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Research Paper

EFFECTS OF CONTAMINATIONS IN BEARING CAPACITY OF SOIL

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ABSTRACT

This paper presents the details of a simple laboratory Electrokinetic remediation model used for removal of chemical effects from an unsaturated soil by keeping in view the plane source model in which the velocity of flow was considered only in one direction and dispersion in two direction. The traced water injected in the saturated porous medium is collected in a set of observation locations and the depositions of contaminants are collected by electrodes attached in the instrument and the bearing capacity is determined with and without contaminants. The obtained values of bearing capacity are checked with the values from graphs drawn and also from thumb rule given by Terzaghi, Prandtl and Meyerhof. This paper also focuses on the model studies of sorption and desorption of Arsenic on different unsaturated soils. It was also observed that maximum decontamination of contaminant occurred within 4 hours (average) in gravel unsaturated soil, where 2 hours in clayey unsaturated soil. The decontamination efficiency range of model was found 65% to 85% depending upon particle size of the unsaturated soil and the concentration of the contaminant.

Keywords: presents, dispersion, decontamination, concentration

Introduction

This paper presents the results of an experimental investigation undertaken to evaluate different purging solutions to enhance the removal of contaminants, particularly arsenic from low buffering clay, specifically alluvial, during electrokinetic's remediation. Experiments were conducted on alluvial spiked with As (III) and As (IV) in concentrations of 100mg/kg, and 50mg/kg, respectively, which simulate typical electroplating waste contamination. A total of five different tests were performed to investigate the effect of different electrode purging solutions on the electrokinetic's remedial efficiency. A constant DC voltage gradient of 1 V/cm was applied for all the tests. The removal of soluble arsenic in water from the unsaturated soil using tap water as the purging solution was very low. When I M acetic acid was used as the purging solution in the cathode, the removal of arsenic was increased to 20%, respectively. Using 0.1 M ethylene diamine tetra acetic acid as the purging solution in the cathode, 83% if the initial As was removed. A sequentially enhanced electrokinetic remediation approach involving the use of water as a purging solution at both the anode and cathode initially, followed by the use of acetic acid as the cathode purging solution and a NaOH alkaline solution as the anode purging solution was tested. This sequential approach resulted in a maximum removal of As (III) and As (IV) 68-71, and 71-73%, respectively. This study shows that the sequential use of appropriate electrode purging solutions, rather than a single electrode purging solution, is necessary to remediate multiple soluble arsenic in water in unsaturated soils using electrokinetics.

SOIL PROFILE HISTORY

The Archaean crystallines comprising granites, gneisses and charnockites from the major litho units of the Chhattisgarh state. They form discontinuous, unconfined and semi-confined to confined aquifers. All the districts are covered partly or wholly with these crystalline formations. Weathered mantle and fractures form the main repository of ground water in these rock formations.

Next major litho in the area are the Proterozoic, arenaceous, argilaceous and calcareous rocks of Chhattisgarh, Indravati, Nawagarh and Sukma Groups. Ground water potential zone is restricted to weathered caverns, fracture and formation contacts. The karstified–calcareous rocks are more productive than compact -sillicfied arenaceous rocks. The gypsiferous Maniari shales are highly porous and form potential aquifers. The stratification in the Indravati basin is more intense and has high ground water potential. These rocks are seen in all districts except Koriya, Surguja, and Jashpur. Rocks belonging to Gondwana Super Group consisting of Sandstone, Shale with or without coal are the third major litho unit of this state. The sandstones have primary and occasional secondary porosity. Free flowing artesian conditions are reported from localized pockets. Ground water with temperatures up to 50° Centigrade has been recorded frorn Tamnar of Raigarh districts. These formations are seen in Jagdalpur, Korba, Koriya, Surguja and Raigarh district. The unconsolidated formation of Quaternary age comprising alluvium, clay, silt, laterite etc. form thin and extensive unconfined aquifers in several isolated patches and near major river courses with thickness up to 30 m bgl.

EXPERIMENTAL METHODOLOGY

It is a schematic of the electrokinetic's test setup (please refer to plate) used for the study. The setup consists of an electrokinetics cell, two electrode compartments, two electrode reservoirs, a power source, and a multimeter. The Plexiglas cell had an internal diameter of 5.8cm and a total length of 35cm. to control the glow into the cell each electrode compartment consists of a valve, a slotted graphite electrode, and a porous stone. The electrode compartments were connected to either end of the cell using screws. The electrode reservoirs were made of 3.8cm inner diameter Plexiglas tubes and were connected to the electrode compartments using Tygon tubing. Exit ports were created in the electrode the electrolysis of water escape. The other end of thes gas tubes was connected to the reservoirs to collect any liquid that was removed along with the gases. A power source was used to apply a constant voltage to the electrodes, and a multimeter was used for monitoring. The load is applied on the top of the unsaturated soil through piston ball and bearing capacity is determined for contaminated and non-contaminated unsaturated soil.

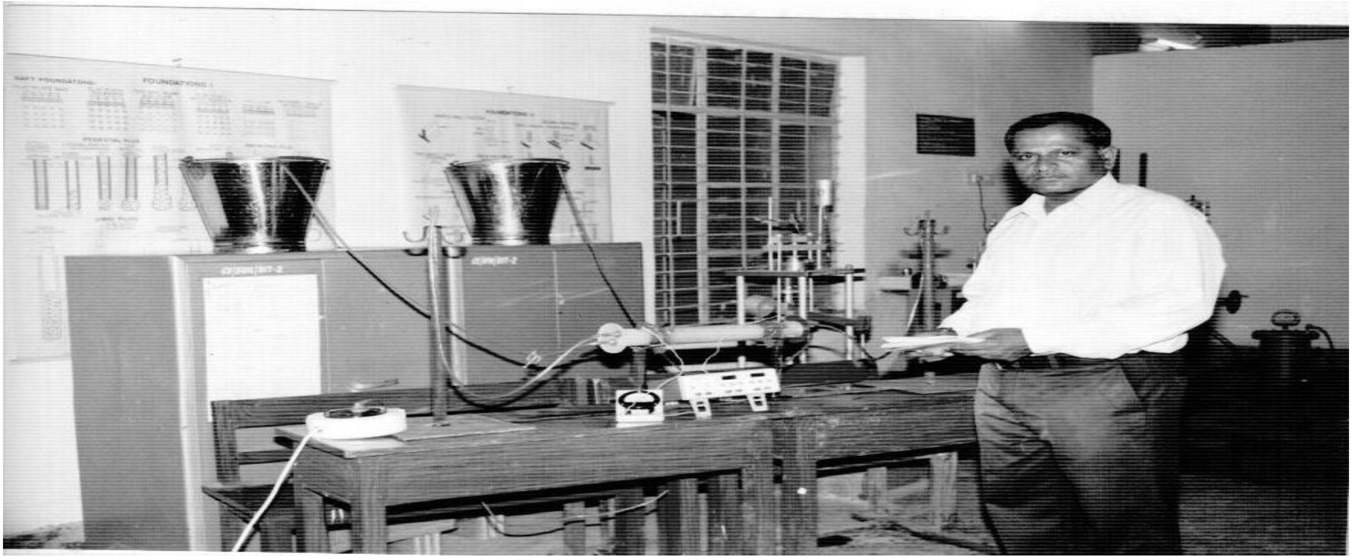

Plate: Photographs of Electrokinetic's Model:

LITERATURE REVIEWS:

Investigators	Purpose	Unsaturated soils	Contaminants	Used Water	Purging Solutions Cathode Anode	Electric Potentials (VDC/cm)
Saitchek (2002)	To evaluate the use of different surfactants for the electrokinetic's removal of phenanthrence from kaolin	Kaolin	Phenanthrene	Deionised water	Deionised Water	1
Reddy (2002)	To evaluate the effect of the initial form of chromium on its remedial efficiency form different contaminated clays	Kaolin & Glacial till	Cr (VI), Cr (III) and Cr (VI) and Cr(III) combined	Potable Water	Potable Water	1
Reddy et.al. (2001b)	To evaluate the effect of Cr, Ni and Cd, when combined together compared to when these contaminants existed by themselves.	Kaolin & Glacial till	Cr (VI), Cr(III) and Cd(II)	Potable Water	Potable Water	1
Chinthamreddy (1999a)	To evaluate different purging solutions for the removal of multiple heavy metal contaminants from kaolin	Kaolin	Cr(VI), Ni(II) and Cd(II)	Potable Water	Potable Water	1
Reddy et al. (1997)	To evaluate the effects of unsaturated soil composition on the removal of Cr(VI)	Kaolin, glacial till, Na-montmorillonite	Cr (VI)	Deionised Water	Deionised Water	1.0
Reddy and Shirani (1997)	To investigate the removal of cationic contaminants from glacial till	Glacial till	Na and Ca as surrogates	Deionised water	Deionised water	0.785, 1.05

This paper presents a brief review of literature on experimental investigation and mechanism of contaminated soils. The load deformation behavior of contaminated soils and various factors affecting it have been critically reviewed and gaps have been identified. Mechanism of alluvial Soil, root soils and arsenic bearing soils (both oriented and randomly distributed) has been discussed and the gaps in theoretical approaches have been identified and therefore an approach has been presented. The limitations and gaps in available literature along with the objective of the present study have also been defined. Arsenic contamination of soil and drinking water is a source of major concern in various places around the world. Ingesting arsenic can cause various cancers and is very harmful to the immune system.(Case study: Arsenic, 2003) . Ongoing research into causes of high arsenic levels are still being conducted and there is some evidence of how arsenic contaminates the ground and soil.

Arsenic has been identified in at least 784 of the 1,662 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2005). However, the number of sites evaluated for arsenic is not known. It is mostly found in nature in minerals, such as realgar (As_4S_4), orpiment

(As_2S_3), and arsenolite (As_2O_3).and only found in its elemental form to a small extent. There are over 150 arsenic-bearing minerals (Budavari et al. 2001; Carapella 1992). While arsenic is released to the environment from natural sources such as wind-blown dirt and volcanoes, releases from anthropogenic sources far exceed those from natural sources. Anthropogenic sources of arsenic include nonferrous metal mining and smelting, pesticide application, coal combustion, wood combustion, and waste incineration. Most anthropogenic releases of arsenic are to land or soil, primarily in the form of pesticides or solid wastes. However, substantial amounts are also released to air and water. Approximately 80% of the total amount of arsenic that is released to the environment from anthropogenic activities is released to the soil. The major anthropogenic sources contributing to arsenic in soils include the application of pesticides and disposal of solid wastes from fossil fuel combustion and industrial processes. organoarsenical pesticides (e.g. monosodium methanearsonate, disodium methanearsonate) applied to soils are metabolized by soil bacteria to form alkyI arsines and arsenate (HOOD, 1985;US DHHR, 1992). Land application of sewage sludge has proven to be another source of arsenic in soil. While arsenic has been observed in soil at various hazardous waste sites, it is not always obvious that it was a result of the waste site or from natural causes.

MECHANISM OF ARSENIC MOBILSATION IN SOIL:

Arsenic mobilisation mechanism is a much debated (Nickson et al., 2000 and references therein) yet unsettled issue. The mobility of arsenic at a given area could be affected by many factors such as the redox conditions(Eh), pH, presence of the competing anions and complexing ions, salinity, clay content, grain size and composition of the soil and sediment, presence of other metal ions, and the non metals such as S and P in the system. Its transport and uptake may be further affected by groundwater flow rate, nature of the plume below the subsurface, contaminant phases (dissolved, adsorbed, etc.) and temporal variation of above parameters enumerated above. Arsenic is reported to occur mainly in two forms in groundwater i. e., as arsenopyrite (FeAsS), usually in clay-silt sequences or as adsorbed phases onto the Fe-oxyhydroxides (Thornton, 1994; Bodek et al, 1988). Heavier soils with a higher clay content and hydrous oxide content adsorb more arsenic than do lighter sandier soils with low clay content. In addition, arsenicals react with ions in solution, such as iron, aluminum, calcium, and magnesium, but may also include manganese and lead.

Hence a soil may be saturated relative to some compounds and not others. The pH of the soil will affect the solubility of these compounds; therefore, changing the soil ph may affect each arsenical's solubility.

Al-tabba (1994) effect of particular contaminant, as its concentration is increased, on some of the geotechnical properties of natural and compacted Clay. The arsenic disulphide contaminant is a soluble organic polymer in the form of poly, which has wide applications in industry as a solvent and aggregate stabilizer with coconut oil. The research work presented here forms an initial part of a research programme at Chhattisgarh state investigating the effects of various types of Arsenic contaminant solutions on clay structure hence its geotechnical properties are changed.

According to Meegoda et.al. (1994), the compressibility of fine-grained soil is changed due to changes in effective stress brought about by changes in the internal arrangement of particles due to physical forces & changes in environmental conditions.

TESTING PROCEDURE:

Approximately 650 gm of dry soil was used for each test. Arsenic as source of As (III) and As (V). The amounts of chemicals to yield the desired concentration were weighed and dissolved separately in deionized water. These contaminant solutions were then added to the soil and mixed thoroughly with a stainless steel spatula in container. The amount of deionized water that was used was according to the testing program in table (1). The contaminated soil was then placed in the electrokinetic cell in layers and comacted uniformly using a hand compactor. The weight of soil required in the reactor was determined and the soil-water-contaminant mixture was equilibrated for 24 hours. The electrode compartments were then connected to the electrokinetic filter papers were inserted between the electrodes and the porous stone and soil. The electrode **c**ompartments were connected to the anode and cathode reservoir using Tygon tubing. The reservoirs were then filled with deionized water. Throughout the test duration, the elevation of water in both the reservoirs was monitored and adjusted to prevent a hydraulic gradient forming across the specimen. The electrokinetic cell was then connected to the power supply and a voltage gradient of 5 VDC/cm was applied to the soil sample. The electric current and voltage across the soil sample as well as the water flow at the anode and cathode reservoir was measured different time periods throughout the duration of the experiment. Each test was terminated after operating for 120 hours. At the completion of each test, aqueous solutions from the anode and cathode reservoirs and the electrode assemblies were collected and the volumes measured. Then, the reservoirs and the electrodes assemblies were disconnected, and the soil specimen was extruded from the cell using a mechanical extruder. The soil specimen was sectioned into five parts at distance of 0 to 4 cm (section 1), 4 to 8 cm (section 2), 8 to 12 cm (sectio 3), and 12 to 15.5 cm (section 4), and 15.5 to 19.1 cm (section 5), from the anode, respectively. Each part was weighted and preserved in a glass bottle. The total cost of the apparatus was Rs 5000/-.

OBSERVATION TABLES

Table 1 below shows the testing program and the variables used in the five different electrokinetic's tests.

Table 1. Five different electrokinetic's tests.

Test	Desigantion	Contaminant Concentration	Initial Moisture Content (%)
1.	RNK-I	As(III) – 100, As(IV) – 50.	30
2.	RNK-II	As(III) – 100, As(IV) – 50.	50
3.	RNK-III	As(III) – 100, As(IV) – 50.	70
4.	RNK-IV	As(III) – 100, As(IV) – 50.	30
5.	RNK-V	As(III) – 100, As(IV) – 50.	30

Table 2. Composition and Properties of Alluvial Unsaturated soil of Koudikasa Site (Distt.-Rajnandgaon)

PROPERTY	VALUE
Mineralogy	Kaolite: 100%
Particle size distribution (ASTM D 422)	
Gravel	78%
Sand	12%
Silt	08%
Clay	02%
Atterberg Limits (ASTM D 2487)	
Liquid limit	56.00%
Plastic limit	30.40%
Plasticity index	25.6%
Specific gravity (ASTM D 854)	2.60%
Moisture – unit weight relationships	
Maximum dry unit weight	15.4 KN/M^3
Optimum moisture content	29%
Hydraulic conductivity	1.0*10^{-8}
Cation exchange capacity (ASTM D 9081)	1.0-1.6 meq/100g
pH (ASTM D 4972)	5.9
Organic content (ASTM D 2974)	Nearly Nil
USCS classification (ASTM D 2487)	CL

CONCLUSIONS

This paper provides an overview of electro kinetic remediation and presents the result of five bench-scale electro kinetic experiments performed to investigate the effect of initial moisture contents and initial contaminant concentration on contaminant migration and removal in soils. The first three experiments were conducted using different moisture contents of 30, 50 and 70, with same contaminants As (III) and As (IV) at contamination of 100 mg/kg and 50 mg/kg, respectively. Then two additional experiments were conducted at same contaminant concentration but with same moisture content. Overall, it was concluded that the initial moisture content affects the electro kinetic process but it does not significantly influence the migration and removal of arsenic contamination and the result indicates that the initial contaminant concentration affects the migration and removal, but the effect is dependent on the type and concentration of the arsenic contaminants that are present.

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