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Remediation of copper contaminated kaolin by electrokinetics coupled with permeable reactive barrier

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Abstract

Electrokinetics is an in situ soil remediation technique by which the flow direction of the pollutants can be controlled and the soil with low permeability can be treated. In this study, the remediation of copper contaminated kaolin by electrokinetic process coupled with activated carbon permeable reactive barrier (PRB) was investigated. The experimental results showed that the integration of PRB with electrokinetics successfully removed copper from kaolin with pH control of the catholyte. The average removal rate reached the highest of 96.60% when the initial Cu^{2+} concentration was 2000 mg/kg. Compared to the electrokinetic process without PRB, the application of the coupled system could reduce the pollution of the electrolyte.

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Keywords: Electrokinetics; Permeable reactive barrier; Soil remediation; Heavy metal

1. Introduction

Soil is the basic environmental elements constituting ecosystem, and the important material basis of human being surviving and developing. However, soil contamination with heavy metals and organic pollutants has become one of the major environmental and human health concerns worldwide[1]. Currently, various technologies for soil remediation have been developed, including solidification/stabilization[2], phytoremediation[3], soil washing[4], bioremediation[5] and electrokinetics (EK)[6].

EK is a promising technology to remediate fine-grained soils contaminated with inorganic, organic, and mixed contaminants, which is particularly suitable for low-permeability clay and silt soils. The EK process involves a direct-current electric field imposed on the contaminated soil, and the pollutants migrate towards the side of the system by the combined mechanisms of electroosmosis, electromigration, and/or electrophoresis[7]. Therefore, the

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flow direction of the contaminants can be controlled, and the remediation seldom brings secondary pollution. It has become an important development direction of soil remediation.

Studies on the electrokinetic remediation of contaminated soils indicate that many factors can affect the process and the removal efficiency. Many researches focused on the way how to improve the efficiency, reduce costs and facilitate the applicability, and some prove to be effective, such as: (1) controlling the pH of the electrolyte[7]; (2) adding surfactants, complexing agents (chelating agents) or high molecular polymer[8,9]; (3) application of an combined system, such as EK-bioremediation[10], EK-oxidation/reduction[11,12] and EK-PRB[13,14,15]. The integration of PRB with EK provides the capability for enrichment or detoxification of the contaminants with different kinds of PRB materials during the remediation, which makes it possible to treat soil contamination with complex pollutants[16]. The remediation using Pd/Fe PRB coupled with EK was studied to remove pentachlorophenol[13] and hexachlorobenzene[15] from the soil, and the dechlorination of the pollutants was proved. Some adsorbents were used as PRB such as carbonized foods waste[17], acalcined hydrotalcite[18], and activated bamboo charcoal[16], which facilitated the removal of heavy metals (Cu^{2+}, Cr^{6+}, Cd) from the soil during the EK remediation.

In this study, a combined system of EK-PRB with activated carbon was used to remediate copper contaminated kaolin. The activated carbon serves as an adsorbent of the contaminant during the electroosmosis and electromigration process, reducing the pollution of the electrolyte. This study aims to investigate the effects of operating conditions on the remediation, the removal rates of the contaminant and the change of the soil characteristics for this EK-PRB system.

2. Materials and methods

The schematic diagram of the lab-scale reactor is shown in Fig. 1. The reactor consists of three compartments: the anolyte cell (80 mm × 100 mm × 80 mm), the soil cell (250 mm × 100 mm × 80 mm), and the catholyte cell (80 mm × 100 mm × 80 mm). The filter paper was placed between the soil and the electrode compartments to prevent soil particles from penetrating into the electrolyte cells.

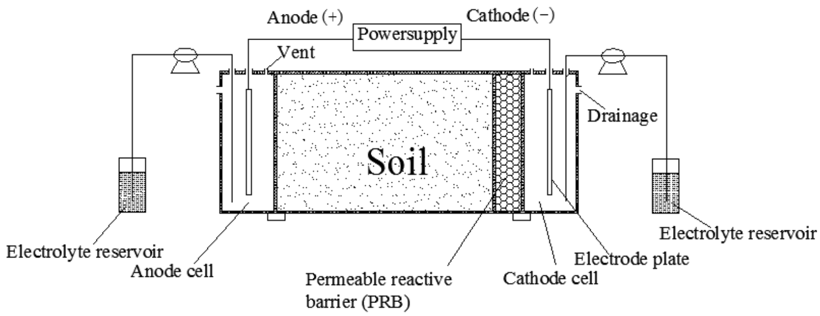

Fig. 1. The schematic diagram of the lab-scale electrokinetic reactor

The kaolin used in this study was produced by Sinopharm Chemical Reagent Co., Ltd in China. Before being packed in the cell, the kaolin was added with $Cu(NO_3)_2{\cdot}3H_2O$ at a certain Cu^{2+} initial concentration (mg Cu^{2+}/kg kaolin) and a moisture content of 40%. After being packed in the cell, the kaolin was balanced with $NaNO_3$ solution (0.1 M) in both sides of the electrode compartments for 24 hours.

A series of experiments were performed under different operation conditions (Table 1). Activated carbon was used in some experiments (EK1~EK3) to develop the PRB system. The soil cell was loaded with 1500 g kaolin for EK0 and 1200 g kaolin for EK1~EK3. The Electrolyte solutions for the anode and the cathode were prepared with $NaNO_3$ (0.1 M), and refreshed with $NaNO_3$ (0.1 M) and citric acid-sodium citrate buffer solution (pH = 5) respectively by two peristaltic pumps at a flow rate of 1.67 mL/min during the remediation process. Two graphite plates (90 mm × 80 mm × 5 mm) were used as the anode and the cathode. The experiments were run at a constant voltage gradient of 1.0 V/cm for 4 days.

Upon the completion of the remediation process, the kaolin was separated equally into four (EK1~EK3) or five (EK0) sections, and a fraction of each section was taken to determine the soil pH, water content, electrical