A Study on Contaminant Transport through Soil

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Abstract. Soil in ecosystem is contaminated by various environmental activities taking place in day today life. Major contaminants in soil are chlorides, fluorides, nitrates, iron, silicates etc. The present study deals with the transportation of contaminants like sodium chloride (Nacl) and sodium fluoride (NaF) in soil by advection-diffusion method. The tests are carried on soil mixed with varying percentages of sand from 10% to 40%. In the present study the dosage of contaminants i.e. Nacl and NaF are varied from 0.1N to 0.4N respectively. The column of size 60cm is utilized and upto 40cm height soil is compacted from the base. The solutions of additives are pumped at the rate of 0.208 ml/sec. The time of flow at the entry and exit of soil column is observed and solution is collected from the exit point to evaluate percentage absorption by the soil. For different normalities of sodium chloride such as 0.1N, 0.2N, 0.3N, 0.4N corresponding relative concentrations obtained are 0.078, 0.073, 0.062, 0.056 and similarly relative concentrations for sodium fluoride are also determined. The soil absorption capacity increases with increasing the concentration of contaminants. For all normalities of contaminants the nature of results obtained follows the footprint of breakthrough curves.Strength parameter of contaminated soil is evaluated by unconfined compressive strength test. The strength of sodium chloride contaminated soil is increased irrespective of concentrations and decreased with increase in percentage addition of sand. For sodium fluoride contaminated soil reduction in strength is observed.

Keywords: Soil Column, Sodium Fluoride, Sodium Chloride, Breakthrough Curves.

1 Introduction

Contaminants regardless of whether as a harmful liquid or as a solution of a harmful chemical type solvate in water are sometimes overflow at ground surface by accidentally. A liquid contaminant will pass downward through the surface zone, finally reaching a bottom-line water table. Various organic, physical and chemical processes may take place along its surface zone. Once reaching the water level, the liquid contaminant will be transported through the water level to the latter's outlets. Along its way towards the water level outlets are rivers, lakes, springs or pumping wells, the concentration decreases by various processes, physical, chemical and biological. The executive of the water level must carry both management of water quantity as well as water quality. Definitely, the best action is to make every possible effort, relevant technological means, regulation and education, to prevent contamination. Contamination of groundwater has become a key environmental issue particularly with the ever increasing demand for energy and resource development. Geotechnical engineers as result are more and more faced with the difficult task of designing waste management facilities that prevent the contamination of groundwater. To design such facilities requires an understanding of processes that govern tile transport of contaminants. The complexities of designing these structures are compounded by the lengthy required design life which may be hundreds of years or more [2, 7]. The main moto of the work is to analyze the mass transport phenomenon from a geotechnical point of view and to demonstrate the significance of the processes by analyzing the contaminant migration through soil media. The transport processes is based on the equations of flow laws. The flow laws combined the mass balance equation and casing where reduction of contaminant. It is called as the general governing differential equation for contaminant migration. Advection and dispersion are two basic processes. Advection means the contaminant will move along with the moving water. Dispersion means contaminant is mixed with the water or flow system. The advection and dispersion transport processes can be studied by a steady flow of water in a long the soil column [16].

2 Materials and Methodology

The soil sample is collected from Bagalkot at a depth of 1.5m beneath the ground surface. Soil is classified as a inorganic soil with a group symbol CI as per IS classification system. To ease the flow of contaminant through the soil different percentages of sand is mixed , further solutions of sodium chloride (Nacl) and sodium fluoride (NaF) with different concentrations is added to determine absorption capacity. Sodium chloride is having a 1:1 ratio of sodium and chloride ions and molar mass of 58.443 g/mol. Sodium fluoride an inorganic ionic compound, its molar mass is 41.988 g/mol. The Table 1 gives a summary of laboratory tests which are conducted as per relevant IS codes.

2.1 Sample Preparation for Soil Column Experiment

For the present study the transparent acrylic pipe of 60 cm height and diameter of 10 cm is used. For calculated maximum dry density and optimum moisture content, the soil sample is compacted upto the height of 40cm from bottom of the column and outlet is provided to collect the solution. The schematic of experimental setup is portryed (Fig 1). The soil is placed in four layers and each layer is compacted using light compaction. To increase the permeability of base soil sand is used randomly with varying percentages of 10%, 20%, 30%, and 40% by weight.

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Table 1. Basic properties of the soil

Properties	Values
Specific Gravity	2.58
Grain Size Distribution (%)	
Sand	37.2
Silt and Clay	62.8
IS Soil Classification	CI
Consistency Limits (%)	
Liquid Limit	39
Plastic Limit	18
Plasticity Index	21
Compaction Characteristics	
Optimum Moisture Content (%)	16.4
Maximum Dry Density(kN/m^3)	18.6
pH	7.86

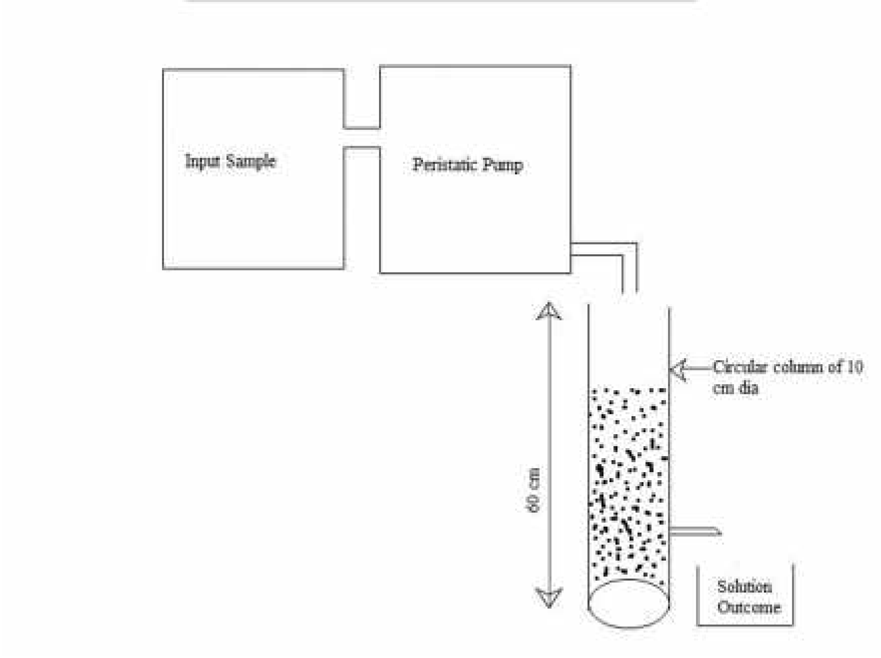

Fig. 1. Schematic of experimental Setup.

2.1 Preparation of Solutions

Sodium Chloride and Sodium Fluoride are weighted according to their molecular weights. For 0.1 normality 5.844 gm of Nacl is dissolved in 1000 ml distilled water to prepare solution of contaminant, similarly 4.2 gm of NaF is dissolved in 1000 ml distilled water to prepare solution [7]. The solution is pumped with peristatic pump with keeping constant flow rate of 0.208 ml/sec in to the column. The initial time is noted down at the start of pumping and also at different intervals of distance up to 30 cm without disturbing the column until solution oozes out from the outlet and final time is recorded.

2.2 Sample Preparation for Unconfined Compressive Strength Experiment

The unconfined compressive strength test is conducted for both contaminated soil samples. The modules are tested after 7 days, 14 days and 28 days of curing period.

3 Results and Discussions

3.1 Breakthrough Curves

Breakthrough curve represents the plot between time and the measured solute concentration at the outlet of soil column. If the supplied solute source at the inlet has a constant concentration and it remains throughout the experiment, it is known as continuous solute source. The plot between relative concentration and number of pore volumes (Fig.2) [15]. Based on the soil column experiment the relative concentrations to time plots are obtained.

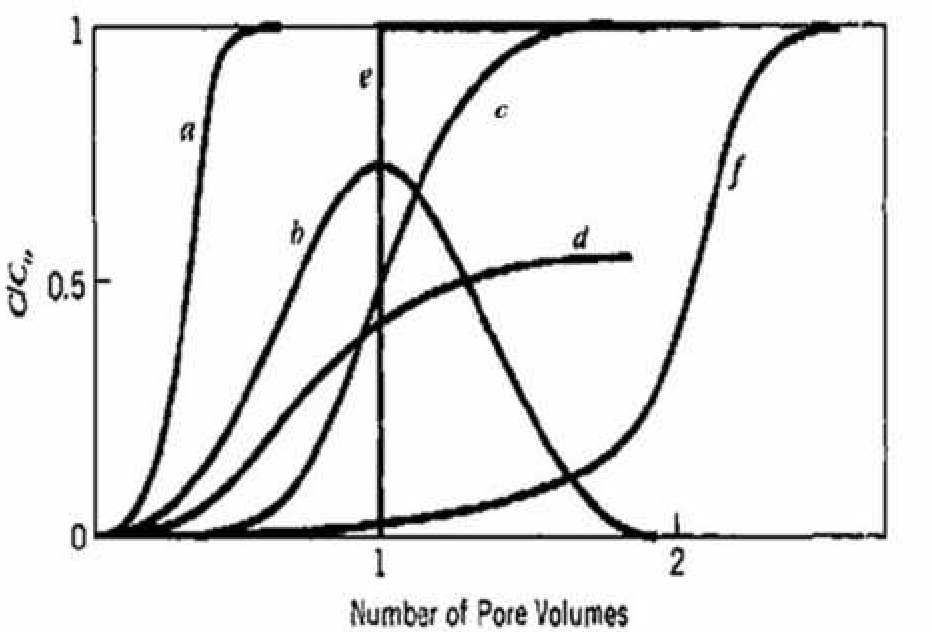

Fig. 2. Different types of breakthrough curves.

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The variation of relative concentration for sodium chloride solutions with different normalities to base soil with respect to time is plotted (Fig.3). For 0.1N initially relative concentration was zero, as time period increases the relative concentration incremented from 0 to 0.078 and reaches peak. Further increase in the time resulted in the reduction of relative concentration and remains constant throughout, similar trend is observed for all other normalities.

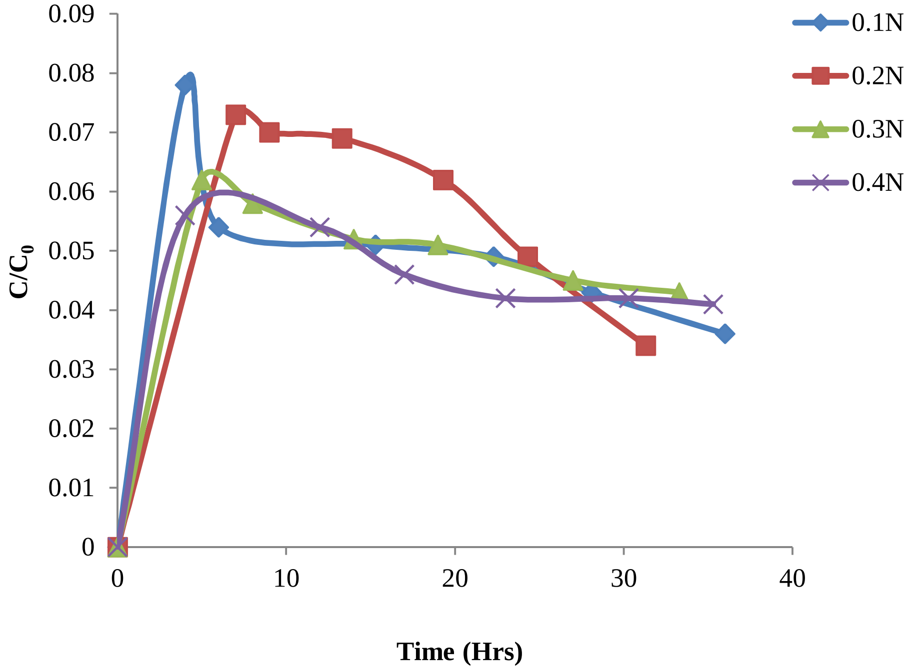

Fig. 3. Variation of relative concentration with time.

The breakthrough curves for sodium chloride solutions with time to the different normalities to base soil mixed with 10% sand and base soil mixed with 20% sand with time respectively (Fig. 4 and Fig. 5). Initially relative concentration was zero as percolation period increases the relative concentration increased for 0.1N of about 0.0884 and reaches the peak. For different combinations of soil+sand similar trend is attained. Further as time period increases the relative concentration reduced and remained constant irrespective of normalities. The variation of relative concentration for sodium fluoride solutions with different normalities to base soil with respect to time is depicted (Fig. 6). Initially relative concentration was zero, as time increases the relative concentration increased for 0.1N gets increased till 0.04 and reaches the peak. Further relative concentration increased with time increment and remained constant, similar nature for all normalities is observed.

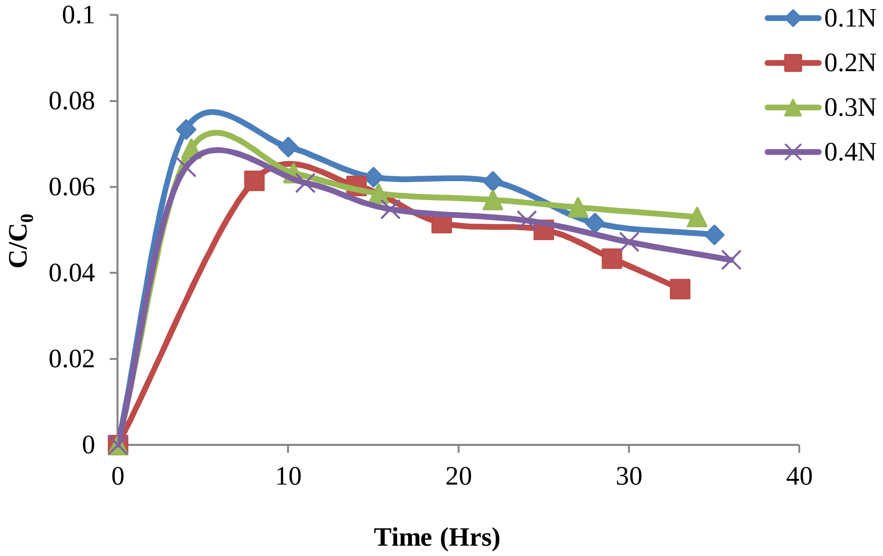

Fig. 4.Breakthrough curves of sodium chloride contaminated soil + 10% sand.

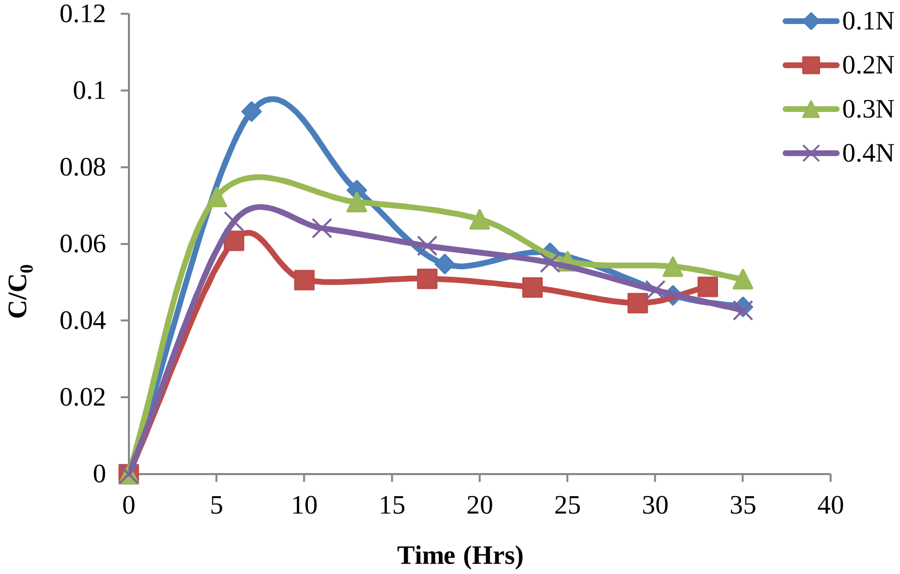

Fig. 5.Breakthrough curves of sodium chloride contaminated soil + 40% sand.

Plot showing the variation of relative concentration for sodium fluoride solutions with different normalities to base soil with respect to time is depicted (Fig. 6). Initially relative concentration was zero as percolation period increases the relative concentration increased for 0.1N of about 0.03 and reaches the peak. For different combinations

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of soil+sand similar trend is attained. Further as time increases the relative concentration increased and remained constant throughout similar trend is observed for all normalities.

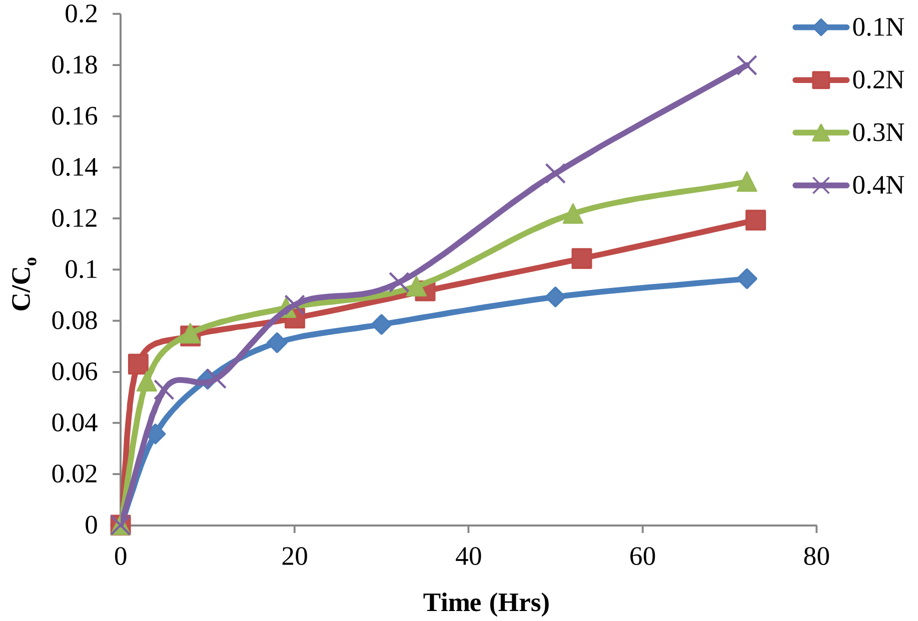

Fig. 7. Variation of relative concentration with time.

The breakthrough curves for sodium fluoride solutions with time to the different normalities to base soil mixed with 10% sand and base soil mixed with 20% sand with time respectively is obtained (Fig. 8 and Fig. 9). Initially relative concentration was zero as percolation period increases the relative concentration increased for 0.1N of about 0.03 and reaches the peak. For different combinations of soil+sand similar trend is attained. Further as time increases the relative concentration increased and remained constant throughout similar trend is observed for all normalities.

3.2 Unconfined Compression Strength of Different proportions

The unconfined compressive strength is carried out for four different contaminated soil samples i.e., soil, soil+10% sand, soil +20% sand, soil +30% sand and soil +40% sand. Unconfined compressive strength of sodium chloride contaminated soil and sodium fluoride contaminated strength are depicted (Fig. 10 and Fig.11) respectively. The strength of sodium chloride contaminated soil is increased irrespective of concentrations and decreased with increase in percentage addition of sand. For sodium fluoride contaminated soil reduction in strength is observed.

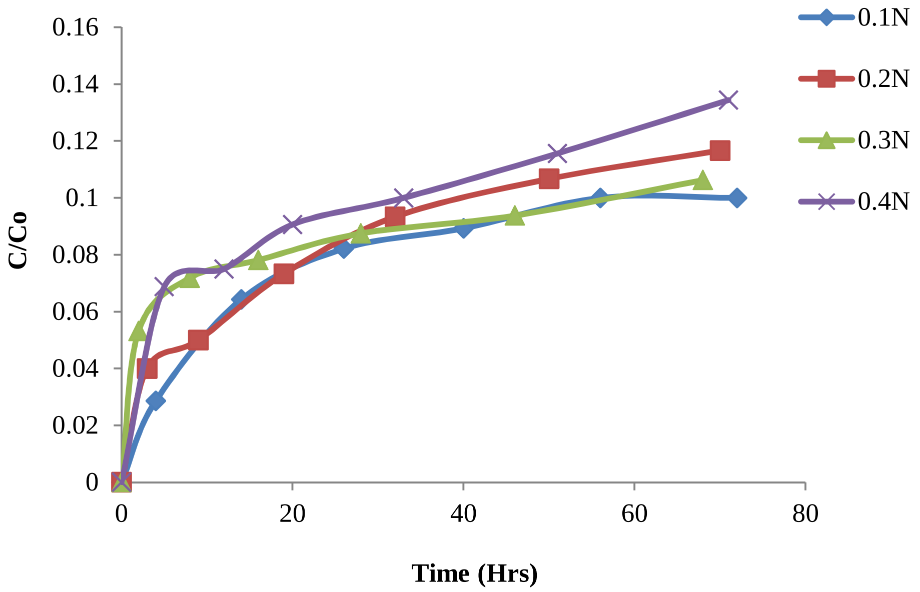

Fig. 8. Breakthrough curves of sodium fluoride contaminated soil+10% sand.

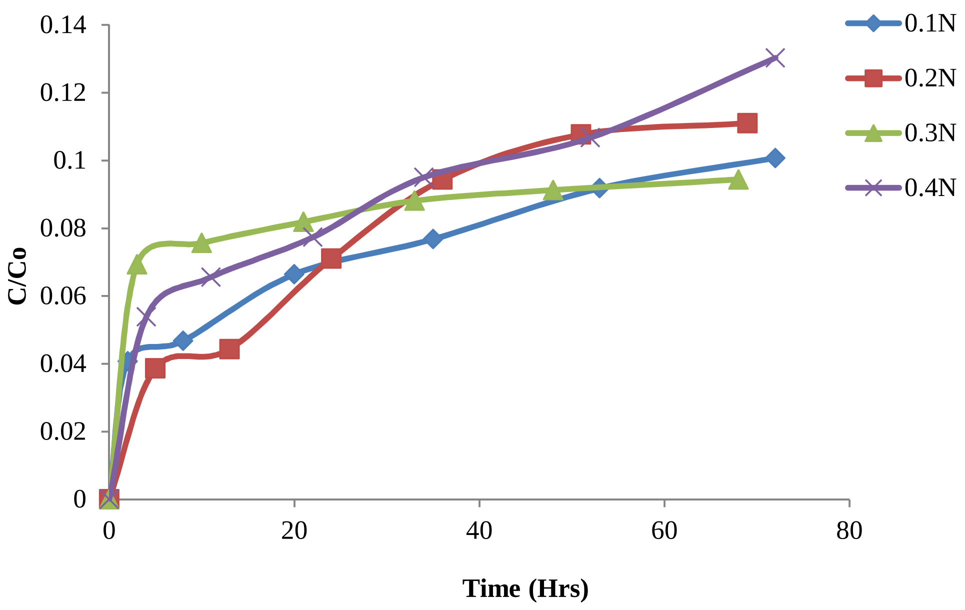

Fig. 9. Breakthrough curves of sodium fluoride contaminated soil+ 40% sand.

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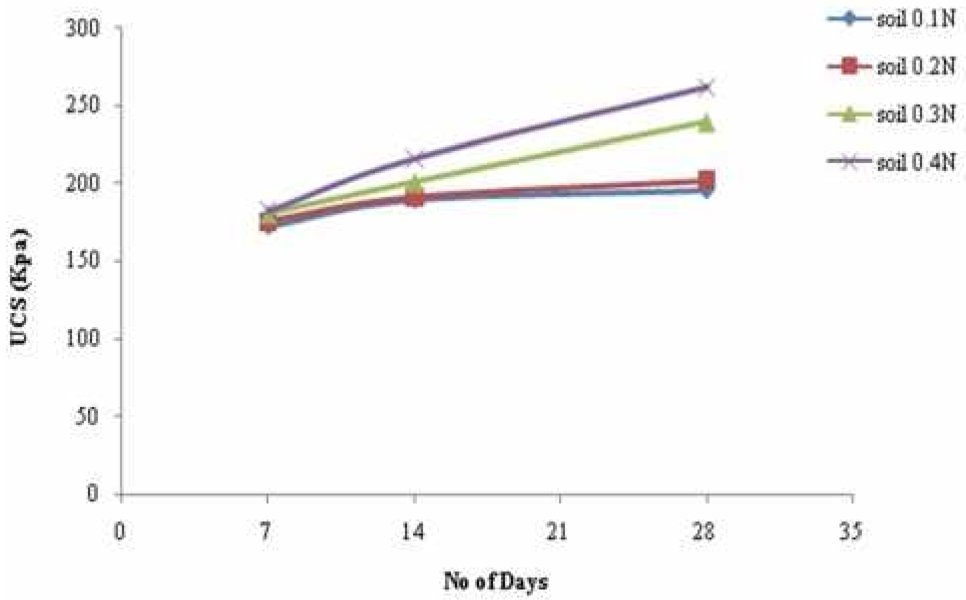

Fig. 10. UCS of contaminated soil with different concentrations Sodium chloride.

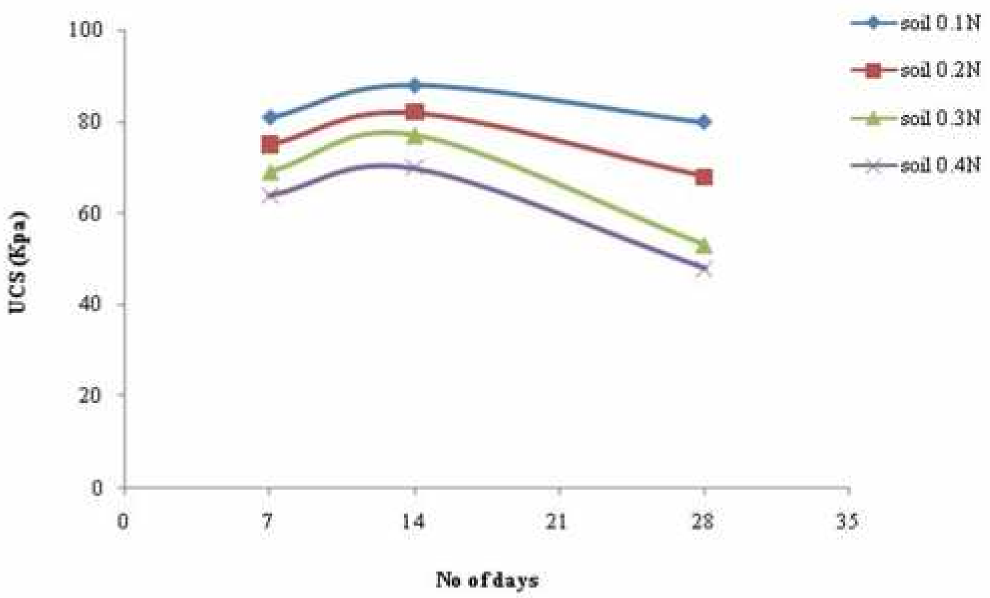

Fig. 11. UCS of contaminated soil with different concentrations Sodium fluoride.

4 Concluding Remarks

The following conclusions are drawn based on the results of laboratory studies.

1. The soil absorption capacity increases with increase in concentration of contaminants.
2. The result indicates a linear increase in relative concentration for sodium chloride contaminated soil. Different relative concentrations for different combinations are for soil 0.28, 0.32for soil +10% sand,0.33 for soil +20% sand,0.33 for soil+30% sand,0.34 for soil+40% sand.
3. For sodium fluoride contaminated soil the relative concentrations obtained were 0.58 for soil, 0.52 for soil+10% sand, 0.52 for soil+20% sand, 0.52 for soil+30% sand, 0.52 for soil+40% sand. The trend of decrement in relative concentration is observed for all different normalities of sodium fluoride contaminated soil.
4. As porosity increases the flow path for the contaminants increases and spreads through the soil longitudinally and as it spreads laterally the concentration of contaminant reduces.
5. For all normalities of contaminants the nature of results obtained follow the footprints of breakthrough curves.
6. The strength of UCS increased for sodium chloride contaminated soil samples. For soil the UCS value obtained for 0.4N is 262 kPa and for different combinations the strength increased.
7. For different combinations of sodium fluoride contaminated soil the UCS value corresponding to 0.4N is 48 kPa, soil+10% sand is 56 kPa, soil+20% sand is 54 kPa, soil+30% sand is 49 kPa, soil+40% sand is 44 kPa.
8. It provides a much closer approximation of the physical conditions and chemical processes occurring in the field. When soil is contaminated by sodium chloride, strength of the soil is increased. It can be concluded that sodium chloride is not a harmful contaminant and it can be used as a stabilizing agent. The strength of sodium fluoride contaminated soil is decreased with longer curing period.

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