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Chemical stability and toxicity of nanoscale zero-valent iron in the remediation of chromium-contaminated watershed

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HIGHLIGHTS

- The reaction products were stable in their chemical property.
- The negative effect of the released toxic ion was temporary.
- The toxicity caused by the nZVI would gradually vanish with time.

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ABSTRACT

Nanoscale zero-valent iron (nZVI) technology is promising for treating the oxidizing pollutants. Understanding the potential risk of nZVI in solution is important for in situ remediation. In this work, the impacts of nZVI on the chemical properties of solution and microorganism were investigated to assess the risk of environmental exposure of nZVI. The effects of salinity (NaCl), pH and humic acid on the chemical stability of nZVI were studied, the concentrations of released toxic ions within 36 days were examined, and the toxicity of solution was evaluated based on the luminous bacteria-based toxicity test. The results indicated that nZVI was chemically stable as the total chromium concentration was below 0.05 mg/L all along and the maximum concentration of released total iron ion was 0.22 mg/L. The results of the toxicity test showed that the reaction products were non-toxic to microorganism even if they existed in solution for a long-term time.

1. Introduction

Nanoscale zero-valent iron particles are increasingly applied in environmental remediation [1,2]. Its high treatment efficiencies in the laboratory and at pilot scale field site suggest that nZVI technology is promising [3,4]. However, the potential hazards of nanomaterial in the environment have already caused great concern [5]. As a burgeoning in situ remediation method, the potential environmental benefits and risks of nZVI are largely unknown at the present [6]. Although toxic substances including halogenated organic compounds [7,8] and heavy metals [9,10] could be detoxified by nZVI in the environmental mediums, its detrimental effect like releasing toxic ions is still lack of study. Few researches focused on the environmental risks of nZVI or its reaction products. Barnes et al. [11] indicated that the oxidation–reduction potential, dissolved oxygen and pH value in the surfacewater were influenced by nZVI. Similar impacts on bacterial population were also observed [3]. As is known, the generated Fe^{2+} ions from the reaction between nZVI and H_2O could be toxic to microorganism [12,13]. So it is necessary to investigate the potential releasing toxic ions from nZVI or its reaction product.

Zero-valent iron has shown great achievement for heavy metal contaminant treatment [14–16]. For example, the ZVI was applied in chromium-removal process concerning the groundwater remediation [17]. Although the Cr(VI) was removed, the injected particles remained and probably transformed into $(Cr_xFe_{1-x})(OH)_3$ or $Cr_xFe_{1-x}OOH$ [18]. While the ecological environment would be impacted, exploring what types of changes in the chemical property of groundwater/surfacewater would allow the researchers to better understand whether the nZVI technology is environmentally benign [6]. Changes in the chemical property might greatly impact the microbial communities [3]. For example, the oxidation–reduction potential would decrease after the injection of nZVI [19], and there are dissolved ions like NO_3^- and SO_4^{2-} that could be reduced as NH_4^+ and HS^- in the solution, which may cause potential toxicity to

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