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Aerobic/anaerobic/aerobic sequenced biodegradation of a mixture of chlorinated ethenes, ethanes and methanes in batch bioreactors

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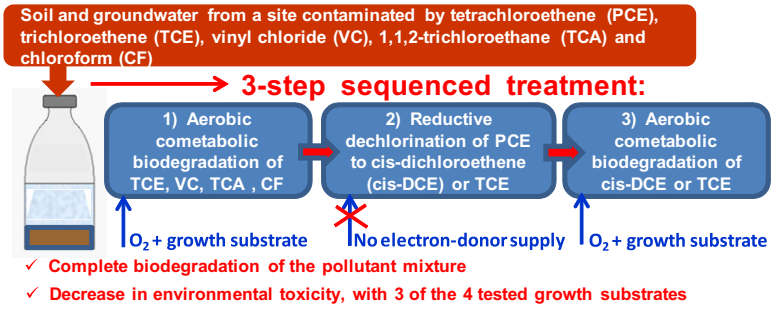
HIGHLIGHTS

- Aerobic/anaerobic/aerobic treatment biodegrades complex chlorinated solvent mixture.
- First aerobic step: low- and medium-chlorinated solvents degraded by cometabolism.
- Anaerobic step: tetrachloroethene degraded to cis-dichloroethene or trichloroethene.
- Second aerobic step: cis-dichloroethene or trichloroethene degraded by cometabolism.
- The anaerobic step is likely fed with dead cells grown during the aerobic step.

GRAPHICAL ABSTRACT



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ABSTRACT

A novel aerobic/anaerobic/aerobic treatment was implemented in batch reactors containing aquifer materials from a site contaminated by tetrachloroethylene (PCE), trichloroethylene (TCE), vinyl chloride (VC), 1,1,2-trichloroethane (1,1,2-TCA) and chloroform (CF). Consortia grown aerobically on methane, propane, *n*-pentane and *n*-hexane completely biodegraded the chlorinated solvent mixture, via aerobic cometabolism of VC, CF, TCE and 1,1,2-TCA, followed by PCE reductive dechlorination (RD) to 1,2-cis-dichlorothylene (cis-DCE) or TCE, and cis-DCE/TCE cometabolism in a further aerobic phase. *n*-Hexane was the best substrate. No electron donor was supplied for RD, which likely utilized cellular material produced during the aerobic phase. Chloride release was stoichiometric with chlorinated solvent biodegradation. According to the *Lepidium sativum* ecotoxicity test, a decreased toxicity was observed with propane, *n*-pentane and *n*-hexane, but not methane. A kinetic study of PCE RD allowed to estimate the PCE maximum specific rate (0.57 ± 0.07 mg $mg^{-1}_{protein}$ day^{-1}) and half-saturation constant (6.7 ± 1.5 mg L^{-1}).

1. Introduction

Chlorinated aliphatic hydrocarbons (CAHs) can be biodegraded through aerobic cometabolic oxidation, direct metabolic oxidation and anaerobic reductive dechlorination (RD). Aerobic cometabolism allows the rapid transformation of the vast majority of CAHs by bacteria grown on methane, propane (Frascari et al., 2006a), butane (Ciavarelli et al., 2012), ammonia (Kocamemi and Çeçen, 2009), benzene, toluene, and xylene (Wu et al., 2008), vinyl chloride (VC) (Mattes et al., 2010), and phenol (Hopkins and McCarty, 1995). Aerobic cometabolism presents inherent limits, such as competition between CAHs and primary substrate, the toxic effect of some metabolites and the risk that an excessive microbial growth clogs the aquifer porosity (Tiehm and Schmidt, 2011). Although the pulsed injection of growth substrate can partly

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