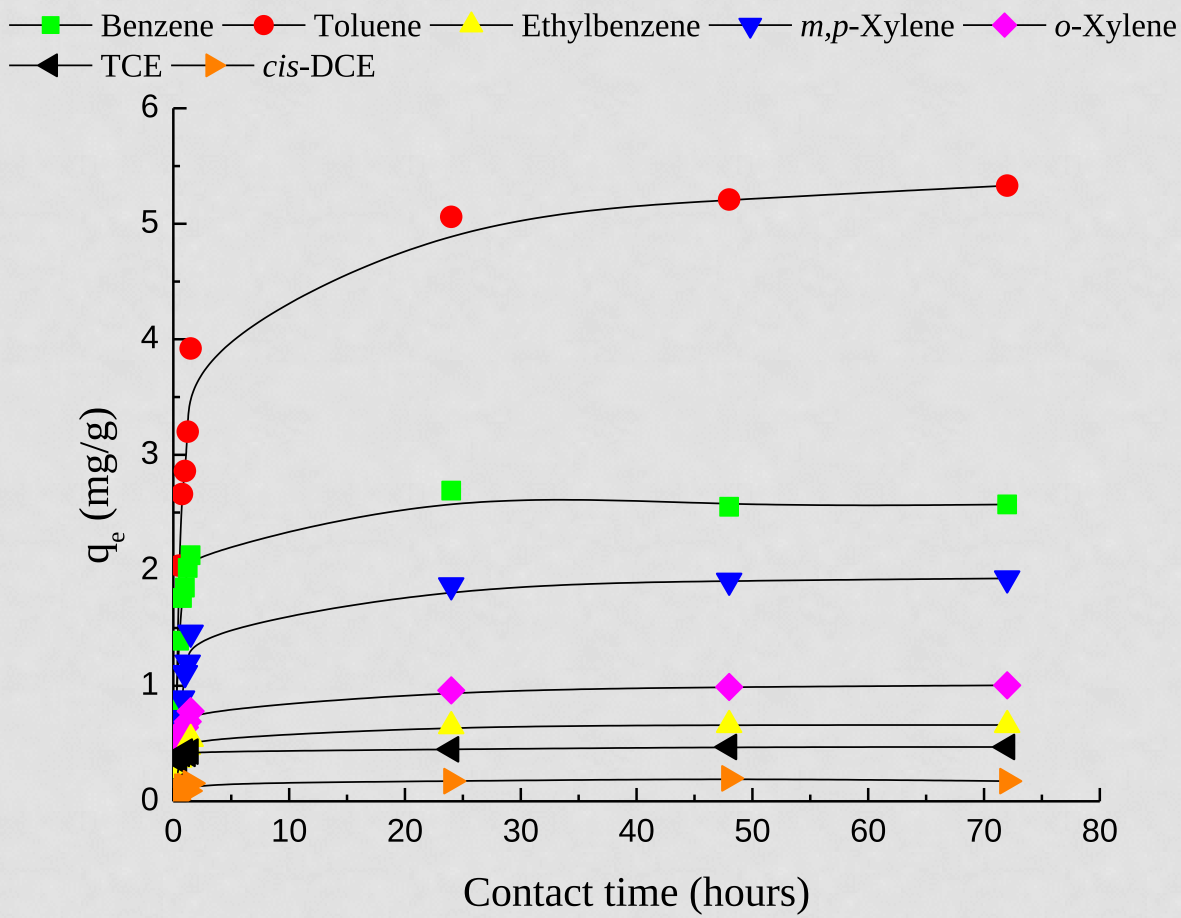
Microbial culture



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

RESULTS

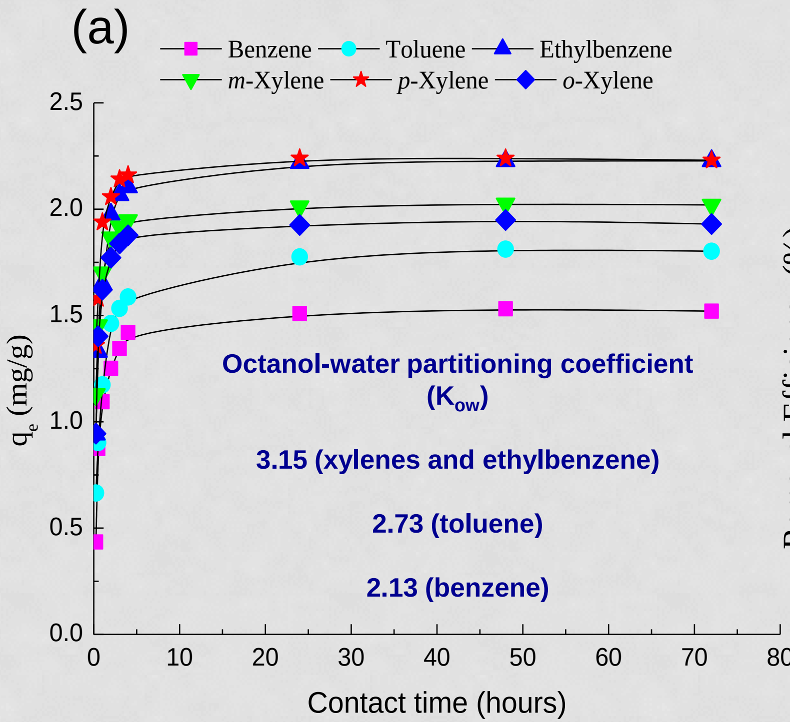
Adsorption studies

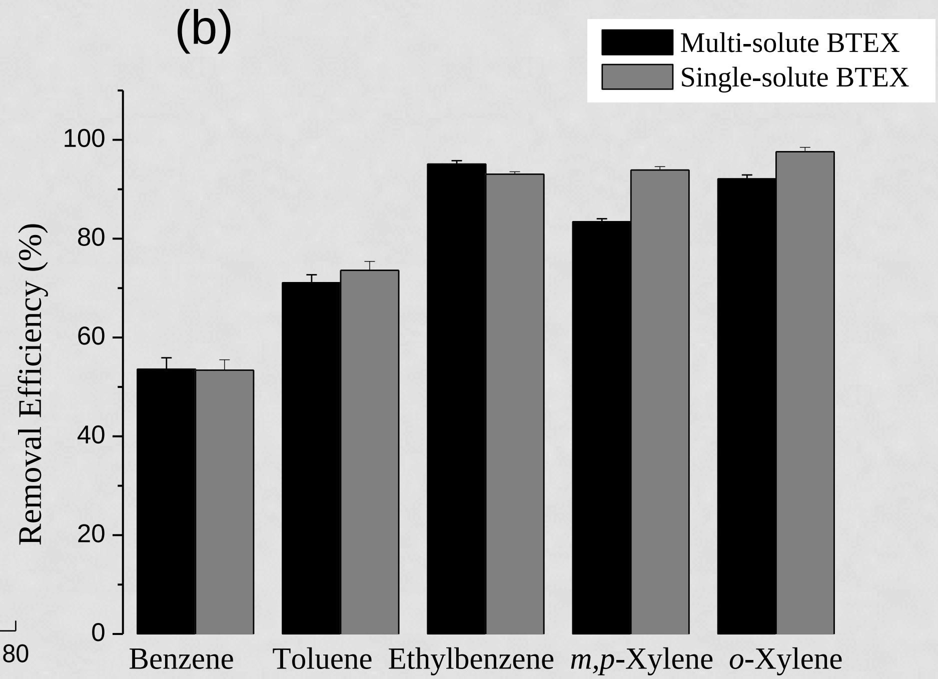


Adsorption kinetics of individual BTEX compounds (total concentration, 300 mg L^{-1}), TCE (10 mg L^{-1}), and *cis*-DCE (5 mg L^{-1}). Mass of tire: 26 mg/mg.

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

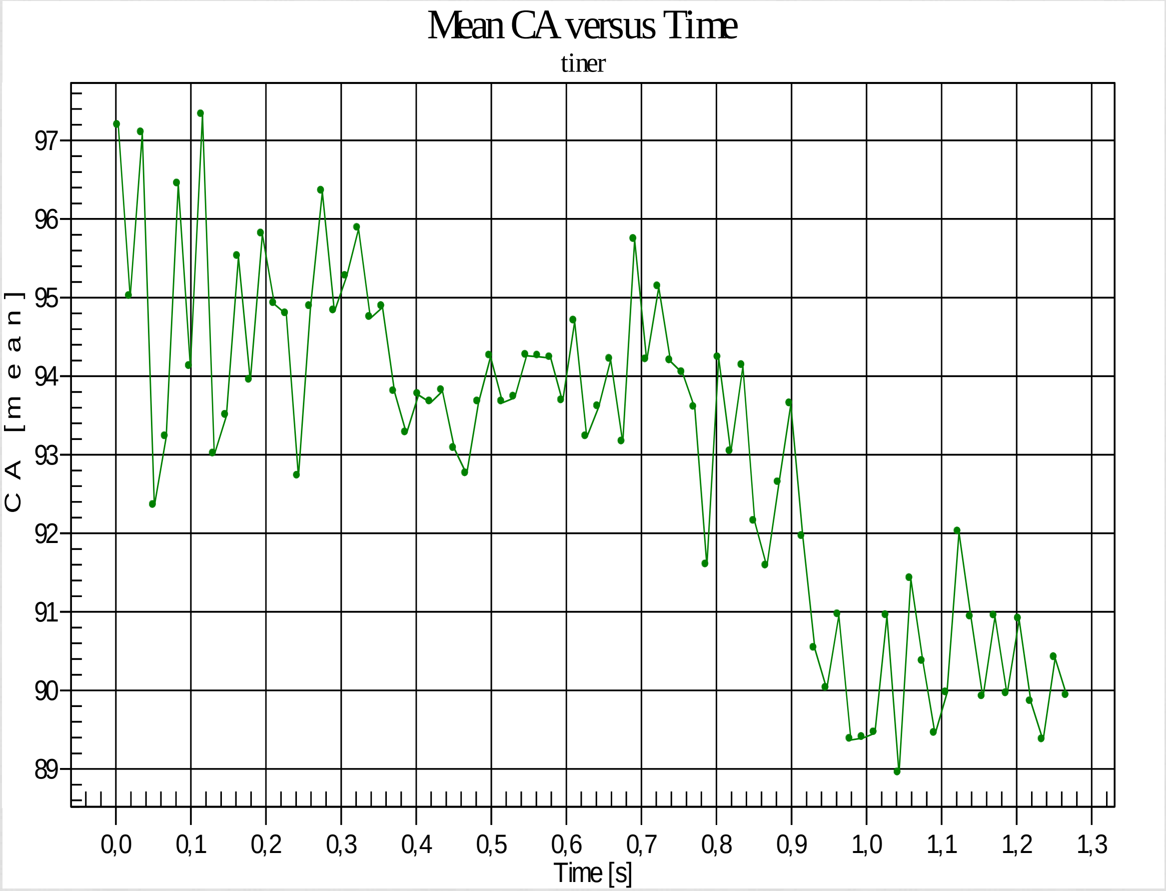
Removal efficiency (%) for each compound in mixture under different conditions after 5 days of incubation

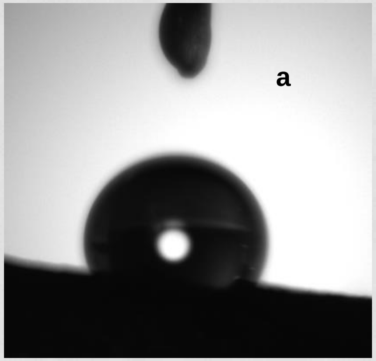
Surface area (cm^2)	Benzene	Toluene	Ethylbenzene	*m,p*-Xylene	*o*-Xylene	*cis*-DCE	TCE
$T^{1.5}$7.2	70.6±3.2	75.4±2.3	92.8±1.4	92.0±1.1	92.1±0.9	47.0±3.4	54.1±3.4
$T^{3.0}$14.4	84.2±2.1	82.4±1.2	95.6±1.8	96.8±0.4	97.2±0.3	53.7±3.1	64.0±2.8
$T^{4.0}$ 19.2	88.6±1.3	82.8±2.2	98.3±0.3	97.6±0.2	97.9±0.4	64.6±2.2	62.5±2.5
$MT^{1.5}$7.2	99.6±0.2	100	95.5±0.7	96.5±0.3	98.2±0.2	60.0±1.7	70.3±1.7
$MT^{3.0}$14.4	100	100	97.8±0.4	96.3±0.4	98.5±0.3	60.8±2.4	71.6±2.5
$MT^{4.0}$19.2	100	100	100	96.8±0.3	99.0±0.1	61.6±0.9	73.0±2.8
BM	99.5±0.2	97.6±0.1	88.0±0.4	64.5±3.3	56.0±2.7	20.4±1.2	36.3±2.0

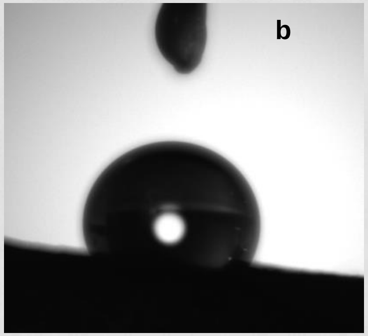
- T: Tire in the absence of microorganisms
- MT: Tire with microorganisms
- BM: Microorganisms only
- 1.5, 3.0, 4.0: Different mass of tires

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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