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Ethyl lactate-Fenton treatment of soil highly contaminated with polycyclic aromatic hydrocarbons (PAHs)

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HIGHLIGHTS

- ▶ PAH degradation in soil using ethyl lactate-Fenton was superior to ethanol-Fenton.
- ▶ A two-step ethyl lactate-Fenton treatment effectively degraded all tested PAHs.
- ▶ Ethanol-Fenton treatment was highly selective towards ANT and BaP degradation.
- ▶ Higher pseudo-first order kinetic constants were obtained for ethyl lactate-Fenton.
- ▶ Enhanced solubility and desorption were the main factors in treatment efficiency.

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ABSTRACT

This study reports on a novel ethyl lactate based Fenton treatment for soils contaminated with polycyclic aromatic hydrocarbons (PAHs). The degradation of four PAHs, i.e. phenanthrene, anthracene, fluoranthene and benzo[a]pyrene in soil using this novel treatment was compared to ethanol-Fenton and conventional Fenton treatments. Ethyl lactate/water system manifested a greater desorption capacity than ethanol/water system. A 6 h ethyl lactate/water ($f_c = 0.60$) pretreatment followed by a 4 h ethyl lactate/water ($f_c = 0.20$) based Fenton treatment effectively degraded all tested PAHs (>97% removal). Ethanol/water treatment was highly selective towards the degradation of anthracene and benzo[a]pyrene, with ~30% of phenanthrene and fluoranthene remaining untreated, while conventional Fenton resulted in 31–57% of untreated PAHs after 24 h. The pseudo-first order kinetic reaction rate constants of ethyl lactate/water based Fenton system were 12–42 times higher than conventional Fenton treatment in soil. The efficiency of treatment was mainly caused by enhanced solubility and desorption, and to a less extent, PAH reactivity, hydrogen peroxide stabilisation and enhanced $^{\cdot}OH$ radicals generation by the Fe^{3+}/lactate complex formed.

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a class of several hundred individual compounds that are known to be toxic, mutagenic, carcinogenic and tetratogenic. Their presence in the environment is mainly associated with anthropogenic sources especially manufactured gas plants (MGPs), wood treatment facilities, as well as coke and asphalt production.

Many types of remediation technologies have been explored for the removal of PAHs from soils involving physical, chemical, biological, thermal and electrokinetic processes [1]. Of these, only chemical, biological and thermal treatments are destructive technologies while other processes provide temporary solutions of contaminant containment or phase transfer. For in situ destructive treatments, both chemical and biological approaches have been used. Nonetheless, bioremediation is time consuming especially for highly recalcitrant compounds such as PAHs. Additionally, the process is complicated by environmental and microbial factors. In contrast, chemical oxidation especially advanced oxidation processes (AOPs) offer the advantage of being a faster and more efficient treatment method [2–4]. Amongst the AOPs, Fenton treatment involves the generation of hydroxyl radicals ($^{\cdot}OH$) that offers a high oxidation potential over other conventional oxidants like ozone (O_3), hydrogen peroxide (H_2O_2) and potassium permanganate ($KMnO_4$) [5]. However, the treatment can be constrained by mass transfer limitations and low PAH availability. This can be attributed to three factors; (a) PAHs have low water solubility

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