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Effect of Treated and Untreated Textile Effluent on the Strength, Plasticity and pH characteristics of Kaolinite Clay

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***Abstract:** Both solid and liquid wastes are increasingly getting mixed up with soils leading to a change in soil environment. These in turn changes the geotechnical properties of soil. Among the liquid and solid wastes, liquid wastes create more problems and occur most abundtantly. The change in soil properties caused by these wastes in liquid form can affect the stability of foundation thereby affects the safety of human beings. Owing to these facts a greater focus must be given to understand the modification of soil properties due to chemical contamination. Textile industry is one of the growing industries in India. The effluent released by the industry is increasing day by day. The effluent can cause either improvement or deterioration to the soil properties. If the variations in soil properties after the addition of the effluent are positive in nature then the effluent can be added or disposed to that soil, but if the result is reverse the effluent must be treated. In this study, the effect of textile effluent on the geotechnical properties of Kaolinite soil is studied. Textile effluent is added in 25, 50, 75 and 100% to the soil. Since it causes deterioration in soil properties, treated effluent is used. Both primary and secondary treatments were opted in this study. Lime and alum is used in primary treatment. In secondary treatment, alum treated effluent is let into the Reed Bed system. The Strength, Plasticity and pH behaviour of the soil by the addition of treated and untreated effluent was also noted.*

***Keywords:** Kaolinite, Textile Effluent, Reed bed, Lime, Alum*

I. INTRODUCTION

With the industrial development in India, the waste management systems did not develop accordingly. Almost all industries are seen to discharge their wastes into water and on land without any treatment or after partial treatment. Indiscriminate disposal of liquid and solid wastes, especially on land, has caused serious environmental problems. The inorganic and organic pollutants present in industrial effluents generally affect the geotechnical properties of soil. An understanding of the soil-pollutant interactions and the effect of various contaminants or industrial effluents on geotechnical properties of soils helps for various engineering applications. It is therefore necessary to understand the soil-pollutant interactions, the effect of contaminants or industrial effluents on the various geotechnical properties, for assessing the suitability of ground soil for engineering purpose or initiate suitable measures to make the ground soil fit for construction. In this paper, an attempt is made to study the effect of textile effluent on Kaolinite clay. Textile effluent is added in four different concentrations with an increment of 25%. If there is an improvement in the soil properties, it is useful. Otherwise, the effluent must be treated. The treatment is done by primary or secondary treatment. Primary treatment adopted here is adding coagulants such as lime and alum. By coagulation and flocculation these can restore the soil properties.

Secondary treatment adopted here is reed bed technique. A reed bed is essentially a basin that is lined with an impermeable membrane, filled with gravel and planted with macrophytes such as reeds and rushes. Reeds are the coarse grasses growing in wet places. Reed bed is one of the natural and cheap methods of treating domestic, industrial and agricultural liquid wastes. Application of root zone technology is finding wider acceptability in developing and developed countries, as it appears to offer more economical and ecologically acceptable solution to water pollution management problems. Wastewater (black or grey) passes through the root zone of the reeds where it undergoes treatment via physical, chemical and biological interactions between the wastewater, plants, micro-organisms, gravel and atmosphere. The existence of root zone system creates channels for the water to pass through. The roots introduce oxygen down into the body of soil and provide an environment where aerobic bacteria can survive. These organisms are necessary for the breakdown of many types of compounds in particular in the oxidation of ammonia to nitrate. This is the first step in the biological breakdown of nitro compound. Finally, the process of nitrification takes place. That is the plants themselves take up a certain amount of nutrient from the waste water.

II. MATERIALS AND METHODS

A. Clay

Commercially available low plastic clay was purchased from English East India Clay Limited Trivandrum. The chemical composition of soil sample is given in table 1. The soil sample was mixed with textile effluent in different concentrations such as 25, 50, 75 and 100% and was stored in an air tight container for one day and tested. The physical properties of soil sample are given in table I. It is classified as low plastic clay (CL) as per IS classification. The scanning electron microscopic image of the soil sample is given in fig 1.

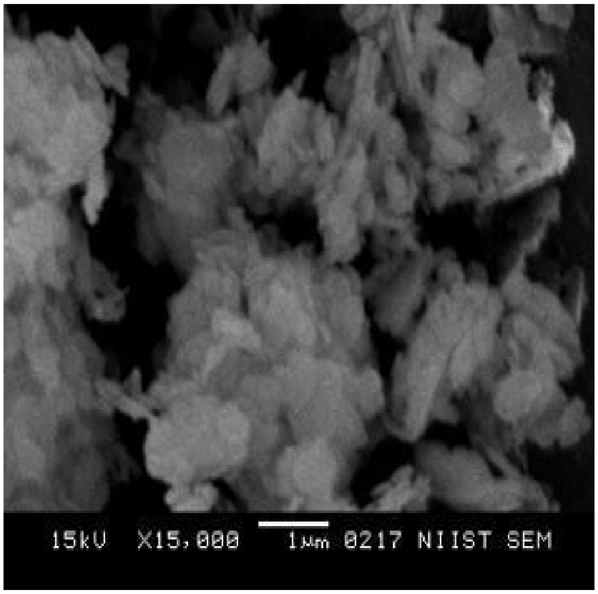

Fig.1. SEM image of Kaolinite

TABLE I. PROPERTIES OF KAOLINITE

PROPERTIES	VALUES
Specific Gravity	2.65
Liquid limit (%)	33.9
Plastic limit (%)	22.4
Plasticity index (%)	11.5
IS classification	CL
OMC (%)	24.4
Dry density(g/cc)	1.55
% clay	50.8
% silt	44.2
% sand	5
UCC strength (kN/m^2)	72
Free swell index	0.52

B. Textile Effluent

With respect to both the quantity and composition, the textile processing wastewater is recorded as the most polluted sources among all industrial sectors. Many scientists have documented adverse effects of different industrial effluents on the growth of plants. Dye waste water has also been found toxic to several crop plants. The bulk effluents generated from textile industries are discharged either treated or untreated over the soil leading to changes in soil properties causing improvement or degradation of engineering behavior of soil. The contaminant used in this study is textile effluent. It was collected from Palakkad district. The effluent is colored and is soluble in water. The characteristics of textile effluent are given in table II.

TABLE II. CHARACTERISTICS OF TEXTILE EFFLUENT

Analytical Parameters	Real Sample (avg.)
COD (mg/l)	750
BOD (mg/l)	192
Turbidity(NTU)	119
Sulphide (mg/l)	126
Chloride (mg/l)	1200
Hardness (mg/l)	410
Alkalinity (mg/l)	1140
Total suspended solids (mg/l)	460
Total dissolved solids (mg/l)	2180

C. Coagulants

Coagulants such as lime and alum are used in this study for the treatment of textile effluent. Lime was purchased from Agro Industries, Trivandrum. The chemical composition of lime is $Ca(OH)_2$. It is an odourless white powder passing through 75 micron IS sieve and is having a density of 2.21 g/cm^3. One significant application of calcium hydroxide is as a flocculent, in water and treatment. Alum was purchased from chemical laboratory, Trivandrum. The chemical composition of alum is $KAl(SO_4)_2 \cdot 12H_2O$. It is white in colour passing through 75 micron IS sieve and is having a watery metallic odour. The main use of alum is as a chemical coagulant for the decolourisation of industrial waste water. For the treatment of textile effluent, lime and alum was added separately at optimum percentage. The optimum percentage of lime in effluent treatment is 10% and that of alum is 5%. Then it was mixed with soil and kept in an air tight container for one day.

D. Constrution and Working of Reed Bed

Headley and Davison (2003) summarised the results of 28 different studies on 13 reed bed systems and derived design models for BOD and nitrogen. These design models have been used to derive a simpler rule of thumb approach that can be used to determine the size of the reed bed. Rule-of thumb surface areas for a range of water depths are provided in Table III.Filter beds should not be deeper than the depth to which plants roots can grow as water tends to flow below the dense bed of roots. Shallow filters are more effective compared to deeper beds of same volume. So a depth of 0.3m is adopted here and from thumb rule, surface area of the bed is adopted as 5 m^2. The unit was constructed by placing separate layers of gravel and sand. After arranging the layers, the plants were planted in the unit. Then textile effluent was let into the root zone system and the samples were collected. The different stages of construction of reed bed is shown in fig 2. The existence of root zone system creates channels for the water to pass through. The roots introduce oxygen down into the body of soil and provide an environment where aerobic bacteria can survive. These organisms are necessary for the breakdown of many types of compounds in particular in the oxidation of ammonia to nitrate.

Fig 2 Construction Stages of Reed Bed

TABLE III. RULE OF THUMB SIZING OF A REED BED
(Headley and Davison; 2003)

Water Depth (m)	Surface Area (m^2)
0.3	5
0.4	4
0.5	3
0.75	2.5

III. RESULTS AND DISCUSSIONS

A. *Effect of Untreated Effluent Soil*

The effect of untreated effluent on the properties such as plasticity index, optimum moisture content, maximum dry density, pH and unconfined compressive strength are listed below.

1) *Effect on Plasticity Index:*

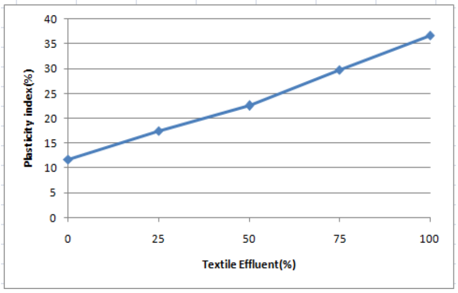

Fig 3 Variation of plasticity index with varying percentages of untreated effluent

The plasticity index increases with increasing percentage of textile effluent which is a negative trend. This may be due to the change in soil structure. The flocculent structure is lost when mixed with textile effluent which is evident from the scanning electron microscopic image as shown in Fig4.

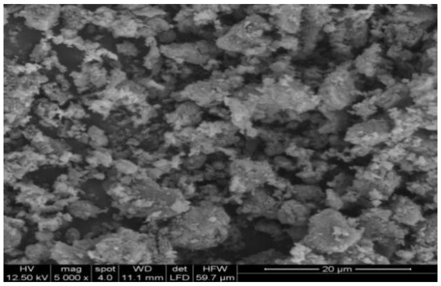

Fig 4 SEM image of Kaolinite mixed with textile effluent

2) *Effect on pH:* The pH of the soil sample mixed with effluent was determined by using pH meter. The pH of the textile effluent is obtained as 7.45. When it is mixed with soil, pH of the resulting mixture is found to be decreasing and the variation is shown below.

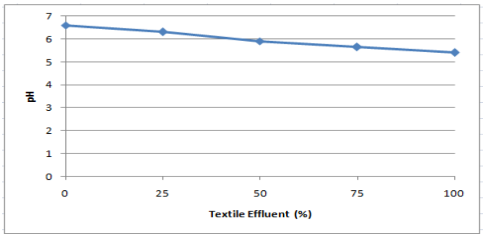

Fig 5 Variation of pH with varying percentages of untreated effluent

The decrease in pH is harmful to the soil. This decrease is one of the reasons for the deterioration of soil properties that can harm the safety of building foundations.

3) Effect on Unconfined Compressive Strength:

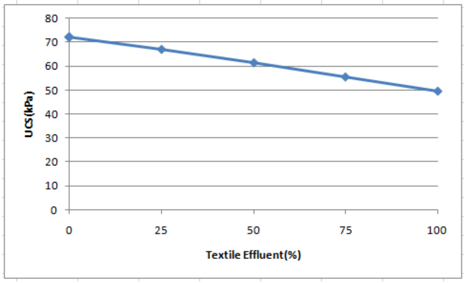

Fig 6 Variation of UCS with varying percentages of untreated effluent

The UCS decreases with increase in percentage of textile effluent. This may be due to weak chemical bonding so that degree of flocculation is reduced. Since flocculated structure has higher shear strength than dispersed, UCS is reduced.

B. Effect of Treated Effluent on Soil (By Lime and Alum)

Since the addition of textile effluent caused a negative impact on Kaolinite, the effluent was treated. The results of the treatment by using coagulants such as lime and alum are listed below.

1) *Effect on Plasticity Index:* The plasticity index slightly increases with treated effluent, but the increase is small. The increase of plasticity index is higher for lime treated effluent than alum treated effluent. When alum treated effluent is mixed with the soil, the plasticity index remains almost same as that of the original soil sample. This may be due to the coagulation and flocculation by alum.

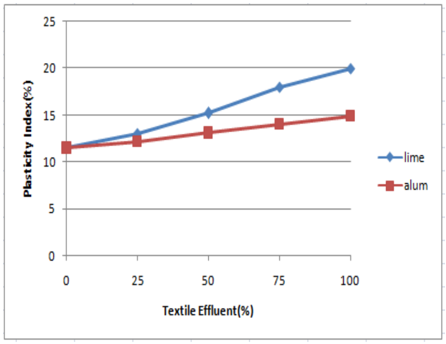

Fig 7 Variation of plasticity index with varying percentages of treated effluent

2) *Effect on pH:* The pH is the most important factor that affects the working of the coagulants. The optimum pH zone for alum flocculation of effluent from the activated sludge treatment plant is 5.75±0.25. Hence alum is more suitable for textile effluent treatment. Lime is found to be more effective for high pH range though it can be used for low pH range also. (Malhotra et al)

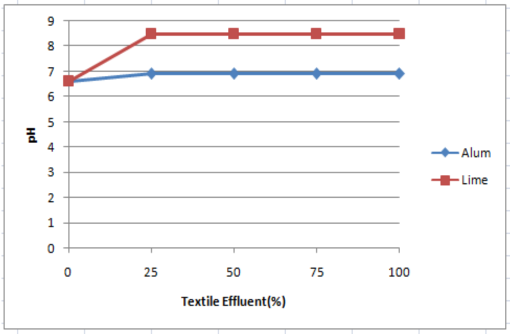

Fig 8 Variation of pH with varying percentages of treated effluent

The pH of soil sample mixed with alum treated effluent remains neutral whereas that of lime treated effluent remains alkaline in nature.

3) *Effect on Unconfined compressive Strength:* The unconfined compressive strength increases with increase in concentration of treated effluent and the strength of the soil mixed with 100% treated effluent is even more than the strength of the original soil. The strength is more for alum treated effluent than lime treated effluent. It is because of the pH of the resulting soil sample. When lime is used as the coagulant, pH increases and soil becomes slightly alkaline in nature. But when alum is used pH of the soil sample remains almost neutral. So more improvement in strength is observed when alum is used. The optimum pH zone for alum flocculation is also a reason.

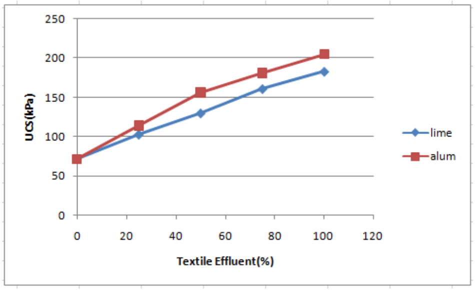

Fig 9 Variation in UCS with varying percentages of treated effluent

C. *Treated Effluent on Soil (by Reed Bed afetr the addition of coagulant)*

Another treatment method employed to determine the effect of treated textile effluent and to minimize the damage due to untreated effluent was reed bed. Reed Bed system employed had a capacity to treat the effluent at a rate of 4l/hr. Since Alum showed the maximum improvement in soil properties, it was chosen as the coagulant for the effluent treatment using reed bed. Hence the textile effluent was initially treated with Alum and the resulting mixture was let into the reed bed system. Later the treated effluent from the reed bed apparatus was collected and was mixed with soil to determine its effect on pH, UCS and plasticity index.

1) *Effect on Plasticity Index:*

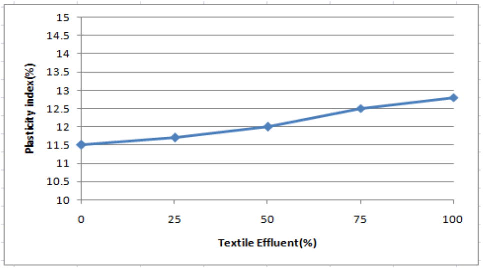

Fig 10 Variation in plasticity index with varying percentages of treated effluent obtained from Reed Bed

The plasticity index of the resulting mixture remains almost same as that of the original soil sample. Only slight increase was observed. This is because the reeds has purified the effluent by aerobic action and reduced its deleterious effect.

2) *Effect on pH:*

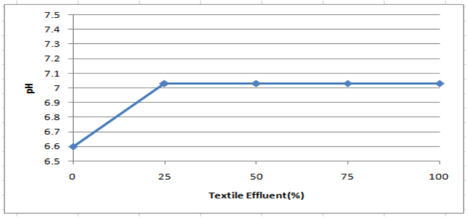

Fig 11 Variation in pH with varying percentages of treated effluent obtained from Reed Bed

The Reed Bed technique helps to adjust the pH to neutral and thus the resulting soil samples mixed with treated effluent shows improvement in properties. The roots are primarily responsible for the treatment.

3) Effect on Unconfined Compressive Strength

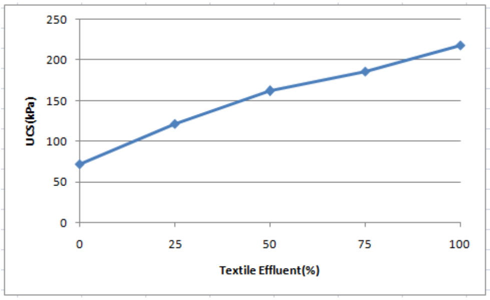

Fig 11 Variation in UCS with varying percentages of treated effluent obtained from Reed Bed

The UCS of the soil sample mixed with treated effluent increases with increase in concentration and the strength of the soil sample mixed with 100% treated effluent is approximately three times more than that of the original soil sample. This is because of the removal of pollutants in the textile effluent by the reeds. Also since the pH is balanced, strength increases.

IV. CONCLUSIONS

Textile effluent has a negative impact on Kaolinite soil and it is corrected by using primary and secondary treatment. Both lime and alum is effective but alum is more due to its optimal pH zone. The strength of soil mixed with untreated effluent is very low whereas strength of soil mixed with treated effluent is high even more than that of original soil sample. The maximum improvement in soil properties is achieved when alum treated effluent is used. It is because of the neutral behaviour of the soil whereas soil enters into alkaline nature when lime treated effluent is used. The flocculent structure is lost when untreated effluent is used whereas it is regained when treated effluent is used. Since alum gives maximum improvement in soil properties, alum treated effluent is let into the Reed Bed system. It is a low cost simple technique and can carry a large amount of effluent. The properties of the soil are improved and its strength is 200% more than that of the original soil sample when treated effluent from Reed Bed is used. It is because of the aerobic and anaerobic action occurring in the Reed Bed. Hence textile effluent must be treated before discharging into Kaolinite soil.

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