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Influence of temperature and hydraulic conductivity of soil on electrokinetic decontamination

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1. Introduction

Most nuclear facility sites have been contaminated by a leakage of radioactive waste-solution due to corrosion of the waste-solution tanks and connection pipes by their long-term operation set up around underground nuclear facilities. Therefore, a method to remediate a large volume of radioactive soil should be developed. Until now the soil washing method has been studied to remediate soil contaminated with uranium, cobalt, cesium, and so on [1]. However, it has a lower removal efficiency of nuclide from soils and generated a large volume of waste-solution. In addition, its application to the soil composed of fine particle is impossible. Thus, the electrokinetic method has been studied as a new technology for soil remediation recently [2].

The electrokinetic process holds great promise for the decontamination of contaminated soil because it has a high removal efficiency and is time-effective for low permeability. Electrokinetic decontamination can be used to treat soil contaminated with inorganic species and radionuclides [3]. The main mechanisms of a contaminant's movement in an electrical field involved in electrokinetic technology are the electro-migration of the ionic species and electro-osmosis. Electro-migration probably contributes significantly to the removal of contaminants, especially at high concentrations of ionic contaminants and/or a high hydraulic permeability of soil [4]. The cathode reaction should be depolarized to avoid the generation of hydroxides and their transport in soil. The selected liquid, also known as a purging reagent, should induce favorable pH conditions in soil, and/or interact with the incorporated heavy metals so that these heavy metals are removed from the soil [5].

2. Methods and Results

2.1 Manufacturing of the laboratory electrokinetic decontamination equipment

The laboratory electrokinetic decontamination equipment of about 1L in size had been manufactured for the decontamination of radioactive soil near the nuclear reactor, as shown in Fig. 1. This laboratory electrokinetic decontamination equipment consists of an electrokinetic soil cell of 972 mL (12×9×9 cm), an anode electrode chamber (12×9×7 cm), a cathode electrode chamber (12×9×8 cm), a reagent reservoir (25×25×25 cm), an electrolyte effluent system, a pH meter, a power supply, and so on. A dimensional stable anode (DSA, 8×12 cm) was established in an anode electrode chamber to prevent the dissolution of the electrodes, and a titanium electrode was established in the cathode electrode room. The thickness of the soil cell was proportional to the decontamination period. In order to finish the soil decontamination experiment within 1 week, the thickness of the soil cell was determined to be 9 cm in consideration of pre-experiment results.

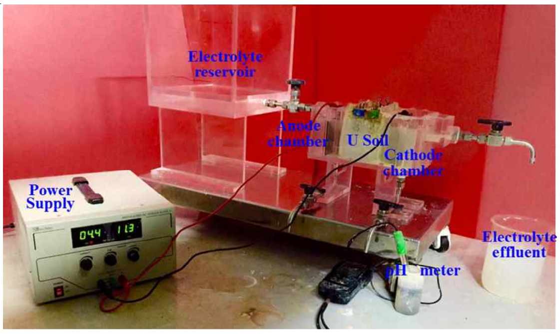

Fig. 1. Laboratory electrokinetic decontamination equipment manufactured for experiment

2.2 Experiment results according to the electrolyte temperature in the cathode chamber

The results of electrokinetic experiment operated at 75, 80, and 85℃ electrolyte temperatures in the cathode chamber are shown in Fig. 5. The removal efficiencies were proportional to the elapsed time. The removal efficiencies of uranium for 2 days were 77-87%. In addition, the removal efficiencies according to the elapsed time after 5 days were reduced. When 75℃ was applied, the time required for the removal efficiency of uranium to reach 92.1% was 6 days. When 80℃ was applied, the time required for the removal efficiency of uranium to reach 92.2% was 5 days. When 85℃ was applied, the time required for the removal efficiency of uranium to reach 93.1 % was 4 days. Even if a high temperature appears a high removal efficiency, the generation rate of sulfate gas discharged from anode and cathode chambers in the electrokinetic equipment increases due to a high temperature. Also, a high temperature of the electrolyte in cathode chamber used to break the pH meter apparatus in cathode chamber.

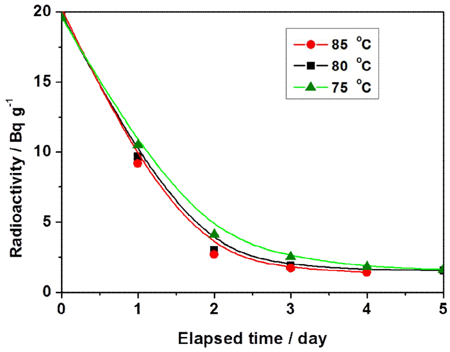

Fig. 2. Experiment results according to the electrolyte temperature in the cathode chamber

2.3 Experiment results according to the hydraulic conductivity of soil

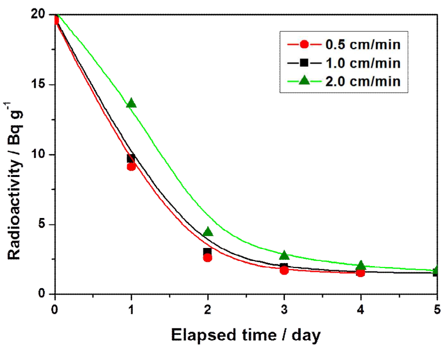

Fig. 3 Experiment results according to the hydraulic conductivity of the soil

The results of electrokinetic experiment operated at a 0.5, 1.0, 2.0 cm/min hydraulic conductivity of soil in the soil cell are shown in Fig. 6. The removal efficiencies were proportional to the elapsed time. The removal efficiencies of uranium for 2 days were 78-87%. In addition, the removal efficiencies according to the elapsed time after 2 days were reduced. When 0.5 cm/min was applied, the time required for the removal efficiency of 137uranium to reach 92.1% was 4 days. When 1.0 cm/min was applied, the time required for the removal efficiency of uranium to reach 92.2% was 5 days. When 2.0 cm/min was applied, the time required for the removal efficiency of uranium to reach 92.4% was 6 days. For a reduction of hydraulic conductivity of soil in the soil cell, the soil in the soil cell should be hardened. Thus, electrolyte contaminated with uranium in the cathode chamber should be prevented from infiltrating into the clean electrolytes in the anode chamber.

3. Conclusions

The removal efficiencies of uranium from contaminated soil in manufactured laboratory electrokinetic decontamination equipment were proportional to the elapsed time. The removal efficiencies of uranium for 2 days were 77-87%. In addition, the removal efficiencies according to the elapsed time after 2 days were reduced. When 75, 80, and 85℃ electrolyte temperatures in the cathode chamber were applied, the time required for the removal efficiency of uranium to reach 92% was 6, 5and 4 days. Moreover, when a 0.5, 1.0, and 2.0 cm/min hydraulic conductivity of soil in the soil cell was applied, the time required for the removal efficiency of uranium to reach 92% was 4, 5, and 6 days.

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