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Electrokinetic Extraction of Pollutants from the Vicinity of Unregulated Landfill Site

동전기적 추출에 의한 비위생매립지 주변 오염지반의 정화

Lee, MyungHo[1]* 이명호
Chung, Ha-Ik[2] 정하익

ABSTRACT

This paper presents preliminary field investigations on the electrokinetic (EK) remediation coupled with permeable reactive barrier (PRB) system. unregulated and old-fashioned landfills are one of the primary contributors to various contaminated soil problems. In-situ EK remediation technology has been successfully applied to the environs of unregulated landfill site, located in Kyeong-Ki province, Korea. Atomizing slag was adopted as a PRB reactive material for the remediation of groundwater contaminated with inorganic and/or organic substances. From the preliminary investigations, the coupled technology of EK with PRB system would be effecitve to remeidate contaminated grounds without the extraction of pollutants from subsurface due to the reactions between the reactive materials and contaminants

요지

비위생매립지(非衛生埋立地)의 설치는 매립지 주변의 지반오염에 심각한 영향을 미친다. 동전기정화기법(動電氣淨化技法, Eelectrokinetic Remediation Technology)은 주로 무기오염물질에 의해 오염된 저투수성(低透水性)지반의 정화에, 투수성반응벽체(透水性反應壁體, Permeable Reactive Barrier)는 주로 지하수 내의 유기오염물질의 분해 등에 각각 효과적이다. 본 연구에서는 동전기정화기법과 투수성반응벽체의 장점을 복합적으로 비위생매립지 주변의 오염현장에 적용하여 정화효과를 조사하였다. 환경오염원이자 폐기물인 제강슬래그를 재활용한 오토마이징슬래그(Atomizing Slag)를 투수성반응벽체의 반응물질로 이용하였다. 현장적용 실험결과, 동전기정화기법과 투수성반응벽체의 장점을 복합적으로 적용한 EK & PRB System(EPS)이 원위치(原位置, In-Situ) 정화효율을 높여줌을 알 수 있었다.

Keywords **:** In-situ electrokinetic remediation, Permeable reactive barrier, Contaminated landfill site, Atomizing slag, Clayey soils

1. INTRODUCTION

The pollution of groundwater resources with toxic metals, such as lead (Pb) and cadmium (Cd), has been significant threat and damage to human health and environment due to their solubilities and mobilities [1]. For instance, cadmium causes the notorious Itai-Itai disease that results in serous skeleton deformation and kidney damage [2]. Various chlorinated organic compounds, including trichloroethylene (TCE), are widely used as solvents in various industries. When entering the subsurface environment, they generally would pose great

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[1]* BK Research Associate, Dept. of Civil & Environ. Eng., Hanyang University, E-mail: mhleecok@hanmail.net

[2] Research Fellow, Geotechnical Eng. Research Dept., Korea Institute of Construction Technology

threats to the environment and human health. For example, TCE is harmful to the respiratory system, the circulatory system, and the central nervous system of human bodies [3]. Therefore, there is a need for an effective and economical technique to remediate contaminated ground and groundwater.

Electrokinetic (EK) remediation has been proven to be a very effective tool to clean up heavy metal contaminated fine grained soils [2]. Figure 1 presents a schematic diagram of the in situ EK soil processing. The EK remediation is a relatively new method, which involves passing a low electrical current between electrode pairs imbedded in the contaminated ground for the removal of subsurface contaminants via electrophoresis, electroosmosis and electromigration [4]. This technology can be used in combination with other cleanup techniques [5-7].

Groundwater remediation using permeable reactive barriers (PRB) is a new and innovative technology. So far, only a relatively small number of technical scale installations exist and so experience of these systems is limited. The in-situ PRB system is shown in Fig. 2. The PRB is one of the passive remediation technologies, which is for the remediation of contaminated groundwater [8]. A typical in situ configuration consists of a PRB system placed across the flow path of a contaminated plume. As the plume flows through the PRB under natural gradients, contaminants are destroyed to non-toxic end products without soil or water excavation [9].

Figure 3 (a) shows a schematic diagram of the in situ EK remediation, which requires a pumping system at the cathode in order to extract the contaminant flux migrated from the anode towards the cathode. However, as shown in Fig. 3 (b), if the cathode electrode was installed with reactive materials, the migrating pollutants from the anode towards the cathode could be destroyed by passing through the PRB system. The purpose of this research is

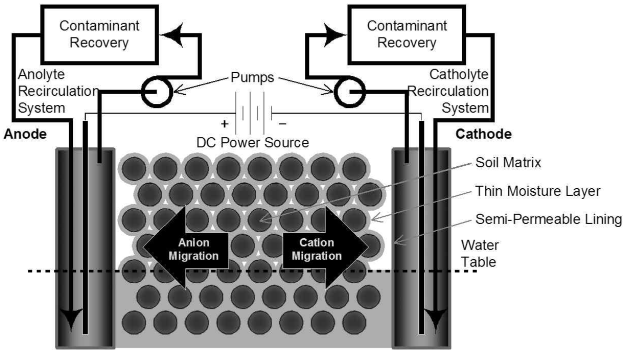
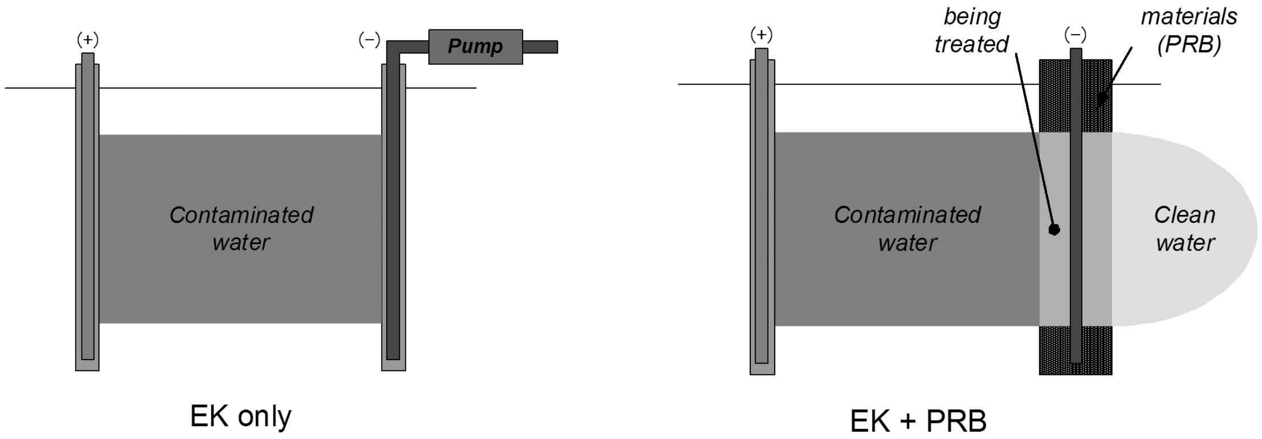


Fig. 1. In−situ electrokinetic processing

Fig. 2. In−situ permeable reactive barrier



(a)

(b)

Fig. 3. Proposed in situ electrokinetic remediation and permeable reactive barrier system

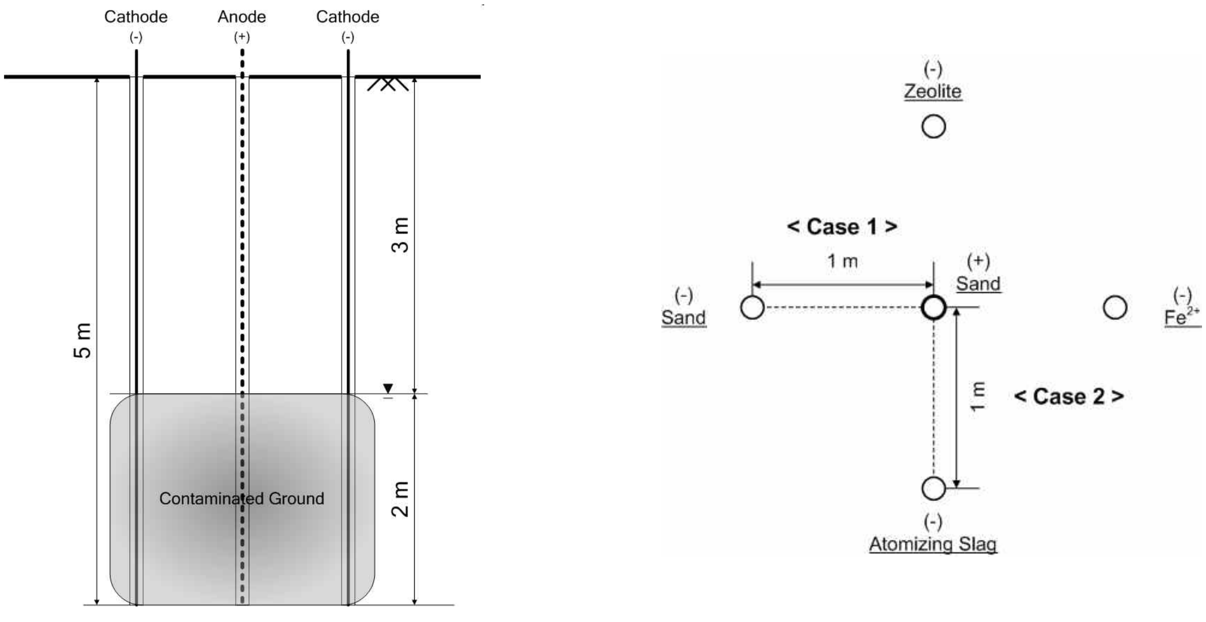
to investigate a feasible application of the EK technology coupled with PRB system to remediate in-situ contaminated ground of low permeability soils.

2. MATERIALS AND METHODS

Sano-Dong landfill site located in Kyungki province is one of the simple, unregulated, and old-fashioned landfills in Republic of Korea, so that there may be possibilities of groundwater contamination due to the leachates from the landfill. Thus, the in-situ EK tests were carried out in the environs of Sano-Dong landfill site in order to investigate the contamination of soils and groundwater around the landfill site as well as the applicability of the EK technology in the field. The treatment zone was determined by the groundwater level: i.e. 3 to 5 m below the ground surface as shown in Fig. 4 (a). The in-situ EK system basically consists of an array of electrodes, electrode wells, a DC power supply, vacuum pump, water reservoir, and process tubing to inject water to the anode electrode well and to extract contaminants from the cathode electrode wells.

The electrode array consists of a series of anode and cathodes housed in wells. Figure 4 (b) illustrates the array of anode and cathodes that were installed within the test area. It can be seen that the anode well is located in the centre, and the cathode wells are located in radial shape at the distance of approximately 1 m apart from the central anode well. The applied electrical potential difference between the electrodes was approximately 100 V (i.e. voltage gradient of 1 V/cm). Two different conditions were considered in this study: case 1 for the EK extraction system (both anode and cathode wells filled with sand) and case 2 for the EK extraction with PRB system (cathode well filled with atomizing slag). Slotted PVC columns (0.08 m i.d. and 5 m long) were used as the electrode chambers.

Figure 5 presents the EK experimental setup. After the installation of PVC chambers into bore holes (0.16 m i.d.), the surroundings were filled with either sand or atomizing slag for various purposes. Thereafter, electrodes (stainless steel rod of 0.01 m o.d. and 5.5 m long) and drainage tubes were installed into the electrode wells. The electrodes were connected to a DC power supply (Agilent E3612A), and the inlet and outlet tubes were connected to a water reservoir and vacuum pump, respectively. A constant electric field, rather than a constant electrical current, was applied to the ground because significant



(a) (b)

Fig. 4. Schematic diagram of electrode layout

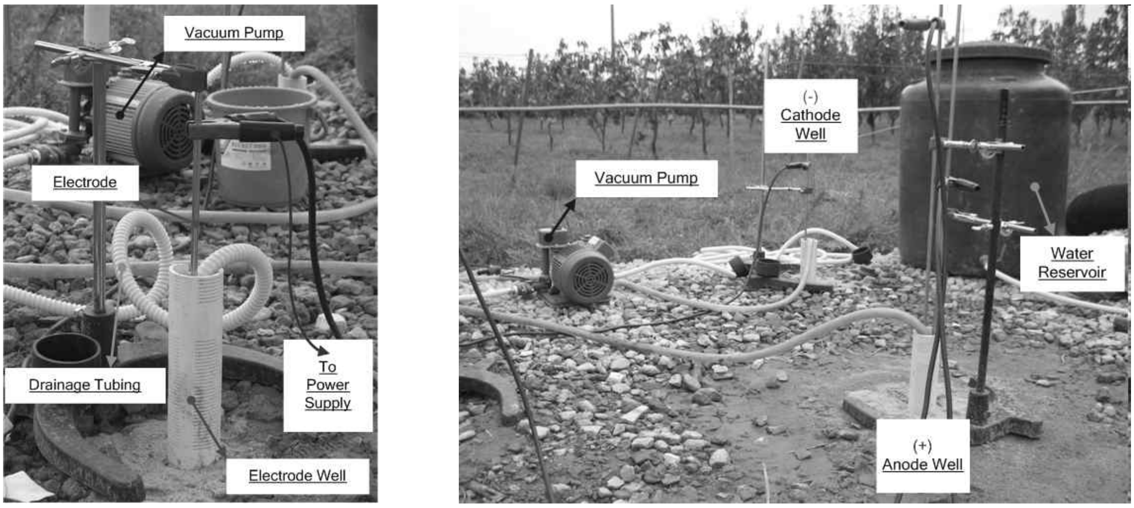


Fig. 5. Details of electrode well and experimental setup (stainless steel electrode, electrode holder, electrical wire to the power supply, drainage tubing, and vacuum pump)

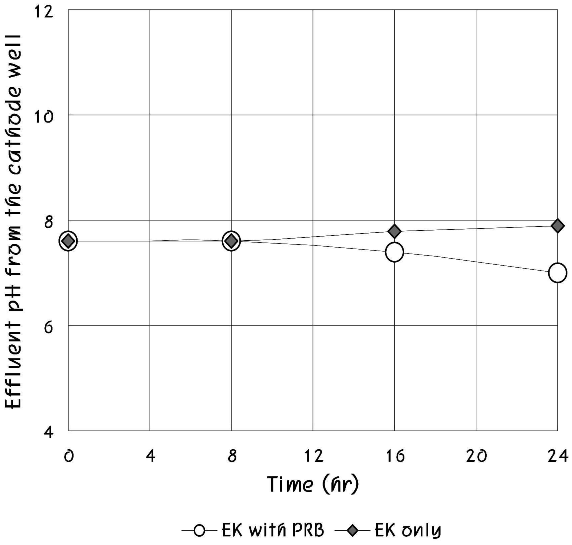


Fig. 6. Effluent pH, collected from the cathode well, against time results

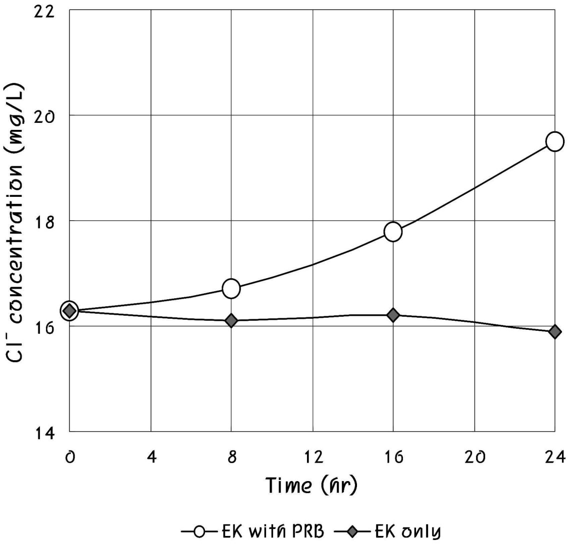


Fig. 7. Chlorine concentration against time results

power loss may occur due to the increase of soil resistance by the depletion of ions resulting in the premature termination of experiment [10].

3. RESULTS AND DISCUSSION

Figure 6 shows the variation of effluent pH collected from the cathode well during the EK soil processing. It can be seen that there are no big differences in the effluent pH values under the EK system and the EK with PRB system. However, in the case of EK system, the pHs increase with increasing processing time, whereas the pHs for the EK with PRB system gradually decrease during the EK treatment.

The initial chlorine concentrations for both EK system and EK with PRB system were approximately 16 mg/L, and the chlorine concentration under the EK system rather maintained the initial value as shown in Fig. 7. However, in the case of EK with PRB system, the chloride concentration was continuously increasing during the EK treatment. It appears that the migrating organic pollutants from the anode towards the cathode due to the electroosmotic advective flow passing through the PRB material, and some of the organic contaminants were

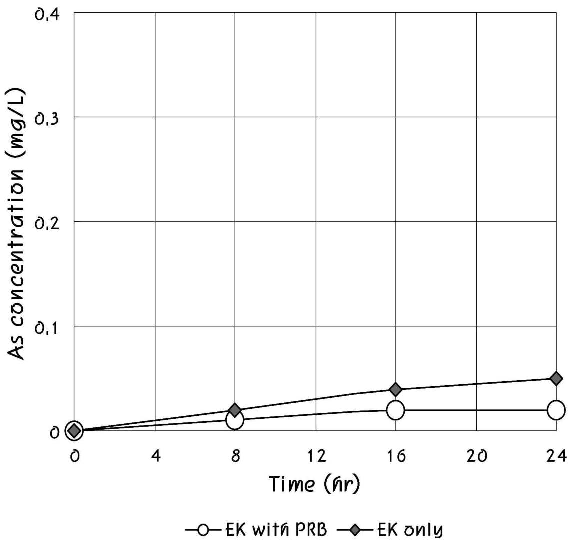


Fig. 8. Arsenic concentration against time results

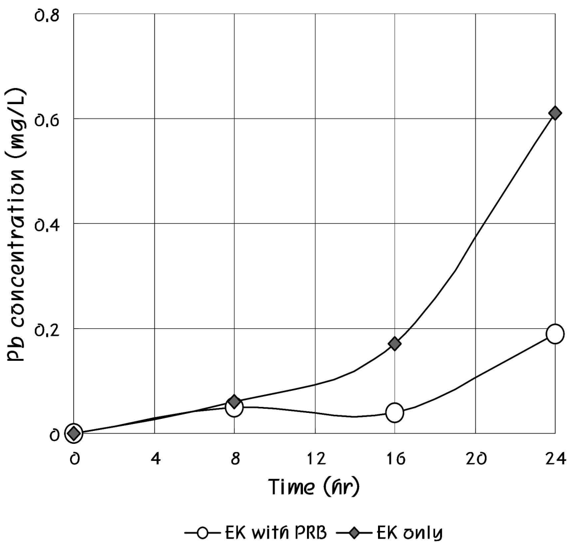


Fig. 9. Lead concentration against time results

destroyed by the reactions with atomizing slag.

Toxic pollutants were found to be extracted from the contaminated ground by both the EK system and the EK with PRB system as shown in Figs. 8 and 9. There is an increasing tendency for the migrating pollutants towards the cathode well due to the EK treatment. In the case of EK with PRB system, the migrating contaminants towards the cathode well appears to adsorb onto the reactive material, and those of concentrations were not high. The removal rate of heavy metal contaminants was slightly higher than that of organic contaminants due to the effects of electroosmosis and the additional effect of electromigration for their positive charges.

4. CONCLUSIONS

Experimental results showed the effluent pH under the EK with PRB system was maintained constant during the treatment, which may be due to the reactions between the hydroxyl ions and the reactive materials. The chloride concentrations were higher under the EK with PRB system than those under the EK system, which seemed to be caused by the depletion of organic contaminants. The heavy metal contaminants were removed by the effects of electroosmosis and electromigration under the EK system. In the case of EK with PRB system, the majority of migrating heavy metals adsorbed onto the atomizing slag, and hence the heavy metal concentrations were lower than those under the EK system. From the preliminary field investigations, the coupled technology of EK with PRB system would be effective to remediate contaminated grounds without the extraction of pollutants from subsurface due to the reactions between the reactive materials and contaminants.

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