3C 880 PDF

ELECTROKINETIC REMEDIATION: TECHNOLOGY STATUS

Yalcin B. Acar
Civil and Environmental Engineering Department
Louisiana State University
Baton Rouge, LA 70803
Phone: (504) 388-8638

Akram Alshawabkeh, Robert J. Gale, Robert E. Marks and Susheel Puppala
ELECTROKINETICS INC.
The Louisiana Business and Technology Center
Suite 105, South Stadium Drive
Baton Rouge, LA 70803
(504)388-3992

Randy Parker
Risk Reduction Engineering Laboratory, USEPA
26 West Martin Luther King Drive
Cincinnati, OH 45268
(513) 569-7271

and

Mark Bricka
US Army Engineer Waterways Experiment Station
Hal's Ferry Road
Vicksburg, MI 39180
(601) 634-3700

INTRODUCTION

The demand to develop innovative and cost-effective in-situ remediation technologies in waste management stimulated the effort to employ conduction phenomena in soils using an electric field to remove chemical species from soils (1-6). This technique variably named as *electrokinetic remediation, electro-reclamation, electrokinetic soil processing, electro-chemical decontamination* , *electrorestoration or electrochemical soil processing* uses low-level DC in the order of mA/cm^2 of cross sectional area between the electrodes or an electric potential difference in the order of a few volts per cm across electrodes placed in the ground in an open flow arrangement. The groundwater in the boreholes or an externally supplied fluid (processing fluid) is used as the conductive medium. Open flow arrangement at the electrodes allows ingress and egress of the processing fluid or the pore fluid into or out of the porous medium. The low-level DC results in physico-chemical and hydrological changes in the soil mass leading to species transport by coupled and uncoupled conduction phenomena in the porous media. Electrolysis reactions prevail at the electrodes. The species input into the system at the electrodes (either by the electrolysis reactions, or through the cycling processing fluid) and the species in the pore fluid will be transported across the porous media by conduction phenomena in soils under electric fields. This transport coupled with sorption, precipitation and dissolution reactions comprise the fundamental mechanisms affecting the electrokinetic remediation process. Extraction and removal are accomplished by electrodeposition, precipitation or ion exchange either at the electrodes or in an external extraction system placed in a unit cycling the processing fluid (1,2,4).

Electrokinetic remediation technology has recently taken significant strides. Electrokinetics Inc. of Baton Rouge has completed large-scale pilot studies using spiked and naturally contaminated soil deposits under the USEAPA SITE program. In collaboration with the US Army Waterways Experiment Station, Electrokinetics Inc. is currently carrying out a field study of extracting lead from soils at a Firing Range that belongs to the US Army. This demonstration study will be independently evaluated by the USEPA under the SITE program. The purpose of this paper is to present some of the recent developments in this technique and to outline the ongoing activities.

BACKGROUND

Three pilot-scale studies were conducted by Electrokinetic Inc. under the SITE program; two pilot-scale tests using kaolinite spiked with lead at initial concentrations of 850 mg/kg, 1,500 mg/kg and another using fine sand and kaolinite mixture spiked with lead at 5,322 mg/kg. The kaolinite used had lead adsorption capacity of about 1,100 mg/kg. Lead nitrate salt is used as the source of lead. Tap water is used both as the catholyte and the anolyte. Other details of testing are presented by Alshawabkeh and Acar (3) and EK (5). Figure 1 shows the lead concentration profile after 123 days of processing at a current density of 133 $\mu A/cm^2$. More than 90 % of the lead in the soil is transported across to the cathode compartment. Lead prematurely precipitates close to the cathode compartment at its hydroxide solubility value if the chemistry of the electrolyte at the electrodes is not altered or controlled (unenhanced electrokinetic remediation) . One objective of these pilot-scale tests was to formalize and validate the principles of multi-species transport under electric fields. An appreciation of the relation between the mechanics and chemistry is only possible when precipitation close to the cathode compartment is allowed. Therefore, pilot-scale tests did not employ any enhancement technique.

The development of the theoretical formalisms pertaining to multi-species transport under electric fields, preparation of the associated numerical model and design/analysis packages are supported by the USEPA under the Gulf Coast Hazardous Substance Research Center program at Lamar University. The total lead profile predictions of the model pertinent to the the specific initial and boundary conditions in

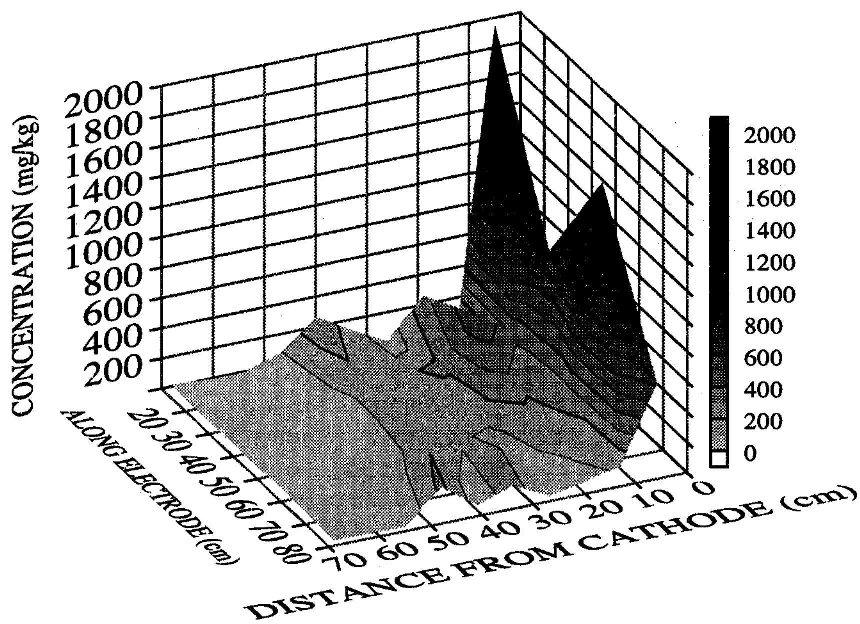

Figure 1. Lead concentration profile after 123 days of processing kaolinite/fine sand mixture spiked at 5,322 mg/kg (3).

the pilot-scale test presented in Fig. 1 are given in Figure 2. The acid generated by the electrolysis reactions at the anode and the lead released in to the pore fluid either by the dissolution or by the aqueous phase reactions travel towards the cathode compartment under the multi-species transport phenomena in soils under electric fields. Lead precipitates close to the cathode compartment at its hydroxide solubility value with the increase in the hydroxide concentration due to the prevailing cathodic reaction. The 50 day predictions shown in Fig. 2 are compared with the pilot-scale test results in Fig. 3. The agreement between the theoretical model and the pilot-scale test results demonstrate that the principles of the process are quite well rationalized and understood. The design analysis package which will include the generalized model is developed through joint collaborative effort between Electrokinetics Inc. and US Army Waterways Experiment Station.

The need to overcome the shortcoming of precipitation close to the cathode compartment prompted Electrokinetics Inc. and the US Army Waterways Experiment Station to collaborate and evaluate the feasibility of employing different techniques in enhancement of the process. The objective of the study was to promote transport of the positively charged species in to the catholyte where they could be removed either by electro deposition, by membrane separation or through ion exchange schemes. Acar and Alshawabkeh (1) discuss further the need for enhancement and propose different enhancement techniques which prevent the encountered precipitation. Figure 4 shows the extraction of different species in time from a 'real world' soil using the acetic acid cathode depolarization technique. The solubility of the species by the anodic acid and their migration under electrical fields are important considerations in electrokinetic remediation. The most soluble species will be the first ones to come out in solution and hence be transported towards the respective electrodes.

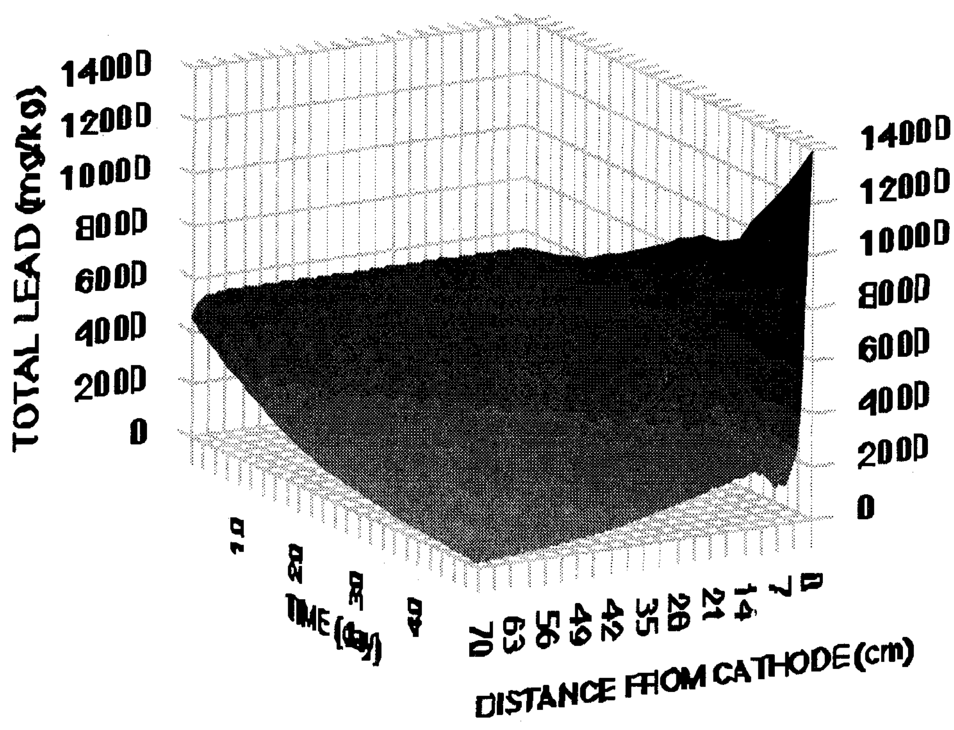

Figure 2. Prediction of total lead concentration across the electrodes using the Finite Element Model for Multi-Species Transport in Soils under Electrical Fields (FEM-MTSE) [Boundary and Initial Conditions pertinent to the Pilot-Scale Study are employed; 100 elements are used] (3,5].

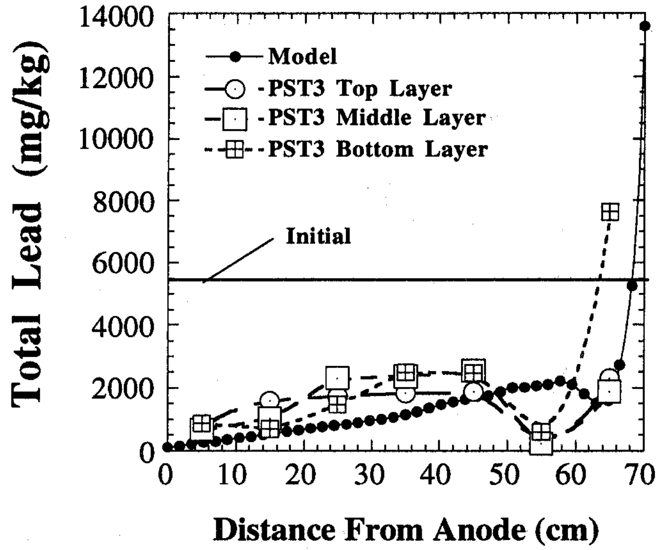

Figure 3. Comparison of lead profile predicted by the FEM-MSTEF with those measured in the pilot-scale study (3,5).

Although acetic acid depolarization technique is successfully used in remediating lead, chromium, zinc and other heavy metals from soils retrieved from sites across the nation and also from Europe, the technique generates significant amounts of liquid that needs to go through a secondary processing. Electrokinetics Inc. has developed an electrode system (CADEX™) that promotes electrodeposition of the species and minimizes the need for secondary processing.

In collaboration with the US Army Waterways Experiment Station, Electrokinetics Inc. is currently conducting a field-scale demonstration study at Fort Polk, Louisiana. The site is located in a creek. The surface deposits within the first two feet are contaminated with lead at concentrations of 3,500 mg/ kg (± 500 mg/kg). The lead in the deposits leached from the bullets left in the firing range over years of exposure to the environment. Preliminary chemical speciation and corrosion studies indicate that minute quantities of lead leach from the individual particulates and the contamination is mainly due to the quantity of the bullets left at the site. An area of about 2,000 ft^2 at this site is being processed. CADEX™ electrode system is used at this site. Onsite remediation is expected to continue for about six months to a year and the goal of the study will be to continue the process until levels of 100 mg/kg or less are reached. USEPA will have an independent evaluation of the demonstration study through the SITE program.

SUMMARY AND CONCLUSIONS

Electrokinetic extraction technique has gone through the phases of bench-scale testing and pilot-scale testing. Precipitation of species close to the cathode compartment has been a bottleneck for the process. Acetic acid depolarization technique and other depolarization schemes have been developed (4). Extraction of heavy metals by bench and pilot-scale tests from 'real world' soils retrieved from sites across the nation and from Europe demonstrate that the technique may be efficiently and cost-effectively used at selected sites. Currently, a field demonstration study is ongoing in the USA.

A theoretical model has been developed and its numerical implementation has been completed. The predictions of this model compared with the results of the pilot-scale studies demonstrate that the

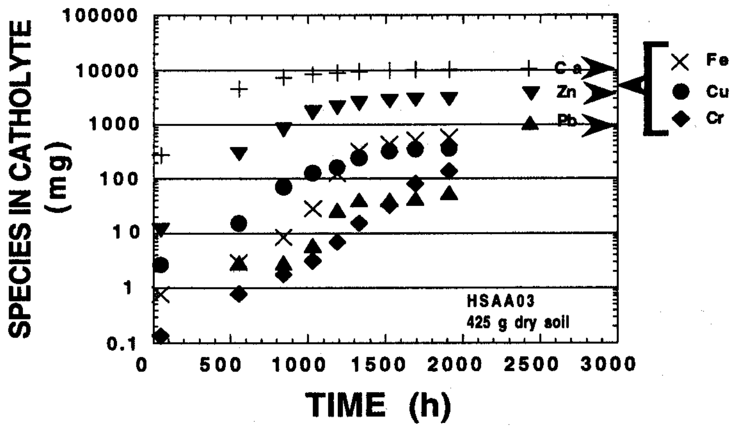

Figure 4. Breakthrough of Different Species in Enhanced Electrokinetic Remediation of a Specimen from a US Army site (EK 1994)

principles of the technique have been well rationalized. Currently, the model is being generalized and conditioning schemes are being incorporated. Design/analysis packages are being developed. Construction guidelines will be written upon completion of the field study. When cost-effectiveness and technical feasibility of other remediation optionsprohibit their use, electrokinetic remediation is expected to offer an alternative at sites contaminated with inorganic species. The technique also is in the process of being scrutinized and developed for injection, specifically to engineer insitu bioremediation of organic species through injection of process additives, nutrients and microorganisms.

REFERENCES

1. Acar, Y.B., Alshawabkeh, A. Principles of Electrokinetic Remediation . Environmental Science and Technology, vol. 27, n. 13, pp. 2638-December 1993.

2. Acar, Y. B., Gale R. J., Alshawabkeh, A., Marks, R. E., Puppala, S., Bricka, M., Parker, R. "Electrokinetic Remediation: Basics and Technology Status," Journal of Hazardous Materials, Elsevier Science B.V., Amsterdam, Netherlands, 40(3), February 1995, pp. 117-137.

3. Alshawabkeh, A., Acar, Y. B., "Electrokinetic Remediation: I. Pilot-Scale Tests; II. Theory" Journal of Geotechnical and Geoenvironmental Engineering, ASCE, (in review)

4. EK(1994). *An Investigation of Selected Enhancement Techniques in Electrokinetic Remediation,* Report submitted to US Army Waterways Experiment Station, Electrokinetics Inc., Baton Rouge, Louisiana, 1993, 160 p.

5. EK(1995). *Theoretical and Experimetal Modeling of Removing Contaminants from Soils by an Electrical Field,* Report submitted to USEPA by Electrokinetics Inc., Baton Rouge, Louisiana, 375 p. (in press).

6. Lageman, R.; Wieberen, P.; Seffinga, G. Electro-Reclamation:Theory and Practice. Chemistry and Industry, Society of Chemical Industry, London, pp. 585-590, 1989.

7. Shapiro, A. P.; Probstein, R.F. (1993) " *Removal of Contaminants from Saturated Clay by Electroosmosis,*" Environmental Science and Technology, 1993, 27 (2), pp. 283-291.

SITE Demonstration of Bioremediation of Cyanide at the Summitville Colorado Site

Leslie C. Thompson
Pintail Systems, Inc.
11801 E. 33rd Ave. Suite C
Aurora, CO 80010
(303) 367-8443

Randy Fischer
Dames & Moore
633 17th Street, Suite 2500
Denver, CO 80202
(303) 294-9100

Scott W. Beckman
Science Applications International Corp
411 Hackensack Ave, 3rd Floor
Hackensack, NJ 07601
(201) 489-5200

Introduction

The Summitville Mine in southern Colorado is located in the San Juan mountains at an average site altitude of 11,500 feet. Summitville was the site of mining operations that began in 1873 with the discovery and development of gold placer and lode deposits. The site was actively mined for gold, silver and copper between 1873 and 1947. From 1947 to 1986 the mine area was inactive until the Summitville Consolidated Mining Corporation, Inc. (SCMCI) a wholly-owned subsidiary of Galactic Resources, Ltd. started an open pit mine and heap leach operation at the site.

SCMCI ran a large tonnage open-pit and cyanide heap leach operation from 1986 to 1992. Gold ore (approximately 10 million tons) was mined, crushed and stacked on a lined, bowl-shaped leach pad. The mine experienced problems with water balance and unplanned solution discharges from the start of the mine life. Solution containment complications and ineffective water treatment contributed to environmental problems. Despite the production of 249,000 troy ounces of gold during the mine operation SCMCI was unable to meet remedial requirements and notified the state of Colorado of its intention to file a Chapter VII bankruptcy in December 1992. The EPA Region VIII Emergency Response Branch took over site operations on December 16, 1992 to prevent a catastrophic release of hazardous substances to the environment. The Summitville Mine site was added to the National Priority List in June 1994.

There are multiple sources of contamination at the site due to historic and SCMCI mining operations. Emergency response operations at the site have prevented releases of severely contaminated solution and studies are underway to define a permanent solution to detoxification or neutralization of the various mine waste units. This report addresses demonstration of an innovative bioremediation technology for treatment of cyanide and soluble leachable metals in the heap and heap solutions.

The heap leach pad consists of approximately 10 million tons of cyanide-leached ore and 90 to 150 million gallons of process solution. EPA Region VIII commissioned a Focused Feasibility Study (FFS) and Report of Investigation (RI) to evaluate remedial options for the Heap Leach Pad (HLP). The RI/FFS was completed by Morrison Knudsen Corporation and submitted to EPA Region VIII on August 19, 1994.

A Request for Proposal (RFP) was issued by Environmental Chemical Corporation (ECC) in October 1993 at the request of USEPA Region VIII, Department of the Interior and Bureau of Reclamation. The RFP requested interested companies to provide information on their ability to