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Reductive transformation of pentachloronitrobenzene by zero-valent iron and mixed anaerobic culture

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HIGHLIGHTS

- The bio-iron system showed sufficient *p*-CNB removal capacity.
- Optimum pH, high iron dosage and ethanol enhanced the *p*-CNB removal.
- Nitrate and sulfate suppressed the bio-iron system performance.
- Dissolved oxygen did not influence the bio-iron system significantly.
- Reduction and adsorption/co-precipitation was the major *p*-CNB removal mechanisms.

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ABSTRACT

The simultaneous pentachloronitrobenzene (*p*-CNB) reduction by both zero-valent iron (ZVI) and microorganisms was investigated through batch experiments. Compared to the mono-iron system, the bio-iron system showed more sufficient *p*-CNB removal capacity. A *p*-CNB removal rate of 94.2% and 59.8% was obtained in the bio-iron system and the mono-iron system with a corresponding pentachloroaniline (*p*-CAN) recovery rate of 59.4% and 29.8%, respectively. The *p*-CNB removal rate increased significantly from 26.9% to 92.2% with an increase of iron dosage from 0 to 3.0 g L^{-1}. The results also showed that the maximum *p*-CNB removal rate and corresponding *p*-CAN recovery rate were 95.6% and 56.4% at an initial pH of 6.0, while lower pH values would inhibit the removal of *p*-CNB in this combined system. It is found that organic substrates can improve the *p*-CNB removal rate, among which ethanol was found to be the most effective electron donor for this bio-iron system and the corresponding *p*-CNB removal rate in presence of ethanol was 98.2%. Common electron acceptors in groundwater were found to inhibit the reduction of *p*-CNB in the following order: $NO_3^- > SO_4^{2-} > O_2$ and it suggested that sulfate and oxygen exert limited inhibition effects on the reduction.

1. Introduction

As the most common chloronitrobenzenes (CNBs), pentachloronitrobenzene (*p*-CNB) is widely used in various industrial processes such as for the manufacture of insecticides, herbicides, dyes and explosives as well as serving as an agricultural fungicide in crops such as potatoes, wheat, onions and others, resulting in groundwater pollution and chronic threat to water safety [1]. China has produced more than 60% of *p*-CNB annually in the world. The potential genotoxicity and carcinogenicity of *p*-CNB was reported [2] and *p*-CNB is listed as a pollutant that needed to be immediately controlled in China and other countries [3]. The maximum concentration of CNBs is regulated to be 0.05 mg L^{-1} in drinking water according to the Quality Standard for Surface Water in China (GB 3838-2002).

Up to date, very few literatures were found on methods and processes for *p*-CNB removal. Studies on the metabolism of CNBs were mainly focused on oxidative pathways and mechanisms using advanced oxidation processes [4–6]. However, the expensive operation cost limited their applications. Because of the electron-withdrawing property of the nitro and chlorine groups in the aromatic ring, a more cost-effective microbial reductive transformation of chlorinated compounds was extensively used as a predominant biodegradation pathway for removing chloro-aromatics from water [7–9]. Specific bacterial strains were found to be able

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