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Characterization and Treatability studies of Sugar mill effluent

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Abstract: *Industrial waste treatment must be environmentally acceptable and cost effective. The new technologies have been developed to meet the increasingly stringent wastewater quality criteria. The sugar mill effluent has typically significant contaminants viz. Total Suspended Solids (TSS), Bio Chemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), including other parameters like pH, Temperature, Oil and Grease and Total Dissolved Solids (TDS).The present study involves characterization and treatability studies on sugar mill effluent collected from Sugar Mill located in the state of Gujarat. The concentration of significant constituent has been determined from composite sampling and analyses have been conducted using Standard Methods. The treatability studies have been carried out in Environmental Engineering Laboratory of Civil Engineering Department, BVM Engineering College, Vallabh Vidyanagar, for various treatment options viz. Coagulation and Flocculation, Prolonged Aeration, Prolonged Aeration followed by Adsorption and Anaerobic treatment followed by Aerobic treatment. During the study it has been found that the primary treatment followed by flocculation with biological treatment especially anaerobic treatment followed by Aerobic treatment is effective and has shown remarkable results during the present investigation in the laboratory.*

Key Words: *Characterization, Treatability Studies, Prolonged Aeration, Coagulation & Flocculation, Aerobic and Anaerobic treatment.*

1. INTRODUCTION:

Sugar industry is one of the most important agro-based industries giving rise to significant impact on rural economy in India. Today, India has 453 sugar mills in different parts of the country constituting 252 mills from Co-operative sector and 134 mills from private sector. India is second largest producer of sugarcane next to Brazil at 18.5 million tonnes. Crystal sugar is produced in organized sugar mills located in different parts of the country, the highest concentration being in U.P. in the north and Maharashtra in the west (1). There are also wide spread small scale industries producing raw sugar 'khandsari' (2)

One of the industrial wastes of serious consequences from the point of view of pollution of streams and rivers in India is on account of the effluent from the sugar industries. Most of the sugar mills are located in rural areas where there is no large watercourse for effective disposal of the effluents by dilution. The disposal of these wastes has presented one of the most urgent and serious problems to the health as well as the pollution control authorities throughout the country (3) Sugar industry is basically seasonal in nature and operates only for 120 to 200 days in an year (Early November to April). A significantly large volume of waste is generated during the manufacture of sugar and contains a high amount of pollution load particularly in terms of suspended solids, organic matter, and press mud, bagasse and air pollutants. (1)

The rapid growth of industries in the world, produce a large quantity of waste so the proper treatment and disposal method is necessary to protect our environment. (4) Industrial waste management plays a vital role in the preservation and conservation of the quality of the environment. There are 2 end products resulting from wastewater plants: (a) effluent (b) sludge. (5)

Sugar mills consume around 1,500-2,000 L of water and generate about 1,000 litres of wastewater per tonne of cane crushed, the effluent is mainly floor washing waste water and condensate water. Leakages in valve of the pipeline add sugarcane juice, syrup and molasses in the effluent. The sugar mill effluent has a BOD of 1,000-1,500 mg/L. Initially it appears very clean, however after stagnating for some time it turns black and starts emitting foul odour. If discharged untreated it depletes dissolved oxygen and make the environment unfit for aquatic life in the receiving waters. (6)

The most useful way of disposing organic sludge from a sugar industry is to convert them to an energy source. The purpose of sludge digestion is to remove the organic matter and to concentrate it in a much smaller volume for ease of handling and disposing. Sugar mill sludge contain a large organic fraction which can be digested anaerobically to obtain a stable product which can be used as a fertilizer in addition to the biogas produced which can be used as a fuel. (7)

The most common means of treating the sugar effluent is by biological means that is aerobic and anaerobic treatment methods. The sugar mill effluent, which is highly organic in nature, was utilized for this study.

2. MATERIALS AND METHODS:

The present investigation involved characterization and treatability studies on the effluent generated by one of the sugar mills located in India. This sugar mill has a crushing capacity of 2,500 tons of canes/d. The water consumed by the mill is 1,000 m^3/d and the amount of wastewater of an average emanated is 700 m^3/d.

The studies were carried out for a period of 5 months. Variation in the flow rate and the concentration adds variability to the treatment operation. It was therefore essential to study the variation in flow as well as concentration during the characterization and treatability studies. This is essential to produce an acceptable treatment. Tentatively a study on the variation of the quality of wastewater each week was envisaged. The sampling strategies were drawn accordingly.

There are basically two types of samples that can be collected in a sampling methodology. All precautions to obtain a representative samples were taken (8)

Grab sampling: The process of collecting discreet aliquots representing a specific location at a specific time is called as Grab sampling. In other words grab samples are not combined with other samples. In the present study the pH and temperature were measured at the location site itself. This is because such parameters cannot be preserved and they change with respect to time (8)

Composite sampling: The process of collecting discrete samples and then composited of two or more specific discrete samples collected at various sampling locations and / or at different times. In other words composite samples are prepared by rigorous mixing of equal aliquots of grab samples. These samples represent the composition of waste with reference to location as well as time. They are location and time proportioned. (8)

The parameters viz. BOD, COD, TSS have been measured by collecting composite samples. 1.5L sample was composited each day and the composite sample was preserved using 2 ml. H_2SO_4 so that its integrity is not altered. Thus 24 hour composite samples collected for a period of a week was considered for present study.

Analytical result therefore represent an average concentrating for the points where grab samples were collected or an average concentration for the time period during which the grab samples were collected. A properly prepared composite sample is also homogenized. The details showing the collection of sample is reported in Table 1

Table 1 Sampling Programme

Discrete Sampling				Composite Sampling
Sr. No.	Week	Time of Grab Sampling	Quantity (L)	Total Quantity (L)
1.	1	9 AM, 6PM	1.5, 1.5	21
2.	2	9 AM, 6PM	1.5, 1.5	21
3.	3	9 AM, 6PM	1.5, 1.5	21
4.	4	9 AM, 6PM	1.5, 1.5	21
5.	5	9 AM, 6PM	1.5, 1.5	21

The composite samples were analyzed in Environmental Engineering Laboratory of Civil Engineering Department of BVM Engineering College, Vallabh Vidya Nagar. The samples were analyzed for all significant parameters continuously during the course of study. The analysis of sample were carried out in accordance with Standard Methods. (9) The results have been reported in Table 2. The composition of effluent showing the range of concentration of each of the parameter is reported in Table 3

Subsequent to the characterization studies treatability studies were carried out using the following apparatus

1. Jar test using coagulant -Jar test using coagulants requires a 6 blade laboratory stirrer or jar tester as well as 6 beakers. The procedure for carrying out the test is as under
a. Each beaker of 500ml was placed under each stirring paddle.
B. 500 ml of raw water sample (measured using graduated cylinder) was placed in each of the beaker.
c. Coagulants as Alum and Ferrous Sulfate were used and their required concentrations were prepared.
d. Successive dosage of coagulants that is 1-10% were added in each subsequent beakers with measuring pipettes during each test experimentations.
e. The stirring paddles were lowered into the beakers and stirring was started for rapid mixing.
f. The mixing was done for one minute at a speed of 150 rpm after this flocculation condition was provided.

G. 10 minutes' flocculation period was given for the formation of flocks and degree of agitation was 50 rpm during each experimentation.
h. After this 20 minutes' settlement period was provided to make the flocs settle at the bottom
I. The supernatant was taken and the various parameters again measured.
j. The supernatant was also used for the subsequent treatment processes.

2. Lab Scale Anaerobic Digester
A simple batch reactor was used for the purpose of assessing treatability. The test has been conducted under a constant room temperature. The test assembly for anaerobic treatment included
a. One stoppered digester bottle equipped with feed arrangement.
b. Arrangement for gas vent (as there was no plan for collection of gas)

3. RESULTS AND DISCUSSION - CHARACTERIZATION STUDIES:

Table 2 shows the variation in the concentration of various parameters of the effluent. Table 3 exhibits the range of the values of various significant parameters of the sugar mill effluent.

The pH of the influent is found to be within the limit. However, other parameters including Suspended Solids, Oil and Grease, BOD and COD need to be brought down by changing its characteristics by Physico- chemical and biological treatment.

It is interesting to note that the variations in the concentration of the various parameters are not significant. Table 3 very clearly shows that the SS, BOD and COD hardly have a variation of 30%. One of the important reasons of the same could be composite aliquot. The discrete samples are collected at specific time i.e. at 9 a.m. and 6 p.m. and were composited for a week to study precisely the average variability (8)

The COD is to BOD ratio varies from 1.02 to 1.16. This is found to be almost similar to the results reported in the literature. This is because sugar mill effluent is highly biodegradable and the possibility of refractory contaminant/s in the waste is rare, especially when housekeeping and reuse of condensate have been planned.

Table 2: Characteristics of Sugar Mill Effluent

Sr. No.	Parameters	Values Week-I	Values Week-2	Values Week-3	Values Week-4	Values Week-5
1.	pH	7.09	6.84	7.04	6.93	7.59
2.	Temperature °C	29	32	30	33	34
3.	Suspended Solids	850	750	810	725	770
4.	Oil & Grease	24	27	22	21	18
5.	COD	1184	1200	1210	1134	1202
6.	BOD	1020	1192	1104	1073	1180
7.	COD: BOD	1.16	1.05	1.10	1.06	1.02

All parameters are given in mg/L except pH and Temperature

Table 3 Range of General Characteristics of Sugar Mill Effluent

Sr. No.	Parameter	Range
1.	pH	6.84 – 7.59
2.	Temperature	29 – 34
3.	Oil and Grease	18 –27
4.	Suspended Solids	725 – 850
5.	BOD	1020 – 1192
6.	COD	1134 – 1210
7.	COD: BOD	1.02 – 1.16

All parameters are given in mg/L except pH and Temperature

4. RESULTS AND DISCUSSION - TREATABILITY STUDIES:

3.1 Flocculation Studies

Sedimentation and flocculation are solid separation processes. Separation may occur with gravity as driving force. However, the particles less than 50 μ in diameter cannot be expected to settle by gravity. These particles, colloids are stable particles as they are negatively charged and there is always a bound layer of positively charged particles. They therefore do not agglomerate naturally. In order to stabilize them addition of chemicals to a colloidal dispersion and rapid mixing for obtaining uniform dispersion is carried out. After rapid mixing there is gentle and prolonged mixing. These processes of gentle stirring are called flocculation. The suspended solids concentration in the influent is 770 mg/L, which clearly shows that coagulation and flocculation treatment were necessary.

The flocculation studies were made using coagulants Alum $Al_2 (SO_4)_3.14H_2O$ and Ferrous Sulfate $FeSO_4. 7H_2O$. The results using coagulants Alum and ferrous sulfate have been reported from Table 4. It is clear from the result that the reduction of suspended solids using 5 ml and 10 ml 10 % Alum are 37 % and 46% respectively however using 10 ml 5% FeSO4 . $7H_2O$, 5 ml 10 % $FeSO_4. 7H_2O$ and 10 ml 10% $FeSO_4. 7H_2O$ reduction of suspended solids is found to be 43%, 48% and 50% respectively i.e., the reduction of suspended solids using 10 ml 10% $FeSO_4. 7H_2O$ is quite satisfactory.

The % reduction using various flocculants varies from 7.2 to 15.93% and 6.8 to 14% respectively. The results very clearly show that the dose of 10 ml 10% $FeSO_4. 7H_2O$ is optimum dose. The sizing of chemical dosing tank therefore can be designed based on optimum dose.

If the metallic salts are used without lime the resulting pH becomes very low and hence highly corrosive. However, during the studies using ferrous salts it was found that addition of lime was not required as it does not reduce the pH to very low levels.

Table 4: Analysis of supernatant from Jar test

Sr. No.	Parameter	Initial value	Concentration of supernatant using coagulant and % reduction				
			Alum 5 ml, 10% Case I	Alum 10 ml, 10% Case II	$FeSO_4$ 10 ml, 5% Case III	$FeSO_4$ 5 ml, 10% Case IV	$FeSO_4$ 10 ml, 10% Case V
1.	pH	7.59	6.20	6.38	6.94	6.65	6.54
2.	SS	770	484 (37.14)	416 (45.97)	436) (43.37)	399 (48.18)	387 (49.74)
3.	Oil & Grease	18	12 (33.33)	10 (44.44)	11 (38.88)	10 (44.44)	9 (50)
4.	BOD	1180	1094 (42)	1063 (8.8)	1076 (9.9)	1024 (13.22)	992 (15.93)
5.	COD	1202	1120 (6.8)	1105 (7.4)	1113 (8.06)	1095 (8.9)	1033 (14.05)

All parameters are given in mg/L except pH

3.2 Studies on flocculation followed by prolonged bio aeration (48 hours)

The supernatant from the jar test apparatus was taken for prolonged bio aeration process, where porous diffuser was used as an aeration equipment. The samples were aerated for a period of 48 hours, and they were allowed to settle for 2 hours. The results obtained during the prolonged bio aeration have been reported from Table 5

The removal of BOD is found to be maximum (68%) with the 10 ml 10% $FeSO_4. 7H_2O$ supernatant. Similarly, the removal of SS, COD are also quite appreciable into viz. 54% and 62% respectively. In spite of the fact that the significant removals have been obtained with respect to BOD, SS and COD, the experiments even at the prolonged aeration of 48 hours do not meet the standards specified by Gujarat Pollution Control Board (GPCB) (10). The probable cause could be non-removal of organics in dissolved form. It was, therefore, during the treatability studies, suggested to study the effectiveness of adsorption process.

Table 5: Analysis of supernatant from Prolonged Bio-aeration for 48 hours

Sr.No	Parameter	Supernatant from Prolonged bio-aeration for 48 hrs. and % reduction				
		Case I	Case II	Case III	Case IV	Case V
1	pH	5.97	6.15	6.75	6.52	6.27
2	SS	260 (46.28)	229 (44.95)	247 (43.37)	202 (49.37)	179 (53.74)
3	Oil & Grease	8 (33.33)	6.5 (35)	7 (36.36)	6.8 (32)	5.6 (37.78)
4	BOD	497 (54.57)	438 (59.29)	452 (57.47)	392 (67.71)	321 (67.64)
5	COD	585 (47.76)	507 (55.97)	507 (54.11)	476 (56.52)	397 (61.56)

All parameters are given in mg/L except pH

3.3 Studies on adsorption

Adsorption is a unit process employed in wastewater treatment to control pollution due to odor, color, dissolved organics and heavy metals (11). Subsequent to 48 hours prolonged bio aeration different dosages of powder activated carbon were used to determine probable reduction in SS, BOD and COD, while keeping the time constant at optimum dose of 30 mg of PAC/50ml (the experiments conducted to determine optimum contact time is not shown here). Tables 6, 7 and 8 show the summary of % reduction upon adsorption.

Dose: 30 mg/50ml PAC

As apparent from the Table-6, the maximum reduction is possible with 10 ml 10% $FeSO_{4.}$ $7H_2O$ supernatant. The pollutants reduced are

SS, BOD and COD to 36%, 42% and 42% respectively.

Dose: 35 mg/50ml PAC

The maximum reduction is available with 10 ml 10% $FeSO_{4.}$ $7H_2O$ supernatant. The SS, BOD and COD are 46.53%, 41.12% and 42.31% respectively. This is quite evident from Table-7

Dose: 40 mg/50ml PAC The maximum reduction is available with 10 ml 10% $FeSO_{4.}$ $7H_2O$ supernatant. The SS, BOD and COD are 37.43%, 41.74% and 40.55% respectively. These results have been reported in Table-8

For the adsorption, the optimum dose of the adsorbent is 35 mg/50ml, which can be used for designing the adsorption column of the treatment plant.

Table 6: Analysis of supernatant from Adsorption 30 mg/50ml

Sr. No.	Parameter	Supernatant from adsorption at optimum contact time and % reduction taking dose=30mg/50ml PAC				
		Case-1	Case-II	Case-III	Case IV	Case V
1	pH	5.45	5.72	6.38	6.07	5.84
2	SS	156 (40)	133 (41.92)	151 (38.86)	126 (37.62)	116 (35.19)
3	Oil & Grease	5 (37.5)	4 (41.6)	4.4 (37.14)	4 (41.17)	3.2 (42.87)
4	BOD	315 (36.61)	299 (31.73)	305 (32.52)	254 (35.21)	206 (35.82)
5	COD	356 (39.14)	323 (34.08)	329 (35.11)	290 (39.07)	231 (41.18)

All parameters are given in mg/L except pH

Table 7: Analysis of supernatant from Adsorption 35mg/50ml

Sr. No.	Parameter	Supernatant from adsorption at optimum contact time and % reduction taking dose=35mg/50ml PAC				
		Case-1	Case-II	Case-III	Case IV	Case V
1	pH	5.52	5.89	6.47	6.21	6.11
2	SS	137 (47.03)	114 (50.21)	131 (46.96)	108 (46.53)	102 (43.06)
3	Oil & Grease	4 (50)	3.9 (40)	3.6 (48.77)	4 (41.17)	3.6 (35.78)
4	BOD	279 (43.86)	255 (41.78)	258 (42.92)	217 (44.64)	189 (41.16)
5	COD	321 (45.12)	269 (45.1)	278 (45.16)	265 (44.32)	229 (42.31)

Table 8: Analysis of supernatant from Adsorption 35mg

Sr. No.	Parameter	Supernatant from adsorption at optimum contact time and % reduction taking dose=40mg/50ml PAC				
		Case-1	Case-II	Case-III	Case IV	Case V
1	pH	5.6	5.92	6.54	6.32	6.41

2	SS	149 (42.69)	141 (38.42)	137 (44.53)	125 (38.11)	112 (37.43)
3	Oil & Grease	5.2 (35)	4 (38.46)	4.2 (40)	3.8 (44.11)	3.5 (38.11)
4	BOD	309 (37.82)	271 (38.12)	263 (41.81)	228 (41.84)	187 (41.74)
5	COD	338 (42.22)	299 (38.97)	294 (42.01)	276 (42.02)	236 (40.55)

All parameters are given in mg/L except pH

3.4 Studies on Anaerobic Treatment Followed By Aerobic Treatment

Though substantial reduction in SS, BOD and COD have been found during aerobic treatment followed by adsorption process, the desired norms of the GPCB are not met with. It is therefore indispensable to make an attempt for other technologies to decide the treatability of sugar mill effluent.

The cost effective treatment for the sugar mill is anaerobic digestion followed by aerobic biological digestion. This is because initial anaerobic treatment will reduce the area of land and load on aerobic pond. An attempt has therefore been made to assess the treatability by allowing the supernatant through an anaerobic digester followed by aerobic pond prepared in the laboratory. The laboratory bench scale studies have shown the desirable results. The results have been reported from Table 9 to 11.

It is crystal clear from Tables 9-11 that this technology has given the desirable results (within the GPCB norms). The period of anaerobic digestion was 48 hours and the same was followed by 72 hours of aerobic treatment, through an aquarium porous diffuser. The % reduction in BOD and COD is almost 80% and 75% respectively whereas the reduction in SS is 57 %.The overall reduction in SS, BOD and COD is 87%, 92% and 90% respectively when the sequence of the treatment followed is flocculation, followed by anaerobic, followed by aerobic.

Table 9 Analysis of Jar test (10 ml, 10% $FeSO_4$)

Sr. No.	Parameter	Initial Values	Final Values	% Reduction
1	pH	7.59	6.61	-
2	SS	770	380	50.64
3	Oil& Grease	18	9.2	48.88
4	BOD	1180	989	16.18
5	COD	1202	1027	14.55

All parameters are given in mg/L except pH

Table 10 After Anaerobic Digestion (48 hours)

Sr.	Parameter	Initial Values	Final Values	% Reduction
1	pH	6.61	5.20	-
2	SS	380	229	39.74
3	Oil & Grease	9.2	5	45.65
4	BOD	989	472	52.27
5	COD	1027	508	50.53

Table 11 After Aerobic Digestion (72 hours)

Sr.	Parameter	Initial Values	Final Values	% Reduction
1	pH	5.20	6.70	-
2	SS	229	99	56.76
3	Oil & Grease	5	2.8	44
4	BOD	472	97	79.44
5	COD	508	129	74.41

All parameters are given in mg/L except pH

5. SUMMARY & CONCLUSIONS:

In light of the extensive experiments conducted on the sugar effluent, in the laboratory and discussion on results obtained, following conclusions can be drawn:

a) The quality of combined wastewater generated in a sugar mill is highly biodegradable. The ratio of COD: BOD varies from 1.02 to 1.16. The possibility of refractory component is difficult to be considered.
b) The significant parameters in sugar mill effluent are Suspended Solids, Biochemical Oxygen Demand and Chemical Oxygen Demand.

- The general characteristics of wastewater emanated from sugar mill is shown in Table 6.1
- It is a fact that sugar mill contains appreciable amounts of suspended solids, which may consist of colloidal particles, and other non-settle-able solids. Physico chemical treatment is therefore essential after preliminary treatment.
  10 ml 10% $FeSO_4$. $7H_2O$ has shown desirable removals. As the pH reduction is not found to be very low, ferrous salts with lime treatment is not necessary.
- Treatment options available after Physico- chemical process on the sugar mill effluent are
  a. Prolonged Bio-aeration
  b. Prolonged Bio-aeration Followed By Adsorption
  c. Anaerobic Treatment Followed By Aerobic Treatment
- Anaerobic treatment followed by aerobic treatment has shown desirable results.

Table: 12 Summary of % Reduction after Jar Test

Solution Used	Reduction		
	SS	BOD	COD
10 % Alum 5 ml	37.14	7.2	6.8
10 % Alum 10 ml	45.97	8.8	7.4
5% $FeSO_4$ 10 ml	43.37	9.9	8.06
10% $FeSO_4$ 5ml	48.18	13.22	8.9
10% $FeSO_4$ 10ml	49.74	15.93	14.05

All parameters are given in mg/L

Table: 13 Summary of % Reduction after Prolonged Bio-aeration (48 hours)

Solution Used	Reduction		
	SS	BOD	COD
10 % Alum 5 ml	46.28	54.57	47.76
10 % Alum 10 ml	44.95	59.29	57.47
5% $FeSO_4$ 10 ml	43.34	55.97	54.11
10% $FeSO_4$ 5ml	49.37	61.71	56.52
10% $FeSO_4$ 10ml	53.74	67.64	61.56

Table: 14 Summary of % Reduction after Adsorption (using 30 mg PAC)

Solution Used	Reduction		
	SS	BOD	COD
10 % Alum 5 ml	40	36.61	39.14
10 % Alum 10 ml	41.92	31.73	34.08
5% $FeSO_4$ 10 ml	38.86	32.52	35.11
10% $FeSO_4$ 5ml	37.62	35.21	39.07
10% $FeSO_4$ 10ml	35.19	35.82	41.81

All parameters are given in mg/L

Table: 15 Summary of % Reduction after Adsorption (using 35 mg PAC)

Solution Used	Reduction		
	SS	BOD	COD
10 % Alum 5 ml	47.03	43.86	45.12
10 % Alum 10 ml	50.21	41.78	42.92
5% $FeSO_4$ 10 ml	46.96	45.1	45.16
10% $FeSO_4$ 5ml	46.53	44.64	44.32
10% $FeSO_4$ 10ml	46.03	41.12	42.31

Table: 16 Summary of % Reduction after Adsorption (using 40 mg PAC)

Solution Used	Reduction		
	SS	BOD	COD
10 % Alum 5 ml	42.69	37.82	42.22
10 % Alum 10 ml	38.42	38.12	38.97
5% $FeSO_4$ 10 ml	44.53	41.81	42.01
10% $FeSO_4$ 5ml	38.11	41.84	42.02
10% $FeSO_4$ 10ml	37.43	41.74	40.55

All parameters are given in mg/L

Table: 17 Summary of % Reduction-Treatment system

Treatment Given	% Reduction		
(in mg/L)	SS	BOD	COD
Coagulation Flocculation	50.64	16.18	14.55
Anaerobic	39.74	52.27	50.53
Aerobic	56.76	79.44	74.61

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