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Impact of Sugar Effluent on the Physico-Chemical and Geotechnical Behaviour of Soil

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Abstract
Sugar industries plays major role in the environment pollution. The organic effluent (spentwash) discharged by such industries is one of the most complex, troublesome and strongest organic industrial effluent having extremely high BOD and COD values. Assessment on the effect of sugar effluent application on inorganic pollutants (pH, EC, alkalinity, chloride and sulfate, TS and TDS) and organic pollutants (COD, BOD, TVS) were evaluated in laboratory experiment. The soil - pollutant interaction was critically analyzed and reported to explain the effect of sugar effluent on commercial (bentonite) and natural soil properties. The experiments were conducted under batch and continuous mode operation usingsugar effluent contaminated soil samples with highly clay and silt content. Application of sugar effluent improved the physical and chemical properties of soil by reducing the bulk density and increasing the water holding capacity. The present study showed that the sugar effluent was highly loaded with organic pollutants along with harmful heavy metals which showed significant effect on soil quality and chloride, sulfate present in sugar effluent was reduced by adsorption of sugar effluent through the soil. In this investigation soil columns were developed, and effect of liquid limit, plastic limit and shrinkage limit under expansive and normal soil conditions evaluated of any of soils have been used. COD reduction was achieved ~20 to 48%.
Keywords: Sugar Effluent, Physico-chemical behaviour, commercial and Natural soils, Soil – pollutant interaction, Atterberg limits.

1. Introduction

The 295 distilleries in India produce 2.7 billion liters of alcohol and generating 40 billion liters of wastewater annually. The enormous sugar wastewater has potential to produce 1100 million cubic meters of biogas. The population equivalent of sugar wastewater based on BOD has been reported to be as high as 6.2 billion which means that contribution of sugar waste in India to organic pollution is approximately seven times more than the entire Indian population. The wastewater from distilleries, major portion of which is spent wash, is nearly 15 times the total alcohol production. This massive quantity, approximately 40 billion liters of effluent, if disposed untreated can cause considerable stress on the water courses leading to widespread damage to aquatic life.

2. Experimental investigations

2.1. Sources and collection of effluents

Sugar effluent sample was collected from Gingeetaluk, Villupuran district. The characteristics of sample of effluent were analysed adopting the standard test procedure and results obtained are given in Table 1.

2.2. Effluent parameters

The effluent parameters, namely, pH, Electrical Conductivity (EC), alkalinity, Total solids, Total Dissolved Solids (TDS), Total Volatile Solids (TVS), Chloride, Sulphate, Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD), were estimated as per APHA Standard Methods (2005), for characterizing the effluent, and to determine the outflow from the experimental set-up (i.e. soil-column which is described later), at specifiedintervals.

2.3. Selection of soils

Two types of soil samples namely commercial (Bentonite) and natural soils were chosen for the present study to determine the independent behavior when it is artificially contaminated with the sugar effluent. The natural soil sample used in this study was collected in Gingee region and commercial soil available in market is used. The commercial (Bentonite) and natural soils thus collected are henceforth referred to as CSand NS. The characteristics of the sample of soils were analyzed adopting the standard test procedure and the results obtained are given in Table 2.

Table 1. Characteristics of Sugar Effluent

S.NO	PARAMETERS	RAW EFFLUENT
1	pH	4.30
2	EC (mS)	3.78
3	Cl^-	35450
4	SO_4^{2-}	25600
5	PO_4^{3-}	224
6	COD	156000
7	BOD	54200
8	Fe	5200
9	Mn	1500
10	HCO_3^-	43859
11	TS	114000
12	TDS	112000
13	TSS	2000
14	TVS	10000
15	TVDS	9000
16	TVSS	1000

Note: All values in mg/L, except pH, Electrical conductivity

Table 2. Characteristics of Commercial and Natural Soils (CS& NS)

PARAMETERS			CS - Initial	NS - Initial
Visual Classification	Colour		Light yellowish	Light brown
	Odour		No	No
	Texture		Smooth	Smooth
	Dilatancy		None	None
	Toughness		Low	Low
	Dry strength		High	Low
	Shine test		Medium	Dull
Atterberg Limits	Liquid Limit (%)		150	20.62
	Plastic Limit (%)		35	17.08
	Shrinkage Limit (%)		37.52	32.50
Sieve Analysis	Hydrometer analysis	Clay (%)	35.5	27.5
		Silt (%)	64.5	72.5
	Wet Sieve analysis	Silt & Clay (%)	85	65
		Sand (%)	15	35
Unconfined Compressive Strength (Kpa)			12	38.2

3. Experimental setup

One-dimensional column method is considered best suited to understand soil-pollutant interactions, as it permits investigations of various flow rates and retention times. Although several investigators have adopted one-dimensional soil-column, the methodology (who have investigated the variation of flow rate and concentration of pollutant/(s) with respect to hydraulic travel times) is considered here but only as a con ceptual model" since their methodology is not a true representation of field conditions relevant to the present study. Further modifications were made to it, to suit the present investigations so as to represent/simulate the field conditions, in the laboratory model

3.1. Description of experimental setup

The fabricated experimental setup was used for batch-mode. "HRT is defined as time taken by the first droplet of the effluent to flow from inlet to outlet of soil column. The batch –mode was operated to study the chemical equilibrium that gets established between various types of soils and the pollutants of the wastewaters, 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 wastewater on soil is continuous with varying flow rate and concentration of pollutants). The fabricated experimental setup was used for batch-mode. "HRT is defined as time taken by the first droplet of the effluent to flow from inlet to outlet of soil column. The batch –mode was operated to study the chemical equilibrium that gets established between various types of soils and the pollutants of the wastewaters, 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 wastewater on soil is

continuous with varying flow rate and concentration of pollutants).Fig. 1 shows the schematic view of the experimental setup and Fig. 2 shows the schematic view of the single soil column of the experimental setup

3.2. Preparation of soil specimen

The soil samples (weighing 3.750kg) were mixed with 1:3 ratio of (effluent: water) corresponding to its optimum moisture content and each were loaded in the six soil columns indicated as ET, ST1, ST2, ST3, ST4, ST5, and ST6. The effluent samples from the drain outlet were collected at an interval of 48 hour. The chemical analysis was carried out for the outlet effluent collected from the soil column marked as ET. The soil sample was collected at an interval of 30 days for soil testing from the soil columns.

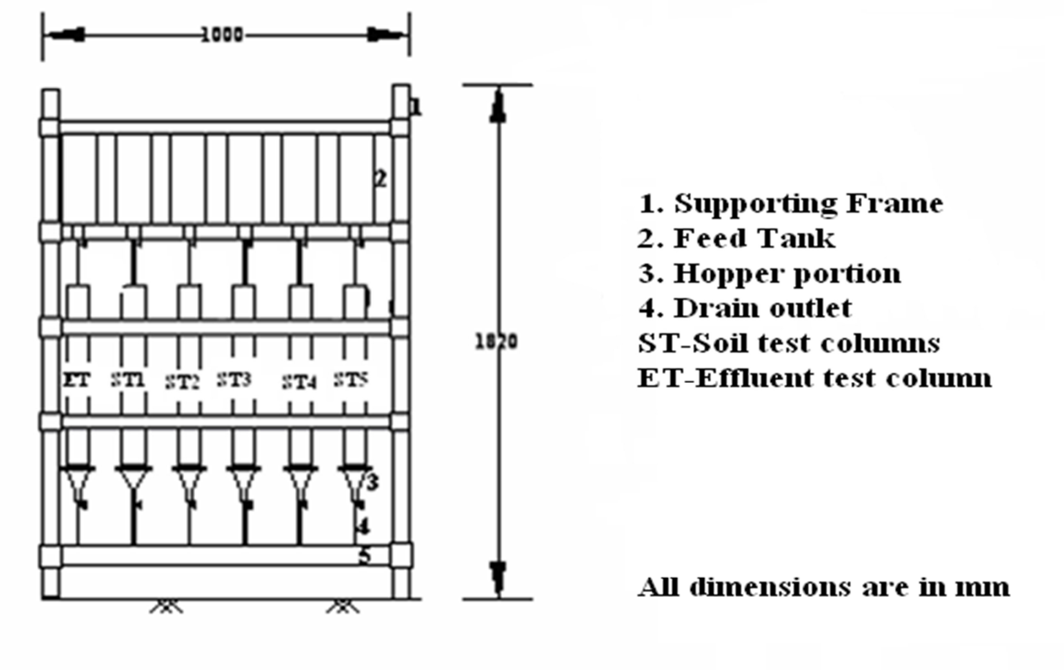

Fig 1. Schematic diagram of the experimental setup

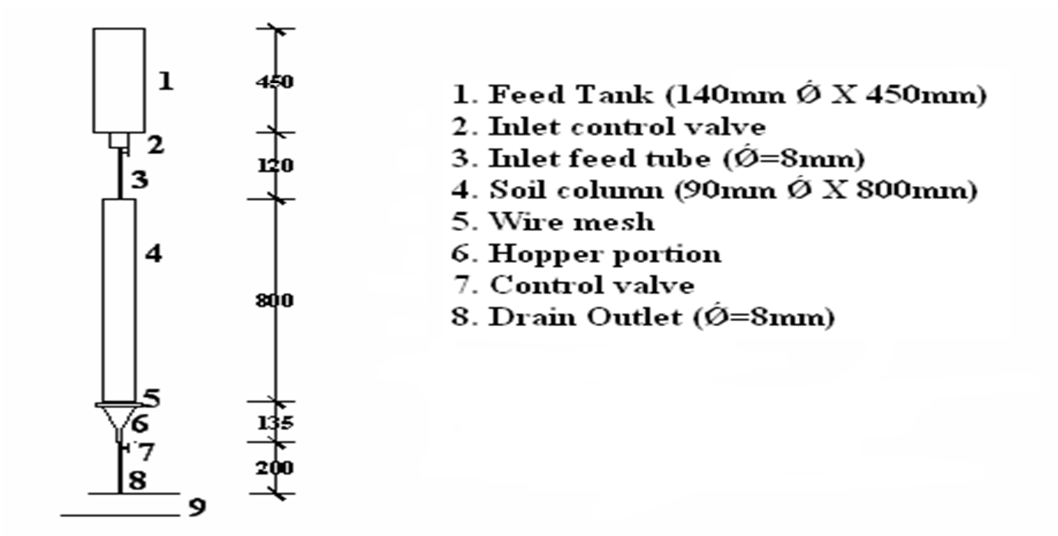

Fig 2. Schematic diagram of the single soil column of the experimental setup

4. Results and discussion

4.1. Effluents test (Batch mode)

4.1.1. pH

The variation of pH on CS was shown that there was suddenly increase in pH values from 4.30 to 6.12 and gradually decreased to 5.25 at the sample collected from bottom of soil column. During the batch mode of operation, thus pH changing initially to alkaline due to the soil aggregates with sugar effluent and latterly changes to acidic condition.

The variation of pH on NS is given was shown that there was suddenly increased in pH values 21st day from 4.81 to 6.65 and gradually decreased to 4.50 at the sample collected from middle of soil column. During the batch mode of operation, thus pH changing initially to alkaline due to the soil transitive to sugar effluent and latterly change to acidic condition.

4.1.2. Chloride

The variation in concentration of chloride on CS was found to be increased from 15640 mg/L to 30750 mg/L, however decreased later on days and stabilized during end of batch mode operation. Increased chloride due to the effluent turns from acidic to saline.

The variation in concentration of chloride on NS was found to be increased from 25650 mg/L to 35670 mg/L, however decreased later on days and stabilized during end of batch mode operation. Increased chloride due to the effluent turns from acidic to saline.

4.1.3. Sulphate

The variation in Sulfate concentration on CS was found to vary from 25,000 mg/L to 10,400 mg/L and stabilized during the end of batch mode operation. There is no higher peak variation. Sulfate concentration decreased due to the nutrient uptake from effluent to soil.

The variation in Sulfate concentration on NS was found to vary from 10,400 mg/L to 13,300 mg/L and stabilized during the end of batch mode operation. There is no higher peak variation. Sulfate concentration increased, because natural soils have higher level of nutrients such as N, P, K, S etc.

4.1.4. Chemical Oxygen Demand

The variation in COD concentration on CS is was found to be decrease from 115000 mg/L to 45000mg/L and stabilized at end of batch mode operation. 48% COD reduction was achieved. Presence of organic load in effluent was reduced due to the particle aggregates with soil.

The variation in COD concentration on NS is was found to be decrease from 95,000 mg/L to 45,000mg/L and stabilized at end of batch mode operation. 49% COD reduction was achieved. Presence of organic load in effluent was reduced due to the particle aggregates with soil.

4.2. Effluent tests (Continuous mode)

4.2.1. pH

The variation of pH after contamination of 75% and 50% concentrated effluent on soil CS was seen that there was gradually decreased from 7.34 to 4.60 and 4.53 to 4.38 at the sample collected from bottom of soil column. During the continuous mode of operation, thus pH changed from alkaline to acidic condition.

The variation of pH after contamination of 75% and 50% concentrated effluent on soil was seen that there was gradually decreased from 5.12 to 4.42 and 4.54 to 4.45 at the sample collected from bottom of soil column. During the continuous mode of operation, thus pH changed from alkaline to acidic condition.

4.2.2. Chloride

The variation of Chloride after contamination of 75% and 50% concentrated effluent on soil CS was found to be increased from 14,230 mg/L to 17,870 mg/L on 75% concentrated effluent and decreased from 18,400 mg/L to 10,600 mg/L on 50% concentrated effluent, however stabilized during end of continuous mode operation.

The variation of Chloride after contamination of 75% and 50% concentrated effluent on soil NS was found to be decreased from 14,800 mg/L to 11,400 mg/L on 75% concentrated effluent and decreased from 11,000 mg/L to 10,200 mg/L on 50% concentrated effluent, however stabilized during end of continuous mode operation.

4.2.3. Sulphate

The variation of Sulfate after contamination of 75% and 50% concentrated effluent on soil CS was found to vary from 38,000 mg/L to 15,400 mg/L on 75% concentrated effluent and vary from 16,600 mg/L to 12,000 mg/L on 50% concentrated effluent and stabilized during the end of continuous mode operation. There is no higher peak variation.

The variation of Sulfate after contamination of 75% and 50% concentrated effluent on soil NS was found to vary from 15,000 mg/L to 10,200 mg/L on 75% concentrated effluent and vary from 11,400 mg/L to 10,400 mg/L on 50% concentrated effluent and stabilized during the end of continuous mode operation.

4.2.4. Chemical Oxygen Demand

The variation of COD after contamination of 75% and 50% concentrated effluent on soil CS was found to be increased from 15,000 mg/L to 58,000 mg/l on 75% concentrated effluent and found to be decrease from 68,000 mg/L to 37,000 mg/l and stabilized at end of continuous mode operation. 43% organic load was increased on 75% concentrated effluent and 30% COD reduction was achieved on 50% concentrated effluent.

The variation of COD after contamination of 75% and 50% concentrated effluent on soil was found to be decrease from 82,000 mg/L to 52,000 mg/l on 75% concentrated effluent and found to be decrease from 65,000 mg/L to 55,000 mg/l and stabilized at end of continuous mode operation. 30% COD reduction was achieved on 75% concentrated effluent and 10% COD reduction was achieved on 50% concentrated effluent. Presence of organic load in effluent was reduced due to the particle aggregates with soil.

4.3. Soil tests (CS & NS)

4.3.1. Liquid limit

Variation of LL after artificial contamination of sugar effluent on CS is shown in Fig 3. LL decreased from 28.5%% to 19.5 % and 17.9% for CS during 90 and 180 days respectively, after artificial contamination of sugar effluent. This study obtained the decrease in LL from their original values obtained in clayey soil has contributed to accumulation and reaction of organic pollutants.

Variation of LL after artificial contamination of sugar effluent on NS is shown in Fig 4. LL increased from 8.5%% to 15.12 % and 28.97% for NS during 90 and 180 days respectively after artificial contamination of sugar effluent. This study obtained the increase in LL from their original values obtained in clayey soil has contributed to accumulation and reaction of organic pollutants. While decreasing concentration of effluent LL was increased.

4.3.2. Plastic limit

Variation of PL after artificial contamination of sugar effluent on CS is shown in Fig 3. PL decreased from 10.5%% to 9.12 % and 8.5% for CS during 90 and 180 days respectively after artificial contamination of sugar effluent. These results shown the PL has decreased from their original values.

Variation of PL after artificial contamination of sugar effluent on NS is shown in Fig 4. PL increased from 10.2%% to 11.17 % and 13.01% for NS during 90 and 180 days respectively after artificial contamination of sugar effluent. This study obtained the increase in PL from their original values obtained in clayey soil has contributed to accumulation and reaction of contaminants.

4.3.3. Shrinkage limit

Variation of SL after artificial contamination of sugar effluent on CS is shown in Fig 3. SL increased from 22.6%% to 29.8 % and 29.8% for CS during 90 and 180 days respectively after artificial contamination of sugar effluent. This result indicates the soil moisture content was increased.

Variation of SL after artificial contamination of sugar effluent on NS is shown in Fig 4. SL increased from 34.38%% to 39.79 % and 39.40% for NS during 90 and 180 days respectively after artificial contamination of sugar effluent. This result indicates the soil moisture content was decreased.

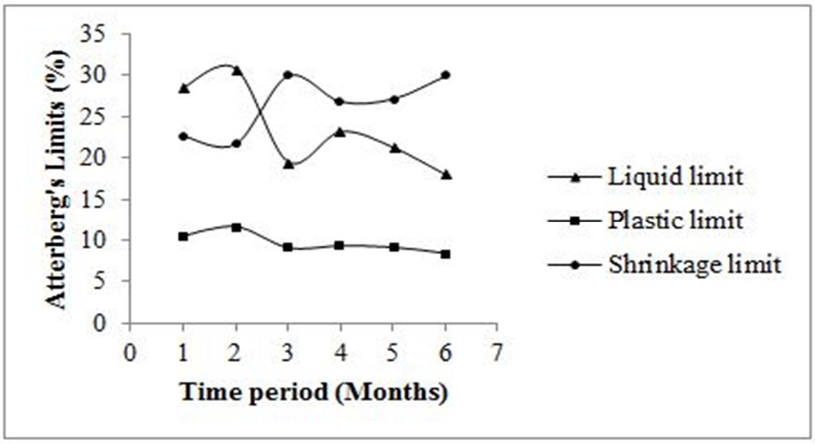

Fig 3. Variation of LL, PL, and SL on soil CS after artificial contamination of sugar effluent

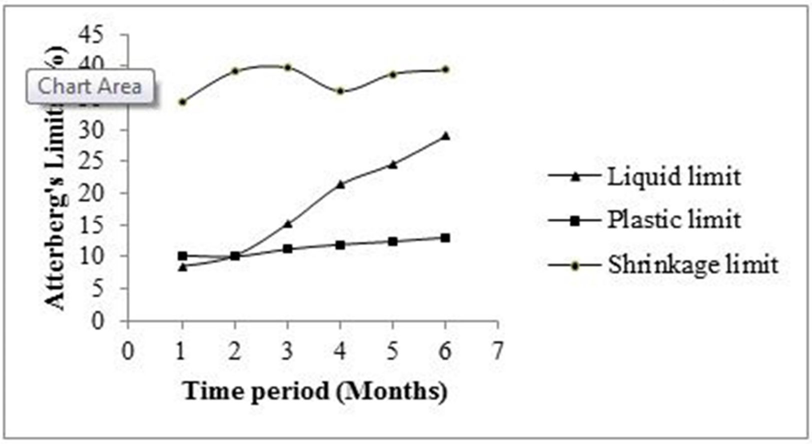

Fig 4. Variation of LL, PL, and SL on soil NS after artificial contamination of sugar effluent

5. Conclusion

- The results were showed that the nature of sugar effluent has altered CS and NSto alkaline condition and latterly changes to acidic condition during batch mode operation. Gradually decreased from its original value during continuous mode operation. This may be due to the unique characteristics of sugar effluent which has substantial organic which undergoes decomposition.
- The increased chloride level on CS during batch mode operation and continuous mode (75% concentration) indicates effluent turns from acidic to saline nature due to the soil association with effluent. Decreased on NS during batch and continuous mode operation due to presence of chloride adsorbed on soil.
- The Sulfate and Orthophosphate was decreased on CS and NS during batch and continuous mode due to adsorption on soil. Naturally soils have higher level of nutrients like N, P, K, S etc.
- The COD concentrations of effluents was found to be decreased from their original values and stabilized at end of batch mode operation. 48% COD reduction was achieved on both CSand NS. During continuous mode operation 43% organic load was increased on 75% concentrated effluent and 30% COD reduction was achieved on 50% concentrated effluent.

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BIOGRAPHY

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