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Development of a Vertical Electrokinetic-flushing Technology for a Radioactive Soil in Korea

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1. Introduction

The soil around the nuclear facilities in South Korea might be contaminated with radionuclides from a long-term operation of these facilities. Because these Korean nuclear facilities were constructed on a sandstone layer, the hydro-conductivity of a radioactive soil excavated from a nuclear site is high. It has been suggested that an electrokinetic-flushing remediation is a suitable technology in consideration of the soil characteristics near a Korean nuclear facility, which has merits of both an electrokinetic remediation and a soil flushing method.

2. Vertical Equipment Manufacture

Electrokinetic-flushing equipment was manufactured, because an electrokinetic-flushing method is suitable for a soil near the domestic nuclear facilities, which has a little higher hydro-conductivity and this electrokinetic-flushing equipment has the merits of an electrokinetic method and a soil flushing method. Also, until now, this electrokinetic equipment has almost always been manufactured as a horizontal type. But this horizontal electrokinetic-flushing equipment has the following problems. Namely, an electrolyte in an anode compartment of this horizontal electrokinetic equipment can be contaminated with radionuclide by a backward flow of an electro-osmosis due to a pH change in a soil cell, and the middle part in the soil cell forms an unsaturated zone, so that the removal efficiency of the radionuclide may be reduced due to its unsaturation. In order to solve such problems, Jing-Yuan Wang(2007) started to develop vertical electrokinetic equipment to remove the contaminants accumulated in a cathode easily. This equipment has a cathode in the upper side so that the reagent in a soil cell might flow upward and the contaminants in a soil cell might be accumulated in the upper side. Upward vertical electrokinetic equipment has been used to remove heavy metals from kaolin[1] and to remove an organic material from a soil[2].

3. Soil Characteristics

Korea currently has about 20 nuclear power plants and a research reactor. Because most nuclear facilities in Korea have been constructed on a hard sandstone rock, the contaminated soil around a nuclear facility contains a lot of sand, which has a higher hydro-conductivity. Experimental soil was extracted from the site around the research reactor, since it might be partially contaminated with ^{60}Co and ^{137}Cs. But a soil which was not contaminated was also excavated, and it was artificially contaminated with Co^{2+} and Cs^{+} for the experiments. The measurement results of the composition and properties of the soil near the nuclear facility used in the experiments are shown. Also, Table shows a particle size percent of the soil near the nuclear facility. The saturation degree of the surface at the nuclear facility site is about 24～32% and the hydro-conductivity of the soil is a little higher.

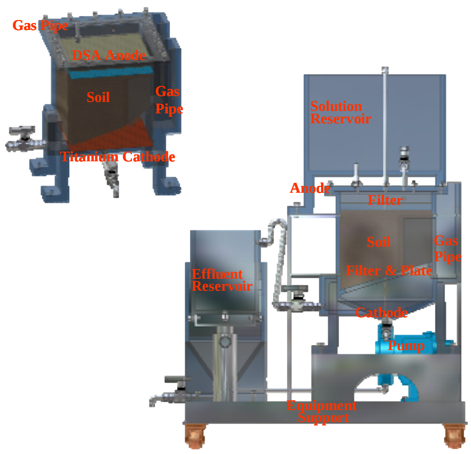

Fig. 1. Schematic diagram of vertical electrokinetic-flushing equipment

3. Results and Discussion

the Co^{2+} and Cs^{+} removal efficiency and the effluent volume by a vertical electrokinetic-flushing under different remediation conditions were measured. The removal efficiency by the vertical electrokinetic-flushing method was about 2~3% higher than that by the horizontal electrokinetic-flushing method. A comparison of the removal efficiencies between the vertical electrokinetic remediation and the vertical electrokinetic-flushing remediation for 20 days is shown in Fig. 2. The average removal efficiency of Co^{2+} and Cs^{+} by the vertical electrokinetic-flushing remediation was 4.6% more than that by the vertical electrokinetic remediation. Even if the reagent injection rate for the a vertical electrokinetic-flushing remediation is increased to 4.8ml/g from 2.4ml/g, the increase of the average removal efficiency of Co^{2+} and Cs^{+} was below 1% like Fig. 2. Therefore, it is suggested that an optimum reagent injection rate for a vertical electrokinetic-flushing remediation is 2.4ml/g.

Figure shows a comparison of the removal efficiencies versus the acetic acid concentration during a vertical electrokinetic-flushing remediation with different acetic acid concentrations. Figure is zeta potential of the soil versus the concentration of the acetic acid. When the reagent concentration was increased from 0.01 M to 0.05M, the removal efficiency of Co^{2+} was slightly decreased by 0.3% and that of Cs^{+} was decreased by 2.1%. The reason for this is thought to be that the negative zeta potential of soil in 0.01M acetic acid was more than that in 0.05M acetic acid. Meanwhile when the reagent concentration was decreased from 0.01 M to 0.002M, the average removal efficiencies of Co^{2+} and Cs^{+} were decreased by 0.7%. Therefore, it is suggested that an optimum concentration of acetic acid for a vertical electrokinetic-flushing remediation is 0.01M. Also, Figure shows the Co^{2+} and Cs^{+} cumulative removal efficiencies versus the acetic acid concentration after a vertical electrokinetic-flushing remediation for 20 days. The removal efficiency of Cs^{+} in the soil near the cathode electrode plate was decreased slightly. In conclusion, the optimum remediation conditions were suggested to be when the acetic concentration is 0.01M, the injection rate of the reagent is 2.4 ml/g, and the remediation period is 20days for the vertical electrokinetic-flushing equipment of a 8.3L volume.

The variation of the electrolyte flow rate versus the remediation time at the cathode compartment during a vertical electrokinetic-flushing was measured. The electrolyte flow rate in a soil cell was reduced with the remediation time. Movement of the pore solution was mainly due to an electro-osmosis and the resultant hydro-head pressure. And when 0.01M and 0.05M acetic acids were used as an electrolyte reagent, the average electrolyte flow rate was about 1,480 ml/day. Also, it was found that the effluent solution volume generated from an electrokinetic-flushing remediation was 90 % lower than that from a soil washing.

V. Conclusion

Vertical electrokinetic-flushing equipment suitable to the geological characteristics of Korean nuclear facility sites was developed for a remediation of a contaminated soil. The optimum remediation conditions were obtained with experiments by using the developed vertical electrokinetic-flushing equipment, which can obtain a high removal efficiency during a short period of time. The removal efficiency of Co^{2+} and Cs^{+} from a soil cell with acetic acid was the highest. It may be because the pH in a soil cell appeared to be the lowest value, when acetic acid was used as an purging reagent. When the results of the vertical electrokinetic remediation and the vertical electrokinetic-flushing remediation were compared, the removal efficiency by the vertical electrokinetic-flushing remediation was 4.6% more than that by the vertical electrokinetic remediation. Also, it was found that the optimum reagent injection rate for a vertical electrokinetic-flushing remediation was 2.4ml/g. Meanwhile, when the reagent concentration was increased from 0.01 M to 0.05M, the removal efficiencies of Co^{2+} and Cs^{+} were decreased. Therefore, the optimum remediation conditions were suggested to be when the acetic concentration is 0.01M, the injection rate of the reagent is 2.4 ml/g and the remediation period is 20 days for the vertical electrokinetic-flushing equipment of a 8.3L volume. In these conditions, the removal efficiencies of Co^{2+} and Cs^{+} were 98.3% and 88.8%.

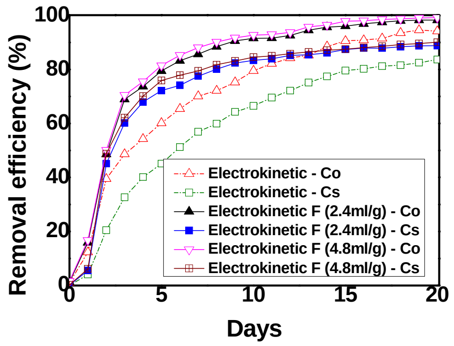

Fig. 2. A comparison of removal efficiencies between a vertical electrokinetic remediation and a vertical electrokinetic-flushing remediation for 20 days

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