



## Soil remediation using soil washing followed by Fenton oxidation



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### HIGHLIGHTS

- ▶ Soil washing with a nonionic surfactant Tween 80 was analyzed.
- ▶ A model considering surfactant adsorption and *p*-Cresol extraction was proposed.
- ▶ Soil washing was used in combination with Fenton oxidation.
- ▶ Reaction is selective to the contaminant degradation.
- ▶ Reaction allows the recovery and reuse of the surfactant.

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### ABSTRACT

Soil washing was applied to a contaminated soil with *p*-Cresol by using a nonionic surfactant (Tween 80). A mathematical model has also been proposed to describe both the pollutant desorption and the surfactant adsorption, taking place simultaneously. The effect of temperature (20–40 °C) and surfactant concentration (0.1–10 g L<sup>-1</sup>) have been analyzed on both kinetic rates. The kinetic desorption rate of *p*-Cresol increases as the initial solubilizer concentration. Desorption of *p*-Cresol was slightly greater with increasing temperature. The obtained kinetic model represents quite well the experimental results.

Soil washing wastewater (20 mg L<sup>-1</sup> of *p*-Cresol and 0.86 g L<sup>-1</sup> of Tween 80) has been treated with Fenton Reagent to remove the pollutant extracted (*p*-Cresol) and to recover the surfactant solution. The pH of the soil washing wastewater was about 6.5 and did not change significantly during the Fenton Reagent treatment. Total conversions of *p*-Cresol were observed, at very short times, at the conditions tested for the Fenton reaction (100 mg L<sup>-1</sup> of H<sub>2</sub>O<sub>2</sub> and 10 mg L<sup>-1</sup> of Fe<sup>2+</sup>). The hydrogen peroxide was not totally exhausted, showing conversions near 60% at 120 min. Besides, the removal of Tween 80 during the Fenton's reaction was lower than 10%, which suggests that the reaction is mainly selective to *p*-Cresol degradation. The toxicity of the liquids, measured by Microtox bioassay, was significantly reduced after the oxidation reaction, suggesting the negligible formation of degradation intermediates with higher toxicity than *p*-Cresol.

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### 1. Introduction

Contamination of soils by toxic and/or hazardous organic pollutants is a widespread environmental problem and the removal of hydrophobic organic compounds (HOCs) from them has become a major concern. A potential technology for rapid removal of HOCs sorbed to soils is soil washing with a solubilizer solution.

Soil washing is a process that uses physical and/or chemical techniques to separate contaminants from soils and sediments. Contaminants are concentrated into a much smaller volume of contaminated residue, which is either recycled or disposed. This technique can be used to treat a wide range of inorganic and organ-

ic contaminants, being used independently or in combination with other treatment technologies.

Among the different HOCs, cresol has been selected as target pollutant. Cresols are isomeric substituted phenols with a methyl substituent at either ortho, meta or para position relative to the hydroxyl group. These compounds are contained in crude oil, coal tar, and fly-ash from coal and wood combustion and are used as solvents, disinfectants, and in the production of fragrances, antioxidants, dyes, pesticides, resins, and as wood preservatives. Among cresols, *p*-Cresol is mainly used in the formulation of antioxidants for lubricating oil and motor fuel, rubber, and polymers. *p*-Cresol is considered to be toxic and has been classified as hazardous pollutants. *p*-Cresol has been selected as a representative of HOCs, since it is difficult to desorb from subsurface media because of slow desorption kinetics from soils and sediments [1,2].

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