Electrokinetic Remediation of Lead Contaminated Soil

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***Abstract*—Electrokinetic remediation is a viable method for heavy metal removal. It is based on the principle that when direct current is passed through heavy metal contaminated soil, certain types of contaminants migrate through the soil pore water to a place where they can be removed. Heavy metals are concentrated into smaller soil volume by this process. This process is an effective soil pre-treatment method before other remediation techniques are applied. The present study evaluated the feasibility of electrokinetic process in concentrating lead (Pb) in a contaminated soil using different types of electrolytes namely 0.1M EDTA, 0.1M citric acid, tap water and electrode materials like graphite and copper. The study also compared the removal efficiency of lead with different time periods like 24 and 48 hours. A voltage gradient of 1V/cm was applied throughout the test. The variation in pH, current & moisture content after the test were also evaluated. A higher removal efficiency of 68% was found when EDTA was used as electrolyte and graphite as electrode material.**

Keywords— Electrokinetic remediation; Lead; EDTA; Citric acid; Copper; Graphite

I. INTRODUCTION

Electrokinetic remediation is an effective emerging technology for the decontamination of heavy metal contaminated soil. It can be used as an in situ or ex situ remediation for fine grained soils (Reddy et al., 2002). In this process a low voltage DC is applied across the electrodes which are inserted into the soil. This causes the generation of H+ and OH- ions at anode and cathode due to the process of electrolysis. The potential difference between the electrodes causes the migration of contaminants to respective electrode chambers. The main contaminant transport mechanisms are electromigration, electroosmosis and electrophoresis. Electrokinetic process has been successfully applied in treating both heavy metals and organic compounds contaminated soil. Enhancement agents like EDTA, citric acid, $NaNo_3$etc can be used to improve the efficiency of electrokinetic remediation.

In the present study the effectiveness of electrokinetic remediation in decontaminating lead contaminated soil is evaluated. It also evaluates the efficiencies of different electrolytes like 0.1M EDTA, 0.1M citric acid and tap water and various electrode materials like copper and graphite.

II. METHODOLOGY

A. Chemicals and soil contamination

The soil used in this study was from English Indian Clays Limited, Thiruvananthapuram. Various tests were conducted to determine properties of the soil according to IS standards and geotechnical properties are given in table 1. The chemicals used in this study are lead acetate to artificially contaminate the soil, EDTA, citric acid. The soil was spiked with solution of lead acetate to acquire a concentration of about 500mg/kg which is above the permissible limit in residential area. The soil was mixed thoroughly and dried in air for one week.

TABLE I. GEOTECHNICAL PROPERTIES OF SOIL

Soil properties	Value
Specific gravity	2.6
Liquid limit (%)	33
Plastic limit (%)	22.6
Shrinkage limit (%)	15.7
Plasticity Index	10.4
IS classification	CL
OMC (%)	24
Dry density(g/cc)	1.43
%clay	51
%silt	45
%sand	4
UCC strength(kN/m^2)	72.25
Free swell(mL/g)	0.5

B. Electrokinetic Setup

The setup consisted of an electrokinetic cell, two electrodes, 5 Ampere DC supply, multimeter. The experiment was conducted in a plexi glass box of dimension 21cmx21cmx15cm. For each test 1.5kg of contaminated soil was compacted into the box and two electrodes of 0.7cm diameter and 7.5cm length was used (Fig 1). The electrodes used in the study were graphite and copper. A low voltage DC of 20V was applied throughout the test. Duration of all the tests was 24 hours. The experiment was initiated by sprinkling different electrolytes for each test. The electrolytes used for the study were 0.1 M EDTA, 0.1 M Citric acid and tap water.

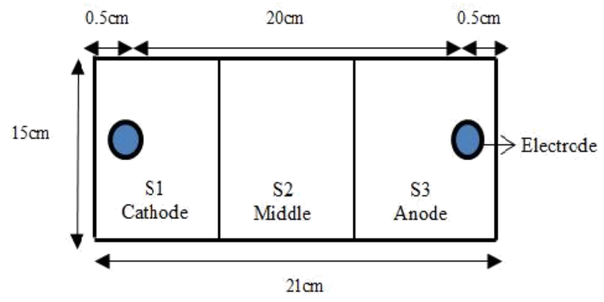

Fig 1: Schematic diagram of setup

The soil was categorized into 3 regions namely S1, S2, S3 representing cathode, middle and anode region as in Fig 1.

TABLE II. EXPERIMENTAL PARAMETERS IN THE STUDY

Exp No:	Electrolyte used	Electrode Used	Time duration (hrs)
1	EDTA	Graphite	24
2	Citric acid	Graphite	24
3	Tap water	Graphite	24
4	EDTA	Copper	24
5	EDTA	Graphite	48

Electric current was measured at equal intervals throughout the test using multimeter and the pH was also measured before and after the test at different sections. The concentration of lead in soil after treatment was determined by inductively coupled plasma atomic emission spectroscopy (ICP-AES) test. Normalised concentration of lead at different sections was calculated by finding the ratio of lead concentration after (C) and before the test (C_0).

III. RESULTS AND DISCUSSIONS

A. *Removal efficiency of different electrolytes*

The Pb distribution of soil is shown in Fig 2.From the results it is clear that 0.1 M EDTA showed better result than 0.1 M citric acid and tap water. As in Fig 3 the normalized concentration of Pb was greater in region S1 (>1) and other regions showed a value <1 which indicates metal migration from soil. Thus it was found that the migration lead occurred from anode to cathode region. When tap water and citric acid were used as electrolyte the Pb mobility was poor, which resulted in less removal of lead. The result showed that EDTA removed about 68% of Pb from the contaminated soil. The effectiveness of electrolytes is in the order of 0.1M EDTA> Tap water> 0.1M Citric acid (Fig 4).

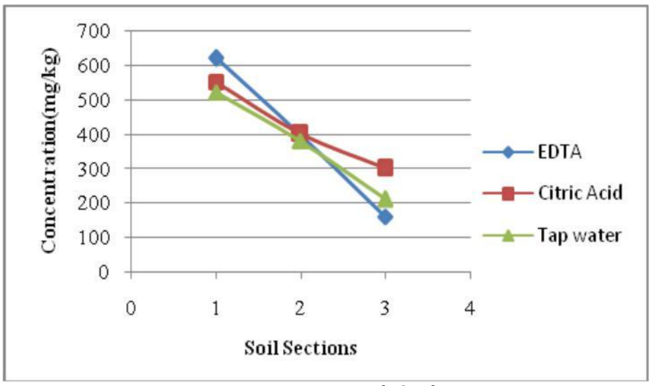

Fig 2: Concentartion of Pb after EK process

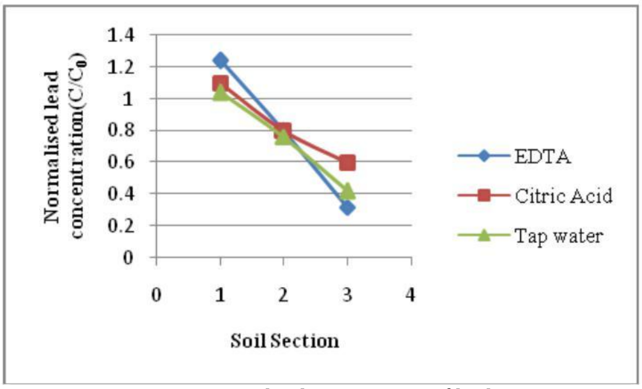

Fig 3: Normalised concentration of lead

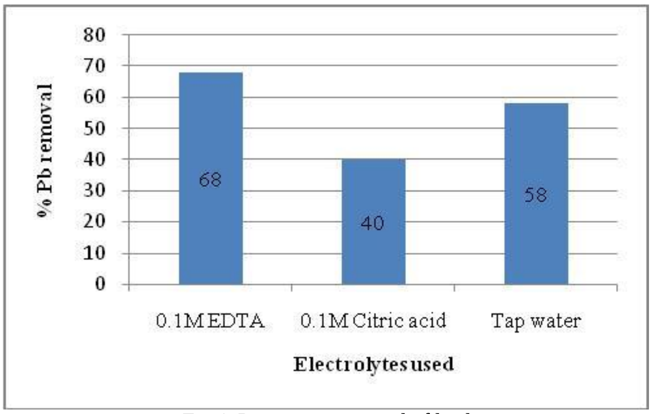

Fig 4: Percentage removal of lead

1. *Electric current and pH variation*

The electric current variations for different electrolytes are shown in Fig 5. It was found that the magnitude of current was higher for 0.1M EDTA and lower for tap water. The higher magnitude for EDTA was due to the presence of more mobile ions than the other two electrolytes. The variations in pH for the tests were shown in Fig 6.Electrolysis of water near to the electrodes resulted in production of acidic and alkaline nature at anode and cathode. The result showed that pH was higher in the cathode region and lower in the anode region. This is due to the production of OH^- and H^+ ions at respective electrodes due to electrolysis.

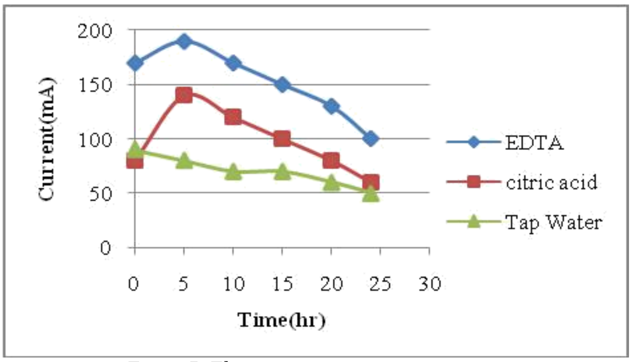

Figure 5: Electric current variation

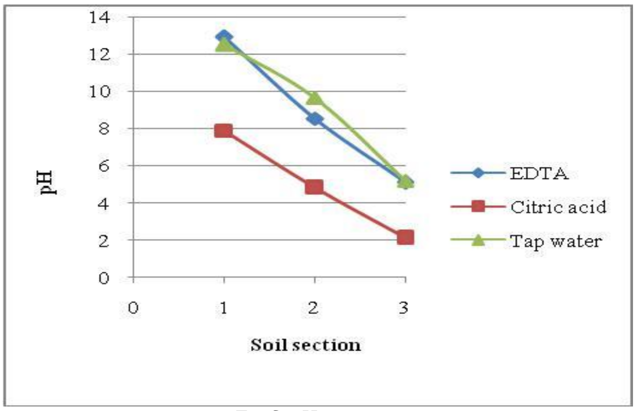

Fig 6: pH variation

B. *Removal efficiency of different electrodes*

To study the efficiency of different electrode material two materials, namely graphite and copper were tested. The concentration of lead at different sections after EK process is shown in Fig 7. From the figure it can be seen that removal efficiency of lead in anode region is same in both the cases but graphite showed better migration of lead in all the three regions. The removal efficiency of the test is 68%. Colour production was observed with both the electrodes. Copper turns to a blue- green colour as it gets oxidized and began to corrode. Graphite also showed degradation with time which resulted in decrease in magnitude of current.

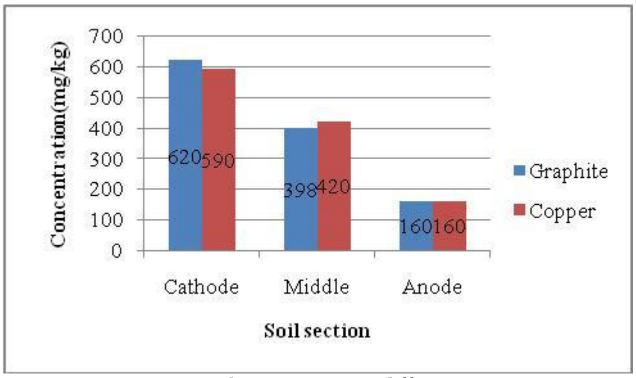

Fig 7: Lead concentration at different sections

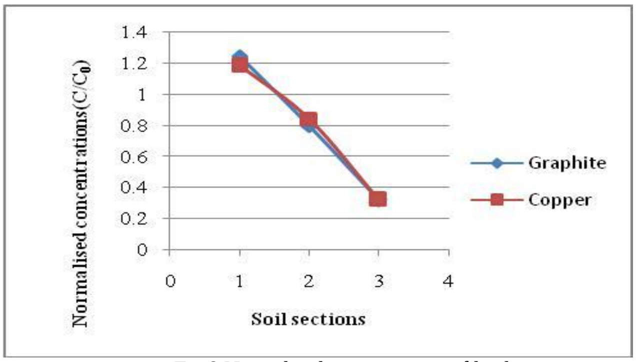

Fig 8 Normalised concentration of lead

Fig 8 shows the normalized concentration of lead at different sections. Lead was found to accumulate in the S1 region with a normalized concentration >1 while other regions showed a concentration <1. From Fig 9 it can be seen that graphite showed better magnitude of current throughout the test than copper. Higher magnitudes of current indicate better migration of ions. The gradual decrease in current was due to the electrode degradation.

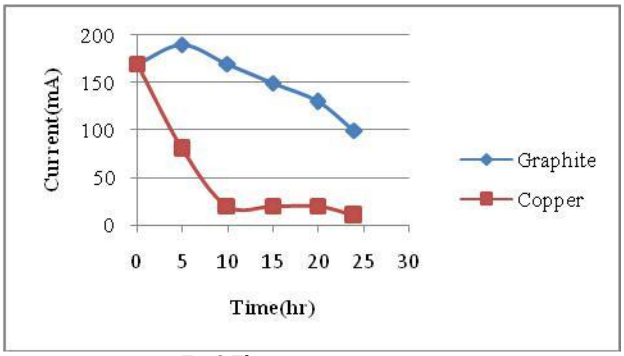

Fig 9 Electric current variation

C. *Removal efficiency with different time duration*

The variation in removal efficiency with increase in time duration was studied with two time durations of 24 and 48 hrs. The percentage removal of lead after EK process is shown in Fig 10. It was found that more amount of lead was concentrated towards the cathode region as the time duration increased.

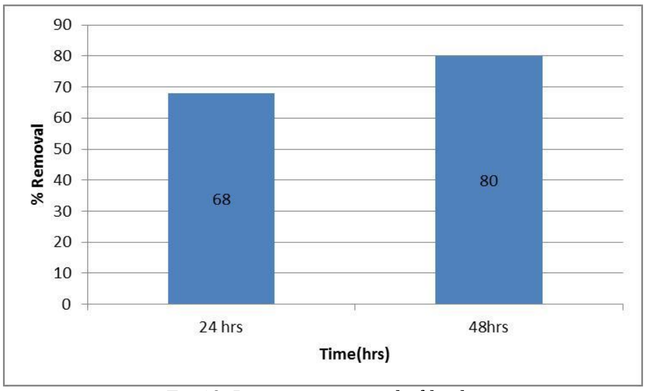

Fig 10: Percentage removal of lead

IV. CONCLUSIONS

The present study evaluated the effect of different electrolytes and electrode material in concentrating lead to a smaller volume of soil.

- The magnitude of current flow was more for EDTA which resulted in better migration of lead. So the effectiveness of electrolytes are as 0.1MEDTA> Tap water>0.1M Citric acid.
- EDTA was found to be better electrolyte in concentrating lead.
- Removal efficiency of lead is same for graphite and copper in anode region; however graphite showed better migration of Pb in all the three regions. A removal efficiency of 68% was obtained with graphite electrode.
- Removal efficiency of lead increased with increase in time duration of test .

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