

Semi-pilot Study of Electrokinetic Process for Phenanthrene Removal from Kaolinite

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Abstract

The electrokinetically enhanced soil flushing had a great potential to improve the removal efficiency of polycyclic aromatic hydrocarbons (PAHs) from low permeable soils. A semi-pilot study of surfactant-enhanced electrokinetic process was investigated for the removal of phenanthrene from kaolinite. A nonionic surfactant, Tergitol 15-S-12 at 10 g/L was introduced as a flushing agent and 0.001M of sodium chloride was used as an electrolyte. When the constant voltage of 100 V was applied to the system for 25 days, only 0.66 kWh of electric power was consumed and the amount of electroosmotic flow was 6.9 L. The removal efficiency of phenanthrene was about 40 % and it can be improved by increasing the ion concentration of the flushing solution or the applied voltage.

Key words: electrokinetic remediation, phenanthrene, nonionic surfactant, kaolinite

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are representative hydrophobic organic carbons (HOCs), which are known as potential carcinogens or mutagens. Because of their low solubilities and slow desorption rates, it is difficult to remove PAHs from subsurface environments using conventional pump-and-treat technologies. The removal efficiency is especially low in low-permeable soils.^{1,2)}

Recently, surfactant-enhanced electrokinetic remediation, which combines electrokinetic process with surfactant-enhanced remediation, has a great potential to improve the removal efficiency for PAH-contaminated soil with a low permeability.²⁾ Generally, to select a suitable surfactant for electrokinetic process, surfactant characteristics must be considered such as ionic character, sorption onto soil, toxicity, and biocompatibility.

In this study, the semi-pilot electrokinetic remediation using Tergitol 15-S-12 was conducted. The removal of phenanthrene from kaolinite and the feasibility of the process was investigated for scale-up.

2. Materials and Methods

The electrokinetic experiment was conducted using Indonesia kaolin (Duckyu Co.), the particle size of which is less than 46 μm . Phenanthrene (Sigma, 96+%) was selected as a representative PAH compound. For the test, the soil was artificially contaminated with phenanthrene at around 500 ppm (mass of phenanthrene/mass of dry soil). A nonionic alcohol ethoxylate surfactant, Tergitol 15-S-12 was used at 10 g/L as a flushing solution.³⁾ 0.001 M of NaCl (Junsei, 99.5+%) was also added as an electrolyte.

The semi-pilot electrokinetic reactor used in this experiment is shown in Figure 1. It is a rectangular reactor (120×10×45 cm, L×W×H), which has two cells and three electrode compartments. There is one anode reservoir with a capacity of 6 L at the center of the reactor and two cathode compartments (4.5 L) are placed at both ends. Graphite and stainless steel were used as an anode and a cathode electrode, respectively.

The soil was uniformly consolidated into the each cell and the total amount of soil was about 40 kg. The flushing solution was supplied from an anode tank with a fixed level of the anode reservoir by a peristaltic pump. The test was operated under a constant voltage of 100 V for 25 days.

During the testing, the electrical current and the effluent volume at each cathode tank were measured periodically. After the operation, the soil was extruded from the reactor and divided into 80 segments to analyze the distribution of water content as well as the residual phenanthrene remaining in the soil.

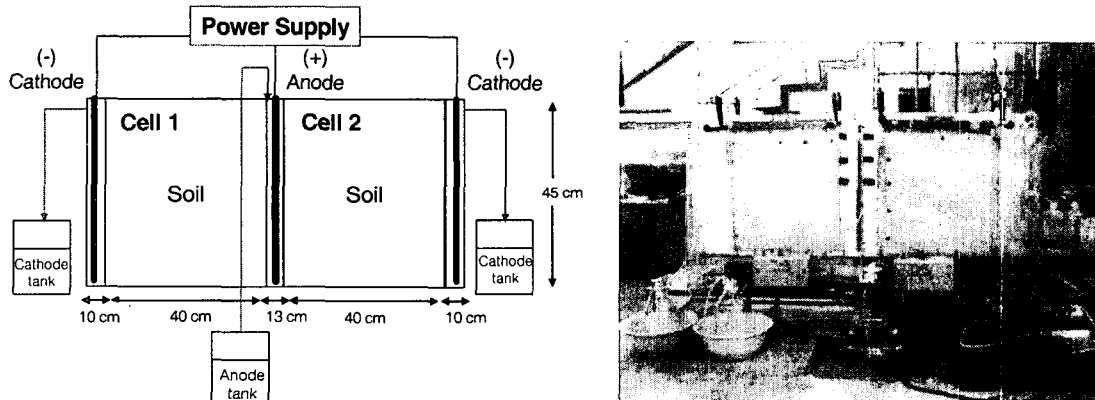


Figure 1. Semi-pilot electrokinetic remediation reactor

3. Results and Discussion

Figure 2 shows the change in the electrical current that occurred during the operation. The current value reached the highest at the beginning of the test, because the ion concentration in the pore solution was greatest due to the dissolution of salts.²⁾ Then, it declined gradually and finally came to nearly zero because of the increase of soil resistance which was induced by the migration of ions toward electrodes. During the operation time, only 0.66 kWh of electricity was consumed. This indicates the electrolyte concentration was too low to support a high electrical current.

The accumulated electroosmotic flow (EOF) during electrokinetic test is presented in Figure 3. At each effluent tank, 2.2 and 4.7 L of EOF were accumulated. The amount of EOF was smaller than the estimated values from a lab-scale electrokinetic test. It resulted from the low electrical current. The parallel arrangement of electricity between two cells resulted in the different rates of EOF; the current might prefer to pass through the soil with a lower resistance.

The distribution of water content was generally uniform throughout the reactor, from 31 to 34 % (Figure 4). It was slightly high at the bottom of the reactor because of the effect of gravity, and around the reservoirs. However, the difference was not significant.

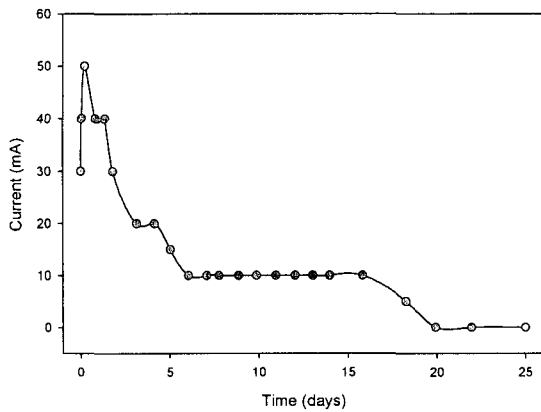


Figure 2. Current profile

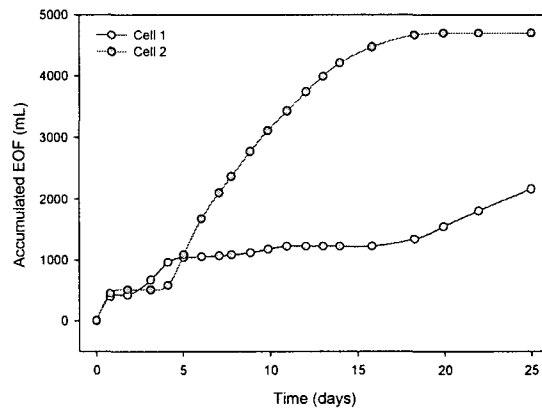


Figure 3. Accumulated electroosmotic flow

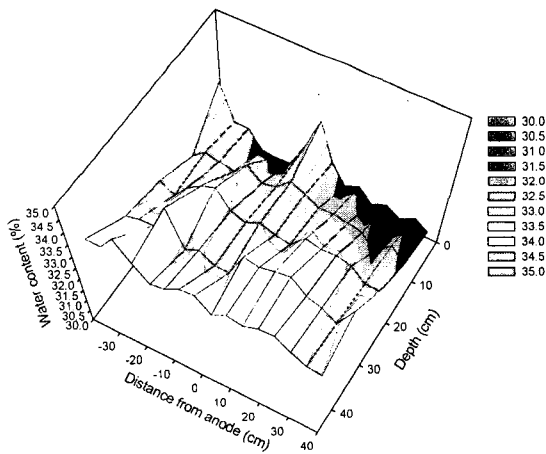


Figure 4. Water content distribution

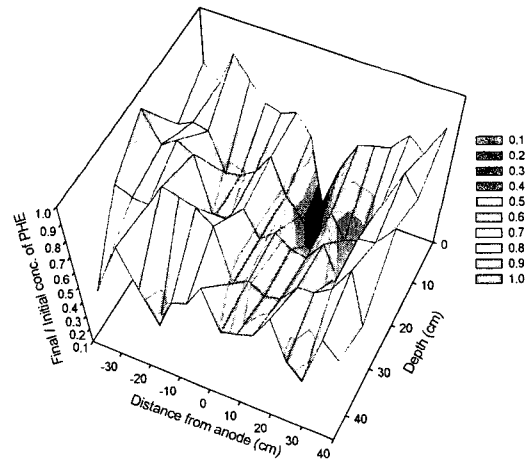


Figure 5. Phenanthrene content in soil

The amount of residual phenanthrene in soil was described as the ratio of its final to initial concentration in Figure 5. After the remediation process, 39.2% of phenanthrene was removed throughout the reactor. The removal efficiency in cell 2 was higher, 44.6%, than that in cell 1 (33.9 %), since the higher amount of EOF in cell 2 enhanced the flushing of phenanthrene. Phenanthrene concentration was relatively low near the anode because the contaminant was transported from anode to cathode by EOF. There was no difference of phenanthrene concentration in the vertical direction.

4. Conclusions

The semi-pilot electrokinetic test was conducted for the removal of phenanthrene from kaolinite. When it was operated under the constant voltage (100V) for 25 days, the amount of EOF was 6.9 L and 39.2% of phenanthrene was removed. The accumulated EOF was not enough to achieve a high remediation level because of the low ion concentration.

To improve the removal efficiency, the EOF should be generated continuously. Especially, it can be attained by using a high concentration of electrolyte or supplying a high voltage under the constant voltage system.

From the results of the semi-pilot test, the scale-up feasibility of the electrokinetic process for phenanthrene removal was shown.

Acknowledgement

This research was supported by a grant (M1-0412-00-0001) from National Research Laboratory Program of Korean Ministry of Science and Technology.

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