

## **Decontamination of Soil By Electro Kinetic Treatment**

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**Abstract.** Soil is a most essential part of the environment. Now a days soil is contaminating due to the human activities hence it was very essential to find the methods for decontaminating the soil. There are many existing methods for the decontamination of sandy soil, as the decontamination of clayey soil was difficult as it has very less porosity hence movement of ions becomes very difficult. Electro kinetic treatment is one of the methods which can be used for the decontamination of clayey soil. Electro kinetic treatment is a process of removal of heavy metals and organic contaminants and radio nuclides from the soil by applying direct current. Electro kinetic treatment lab test was conducted on a soil which was contaminated by a leachate. Test was conducted for four days and the corresponding results like voltage drop, pH, and conductivity were noted down. This paper tells about the brief information about the electro kinetic treatment and the experimental study of it and also the results. The results obtained from the test are good and acceptable.

**Keywords:** Electrokinetic Treatment; Leachate; Soil; Contamination

### **1 Introduction**

From the last so many decades it has become very difficult to extract the contaminants like heavy metals from a contaminated soil and it has been very challenging work for the engineers as well as for the scientists. There exist many processes to clean up the hazardous waste site however the technological challenge, cost and efficiency of these options may vary widely. There are some economical methods like conventional ground burial and land disposal but these methods do not provide a permanent solution, and in most of the cases they are not necessarily the most effective solution [1]. For removing organic and inorganic contaminants from the solid porous media, the most common ex-situ methods employed include soil washing, and ligand extraction. As the ex-situ methods suffer from several problems they are not technologically challenged that much. Some of the problems faced in the ex-situ methods are excavation of large mass of soil media and transferring it from one place to another and placing it in an external reactor, the above-mentioned processes suffer from several disadvantages. There are several in-situ methods which includes vacuum extraction, hydraulic fracturing, thermal desorption, electro kinetic

decontamination, immobilization by encapsulation, bio treatment, and placement of barrier systems are already in use for the decontamination of soil. Most of these methods are used for the removal of organics present in the soils. Among these in-situ methods electro kinetic decontamination (EKD) is in use from last few years. Major advantage of electro kinetic decontamination is that it is an in-situ process and it is suited for the porous soil and as well as for the cohesive soil which has low porosity where other processes can be ineffective, and from this process accelerated rates contaminant extraction and transport may be achieved. The basic concepts and an overview of the EKD processes and their real-life applications, as of now, in geotechnical and geo environmental engineering have been reviewed and presented in this paper.

### **1.1 Development of electrokinetic process**

When a DC current was applied to a mixture of clay-water Reuss (1803) observed the electro kinetic phenomena. Under the electric field he moved through the capillary towards the cathode. The flow of water immediately stopped when the electric potential was removed. Electroosmosis is distinguished by Napier (1846) and found through a membrane, the electric potential difference resulting from streaming potential. In 1879 first electroosmotic phenomena analytically were treated by Helmholtz. A mathematical basis was provided. Later modified it to apply to electrophoretic velocity by Pellatt (1904) and Smoluchowskic (1921) [3]. Cassagrande's studies in stabilizing clays by Electroosmosis started in the early 1930's. Electrical gradient was introduced 70 years ago. To stabilize the soil mainly by removal of the water. In the early period most of the studies were directed towards soil stabilization from removal of water and generally concentrated on the exploration of EK technologies showed marked interest in the early 1980's for the removal of toxic chemical species in dewatering of fine gravel soils by electroosmosis. In 1960's electro migration was used by Russian researchers in prospecting for metals. The early 1980's showed marked interest in the EK exploration technologies for the removal of chemical toxic species in ionic form in the soil in Europe and the US [4]. For further researches and field studies are encouraged by the successful applications resulting in understanding of the in-situ remediation of contaminated sands from various processes in EK.

## **2 Electrokinetics**

The term "electro kinetics" (EK) refers to the introduction of the associate electrical gradient (as critical a hydraulic or pressure gradient) within the soil to mobilize or promote the migration of water and/or varied chemical species towards the well-liked conductor. Electro kinetics is a soil redress technology is comparatively young have become another procedure for the removal of noxious chemical species in ionic type within the soil within the late 1980s. Electro kinetics could be a method that separates and extracts significant metals, radio nuclides, and organic contaminants

from saturated or unsaturated soils, sludge, and sediments. A low intensity electricity is applied across conductor pairs that are implanted within the ground on all sides of the contaminated soil mass. The electrical current causes electron diffusion and particle migration (electromigration) and activity, that move the binary compound part contaminants within the submerged from one conductor to the opposite. Contaminants within the binary compound part or contaminants desorbed from the soil surface area unit transported towards individual electrodes looking at their charge. The contaminants could then be extracted to a recovery system or deposited at the conductor. Surfactants and complexing agents are accustomed to increase solubility and assist within the movement of the material.

### **2.1 Process and mechanisms**

When an electrical field is formed across a soil volume, it provides a drive that will induce mass movement of particles, almost like the impact of different driving forces, like pressure gradient, concentration gradient, and thermal gradient. Especially, the appliance of an electrical field causes the following main transport phenomena in soils: Electroosmosis, electromigration, dielectrolysis, of these electrokinetic phenomena square measure extremely influenced by the surface charge densities of the soil particles, and so by the soil mineralogical composition.

### **2.2 Electro osmosis**

Electroosmosis may be a bulk transport of water, that flows through the soil as a result of the applied electrical field. The fluid migration happens principally from the anode to the cathode, because of the predominance of an electric charge on the soil particle surfaces. The electroosmotic flow is caused by the very fact that once an electrical field is applied to the soil, the surplus of cations on the brink of soil particles surface (double layer) tend to move towards the cathode. The movement of those ions and the water molecules related to these species (hydration shells), imparts a web strain on the pore fluid encompassing the hydrations shell

### **2.3 Electromigration**

The second transport mechanism generated by the voltage gradient is electromigration, that is that the movement of ions within the pore answer beneath the influence of an electrical field. Positive ions (cations) migrate towards the cathode whereas negative ions (anions) square measure transported towards the anode. Due to electromigration, ions tend to concentrate close to the alternative charged conductor. The particle quality may be a term want to describe the speed of migration of a particular ion species beneath a unit field. In soils, the speed of ionic migration will be higher outlined by the effective ionic quality, that conjointly accounts for soil porousness and crookedness, which might considerably affect particle migration.

## **2.4 Electrophoresis**

Electrophoresis consists of the movement of charged particles and colloids below the influence of an electrical field. Once an immediate current (DC) force field is applied across a colloid, charged particles and colloids that are suspended within the pore fluid are electrostatically interested in one among the electrodes and repelled from the opposite. Similarly, to the electromigration method. (Ahmad,2004). Usually, for environmental applications, electrophoresis is a smaller amount vital than electroosmosis and electromigration in terms of mass flux though in some cases electrophoresis could play a task in removal, e.g. if the migrating colloids have the contaminants absorbable on them.

## **2.5 Factors affecting electrokinetic technology**

Electromigration rates within the submerged rely on grain size, ionic quality, contamination concentration, total ionic concentration, and upon the soil pore water current density and hydrogen ion concentration. The direction and amount of the contamination movement is influenced by the contamination concentration (anions versus cations), soil sort and structure, pH, surface chemistry, and current density of the soil pore water. The potency of extraction depends upon many factors like the sort of species, their solubility within the specific soil, their electrical charge, their concentration relative to alternative species, their location and kind within the soil, and availableness of organic matter within the soil. Electro kinetics is applicable in zones of low hydraulic physical phenomenon, significantly with high clay content. The technology is best once the cation exchange capability (CEC) and the salinity are low, throughout electro kinetic treatment, electrolysis leads to the formation of  $H^+$  and  $OH^-$ . These migrate towards each other by electro kinetic processes. As these two fronts meet, a speedy transition from low to high hydrogen ion concentration happens, making an area of minimum solubility of metals. These sharp discontinuities in hydrogen ion concentration induced inside the soil mass by electro kinetics may end in a deposition front wherever minerals are precipitated in soil pores, markedly reducing porosity and inhibiting recovery, this could be prevented by flushing the cathode with water or a dilute acid to arrest the migration of the  $OH^-$  front into the soil. The mass flux transported throughout the electro kinetic method depends on the transient chemistry that takes place beneath the influence of induced electrical field. Specifically, the sorption–desorption, precipitation– dissolution, and oxidation–reduction behavior of the contaminants throughout the electro kinetic method influence the rectification efficiencies. Activity refers to the partitioning of the contaminants from the answer or pore fluid to the solid section or soil surface. Activity includes surface assimilation and activity and it is enthusiastic about (1) the sort of contamination (2) the sort of soil (3) the pore fluid characteristics {desorption natural method natural action} is that the reverse process and is to blame for the discharge of contaminants from the soil surface. Each activity and natural action are suffering from soil hydrogen ion concentration changes caused by the migration of H and Buckeye State ions, that are created by the electrolysis reactions [5]. The

hydrogen ion concentration dependent sorption– natural action behaviour is usually determined by playing batch experiments victimization the soil and contamination of explicit interest. The precipitation and dissolution of the contamination species throughout the electro kinetic method will influence the removal potency of the method [6]. The soil removal method is suffering from the element ions generated at the anode migrating across the contaminated soil and neutralizing the chemical group ions at the cathode. However, in some styles of soils, the migration of the element ions is going to be hindered thanks to the comparatively high buffering capability of the soil. The presence of the chemical group ions at the cathode can increase the hydrogen ion concentration worth (pH 10-12). During a high hydrogen ion concentration atmosphere, significant metals can precipitate, and the movement of the contaminants are going to be obstructed. The high hydrogen ion concentration and the low significant metals concentration condition at the cathode might also cause the formation of a charged advanced species at the cathode compartment. The movement of those charged advanced species towards the anode and of the significant metals towards the cathode depends upon the relative quality of the element and chemical group ions. For economical contamination removal, it is essential to stop precipitation and to possess the contaminants in dissolved kind throughout the electro kinetic method. chemical reaction and reduction reactions are vital once coping with antimonial contaminants like Cr. Cr exists most ordinarily in 2 valence states: powerfulness Cr Cr (III) and hexavalent Cr Cr(VI). Cr (III) exists within the cationic hydroxides like Cr (OH)<sub>2</sub> and it will migrate towards the cathode throughout electro kinetic rectification. However, Cr (VI) exists within the kind of oxyanions like CrO<sub>4</sub> that migrate towards the anode. The valence state depends on the soil composition, particularly the presence of reducing agents like organic matter and Fe(II) and/ or oxidizing agents like Mn(IV), therefore it's vital to grasp the valence state of metals and their possible redox chemistry. Conductor acquisition procedures are necessary to induce favorable chemistry and, as a result promote bigger rectification potency.

### **3 Materials Used For The Test**

#### **3.1 Sand**

Sand is a composite material formed by the disintegration of rocks. Sand is a product of several factors such as impact of climate, elevation and slope of terrain, organisms, and the sand's parent materials or original minerals interacting over time. It continuously undergoes to numerous physical, chemical and also biological processes. Sand can be classified into different types based on their particle size and properties.

##### **3.1.1 Properties of sand**

- a) Location: Susodanhatti (Near Desur Belagavi)
- b) Color: Light yellow
- c) Specific gravity: 2.6

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- d) Bulk density: 1.6 g/cm<sup>3</sup>
- e) Voids Ratio: 0.81
- f) Porosity: 0.44

Most sands have a dry bulk density (density of sand taking into account voids when dry) between 1.1 and 1.6 g/cm<sup>3</sup>, while the specific gravity of sand should be between 2.6 to 2.85.

**3.1.2 Wet sieve analysis**

Wet sieving is a process which is used to evaluate particle size distribution of a granular materials. In this method it may be possible that it may undergoes to sample loss, but the percentage loss is very small and wet sieve analysis is accurate and efficient as compared to Dry Sieve analysis.

**Table 1.** Seive Analysis

Sl No	Particle Size (mm)	Mass Retained (gms)	% Mass Retained	Cumulative mass retained	% Finer
1	4.75	1.01	0.239	0.239	99.761
2	2.36	8.81	2.088	2.327	97.673
3	1.18	55.33	13.114	15.441	84.559
4	0.6	80.01	18.963	34.405	65.595
5	0.425	39.05	9.255	43.660	56.340
6	0.3	41.19	9.763	53.422	46.578
7	0.15	124.07	29.406	82.828	17.172
8	0.075	57.25	13.569	96.397	3.603
9	Pan	15.2	3.603	100	0
		421.92			

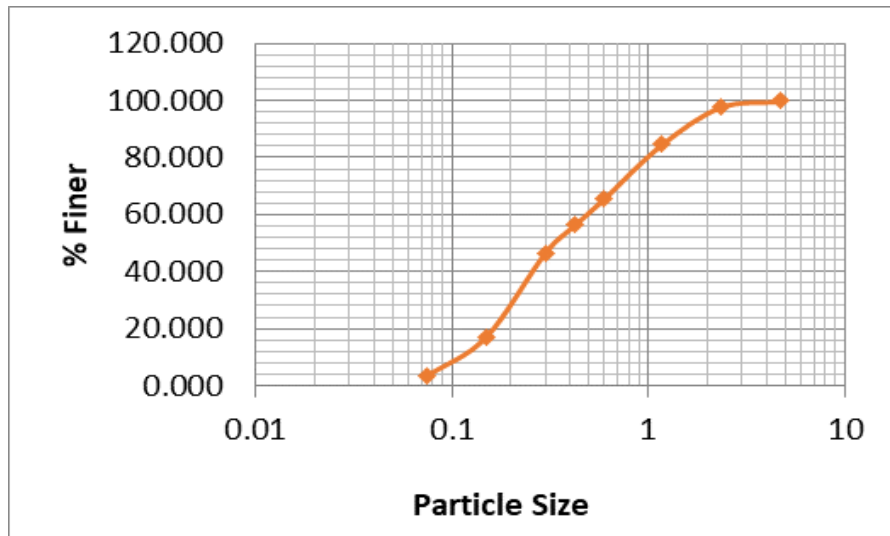


Fig.1. Particle size distribution curve

### 3.1.3 Uniformity Coefficient (Cu) and Coefficient of Curvature (Cc) of Sand

The uniformity coefficient (Cu), curvature coefficient (Cc) and the effective size (D10) are the grading characteristics of the sand. These are the geometric properties of a grading curve that describe a particular type of Sand.

### 3.1.4 Grade curve characteristics

Grade size distribution curve is used to identify the type of soil by using different particle sizes: D60, D30, and D10. This graph plotted on logarithmic scale by taking particle sizes on x axis and percentage finer on y axis. This is plotted based on the observations from sieve analysis conducted on the sand sample.

D10 is called as effective particle size. This means that 10% percent of the particles are finer and 90% of the particles are coarser than D10. This is the size at 10% finer by weight.

Similarly, D60 is the particle size at which 60% of the particles are finer and 40% of the particles are coarser than D60 size. D30 is the size at which 70% is particles coarser than D30 size and 30% particles are finer by weight. Hence, D10, D30 and D60 are used to determine the measures of grade size distribution curve.

We can know particle size for D10, D30 and D60 from the fig.1

$$D_{10} = 0.1$$

$$D_{30} = 0.23$$

$$D_{60} = 0.5$$

### **3.1.5 Measures of gradation**

The uniformity coefficient (Cu) and the coefficient of gradation (Cc) are the measures of sand gradation. These coefficients help to classify the sand as well graded or poorly graded ones.

### **3.1.6 Uniformity coefficient (Cu)**

The uniformity coefficient (Cu) is defined as the ratio of D60 to D10. A value of Cu greater than 4 to 6 classifies the sand as well graded. When Cu is less than 4, it is classified as poorly graded or uniformly graded Sand.

$$Cu = D60/D10$$

$$Cu = 0.5/0.1 = 5$$

Uniformly graded Sand has identical particles with Cu value approximately equal to 1. A uniformity coefficient value of 2 or 3 classifies the sand as poorly graded. Beach sand comes under this category.

Higher value of Cu indicates that the sand mass consists of sand particles with different size ranges.

### **3.1.7 Coefficient of curvature (Cc)**

$$Cc = D30^2/(D10*D60)$$

$$Cc = 0.22 / (0.11*0.5) = 1.058$$

For the sand to be well graded, the value of Cc must range between 1 and 3.

As we got the values of Cu and Cc in range 4-5 and 1-3 respectively. We can conclude that the sand is well graded.

## **3.2 Leachate**

A leachate is a liquid that extracts insoluble and suspended particles while passed through any matter or any other substance of the material. Leachate is a widely used word in the environmental sciences. It has a particular meaning which tells that the liquid, that has dissolved or entrained in environmentally hazard substances may enter the environment. It is most often used in the situations of land-filling of putrescible or industrial waste.

In the tapered environmental situations leachate is a liquid material that drains from land or a mass material and contains significantly raised concentrations of unwanted material derived from the material that it has passed through. Leachate sample is collected from an unsegregated municipal solid waste treatment and disposal facility at No.19, 40 and 42 of Turamuri village, Belgaum Taluk and District in an area 66 acres which is around 10 Km away from the city which is established by city Corporation of Belagavi [7]. Fig.2 and fig.3 shows the images of the site.





**Fig.2.** Waste landfill site at Turmuri



**Fig.3.** Leachate Collection

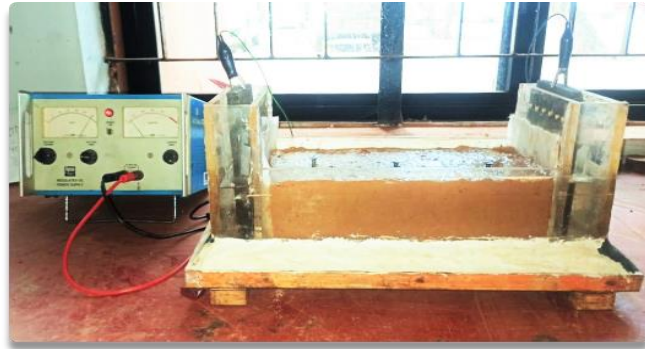
The steady pH for the leachate used lies between 7.6 and 8.9 with total suspended solid (TSS) of 0.22. The pH value is an indicator of the fight of the leachate, aerobic and anaerobic conditions in the waste. Leachate in a mature landfill exhibits pH values greater than 7 while for leachate that has undergone some stabilization is expected to have neutral pH value [2]. The ammonia contents in leachate samples lies between 216 mg/L and 288 mg/L. Ammonia is created from the decomposition of waste mainly proteins. Leachate used in this study is indicated by strong odor and black in color. A similar finding was cited by Jaafar et al. in describing leachate collected from Air Hitam landfill. The measured COD values in leachate ranged between 96 and 112 mg/l.

**Table 2.** Properties of Lechate

Parameters	Values
Color	Black
pH	7.6-8.9
TSS	0.22
ammonia	216-288
COD	2880-3360
Heavy Metals	Ni(106), Cr(277.3), Mn(269), Cd(0.16)

## **4 Methodology**

### **4.1 Electrokinetic treatment**



**Fig.4.** Electrokinetic Treatment Setup

- Power Supply: A Power supply of 30V has been provided to increase the current flow eventually which is noted down.
- Electro kinetic treatment Box  
Dimensions: Length: 30cm, Width: 12.7cm, Height: 8.8cm.
- Graphite Electrodes  
Length: 15.24cm, Width: 7.62cm, Thickness: 12mm.

### **4.2 Procedure**

1. Clean the electro kinetic treatment box. Cover the perforated walls of the box with filter paper and a muslin cloth.
2. Pour the slurry of the soil saturated with the leachate to its liquid limit or saturated with leachate, 14% of the soil. Make sure that there are no air voids or soil lumps. If any, they should be eliminated.
3. Pour water on the either sides of the box as shown in the figure.
4. Insert the copper electrodes in the water connected to the DC supply with the help of cables. A constant voltage of 30V is provided.
5. The water on the either sides of the box are changed periodically and the Current flow is noted before and after changing the water.
6. The test is carried out for a period of three days with a time, interval of 12hours.

Electrolysis reactions (conversion of electrical energy in the form of chemical potential energy) create  $\text{OH}^-$  and  $\text{H}_2$  at the Cathode and  $\text{O}_2$  and  $\text{H}^+$  at the anode. These reactions create a base front near the cathode and an acid front Near the anode that migrates from one to the another. The increase in the mobility of cationic species is aided by acid front, but in some soils, it can retard electroosmosis. The hydroxide front must be controlled to avoid the premature precipitation of some target metal

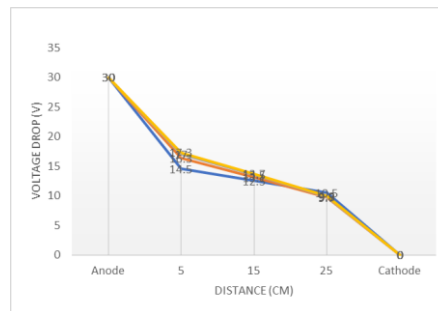
ions. Unfavorable conditions at a site includes oil with a high ion exchange capacity, high buffering capacity, high naturally occurring organic content, very low moisture content and salinity. The presence of subsurface metal structures or utilities can also adversely affect performance.

## 5 Results

### 5.1 Variation of current and voltage



**Fig. 5.** Variation of Current



**Fig. 6.** Variation of voltage drop

Fig.5 Shows the variation of current v/s days. It is observed that initially the Current flow is high. With time, the flow of current through the soil layer started to decrease. As can be seen from Figure 5, the amperage of approximately 100 mA, recorded at the initiation of the experiment, dropped significantly to a level of less than 50 mA, in about 5 days. It shows that the amount of impurities(ions) present in the soil were high at the 1<sup>st</sup> day and as the days passes the impurities are decreased because of which current flow Decreased. Fig 6 shows the variation of voltage drop along the length of the soil. as shown in the graph voltage drop takes place from anode to cathode.

This variation clearly shows that the migration of ions is taking place and the soil is decontaminating.

**Table 3.** Variation of pH and Conductivity

Parameters		pH	Conductivity
Day 1	Anode	2.45	8.60 ms/cm
	Cathode	12.2	4.65 $\mu$ s/cm
Day 2	Anode	3.56	4.30 ms/cm
	Cathode	11.84	1.9 $\mu$ s/cm
Day 3	Anode	4.8	2.86 ms/cm
	Cathode	9.54	0.8 $\mu$ s/cm

Above table shows the pH and conductivity Variations observed during the test. During the experiment at the end of each day pH and conductivity of the solutions present at the anode and cathode are tested and the values are noted down. It is observed that due to electrolysis oxidation occurs at the anode, generating an acid front while reduction takes place at the cathode producing a base front. These electrolysis reactions cause the pH to decrease at the anode and increase at the cathode. As the anode and cathode compartments solutions are replaced with the distilled water each day and the experiment is continued till the variation in the pH of solution should be very less or nearly equal to the pH of distilled water. Correspondingly the conductivity values are also noted down and variation is observed. Initially the conductivity values were high and it decreased to low at the end day it shows that the impurities are reducing due to which the conductivity is decreasing.

## **6 Conclusions**

From the laboratory experiments conducted on the soils, it is evident that this technique may be further developed and used efficiently and effectively as a soil treatment technique. This is especially so when there is an immediate need for treatment and enhancement of physical properties of soil in a locality, within a short time frame, in the maintenance and protection of infrastructure. Similarly, this technique can be used to remediate and clean up already salinised land to prepare for new infrastructure development. Electrokinetic treatment may also support localized revegetation programs, for instance, along roadsides to protect pavements and embankments.

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