

Evaluation of Electrokinetic Remediation of Arsenic Contaminated Soils

Won-Seok Kim, Soon-Oh Kim* and Kyoung-Woong Kim

*Arsenic Geoenvironment Laboratory (NRL), Department of Environmental Science and Engineering,
Gwangju Institute of Science and Technology (GIST), *Department of Earth Environment Science,
Gyeongsang National University (e-mail: kwkim@gjist.ac.kr)*

Abstract

The potential of electrokinetic (EK) technology has been successfully demonstrated for the remediation of heavy metal contaminated fine-grained soils through laboratory scale and field application studies. Arsenic contamination in soil is a serious problem affecting both site use and groundwater quality. The EK technology was evaluated for the removal of arsenic from two soil samples: kaolinite clay artificially contaminated with arsenic and arsenic-bearing tailing soil taken from the Myungbong (MB) mining area. The effect of cathodic electrolyte on the process was investigated using three different types of electrolyte: deionized water (DIW), potassium phosphate (KH_2PO_4) and sodium hydroxide (NaOH). The result of experiments on the kaolinite clay shows that the potassium phosphate was most effective in extracting arsenic, probably resulting from anion exchange of arsenic species by phosphate. On the contrary, the sodium hydroxide seemed to be most efficient in removing arsenic from the tailing soil, and it is explained by the fact that sodium hydroxide increased the soil pH and accelerated ionic migration of arsenic species through increase in desorption and dissolution of arsenic species into pore water.

Key word : Arsenic, Electrokinetic remediation, Kaolinite, Mine tailing

1. Introduction

The presence of arsenic in groundwater and soil can pose a significant threat to human and ecological system. The accumulation of arsenic in the human body can cause fatigue, loss of kidney function, and cancers of the lung, liver, and skin. Soils have been contaminated with arsenic by human activities such as mining, smelting, land filling of industrial wastes, disposal of chemical warfare agents, and agriculture in many areas of the world. Arsenic-bearing tailings, resulting from many gold mining operations, are of concern as potential sources of environmental contamination. Elevated concentrations of arsenic in surface waters and groundwaters around mine tailing dumps,

produced by the dissolution of sulfide minerals such as arsenopyrite (FeAsS), have been commonly reported. Currently, there are thousands of abandoned metal mines in South Korea, most of which have been left without any proper treatment. The tailings from these mines contain several toxic contaminants, including arsenic and heavy metals, with a high potential for deterioration of the surrounding ecosystems. Arsenic and heavy metal contamination of the agricultural soils and crops surrounding these areas has been recently identified as one of the most serious environmental problems facing South Korea. It has been reported that some gold mine tailings in Korea show severely acidic to neutral pH values and contain high levels of arsenic and other heavy metals. The electrokinetic (EK) technique is one of the most promising decontamination processes, and has a high efficiency and time-effectiveness in low-permeable media such as sludge and clay soils. The EK soil processing is also termed electrokinetic remediation, electroreclamation and electrochemical decontamination, and the significance of this method is its low operation cost and potential applicability to a wide range of contaminant types. It is important to understand change in the chemical and mineralogical forms of solid phase arsenic for the evaluation of As mobilization in soils and sediments during EK process.

2. Materials and Methods

Kaolinite was chosen for this study since it is one of the most ubiquitous clay soils in Korea, and is commonly used as a soil medium in electrokinetic processing due to its low swelling property. The MB gold mine is located in a southwestern district near the southern Korean coast. The mine was active in the early 1900s, but closed in the 1970s. The ore deposit is a metasedimentary-hosted hydrothermal gold-bearing quartz vein containing small amounts of pyrite (FeS), arsenopyrite (FeAsS), galena (PbS), sphalerite (ZnS), and chalcopyrite (CuFeS₂); among these, the arsenopyrite is the most likely source mineral of arsenic in the tailings. The tailings have been left without any proper treatment, and the arsenic-bearing tailings are considered as a source of arsenic contamination in the study area.

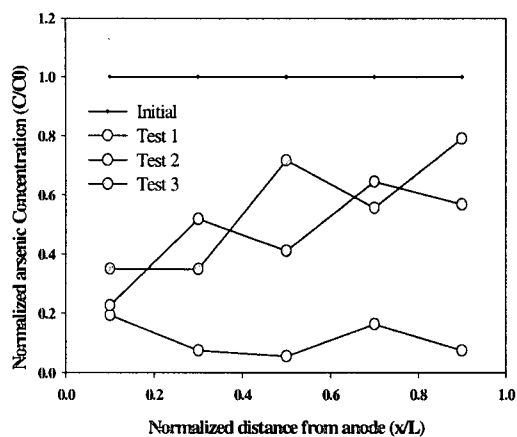
The kaolinite soil was artificially contaminated with Na₂HAsO₄ · 7H₂O stock solution to render 1,500 mg/kg of final arsenic concentration. Arsenic concentration was analyzed using hydride generator-atomic absorption spectrometry (HG-AAS, Perkin-Elmer ZL 5100). A set of six tests was designed and conducted with three different types of catholyte to evaluate the electrokinetic removal of arsenic from the kaolinite and the MB tailing soils. Table shows the operating parameters used in this study.

Table. Summary of experimental program for electrokinetic removal of As(V) from kaolinite and tailing soils

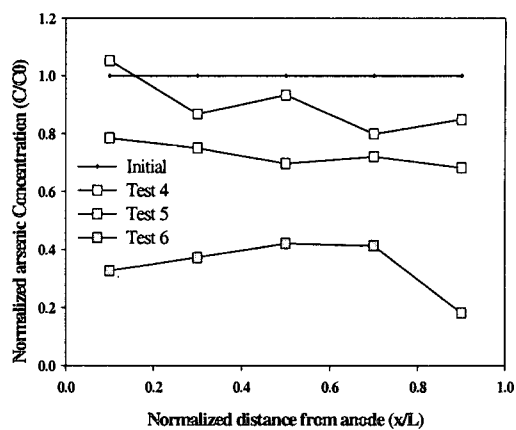
Parameter	Kaolinite			Myoung-Bong mine tailing		
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
	Control	Enhanced		Control	Enhanced	
Anode	Platinum plate, 10 cm (W) × 10 cm (L)					
Cathode	Titanium plate, 10 cm (W) × 10 cm (L)					
Current (A)	0.1					
Dimension	10 cm (H) × 10 cm (W) cross sectional area of soil cell = 100 cm ²					
Length of soil cell (cm)	15					
Initial arsenic concentration (mg/kg)	1,500			3,200		
Duration (hrs)	100			140		
Anodic and cathodic electrolyte solutions	Anode: DIW Cathode: DIW	Anode: DIW Cathode: KH ₂ PO ₄	Anode: Na ₂ CO ₃ Cathode: NaOH	Anode: DIW Cathode: DIW	Anode: DIW Cathode: KH ₂ PO ₄	Anode: Na ₂ CO ₃ Cathode: NaOH

3. Results and discussion

The distribution of residual arsenic concentrations in the soil bed after experiments is shown in Figure. The distribution of residual arsenic concentrations in the kaolinite experiment appeared to be different between tests 1 & 3 and test 2, and it was caused by the combined effect of the electromigration and electroosmosis. In particular, the residual concentration in test 2 was much lower than those in tests 1 and 3, and it indicates that the potassium phosphate significantly enhanced arsenic removal, probably resulting from anion exchange of arsenic species by phosphate. In the case of the kaolinite experiments, the potassium phosphate was most effective in extracting arsenic. The distribution of the residual arsenic concentration shows a different pattern in the experiment on the tailing soil, compared with that in the kaolinite experiment. The residual arsenic concentrations seems to be increased towards the anode, and it indicates arsenic species migrated towards anode through electromigration. In addition, the residual concentration of arsenic was much lower in test 6 than in tests 4 and 5, suggesting that the sodium hydroxide is most effective in removing arsenic species from the tailing soil. It is likely that the desorption of arsenic species is a main mechanism for the removal of arsenic from the tailing soil. Comparing the removal efficiencies of arsenic between the control test using DIW electrolyte and the tests using phosphate and alkaline electrolytes, the use of enhancing agents improved the electrokinetic removal of As from both kaolinite and tailing soils.



(a) kaolinite soil



(b) tailing soil

Figure. The distribution of residual As(V) concentrations in the soil bed after experiment

Conclusion

This preliminary study showed the feasibility of electrokinetic removal of arsenic from soils and improvement of process through use of enhancing agents. The efficacy of the process seems to be significantly influenced by numerous factors, such as pH and redox conditions of system to be concerned, arsenic speciation, and various electrokinetic phenomena (electromigration, electroosmosis, and water electrolysis). Even though this study demonstrates the applicability of electrokinetic process for the removal of arsenic from contaminated soils, more work should be needed to clearly elucidate the transport and removal mechanism of arsenic under electric fields and finally to improve the efficiency of the process.

Acknowledgement

This research was supported by the Korea Institute of Science and Technology Evaluation and Planning (KISTEP) to the Arsenic Geoenvironment Laboratory (NRL) at Gwangju Institute of Science and Technology (GIST), Korea.