REMOVAL OR REDUCING HEAVY METAL (LEAD) FROM SOIL BY ELECTROKINETIC PROCESS

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ABSTRACT

The electrokinetic process is an emerging technology for in situ soil contamination, in which chemical species, both ionic and nonionic are transported to an electrode in soil. These products are subsequently removed from the ground via collection systems engineered for each specific application. Electro kinetics refers to movement of water, ions and charged particles relative to one another under the action of an applied direct current electric field. Electrokinetic experiments were conducted using same type of clay soil taken from the site. Initial total concentrations of lead (II) maintained at 1000mg/kg for each process. The clay soils were to a voltage gradient of 1VDC/cm for over 24hrs, 36hrs and 48hrs.In a porous compact matrix of surface charged particles such as soil, the ion containing pore fluid may be made to flow to collection sites under the applied field. The work presented here describes part of the effort undertaken to investicate the electrokinetically enhanced transport of soil contaminants (lead) in synthetic systems. The result of this experiment presented here indicate that electrokinetic enhancement of contaminant transport in clay soils with different durations, increased duration (48hrs) is best removal efficiency for comparing the other durations (24hrs and 36hrs).

Keywords: Electrokinetics Remediation, Electrokinetics, Lead, Heavy Metals

INTRODUCTION

In general, soil contamination is placing human health at a great risk. Soil contamination is becoming a key environmental issue, due to its importance in ecosystems, and the influence it has on the quality of ground water, plants and food. Some of the most common and most damaging types of soil contaminants are metals. Generally, during routine operations or accidental spills in industry soil may be contaminated with metals. Once metal contaminates the soil, it can have complex interactions with natural binders that can lead to both short (delaying the normal hydration reaction) and long (release of the heavy metals in groundwater) term problems. Presence of heavy metals in soil has great concern with respect to human health and safety. Application of electrokinetic process for the removal of contaminant may vary mainly due to the variation in soil type and type of contaminant in the soil.

The first Electrokinetic phenomenon was observed at the beginning of the 19th Century,when Reuss applied a direct current to a clay water mixture. However, Helmholtz and Smoluchowski were the first scientists to propose a theory dealing with the electro-osmotic velocity of a fluid and the zeta potential under an imposed electric gradient. Electrokinetic remediation, variably named as electrochemical soil processing, Electro-migration, Electrokinetic decontamination or electro reclamation uses electric currents to extract radionuchdes, heavy metals, certain organic compounds, or mixed inorganic species and some organic wastes from soils and slurries. The application of electric current has several effects: (1) It produces an acid in the anode compartment that is transported across the soil and desorbs contaminants from the surface of soil particles; (2) It initiates Electromigration of species available in the pore fluid and those introduced at the electrodes; and (3) It establishes an electric potential difference which may lead to Electroosmosis generated flushing of different species. The dielectric constant and viscosity are properties of the pore fluid. The zeta potential depends on several factors, including the charge on the particle surface and the conductivity of the pore solution. The zero point of charge (ZPC) refers to the pH at which the net charge on the particle surface is zero. Generally, when the pH is below its ZPC, a soil has a positive zeta potential and the electro-osmotic flow occurs towards the anode. Conversely, when

the pH is above the ZPC, the soil has a negative zeta potential and the electroosmotic flow occurs towards the cathode. Electro-osmotic flow can be determined by Eq. (1.1)

$$q = Ke\ Ie\ A$$

Where q is electro-osmotic flow rate, Ke is electro-osmotic permeability, Ie is electrical potential gradient and A is the area normal to the flow. in contrast to hydraulic conductivity of soil which varies over an extremely wide range that depends upon the size of void of the soil and consequently grain size. The coefficient of electro-osmotic permeability is almost independent of grain size. Generally for saturated soil it lies in range of 0.4 to 0.6×10–4m/s. Great efforts have been made on the studies for removal of contaminants from soil in recent past. There were few remedial technologies like soil flushing, phytoremediation, bioremediation etc. but all these technologies are not satisfactory in low permeable soils where electrokinetic's has proved its own ability in such soils (Stichnothe et al., 1996).

In the human body, lead accumulates mainly in the kidneys. At high levels, it can reach a critical threshold and can lead to serious kidney failure. Recent studies have shown that kidney effects may be reversible at low exposures once lead exposure is reduced or removed. Maximum contaminant level (MCL) of metals that could be present in soil is presented in Table 1. It can be seen from Table 1 that permissible concentration limits for metals in soil is very low which, in turn, reflects the toxicity level and hazards associated with these metals [2, 17].

Table 1. Maximum permissible concentration of metals in soil

Metal	Max limit in Soil (mg/kg) US-EPA
Arsenic (As)	14
Selenium (Se)	1.6
Nickel (Ni)	32
Cobalt (Co)	20
Cadmium (Cd)	1.6
Chromium(Cr)	120
Copper (Cu)	100
Lead (Pb)	60
Mercury (Hg)	0.5
Zinc (Zn)	220

Electrokinetic (EK) process has been demonstrated to be a successful and cost-effective remediation technology for both organic and inorganic contaminants removal from low hydraulic conductivity soils by many laboratory and field studies. The major contaminant removal mechanisms involved in this process are the advection of electroosmosis (EO) flow driven under an electrical field, the movement of H^+ ions generated from H_2O electrolysis at the anode advancing through soil toward the cathode, and the migration of charged ions toward the opposite electrodes. Although removal of heavy metal from contaminated soils by EK process has been extensively investigated in past years, study on removal of lead from clay is limited. The aim of the present work is to study the influence of some operating parameters on the removal of lead from a low permeability soil using electrokinetic process.
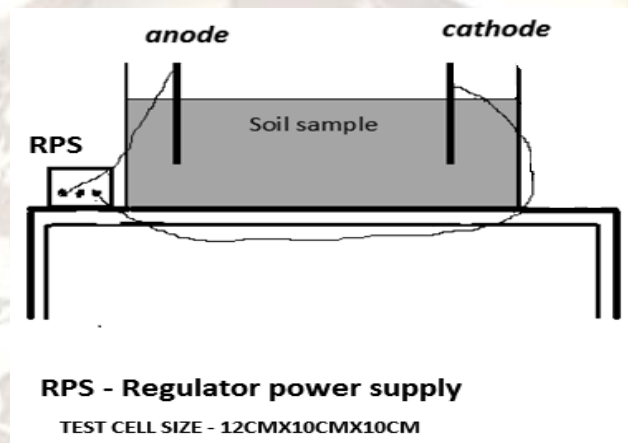
MATERIALS AND METHODS

In the present method soil sample has been collected from unpollted site vettavalam village of Thiruvannamalai district Uttar Pradesh India at shallow depth of 1-3 meter. After collection, the soil sample was air first Dried and washed through 0.425mm sieve to obtain fine grained soil. Particle size distribution analysis indicated that the soil contained approximately 12% clay-size particles. Quartz, feldspar, calcite, dolomite, hematite and the predominant clay minerals Illite and Kaolinite constituted the bulk mineralogy.

The virgin soil physico-chemical properties were taken from previous study. Cadmium nitrate (Cd $(NO_3)_2.4H_2O$), tri-ammonium citrate $(NH_4)_3.C_6H_5O_7$), HNO_3 and other required reagents have been used in the present study. The soil digestion procedure followed is to take 3 g soil samples in BOD bottles and add 30 mL of 1.6 M HNO3. Resulting slurries were shaken continuously for 24 h at room temperature in a shaker. Subsequently, the slurries and filtrates were tested in atomic absorption spectrophotometer (AAS) for analysis at the specific wave length of 228.8nm, for lead. Composition and properties of soil

Sr. No.	Property	Value
1.	Particle Size Distribution	
	Gravel (%)	6.80
	Sand (%)	17.4
	Silt (%)	65.0
	Clay (%)	12.0
2.	Atterberg Limits	
	Liquid Limit (%)	55
	Plastic Limit (%)	26
	Shrinkage Limit (%)	13
	Plasticity Index (%)	35
3.	Activity	1.87
4.	Specific gravity	2.62
5.	Maximum Dry Unit Weight (kN/m3)	18.68
6.	Optimum Moisture Content (%)	14.4
7.	Hydraulic Conductivity (m/sec)	4×10^{-9}
8.	Specific Surface Area (m2/g)	0.18
9.	Cation exchange capacity (USEPA) (meq/100 g)	22
10.	pH	8.52
11.	Organic Content (%)	6.25
12.	Loss on Ignition (LOI) (%)	9.93
13.	CaCO3 (%)	2.5
14.	Soil classification (USCS)	CL
15.	Cd	Not traceable
16.	Silica-Sesquioxide ratio (SSR)	5.74

EXPERIMENTAL SETUP

A schematic test setup used in this experiment is shown in Fig.1. The test set up consists of cylindrical cell made up of Perspex material containing a sample compartment of 6.9 cm inner diameter and 35 cm in length having two electrode compartments) with an anode reservoir and cathode reservoir. At each end of the soil cell, a cork with nylon net is used as reinforcement. It is immediately provided next to filter paper to prevent spreading of fine soil particles from entering into the reservoir. Gas vents were provided in both the electrode compartments to pass gases generated from the electrolysis process. Graphite anode and cathode were fitted at the end of reservoir were connected with a direct-current power supply. Along the longitudinal axis of the cylindrical cell, five auxiliary electrodes were arranged for the purpose of electric field distribution along the sample. The unit was powered by 12 V batteries 40 AH of 4 nos. and current of 40 A outputs. The voltage, current and various incremental voltages of the unit were monitored and logged manually using digital millimeters at regular intervals.

A total 3 Electrokinetic experiment were conducted on clayey soil.First Electrokinetic emediation was conducted with distilled water as a desorbing agent to study the basic EK Principles and theories for 5 days till the current stablise. Second Electrokinetic Remediation was conducted with Tri ammonium citrate as a desorbing agent with 2 M molarity without iron powder day till the current stablise. Third Electrokinetic Remediation was conducted with Tri ammonium citrate as a desorbing agent with 2 M molarity for 6 day till the current stablise and with iron powder with specification 300 mesh , finer than 75 micron . In all investigations, an applied electric field induced electro-osmotic flow moved the pore fluid through the clay from anode towards cathode. At the anode end a purging solution of chosen chemical was introduced at atmospheric pressure and drawn into the clay also by electro-osmosis. A constant DC electric potential was then applied across the specimen in all the experiments for a treatment time of 5 days Current and voltage at each 1 hour interval was measured at every section of cell

RESULTS AND DISCUSSION

Electrokinetic experiments were conducted on the three same soil sample, using an initial pb (II) of 1000mg/kg for the three different duration samples, in order o determine the lead removal efficiency. The distributions of the heavy metals based on this analyses show that the greater migration of metals occurred under induced electric potential. Significant amounts of lead (II) were present in the clay soil taken from the site. It was causing higher migration of these metals during electrokinetic treatment. From the above table results shows the concentration of lead presented on the   sample of the each 1kg in the respective three sections of the soil sample. In these results shows also the three durations. Finally grater removal is more for the duration of 48 hrs when comparing three durations.

Table No.2. Initial Concentration of Lead (II)

SL.NO	CLAY SAMPLES	CONCENTRATION OF LEAD (II) (mg/kg)
1	First sample (1kg)	1000
2	Second sample (1kg)	1000
3	Third sample (1kg)	1000

Table.No.3 Lead Concentration prior to Electrokinetic Treatment (After Mixing to the Sample)

Sl.no	section	CONCENTRATION OF LEAD (II) (mg/kg)
1	S_1 (anode)	830
2	S_2	810
3	S_3(cathode)	840

Table.No.4.Lead concentration after electrokinetic treatment

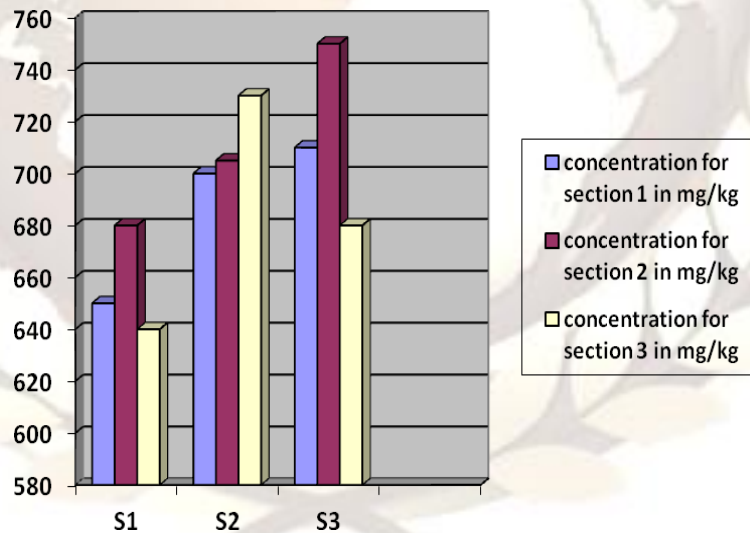| Sl.No	Section	Concentration of Lead (II)(mg/kg)		
		For 24 hrs duration	For 36 hrs duration	For 48 hrs duration
1	S_1 (anode)	650	680	640
2	S_2	700	705	730
3	S_3(cathode)	710	780	680

Fig.2. Concentration of lead for three duration (24, 36 & 48hrs) samples
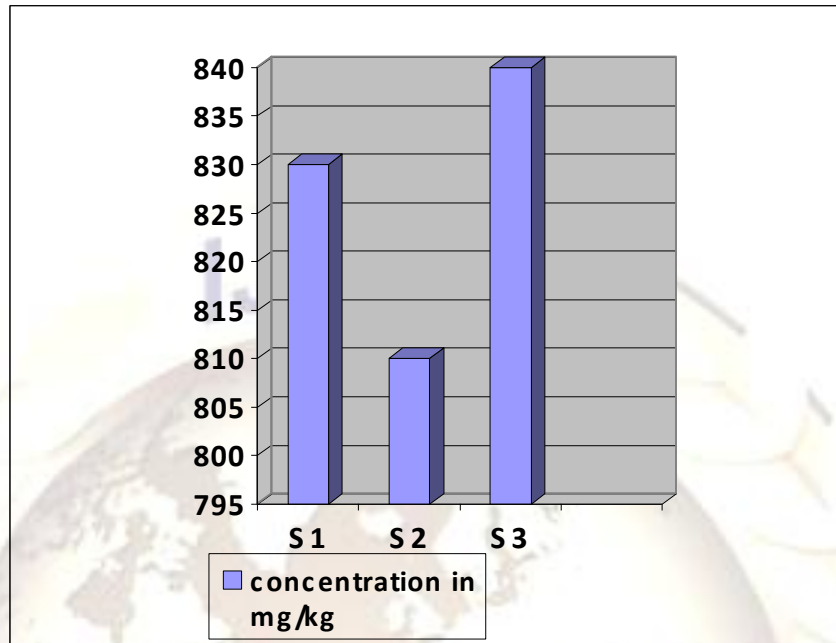
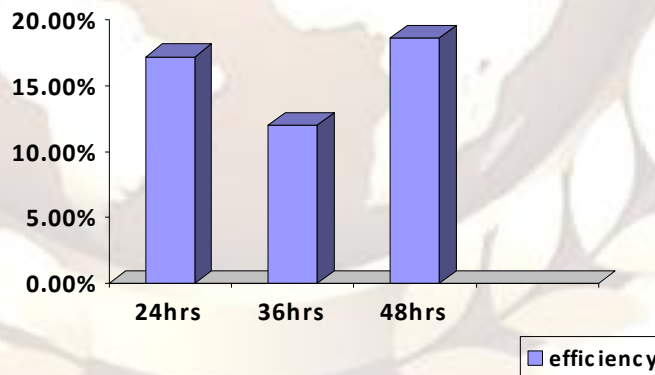Fig.3. **Lead Concentration prior to Electrokinetic Treatment (After Mixing)**

Fig.4.Removal Efficiency for the three durations

CONCLUSION

.   The effects of voltage gradient, initial contaminant concentration, and test duration on the contaminant removal efficiencies for glacial till were similar to those reported for other clays. An increase in the voltage gradient results in an increase in the removal efficiency of the contaminant. However, at high voltage gradients, high current

densities are induced which increase the rate at which H and OH ions are generated due to electrolysis reactions. The rate at which the soil can allow these ions to migrate through it is limited and hence the removal efficiency does not increase proportionally to the rate at which electrolysis reactions occur. A high initial concentration of the contaminant results in better removal efficiency. At concentrations, the amount of contaminants in the dissolved phase is higher and these contaminants can readily be transported by electromigration. By increasing the duration of the treatment process, ion removal is also increased. Based on this experimental work, the applicability of the electrokinetic technique for removingcontaminants from the lead contaminated soil appears to be promising. However, the results are based on the different duration of the electrokinetic process was very worthable because of increasing the time duration efficiency also increased. Here effects from the physical and chemical characteristics are not mentioned so that Further research is need to understand the effects of characteristics for further increasing the removal efficiency.

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