Influence of Pharmaceutical Effluent on the Physico – Chemical Behavior and Geotechnical Characteristics of Clayey and Silty Soils

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Cover Page Footnote
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1. INTRODUCTION

Rapid industrialization has resulted in enormous production of liquid and solid wastes. Indiscriminate disposal of such wastes, especially on land has caused serious environmental problems (Fang, 1986; Fang, 1997). Failure of foundation/structures due to ground contamination/accidental spill of chemicals etc., has been reported (Reddy, 2008, Peirce et al 1987, Sivapulliah et al 1994; Deane et al 1999; Mitchell, 1976; Norihiko Miura et al. 1998 and Sridharan and Rao 1979). It has been established that the inorganic and organic pollutants present in industrial effluents, in general, affect various geotechnical characteristics of fine-grained soils (Abd-Allah and Srorr1998; Kamon et al 2002; Gallipol et al 2003 and Reddy et al 1999). It is therefore necessary to study and understand the soil-pollutant interactions and the effect of contaminants/industrial effluents on various geotechnical properties, for various engineering applications. Critical review of published literature has revealed that only very few studies have been reported on the effect of industrial effluents, especially on natural soils and that the focus so far has been on understanding the effect of pure chemicals on commercial soils (kaolinite and bentonite). Further, effort has not been directed to simulate the process of contamination close to the field conditions in the laboratory studies (Murugaiyan et al 2004; Murugaiyan et al 2005a; Murugaiyan et al 2005b; Murugaiyan et al 2008). Hence, the influence of pharmaceutical effluent (industrial type) on the physio-chemical behaviour and on the geotechnical characteristics (index properties and unconfined compressive strength) of five soils (two commercial soils and three natural soils) have been experimentally investigated.

2. MATERIALS AND METHODS

Basis of selection of various effluents and soils and their characteristics, details of the chosen experimental set-up and the experimental scheme adopted for the study are presented below:

2.1 Selection of Effluent

During early 2000, isolated instances of once fertile lands becoming barren within a year, due to indiscriminate discharge of effluents on land in certain parts of Pondicherry, India, were reported. Hence an extensive survey to cover industries located around 50-75 km radius from the above region were undertaken and a few types of process industries which produce amino acid, surfactant and pharmaceutical effluents, which are considered to be potentially polluting and whose impact on the environment needs constant monitoring, were identified. Critical review of literature has also revealed that studies on the effect of surfactant effluent, on soils are rather rare or scarce. In view of the above, pharmaceutical effluent was selected for the present study and is referred to as E3, throughout this paper.

2.1.1 Source and Collection of Effluents

Samples of the effluents were collected from a process industry located near Pondicherry region of Union Territory of Pondicherry, South India. Effluent characteristics are known to vary with time (i.e. Day/season etc.), which has to be realized in obtaining their characteristics and in using them for various investigations. Generally one year period is expected to cover a full cycle of operation and realize the various operating conditions of a typical process industry. Hence the
samples of the untreated effluent were manually collected continuously for a period of one year, at intervals of every three months, from the equilivalisation unit (i.e. before treatment) of the industry in 50 liters plastic cans (air tight containers) and then brought to the laboratory where they were stored in a deep freezer. The temperature of the deep freezer was maintained at 4°C, to avoid degradation and subsequent change of concentration of pollutants present in the samples of the effluent. The effluent thus collected and stored, were diluted to get the required concentrations for characterizing them and for carrying out the experimental investigations contemplated in the present study.

2.1.2 Effluent Parameters

The effluent parameters, namely, pH , electrical conductivity, alkalinity , total solids, total dissolved solids (TDS), total volatile solids (TVS), chloride, sulphate, chemical oxygen demand (COD) and biological oxygen demand (BOD), were estimated for characterizing the various effluents, in ‘as collected form’ and for the outflow from the experimental set-up ie. soil-column (described later), at specified intervals. The above parameters are comprehensive and sufficient to characterise the effluent and to understand their effect on chosen soils. The procedure for the analyses of the above parameters was followed as per Standard Methods (APHA, 2005). The characteristics of surfactant effluent (E2) are presented in Table 1.

Table 1. Characteristics of Pharmaceutical Effluent (E3)

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Parameter</th>
<th>Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>pH</td>
<td>3-4</td>
</tr>
<tr>
<td>2.</td>
<td>COD</td>
<td>2100-4200</td>
</tr>
<tr>
<td>3.</td>
<td>BOD</td>
<td>2000-2600</td>
</tr>
<tr>
<td>4.</td>
<td>Total Solids</td>
<td>24500-34500</td>
</tr>
<tr>
<td>5.</td>
<td>Total Suspended solids</td>
<td>6000-9500</td>
</tr>
<tr>
<td>6.</td>
<td>Total Dissolved solids</td>
<td>18500-25000</td>
</tr>
<tr>
<td>7.</td>
<td>Volatile Suspended Solids</td>
<td>14000-28000</td>
</tr>
<tr>
<td>8.</td>
<td>Kjeldahl nitrogen (as N)</td>
<td>8 – 15</td>
</tr>
<tr>
<td>9.</td>
<td>Phosphate (as P)</td>
<td>9 – 12</td>
</tr>
</tbody>
</table>

*All parameters except pH and electrical conductivity are in mg/L

2.2 Commercial and Natural Soils - Selection and Source

Two types of commercial soils (kaolinite and bentonite) which are easily available in the market were chosen for the present study to determine the independent behaviour of the above commercial soils when they are artificially contaminated with the surfactant effluent, without any interference effects, which are generally present in natural soil sample. The above two types of commercial soils (denoted as CS1 and CS2, henceforth) are known to cover the entire range of flow characteristics normally encountered in natural soils. The experimental results from the artificial contamination of commercial soils CS1 and CS2 will serve as ‘control’or ‘reference’ for comparing their behaviour with that of natural soils, evaluated under identical conditions. Commercial soil samples were procured from a marketing agency located in (Madras) Chennai, India, where the samples are available in air tight polythene bags weighing 50 kg, and brought to
the laboratory for carrying out the various investigations. The soils thus procured were stored in the air tight containers under room temperature, until actual use. In order to investigate the effect of the effluent (E3) on a few natural soils, a preliminary survey of existing soil types of the region (i.e. Pondicherry) was carryout during early 2000 along with scanning of soil profile data collected over several years for general geotechnical investigations and which were available in the Department of Civil Engineering, Pondicherry Engineering College (PEC), Pondicherry, India. Based on the above and the reported results in literature that the influence of effluents are generally predominant only in fine-grained soils from three different locations were identified from this region where such type of soils are available. Representative soil samples from the identified locations were collected in 50 kg capacity air tight polythene bags and brought to the laboratory and stored in air tight containers under normal laboratory temperature, until actual use. The natural soils thus collected are referred to as NS1, NS2 and NS3, in this paper. The analyses of soil samples were carried out as per the procedure detailed in IS: 2720 (1985). The characteristics and classification of the chosen commercial and natural soils are given in Tables 2 and 3 respectively.

2.3 Experimental set-up

2.3.1 Choice of experimental set-up

One-dimensional column method is best suited to understand soil-pollutant interactions, as it permits investigation of soil-pollutant interactions under various flow rates and retention times. Hence, in the present study one-dimensional soil-column method was selected and adopted. Of the several investigators who have adopted one-dimensional soil- column, only Fox and Drewes (1999) have investigated the variation of flow rate and concentration of pollutant(s) with respect to hydraulic travel times. As one of the objectives of the present study is to understand the physico-chemical behaviour of soil-pollutant interactions under various modes of operations, the methodology adopted for Fox and Drewes (1999) was selected from among the various approaches reported in literature. The experimental set-up adopted by Fox and Drewes (1999) was for studying is the characteristics of recalcitrant compounds (DOC- Dissolved Organic Carbon ) in ground water (ie raw water ) through a soil-column. The above soil- column system simulates aquifer conditions in a series of four 1 meter columns (diameter 140mm) and was operated under saturated, anoxic-redox conditions and the soil samples were collected twice a week after flow through each 1 meter column corresponding to hydraulic travel times of approximately 5,10,15 and 21 days . In fact the experiments, conducted by Fox and Drewes (1999) were only under a batch mode of operation and the hydraulic travel times adopted were found to be too large. Hence, the above methodology cannot be considered as a true representation of field conditions relevant to the present study. It was therefore decided to consider the methodology of Fox and Drewes (1999) as a ‘conceptual model’ and modify it to suit the present investigations and to represent field conditions.

2.3.2 Description of experimental set-up

The experimental set-up contemplated for the present study consisted of FIVE batteries, each battery consists of six soil-columns (identical in dimensions) and totaling to thirty) fabricated according to the schematic diagrams shown in Figs. 1 and 2. Fig 1 shows the schematic view of one battery of the experimental set-up consisting of six soil-columns and Fig 2 shows the
schematic view of one soil-column. Each soil column was made by joining 90 mm outer diameter (OD) and 80 mm height PVC pipes with an anti-corrosive coated MS (mild steel) hopper portion with a wire mesh placed between the soil-column and hopper portion. In the hopper portion, an outlet control valve was fixed to regulate the outlet flow, which in turn is connected to a drain outlet (8 mm diameter). A drain pipe was provided to collect the effluent from the drain outlet.

The effluent to the soil-column was fed through a feed tank (140 mm dia x 450 mm height) fitted with an inlet control valve at the bottom and an inlet feed tube (8mm diameter tube) which connects the soil-column to the feed tank.
Table 2: Characterization of Kaolinite (CS1) and Bentonite (CS2)

<table>
<thead>
<tr>
<th>SI No</th>
<th>Soil properties</th>
<th>CS1</th>
<th>CS2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(A) Index properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Liquid Limit (%)</td>
<td>33.0</td>
<td>157</td>
</tr>
<tr>
<td>2</td>
<td>Plastic Limit (%)</td>
<td>20.7</td>
<td>69.0</td>
</tr>
<tr>
<td>3</td>
<td>Shrinkage Limit (%)</td>
<td>9.2</td>
<td>54.0</td>
</tr>
<tr>
<td>4</td>
<td>Volumetric Shrinkage (%)</td>
<td>79.9</td>
<td>99.4</td>
</tr>
<tr>
<td>5</td>
<td>Specific gravity</td>
<td>2.70</td>
<td>2.65</td>
</tr>
<tr>
<td></td>
<td>(B) Sieve analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Hydrometer Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>% of clay</td>
<td>11</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>% of silt</td>
<td>89</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>(C) Proctor compaction test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Maximum Dry Density (kN/m³)</td>
<td>17.7</td>
<td>14.7</td>
</tr>
<tr>
<td>9</td>
<td>Optimum Moisture Content (%)</td>
<td>20.0</td>
<td>24.1</td>
</tr>
<tr>
<td></td>
<td>(D) Strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Unconfined compressive strength (q_u, N/mm²)</td>
<td>0.012</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>(E) Classification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Compressibility</td>
<td>CL</td>
<td>CH</td>
</tr>
<tr>
<td>12</td>
<td>Swell</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

Murugaiyan and Saravanane: Influence of Pharmaceutical Effluent on Clayey and Silty Soils
The battery of six soil-columns were used for the following purpose/(s):

(i) Samples were collected for soil tests and chemical test from separate soil columns marked as ST, CT, respectively.

(ii) Since three effluents were used to study the effect on two types of commercial soils (CS1 and CS2) six soil-columns are used for simultaneous investigation. Hence, two batteries of soils-columns (each battery having 6 soil columns) were exclusively used for investigations on commercial soils.

(iii) For investigating the effect of natural soils (NS1 NS2, NS3) due to one effluent, a battery of 6 soils-columns were exclusively used.

(iv) Altogether five batteries, two for commercial soils and three for natural soils were used for the entire investigations.
Figure 1. Schematic Diagram of the Experimental Set-up

1. Supporting Frame
2. Feed Tank
3. Hopper portion
4. Drain outlet
5. Drain pipe

ST - Soil Test Column
CT - Chemical Test Column
E₂₃ - Surfactant Effluent
S₁ - Soil S₁
S₂ - Soil S₂
S₃ - Soil S₃

Figure 2. Schematic Diagram of the Single soil column of Experimental Set-up

1. Feed Tank (140mm Ø X 450mm)
2. Inlet Control Valve
3. Inlet feed Tube (Ø=8mm)
4. Soil Column (90mm Ø X 800mm)
5. Wire Mesh
6. Hopper Portion
7. Control Valve
8. Drain Outlet (Ø=8mm)
9. Drain pipe (Ø=50mm)
2.4 Experimental scheme

2.4.1 Modes of operation

The fabricated experimental set-up was used for two modes of study, namely (i) batch-mode and (ii) continuous-mode, with varying hydraulic retention times (HRTs). ‘HRT’ is defined as the time taken by the first droplet of the effluent to flow from inlet to outlet of the soil column. The batch-mode was operated to study the chemical equilibrium that gets established between the various types of soils and the pollutants of the effluents, whereas, continuous-mode of operation was aimed at analyzing and reporting soil-pollutant interactions (with respect to HRT) as applicable to field conditions (i.e. discharge of effluent on soil is continuous with varying flow rate and concentration of pollutants). Hence the effect of 8 hr and 16 hr HRT and 25% and 50% concentrations on soil-pollutant interactions were investigated.

2.4.2 Preparation of soil specimen and operating scheme

Soil samples (weighing about 2.7kg) were mixed with effluents, the quantity added corresponds to the respective optimum moisture content (OMC) for each type of soil and to a height of 650...
mm in the respective soil-column. Chemical analysis was carried out on the outlet effluent collected from the soil-columns marked as CT and soil analysis was performed on the soil samples collected from soil-column marked as ST for the respective soils. Soil samples weighing about 300 gm were collected at intervals of 15 days during both the modes of operation. Effluent samples from the drain outlet were collected at intervals of 24 hrs during the batch-mode and at intervals of 8 hr, 12h and 16hr during the continuous mode of operation.

The basis of selection of the various HRTs are: (i) Any process industry is operated in shifts of 8 hours duration. Hence, 8 hours HRT can represent one shift and it also represents a shock-load imparted to the soil (sample) at maximum flow rate and concentration of pollutants; (ii) On the other hand, 16 hours HRT represents a situation where in the flow and the concentration of pollutants are likely to be minimum.

An effluent volume of 1.2 liters was used to fill the feed tanks for batch-mode of operation. However, for continuous-mode of operation, flow rates for the various soils and for the various HRTs considered were calculated based on the porosity of the soil samples at the end of the batch-mode. The flow rates thus arrived at for various types of soils are summarized in Table 4.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Effluent</th>
<th>HRT (hr)</th>
<th>Flow rates (ml/min) for different soil types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CS1</td>
<td>CS2</td>
</tr>
<tr>
<td>1</td>
<td>Pharmaceutical</td>
<td>8</td>
<td>3.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>1.65</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

Soil-pollutant interactions with respect to changes in concentrations of inorganic pollutants (pH, alkalinity, chloride and sulphate, electrical conductivity – EC, total solids – TS and total dissolved solids – TDS) and organic pollutants (COD, BOD, total volatile solids – TVS) with time (in days) for the two modes of operation and for all combination of soils with the pharmaceutical effluent have been critically assessed. As voluminous experimental data on soil-pollutant interactions is available, the results and discussion in this paper is restricted to highlight the unique behaviour of CS2 and its comparison to the natural soils. However, soil-pollutant interactions for all natural soils with that of amino acid effluent are presented comprehensively and discussed. Moreover results in the form of Tables and Figures presented in this paper are meant to highlight salient behaviour only. But, discussion, inferences and conclusions presented in this paper are based on the comprehensive results obtained.
3.1 Soil – Pollutant Interaction: Effect of Retention Times and Concentrations of Effluent

3.1.1 Soil - Pollutant Interaction: Inorganic Pollutants

The pH value was found to vary from 6.8 to 7.6 at various HRTs. The initial organic content is the value corresponding to zero point in the x-axis in all curves. Hydraulic conductivity is governed by the hydraulic gradient, which is maintained by varying the feed flow rate of effluent and its retention time (Fityus and Smith, 1997). The variation of retention time within the soil, influences the chemical behavior of the soil in presence of the organic and inorganic pollutants of the effluent. The effect of retention time and concentrations of inorganic pollutants present in the effluent on natural soils (NS1 to NS3) are determined. Pharmaceutical effluent shows less variation of chloride concentration (i.e. high retention of chloride 600 to 1100 mg/L) due to their artificial contamination on NS1, at 8 hr and 16 hr HRTs at 50 % concentration (Fig. 3). The retention of chloride attains a maximum of (1251 mg/L) on NS1, at 16 hr HRT, and at 50 % concentration. Such a behaviour is generally attributed to the time-dependent chloride adsorption and diffusion on soil mass NS1. The retention of sulphate was found to reach a high value at the end of 8 hr HRT at 50 % concentration. The retention of sulphate on soil NS1 was not found to be influenced by effluent at 16 hr HRT and at 25 % and 50 % concentration. Sulphate retention was found to reach a maximum of 628 mg/L on NS1, due to the effluent contamination. The above behaviour is visualized on the basis of initiation of reaction (i.e. adsorption process) by sulphate on soil NS1.

![Figure 4. Variation of chloride and sulphate for soil – S during batch and continuous mode](http://scholarworks.umass.edu/intljssw/vol2/iss3/4)
The above behaviour is similar to that of surfactant effluent on natural soils (Murugaiyan et al 2005a; Murugaiyan et al 2005b). Moreover, there seems to be a positive influence due to contamination of effluent ie., from worst to better with respect to actual values of SL. The above phenomenon is also found to be similar to that of surfactant on NS1 to NS3.

3.1.2 Soil - Pollutant Interaction: Organic Pollutants

3.1.2.1 COD & BOD

Based on the experimental analyses of soils, authors observed that the pharmaceutical effluent contains only aromatic solvents and compounds and no metals. The organic pollutants, anililine and benzene aromatic compounds are interpreted as Chemical Oxygen Demand (COD) throughout the analyses. The variation in the concentration of COD & BOD was found to be in the range of about 25631 to 119183 mg/L for NS1; 25764 to 120272 mg/L for NS2, till the end of 59 days, till they attained the steady state on the 60th day. However, for NS3, the concentrations (26031 to 114449 mg/L) was found to remain very high till the end of 42 days and thereafter, there was a drastic reduction and remained constant till steady state was attained on the 52nd day (Fig. 4). Variation in COD concentration was found to reach the lowest and highest concentration between 0 – 10 days for NS1 and 0- 20 days for NS3, signifying the fact that the rate of permeation was faster during initial stages of batch mode. This behaviour is comparable to the study reported by Sridharan (1990) for the migration of chlorinated organic compounds (trichloro ethylene) through the unsaturated zone of the porous medium. The COD concentrations of the effluent were found to vary from 108299 to 120812, 108843 to 120812 and 108843 to 120812 mg/L for 8 hr HRT, and 108843 to 227476, 108843 to 229654 and 109931 to 228564 mg/L for 16 hr HRT, respectively, whereas, BOD concentrations were...
found to vary from 26565 to 29531, 26699 to 29769 and 26699 to 29635 mg/L for 8 hr HRT, and 26699 to 55900, 26966 to 56334 and 26966 to 56601 mg/L for 16 hr HRT, respectively, due to artificial contamination on NS1 to NS3. Variations in the concentration of COD/BOD as observed above could be compared to the reported results of Semer and Reddy (1995) respectively, for the remediation of trichloro ethylene (TCE) and benzene biodegradation in a saturated column.

3.1.2.2.1 Total Volatile Solids (TVS)

Variation in the concentration of TVS are shown in Fig. 4 and it was found to be 6.50 to 8.30 mg/L for all the three natural soils, till 3rd day and thereafter, the variation was found to be very less, till the end of batch mode. Hence, it can be taken that the steady state has been attained on the 35th day for NS1, NS2 and on the 20th day for NS3. The interaction of NS3 in the present case is found to be similar when it is artificially contaminated with the amino acid and surfactant effluents (Murugaiyan et al 2008; Fityus et al 1999). Moreover, the results obtained for NS3 is found to have a similar trend with that of Kim et al. (2005) for their experimental study on volatile organic compound (VOC) transport through compacted clay. Characteristics of the pharmaceutical effluent due to artificial contamination on NS1, NS2 and NS3 soils, for 16 hr HRT at 25 and 50% concentrations. Pharmaceutical effluent attained the steady state condition within a period of 17 days for 8 hr HRT and 14 days for 16 hr HRT at 25% concentration, whereas it attained the steady state condition within a period of 17 days for 8 hr HRT and 13 days for 16 hr HRT at 50% concentration.

3.1.3 Effect of on the Index Properties of Soils (Commercial and Natural)

Liquid Limit (LL) and Shrinkage Limit (SL) of Soils

Liquid limit of kaolinite is not significantly affected, due to (artificial) contamination of three effluents considered. Similarly, bentonite (CS2) exhibits identical behaviour with respect to range of liquid limit values attained, due to contamination of the effluent. On the other hand, CS2, has exhibited significant changes with time, at least up to 150 days. The LL of all three soils were found to increase gently up to 30-45 days of contamination, beyond which, LL decreases up to the end of 138 days of contamination. Of the three soils, NS2 (Fig. 5) shows higher values of liquid limit initially, i.e., up to 45 days, than the liquid limit values of the other two natural soils considered. CS1 exhibited a slight increase in SL values i.e. 6-7 whereas; CS2 has shown considerable variation in SL values (i.e. about 6-26), during the period of contamination, which is significant. Highest SL value was found at the end of the period of contamination, which shows that the behaviour of CS2 has changed form ‘worse’ to ‘good’ with respect to SL. The above behaviour is similar to that of the behaviour exhibited by CS2 due to contamination of amino acid effluent (Sivapullaiah 1995, Murugaiyan et al 2004, Murugaiyan et al 2005b, Murugaiyan et al 2008). On the other hand, CS1 had remained unchanged, which is also similar to the behaviour of CS1 due to contamination amino acid effluent. The SL of NS1 to NS3 exhibit lower values due to contamination of pharmaceutical effluent.
3.1.4 Effect on the Shear Strength of Soils (Commercial and Natural)

The UCC values of the uncontaminated soils are given against zero value in x-axis. The UCC values generally show a moderate increase up to 60 days of contamination and thereafter, decreases gently, for all the five soils. The above behaviour may be attributed to the combined predominant role of sulphate and chloride in flocculating the particles and hence leading to increase in the strength. However, beyond the above initial period, exchange of ions may have ceased and hence would have resulted in dispersion of particles leading to reduction in strength. The above behaviour holds good for all the five soils considered.

![Figure 7. Variation of UCC with time due to artificial contamination of Pharmaceutical effluent on commercial (CS1 & CS2) and Natural soil (NS1 – NS2)](image)

*Figure 6. Variation of Liquid limit for soils during batch and Continuous mode*

*Figure 7. Variation of UCC with time due to artificial contamination of Pharmaceutical effluent on commercial (CS1 & CS2) and Natural soil (NS1 – NS2)*
4. CONCLUSION

(i) Pharmaceutical effluent shows ‘higher retentivity’ of chloride and sulphate in the soil mass due to artificial contamination on CS2 (at 8 hr HRT and 50% concentration). (ii) Organic content (COD) is completely retained in the soil mass CS1, after 8hr HRT till the end of 16hr HRT, when it is artificially contaminated by pharmaceutical effluent. (iii) Pharmaceutical effluent shows a ‘low variation in their chloride concentration’ (i.e. “high retention” in the soil mass), due to artificial contamination on NS1 and NS2, at 8 hr. and 16 hr. HRTs. (iv) The effect of the effluent is to increase the UCC values of all soils, up to 30 – 90 days of contamination and thereafter, to decrease it up to 180-200 days, which is attributed to the soil-pollutant interaction. The effect of the effluent on all the soils considered, is to reduce the UCC values by about 20% (within the period of contamination). Hence, the soil – pollutant interaction should be allowed to complete, before the strength values (i.e., UCC) are determined and used for any engineering judgment.

4.1 Recommendations

(1) Great caution need to be exercised by Geotechnical Engineers and by the various industries, when an ‘organic and toxic’ effluent, is allowed to discharge on a soil mass, containing at least 35% of clay content, when such soil/(s) are to be used for Engineering purposes.

(2) In order to understand the physico - chemical behaviour of an effluent with a soil, it is recommended that (i) chloride, sulphate and COD concentrations of an effluent and (ii) the grain size distribution, voids and the clay content of a soil mass, be determined.

(3) Study of physico - chemical behaviour of an effluent with a soil, may be made mandatory, for assessing the effect of effluent/(s) on the Geotechnical characteristics of soils.

5. REFERENCES


