J. App. Em. Sc: 1 (2) 152-157 April 2006 ISSN. 1814-070X

Sugar Industry Effluent – Characteristics and Chemical Analysis

Abdul Rehman Memon, Suhail Ahmed Soomro and Abdul Khaliq Ansari

Chemical Engineering Department, Mehran University of Engineering & Technology, Jamshoro.

Sugar industry being an important player in the foreign exchange earning, also plays its part in polluting the environment with its discharges. In this study three sugar mills were selected for the analysis of the composition of their effluents, which are the primary source of water pollution, *viz.* Matiari sugar mills, Fauji sugar mills, Tando Mohammad Khan and Habib Sugar mills, Nawabshah. The results of the study showed that the effluents in general exceed the limits specified in NEQS with reference to parameters such as BOD, Chemical Oxygen Demands (COD), Oil and Greases (OG), Total Suspended Solid (TSS). The pollution level found through the analysis can be reduced if the suggested recommended measures are worked upon.

Key words: effluents, environment, composition, sugar waste

Introduction

Sugar industry is a seasonal industry operating for maximum of 4-5 months in one season. The industry uses sugarcane as their raw material along with various chemicals added to increase the face value of the final product (Memon, 1990). During the process a huge amount of water is also used per day and as a result industry generates waste water (effluent) on daily basis. Table 1 shows the wastewater generation from different units of a sugar factory. As stated in Table 1 the wastewater is generally generated in a sugar mill from each section and finally disposed of in a combined form for the outside settlement.. Wastewater from the mill house is usually contaminated with oil and grease. The spillage of oil and grease on the floor of mill house from the machinery and equipment is washed away during floor washing. The wastewater, which is generated from process house mainly results from floor and equipment washing and is highly contaminated with additives and other chemicals used at different processing stages. Boiler house mainly contributes to the production of air pollution and have little share in water pollution. Sugar industry is a large water consumer and there is no stage in sugar production where water is not required. Nevertheless, water consumption can vary due to the technology applied and the nature and quality of raw material used. Mostly water is required in the sugar mills as cooling water for barometric condensers, boiler feed water, for lime preparation, for dilution in evaporators, etc.

Sugarcane entering the factory contains about 70% moisture. As a result, excess water has to be disposed of, even with the most stringent conditions of water reuse. It has been observed that each ton of cane crushed should produce about 0.7 m^3 of water if sugar and water are completely separated. According to Indian Standards, water consumption varies from 1.3 to 4.36 m^3 per ton of sugarcane crushed (Trivedy, 1998). Literature suggests (Jakhrani, 2002) that wastewater generated is about 20% of the water requirement. However, this stoichiometry is not done or applied in the mills in question. Based on this ratio, a sugar mill with crushing capacity of 4500 Tons of Cane per Day (TCD) require 9000 m^3 / day of water with 1: 2 ratio and hence the mills generate the wastewater in the range of 1800 m^3 / day

Corresponding Author:
Soomro, Suhail A.
Tel. 92 221 2771262/ 771642, Fax. 92 22 2771382, email: s_a_soomro@yahoo.com

Table 1: Wastewater generation from each unit in a sugar factory

Main Input	Unit house	Wastewater generated
Sugarcane	Mill House	• Wastewater from bearing house of the mills, contains Suspended Solids and oil contents. Also includes washing water used for floor cleaning, which contains sugar contents.
Sugar Juice	Process House	• Washing of different components such as, Evaporator, Juice heater, Vacuum pan, clarifiers, generates aggressive effluents having high BOD_5, COD and TDS concentrations.
Bagasse / Furnace oil	Boiler House	• Wastewater of wet scrubbers

The sugar mill wastewater is characterized by its brown color, burnt-sugar like odor, high temperature, low pH, high ash or solid residues and contains high percentage of dissolved organic and inorganic matter of which 50% may be present as reducing sugars.

In addition, sugar mill effluents carry the constituents such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Oil and greases in the range, which more often exceed the stipulated National Environmental Quality Standards (NEQS).

BOD is a measure of the tendency of the *habitat of effluent to consume dissolved* oxygen from receiving waters during 5-day incubation period maintained at 20 ^{0}C.

Whereas COD test measures the combined oxygen demands of biochemically reducible contaminants and non-biochemically degradable reduced contaminants. Fats, greases, and lignins are biochemically degradable. However, the rate of oxidation is very slow and they have little effect on the 5-day BOD test but are measured by the COD test.

Total Suspended Solids (TSS) are more accurately termed as non-filterable residue including settleable and non-settleable solids. Suspended solids in water increase turbidity, reducing light penetration and therefore restrict plant production. High level of suspended solids can cause anaerobic conditions on the bottoms of lakes, rivers, and streams due to breakdown of volatile materials in the solids. Lower power of Hydrogen ion (pH) tends to make many substances such as metals and hardness minerals more soluble in water (Jakhrani , 2002).

Oil and grease (OG) float on the surface of receiving waters, which interfere with natural re-aeration and create an unsightly film on the surface of water which can reduce recreational uses. It can be toxic to certain species of fish and aquatic life and can create a fire hazard, if present on the surface of water in sufficient quantity. It may destroy vegetation along the shoreline, which can lead to increased erosion,

Oil and *grease contamination* in wastewater from mill house effluent is *highly objectionable*, because it increases the BOD and COD values in the untreated effluents.

Materials and Methods

For comparative analysis of sugar mills effluents and their characteristics, three plants were selected for this study viz Fauji Sugar mills, Tando Mohammad Khan (FSM), Habib Sugar Mills, Nawabshah (HSM) and Matiari Sugar Mills, Matiari (MSM). All the three mills were frequented to collect the desired number of samples.

Wastewater samples were collected from two sections of the mills i.e. Mill house and Process house and one composite sample from the final drain carrying wastewater of all the sections and going outside the plant premises for the final settlement.

Physical analysis was done *in-situ* (on site), while for chemical analysis, the samples had to be preserved by maintaining the sample container temperature at 4 ^{0}C before being analyzed in the laboratory.

Since sugar mills lies in category B of polluting industries by the Pakistan Environmental Protection Agency (PEPA) (Khan , A. Uddin, 1999; Ahmed, 1997), the analysis of its effluents is comprised of five parameters. The sampling strategy for each parameters and point sources are identified in Table 2:

Table 2: **Wastewater sampling and analytical parameter**

Sr. #.	Sample Point Source	EPA Prescribed Parameters	Total no. of samples from three sugar mills
1.	Mill House	Oil & Greases, pH, TSS	6
2.	Process House	BOD_5, COD, pH, TSS	6
3.	Combined or mix Effluent	TSS, pH, Oil & Greases, BOD_5, COD	6
TOTAL	**3**	**5**	**18**

Analytical Parameters

i. BOD_5 :- The test was carried out by making two diluted samples; one was analyzed as such for its initial Dissolved Oxygen (DO_i) and the other was kept in the incubator for five days at 20 ^{0}C. After five days the sample was again tested for its final Dissolved Oxygen (DO_f) and with the help of following formula BOD of the given sample was determined:

$$\text{BOD in mg/L} = \frac{DO_i - DO_f \times \text{Total Volume of BOD bottle}}{\text{Sample volume taken for dilution}}$$

ii. COD: The test was conducted by standard dichromate reflux method using following equation:

$$\text{COD in mg / L} = (A - B) \times \frac{1000 \times M}{C}$$

Where: A = mL used in titration of blank

B = mL used in titration of prepared sample

C = mL used in titration of standard solution

M = Multiplier (depending upon the sample of volume taken)

iii. TSS:TSS were determined by Photometric method using Hach's DR – 2000 Spectrophotometer.

iv. pH: Jenway direct reading pH meter was used for pH determination.

v. Oil and Greases (OG): Oil contents were actually extracted from water by colorimetric extraction method using DR-2000 Spectrophotometer (Hach, 1993; American Public Health Association (APHA), 1995).

Results and Discussion

Physical Analysis

Color of the wastewater for all the samples was recorded as juicy or brownish, giving a sugarcane juice-like smell. This points out to the presence of sugar residues in the final discharges of wastewater. The wastewater temperature ranged from 42 to 45 ^{0}C, which is above the standard value of 40^{0}C (NEQS limit). It is an established fact that the solubility of oxygen decreases as the temperature and pressure increases. Hence, warm wastewater discharges tend to lower the value of DO. Since metabolism rates may go up at higher temperatures, warm wastewater discharges aggravate environmental problems.

Chemical Analysis

The pH of the effluents is graphically shown in Fig 1. The pH results for process house and *final effluent* samples showed that HSM wastewater was more acidic in nature, since it contained the lowest pH valued of 5.15 and 3.93 respectively. The lower values of pH are due to the change in the manufacturing process of each of the industry with HSM using Defecation Remelt Carbonation Sulphitation (DRCS) process in which derivative acidic compounds of both sulphur and carbon are formed, while FSM use Defecation Remelt Carbonation (DRP). Secondly, HSM wastewater temperature was 45 ^{0}C as compared to 42 ^{0}C for FSM effluent. While pH of mill house samples of all the three sugar mills was found to be in its alkaline range and within the specified limits of 6- 8.

TSS was determined for the effluents of process house and combined mixture.
The values obtained for TSS was again found to be much higher than the fixed standard value of 150 mg/L for TSS. The analytical results for TSS show that MSM wastewater had the highest TSS of 300 mg/L from process house section as compared to other mills samples. This may be largely due to the lack of observation of in-plant control measures. Whereas, final effluent of HSM contained more TSS of 653 mg/L than the other two sugar mills, indicating high cane crushing capacity of the industry and as a result producing large amounts of both fly ash and bottom ash. Besides, the industry also has fiber plant to process bagasse for further uses, hence the coarse bagasse particles are always found there suspended in the air and getting mixed with the final effluent.
The major contributor of TSS in the sugar mills effluents is the shredded Bagasse particles and the flying ash particles as well.
The lowest number of TSS i.e. 169 mg/L found in the process house wastewater were contained by HSM effluent, while for final effluent the lowest value of TSS was registered by Matiari sugar mills i.e. 272 mg/L. All the results for TSS are graphically shown in Fig. 2

BOD_5 and COD were analyzed for process house wastewater and final effluent. On the whole, all the determined values of BOD_5 and COD were higher than the NEQS value of 80 mg/l and 150 mg/l. MSM final effluent had the highest BOD and COD values of
673 mg/L 3673 mg/l. While process house BOD figure of 365 mg/L for FSM was the highest among the three mills. As for COD, MSM effluent registered the highest value among all the samples *i.e.* 1995 mg/l. However, HSM effluent had the lowest BOD and COD values measured both for process and combined effluents *i.e.* 93 mg/L and 181 mg/L for BOD and 390 mg/L and 634 mg/L respectively. Increase in BOD and COD values may by attributed to the spillage of molasses and lost or leaked sugar contents on the floors of the mills, which are swept or washed away to be mixed with the effluents causing higher levels of BOD and COD. The results are graphically represented in Figs. 3 and 4.
OG were determined for mill house samples, where oils and greases are particularly used as well as for final effluent samples. Again the analytical results showed that these were higher than the set standard value of 10 mg/L. HSM effluent from mill house recorded the lowest number for OG *i.e.* 20 mg/L, while similar sample of FSM gave the value of 49 mg/L as the highest. Similarly, final effluent sample of HSM contained lowest OG contents *i.e.* 27 mg/L and FSM effluent had the highest OG contents *i.e.* 185 mg/L. The final effluent OG contents are on the higher side as it carries the effluents of all the lubricated houses of the mills. The graphical representation of results is given in Fig 5.
The data obtained for all the parameters is accommodated in Table 3.

Table 3 .Cumulative Effluent analysi

Parameter (mg/l)	FSM House Effluent			HSM House Effluent			MSM House Effluent		
	Mill	Process	Final	Mill	Process	Final	Mill	Process	Final
PH	7.8	7.4	7.29	8.1	5.15	3.93	8.6	7.6	6.3
TSS		227	396		169	653		300	272
BOD_5		365	474		93	181		345	673
COD		1202	2274		390	634		1995	3673
OG	49		185	20		27	32		47

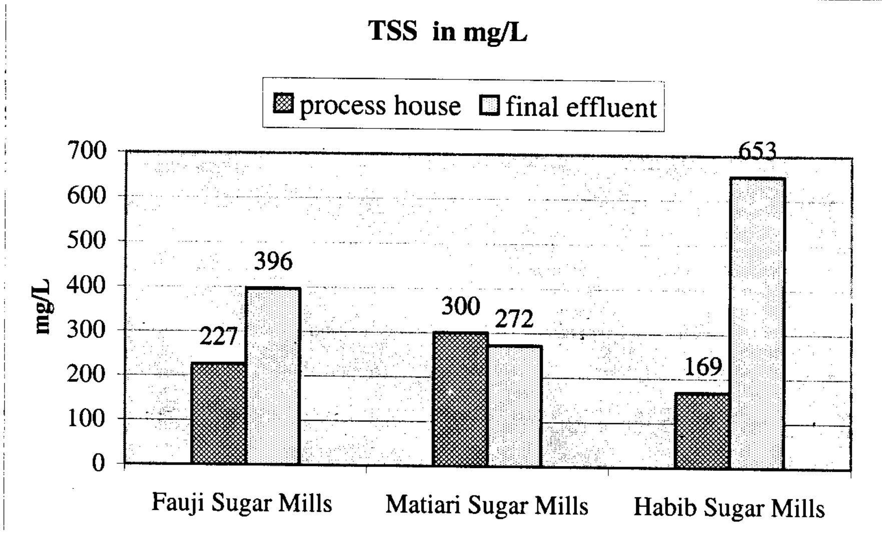

Fig. 2: Effluent TSS

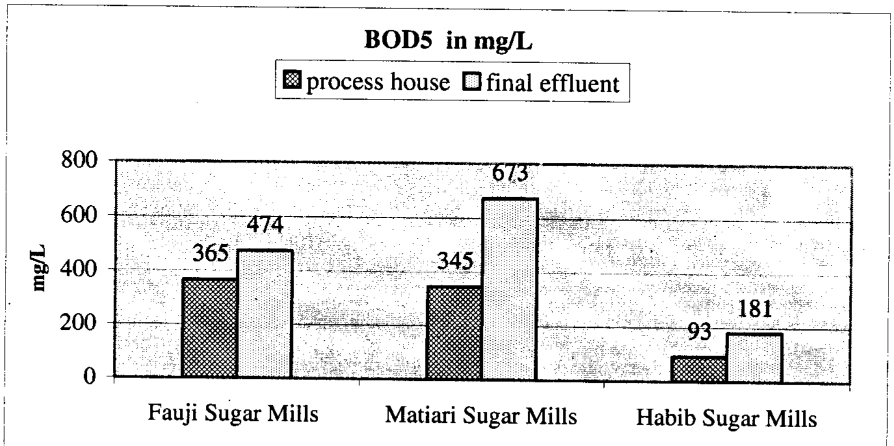

Fig: 3: Effluent BOD5

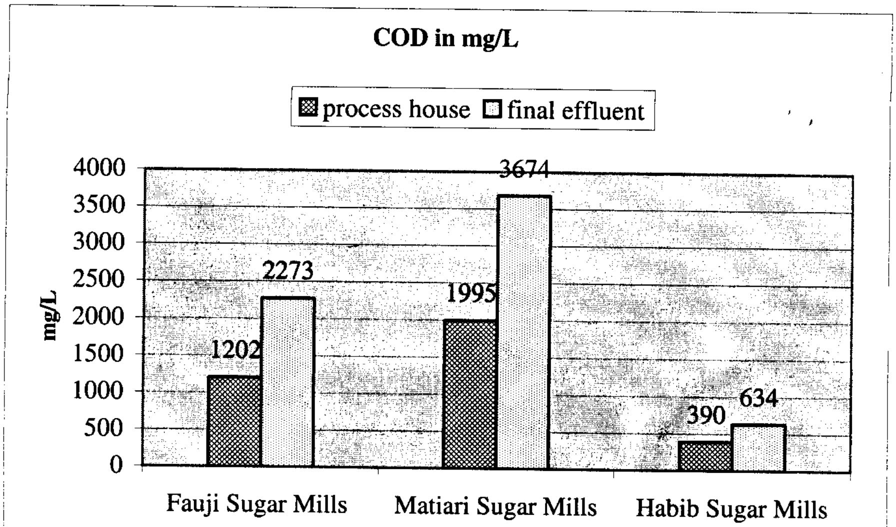

Fig: 4: Effluent COD

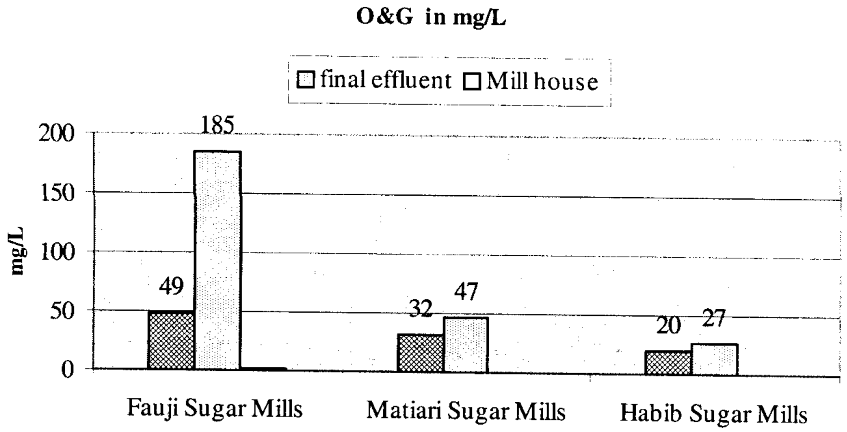

Fig: 5: Effluent O&G

Conclusions

1. Sugar mills have no flow meters installed at the inlet and outlet of each unit operation of the mill and process houses to gauge water consumption or wastewater generation. Installation of flow meters is useful to maintain water consumption and subsequent wastewater discharge ratios. It was also observed that the in-house plant-control measures or good housekeeping practices to minimize the higher levels of pollution were lacking in the sugar mills.

2.The analytical results of final effluent for COD, BOD_5, showed that Matiari sugar mills effluent had very high values i.e. 3673 mg/l, 673 mg/l respectively as compared to Fauji sugar mills (2274 mg/l, 474 mg/l) and Habib sugar mills (634 mg/l, 181 mg/l). Increase in BOD and COD values may by attributed to the spillage of molasses and lost or leaked sugar contents on the floors of the mills, which are swept or washed away to be mixed with the effluents causing higher levels of BOD and COD. TSS contents are higher than the standard value of 150 mg/l, mostly because of the flying paraticles of bagasse before and after it are burned.

3.As per these analyses, one can safely conclude that on the whole sugar mills don't comply with the standards set by the government for industrial wastewaters as highlighted under the banner of NEQS and hence most of the mills are a major source of water pollution.

In order to minimize the level of pollution as obtained through the analysis of the samples, it is suggested that:

- Segregation of oils from effluents will allow for the recovery and reuse of lubricating oil and reduce soil contamination when wastewater is applied for irrigation.
- To reduce the pollution load of sugar industry effluents, following in-plant control measures need to be applied at source, which will significantly reduce the volumes of flow and the quantum of pollution load in the wastewaters from sugar mills:
- Elimination of refuse, pieces of cane and suspended dirt from the used wash water streams by screening before lagooning. This precaution allows a decrease in the BOD load.
- No fixed standard of effluent quantity or flow is there in the NEQS list of 48 parameters. Sugar mills on average discharge 0.8-1m^3 of wastewater per ton of cane crushed. Hence, it is very much important that a standard value may be set for the flow of effluents.
- NEQS must be revised to make it industry specific. The effluent standards are same for all the industries, which in most cases may not be possible for a particular industry to comply with.

Acknowledgement

Authors are highly thankful and appreciative of the cooperation extended in this regard by the management of the sugar mills in question.

References

• Memon, Abdul Rehman, Khalid Pathan, Abdul Majeed Arain (1990), "A study of sugar mills in Sindh," BE Thesis, Department of Chemical Engineering, MUET, Jamshoro.

• Khan , Azharuddin, (1999), "Opportunities for Environmental solutions in Sugar sector," Journal of Engineering Horizons, No. 133, August 1999, pp.7.

•Ahmed, Aftab, (1997), "Pollution Prevention and in-plant control measures in sugar industry", A draft Report by Technology Transfer for sustainable Industrial Development, Islamabad, pp: 16 – 23.

•Hach, (1993), "DR/2000 Spectrophotometer Handbook," Hach company for systems for analysis, Loveland, Colorado, USA.

•APHA, (1995), "Standard Methods for the Examination of water and wastewater," 19th Edition, APHA, WPCF, AWWA, New York, USA.

•Atmospheric Science, www.eurekalert.org

•

•ESCAP/ FAO/ UNIDO, (1994), "Agro-chemicals - News in brief," Fertilizer Advisory, Development and Information Network Asia & the Pacific, Thailand

•Trivedy, R.K. (1998), "Advances in Wastewater Treatment Technologies," 1st Edition, Global Science, Aligarh, pp: 331.Jakhrani , Abdul Qayoom, (2002), "Impact of oxidation ponds on groundwater quality at Hyderabad," MS thesis, Faculty of Engg. MUET, Jamshoro