Electrochemical Remediation of Oil Contaminated Fine Grained Soil

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ABSTRACT— *This paper aims to investigate the effectiveness of electrochemical method as a remediation technique for oil contaminated clayey soil. Experimental setup consists of a square box made up of acrylic sheets, pair of graphite electrodes and a DC power supply. Soil contaminated by diesel engine oil was taken for the testing. The contaminated soil was treated under the current generated by a constant potential. Results showed that a significant reduction in oil content was obtained after electrochemical treatment. Compared to conventional methods followed for contaminated soil remediation, electro chemical treatment was found to be an effective method.*

Keywords— Efficiency, Electrochemical method, Oil contamination, Remediation

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1. INTRODUCTION

Oil contamination is a severe threat to the environment and is considered as a hazardous pollutant to soil. It has been proven that there will be significant changes in soil properties due to these oil products and become unsuitable for construction purpose. Due to industrialization, the consumption of oil products is increasing day by day. Chances of oil pollution are occurring mainly during exploration, transportation and processing of oil. In recent years many soil remediation technologies have been studied and practiced all over the world. The techniques using for remediation depend on type of soil, type of contaminant and economy. In the case of fine grained soil contaminated by oil products, conventional remediation techniques like chemical oxidation, soil washing etc. are not practical everywhere .Incineration and engineered landfill systems are not economical. The application of bioremediation techniques depend on the level of pollutant. Also the technology applied should be environmental friendly and safe to human health. Electrokinetic technologies are adequate alternative to remove pollutants from the soil. Higher efficiency, environmental safety and applicability to a wide range of contaminants are main advantages of this technology.

2. LITERATURE SURVEY

Electrochemical stabilization was used as a means of preventing ground failure in railroads**,** heavy metal removal and sediment treatment. Direct current technologies are very efficient for the mineralization of many organics with low energy expenditure[5][7].In the case of very fine soils, like clays, because of their low permeability and higher sorption capacity it is very difficult to treat with conventional methods. The feasibility of electrokinetic technology on the remediation of mixed-waste contaminated rail road soil, contaminated by lubricant oil and zinc was also investigated[13].The effectiveness of using electrochemical treatment method for fine grained soil has been proved by many researchers[1][5][6][7].

Problematic soils have been distributed all over the world as expansive soils, dispersive soils, high compressible clays, marine clays, sensitive clays, quick clays, saline/sodic soils, soft peat and etc[12].Due to the presence of electrically and chemically active minerals, electro chemical methods are applicable to contaminated clayey soils for remediation. The negative charge on the soil particles cause the interaction between the dipolar water and soil. These interactions cause to bond molecules that make up a layer of diffuse double layer, where bond is known as the Van der

Waals bonds. Electric field from the electrokinetic process act as a driving forces on the bond between water molecule and clay particle. Since the bond formed between water and soil particle is weak, water molecules are released from this bond when electric field is stronger than the bond[**11**].

The formation of an electric double layer at then charged surface of clay particles explains the processes mobilizing the charged particles via three phenomena: electromigration, electroosmosis, and electrophoresis.Electromigration is the movement of ions and ionic complexes in a soil solution due to an applied electric field. Electromigration is the most important transport mechanism aiding electrochemical remediation.The ions move towards the electrode of opposite charge: anions towards the anode and cations towards the cathode[5]. Electroosmosis is the bulk transport of water in a porous media in an applied electric field[7]. Electroosmotic conductivity of fine grained soil is very low, so electric field is a much more effective driving force for the fluid through it than that hydraulic gradient[11],[14]**.**The final phenomenon affecting electrochemical remediation is electrophoresis. It is the transport of particles in an applied electric field and includes all charged particles (e.g. colloids, clay particles, organic particles) **[15].**

3. MATERIAL PROPERTIES

3.1 Soil Properties

The soil used for experimental work has been collected from Vallarpadam, Cochin area. The samples were obtained from the depth of 6.00 m below the existing ground elevation. Wet soil sample was kept on a water dish for 2 weeks to know whether it contains any oil traces. The clay was classified as highly compressible (CH) according to the IS Soil Classification System.

The soil was air dried for 3-4 weeks. Soil is powdered and passed through 425micron IS sieve and stored in air-tight container. Pulverized soil was mixed with sufficient quantity of water so that the water content is optimum (25.5%, from Proctor compaction test). Addition of oil to soil was considered as percentage of weight of oil with respect to dry weight of soil. Inorder to contaminate the soil artificially, known quantity of diesel oil(9% dry weight of soil taken) is added to soil water mixture and mixed thoroughly by hand. Samples were kept in an air tight plastic covers for 2 weeks at room temperature to simulate aging effects. The properties of soil after air drying is shown below in Table1.

Table 1: Soil Properties

Properties	Value
Consistency limits	
Liquid limit (%)	75
Plastic limit (%)	26.8
Shrinkage limit (%)	24.6
Compaction characteristics	
Optimum moisture content (OMC (%))	25.5
Maximum dry density (MDD ,kN/m^3)	15.2
Unconfined compressive strength (kN/m^2)	69

3.2 Oil Properties

To contaminate the soil artificially, the multi-grade diesel engine oil (Bharat Petroleum, Diesel Oil) was used. The properties of diesel oil are shown in Table.3.2

Table 2: Engine Oil Properties

Characteristics	IS 1448	Typical Figures 15W-40
Appearance	--	Clear & Bright
Colour, Visual Observation	--	Red
Density @15°C, gm/ml	P:16	0.8911
K.V at 100° C, cSt	P:25	14.1
Copper Corrosion @ 100° C for 3 hrs	P:15	1a
Flash Point, (COC), °C	P:69	240
Viscosity Index	P:56	113
Pour Point, °C	P:10	-24

4. METHODOLOGY

In order to conduct the experimental investigation of electrochemical soil decontamination from oil, an experimental setup to simulate two dimensional flow of oil through soil was developed and several laboratory tests were performed. Experimental setup consists of a rectangular reactor 25cm long, 25 cm wide and 25 cm high, made up of 1cm thick transparent acrylic sheets, a pair of graphite electrodes and a stabilized DC power supply (providing 30V and 2A). The electrodes were rectangular in shape having dimensions 10 cm length, 3cm width, 1cm thickness. In order to avoid chances of bursting of the bottom plate, clamping rods were fastened to all sides of rectangular box. After positioning the electrodes in the setup, the space between them was filled with the contaminated soil. The soil was compacted to achieve the density of field soil and a constant potential was applied across the electrodes. These experiments were performed at room temperature. Conditioning fluids were not used to adjust the soil pH and buffering capacity. Across the electrodes, no hydraulic gradient was applied. Hence, this test considered as unenhanced electrochemical remediation. Contaminated soil was tested under a constant voltage of 12 V (specific voltage 0.6 V/cm, since centre to centre distance between electrodes is 20cm).

Figure 1: Experimental setup for electrochemical remediation

4.1 Test Configuration

At the end of the trial, the soil specimen was removed from the test setup and was sliced into different segments, in the longitudinal and transverse directions. Each segment was analyzed for soil moisture content, pH and oil content in order to study the extent of electrochemical reactions at different distances from the electrodes.
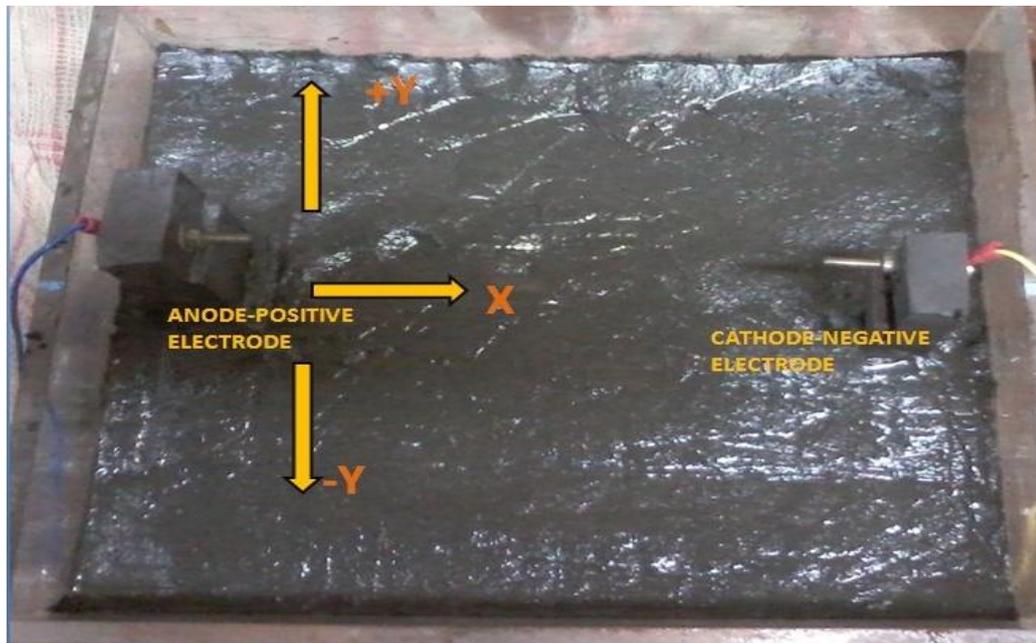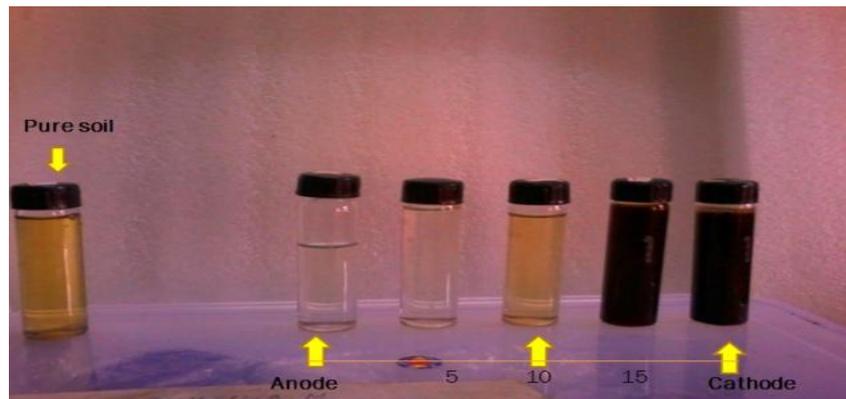

Figure 2: Top view of electrochemical cell with directions

Figure 3: Leachate collected at different distance from electrodes

4.2 pH

The pH of soils was determined by following conventional procedure described by many researchers. Soil was air dried and sieved to remove large particles. 5 g of the sieved soil was taken and mixed with distilled water and stirred in a magnetic shaker. Thereafter, the mixture was allowed to stand for 30 minutes and sieved through Whatman No.1 filter paper. The pH meter was inserted into filtrate and the pH of the soil was measured

Figure 4: pH meter

4.3 Water content

Water content was calculated by oven drying method. Since the flash point of engine oil used is 240^0C, heating to temperatures of about 105^0C, does not cause vapourization of oil.

4.4 Oil content

Oil content was measured by the following procedure. Air dried soil (1gm) was weighed and mixed with n-hexane. Initially, oil was extracted using hexane by shaking it in a mechanical shaker for 30 minutes. Thereafter, the mixture of soil, oil and hexane was filtered into a beaker of known weight through a Whatman No.1 filter paper. The oil content of the filtrate was determined after allowing the mixture to heat, in order to vapourize hexane, so that the remaining oil content could be measured [16]

Figure 5: Soil+oil+hexane mixture and mechanical shaker

Figure 6: Filtration of sample

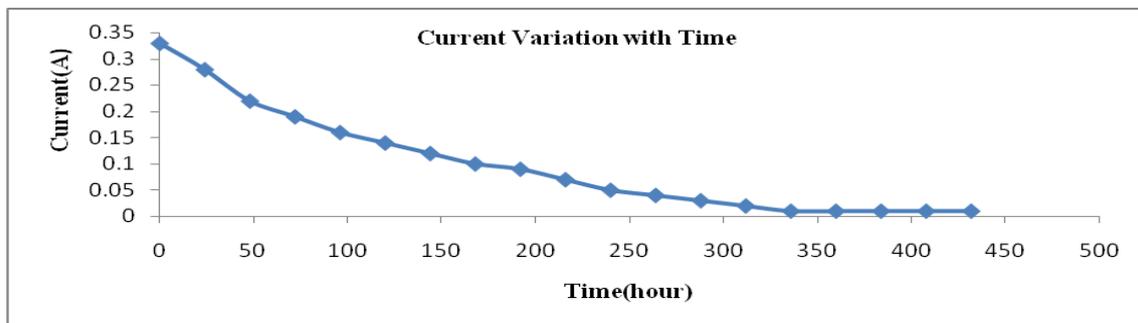## 5. TEST RESULTS

5.1 Current Variation with Time

Figure 7: Current Density Measured at Different Time Interval

The electric current was checked at regular time intervals. As shown in Figure 7, current started to decrease after the application of the potential gradient. Current densities can also be affected by changes in soil pH, which influence chemical precipitations and dissolutions[5]. As during the tests the electric current showed to start to decrease a few days after the beginning of the tests. The electroosmotic flux is significant only in the initial stages of treatment.

5.2 Soil pH

Initial pH of soil was 5.1. At the end of the tests, it is found that ,the soil pH is increased at the cathode and decreased at the anode. It might be the result of hydrolysis of water. Hydrogen ions will be generated at anode and hydroxyl ions will be at cathode according to following equations [5],[6],[7].

At cathode:$4H_2O+4e^-{\rightarrow}2H_{2(g)+}4OH^-$…………………..(1)
At anode : $2H_20{\rightarrow}O_{2(g)+}4H^+ +4e^-$………….……….(2)
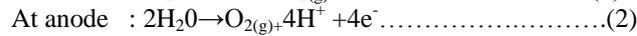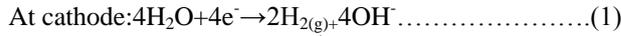
Any significant change in temperature was not observed during the test. Temperature changes will be significant only in the case of higher value of current flow [5].

5.3 Soil Moisture Content

The soil humidity at the beginning of the tests was about 25.5%. The final water content near the anode ranged from 10.6% and slightly higher moisture contents in other section cathode 30.03%.In Y direction towards anode moisture content is decreasing, towards cathode, it is increasing.

5.4 Soil Oil Content

Initially oil content was 9%.After electrokinetic treatment the oil content is reduced to5%at anode and 2%at cathode. In X direction oil content is gradually decreasing towards cathode.In Y direction,towards anode, increase in oil content was observed. From the cathode oil content is gradually increasing in Y direction.
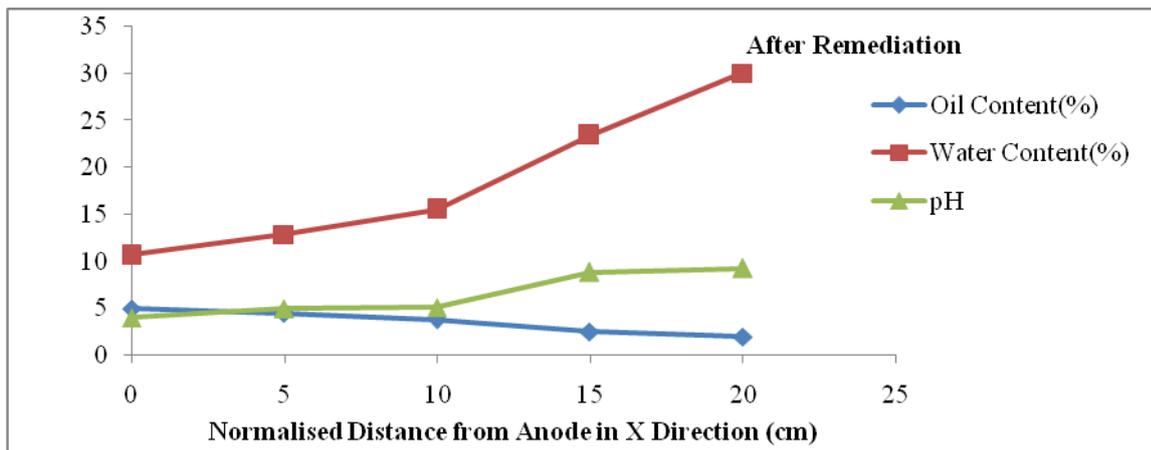

Figure 8: Changes in Oil Content,Water Content and pH After Electrochemical Remediation in X Direction
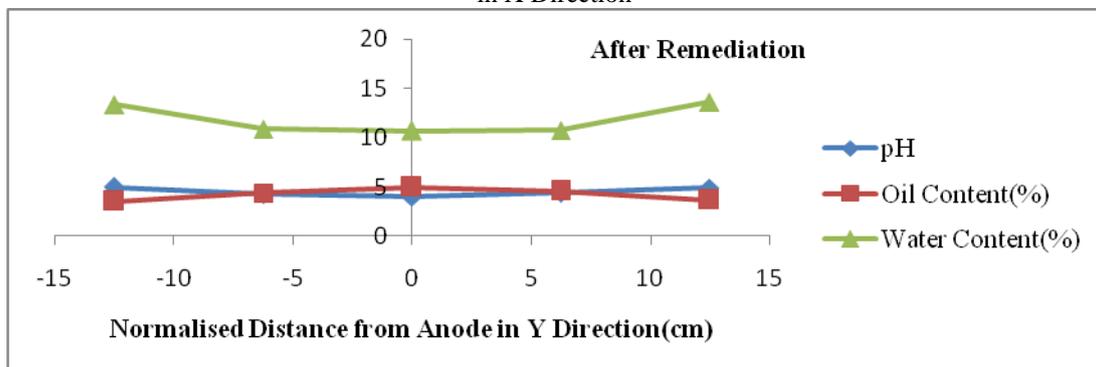

Figure 9: Changes in Oil Content,Water Content and pH After Electrochemical Remediation in Y Direction at Anode
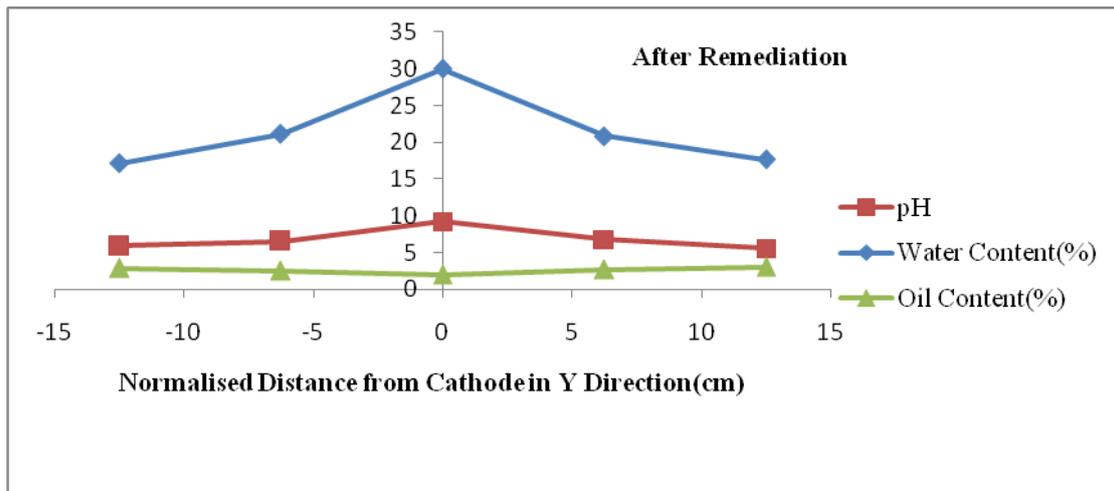
Figure 10: Changes in Oil Content,Water Content and pH After Electrochemical Remediation
in Y Direction at Cathode

6. CONCLUSION

The tests performed allowed to evaluate the effectiveness of using electrochemical reactions for the remediation of oil contaminated soil. According to the results achieved, electrochemical remediation proved to be effective for the remediation of fine-grain soils contaminated by oil. From electrochemical treatment following results were obtained.

- It is observed that about 80%oil at cathode and 45%oil at anode were removed within 18 days by using 0.6V/cm specific voltage.

- Overall efficiency of the treatment and restoration of properties lies in the range of 65-75%.

However higher specific voltages will result in higher energy expenditure and require more complicated setups for real scale applications[5].

7. ACKNOWLEDGEMENT

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