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END-OF-PIPE WASTE WATER DISPOSAL AND QUALITY COMPARISON OF OLD AND NEW SUGAR MILLS IN SINDH

Abdul Rehman Memon*, Niaz Ahmed Memon**, Muddasar Habib***

ABSTRACT

Sugar industry is 3rd largest industry of Pakistan as well as an important player in foreign exchange earnings; but it is also a major contributor to environmental pollution particularly with its wastewater discharges. This assessment study is the first part of the research project "Recurring environmental problems caused by sugar mills and their practicable solution", whereby wastewater handling in terms of its disposal by sugar mills is looked into so as to analyze their implications on the environment. This baseline study will help us assess the severity of the problem as a result of untreated wastewater disposal into the environment, which can lead us to devise a possible treatment plan that is low-cost as well as conducive to local conditions. Towards this end, three sugar mills viz. Matiari sugar mills, Matiari, Fauji sugar mills, Tando Mohammad Khan and Habib sugar mills, Nawabshah were frequently visited along with their immediate vicinities for the collection of samples and for carrying out investigation surveys as regards effluent disposal methods adopted by the concerned sugar mills. The results of this study suggested that sugar mills dispose of its wastewater untreated in every possible way, the pollutional composition of which exceed the limits, as specified in national environmental quality standards, by multiple times with respect to parameters such as Biochemical oxygen demand, Chemical oxygen demand, Oil and greases and Total suspended solids. Our research investigation into this issue concluded that sugar mills wastewater disposal in any given mode had a negative impact on land and water resources ultimately affecting the health and safety of people as well as flora and fauna.

Keywords: Pakistan sugar industry; Baseline assessment; Environmental impact; Wastewater disposal

1. INTRODUCTION

Pakistan is ranked 11th in the world in terms of sugar production and 8th largest sugar-consumer in the world [1]. Sugar industry is the 3rd largest industry of Pakistan, which is in operation for the last 65 years [2]. It is a seasonal industry operating for maximum of 5-6 months in one season from November to April. The industry uses either sugarcane or sugar beet as their raw material along with various chemicals added to increase the face value of the final product [3]. Sugar industry is a large water consumer and there is no stage in sugar production where water in some quantity is not required. However, water consumption can vary due to the technology applied and the nature and quality of raw material used. Mostly water is required in sugar mills as cooling water for barometric condensers, as boiler feed water, for lime preparation, for dilution in evaporators, etc. It has been observed that each ton of sugarcane crushed containing 70% moisture generates 0.7 m^3 of water if sugar and water are completely separated [4]. According to Indian standards, water consumption varies from 1.3 to 4.36 m^3 per ton of sugarcane crushed [5]. Thus, during sugar manufacturing process, huge amount of water is used on daily basis and as a result the industry generates wastewater or process liquid effluent with as much proportions. Sugar mills generate wastewater from each section of a sugar mill, which is mostly disposed of as a combined effluent for its outside settlement. There are three sections in a sugar factory: Mill house, process house and boiler house. The mill house wastewater is usually rich in oil and greases likely due to the spillage of oil and grease on the floor of mill house from the machinery and equipment that is washed off during floor washing. Process wastewater mainly results from floor and equipment washing and is highly contaminated with additives and other chemicals

* Assistant Professor, Department of Chemical Engineering, Mehran University of Engineering and Technology, Jamshoro
** Professor, Department of Civil Engineering, Quaid-e-Awam University of Engineering Sciences and Technology, Nawabshah
*** Assistant Professor, Department of Chemical Engineering, University of Engineering & Technology, Peshawar

used at different processing stages, while boiler house chiefly contributes to air pollution problem with its gaseous and particulate emissions and has little share in water pollution. Literature suggests that wastewater generated is about 20% of the water requirement [5]. Based on this ratio, a sugar mill with crushing capacity of 4500 tonnes of cane per day 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. 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 [3]. In addition, sugar mill effluents carry the constituents such as Biochemical oxygen demand (BOD), Chemical oxygen demand (COD) and oil and greases (OG) in the range, which more often than not exceed the limits as given by national environmental quality standards (NEQS).

Sugar mills' wastewater is mostly disposed of as untreated in the outside environment subject to the mode of disposal adopted. Every sugar mill has its own way to dispense with the wastewater that it generates. In order to investigate this issue, three sugar mills comprising of one new (Matiari sugar mills, Matiari) and two old plants (Fauji sugar mills, Tando Mohammad Khan and Habib sugar mills, Nawabshah) were made the focus of this study in terms of wastewater characteristics along with its disposal mode into the environment.

2. METHODOLOGY

2.1 WASTEWATER DISPOSAL BY SUGAR MILLS

For comparative analysis of old and new plants of sugar mills in terms of wastewater disposal and their characteristics, three sugar mills viz Fauji Sugar mills (FSM), Tando Mohammad Khan, Habib sugar mills (HSM), Nawabshah (both of them old plants) and Matiari Sugar mills (MSM), Matiari (new plant) were frequented for investigation of disposal methods adopted by these mills' along with the collection of wastewater samples for their analyses. Wastewater disposal mode adopted by these sugar mills is discussed hereunder.

2.2 HABIB SUGAR MILLS, NAWABSHAH (HSM)

The factory is a private plant located in Nawabshah at about 125 km from Hyderabad. The cane crushing capacity of the plant is about 7500 tonnes per day [6]. The millers discharge their effluents through a network of long cylinders, which then transfer this wastewater into the ponds or lagoons built outside the plant premises at a distance of 1.5-2 km from the mills. The survey of these lagoons yielded that there were at least 14 lagoons, constructed in a haphazard way over an area of 2 acres, having an average depth of 8-10 ft, where HSM stagnate their effluents for a period of 7-8 months. The schematic presentation of wastewater disposal pattern indicating the relevant routes adopted by Habib sugar mills, Nawabshah is given in Figure 1.

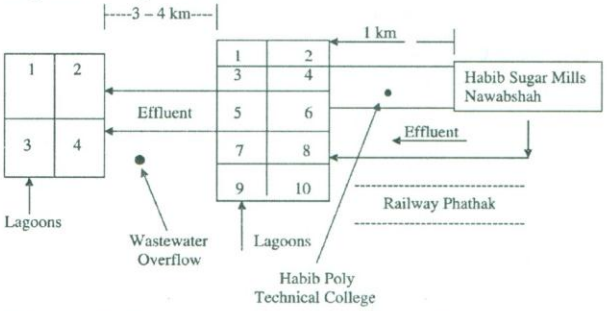

Figure 1: Schematic for wastewater disposal method adopted by Habib sugar mills, Nawabshah.

2.3 MATIARI SUGAR MILLS, MATIARI (MSM)

Figure 2 schematically depicts the wastewater disposal method practiced by MSM. The MSM is located at a distance of 6 km from Matiari town and about 35 km from Hyderabad. The MSM dispose of their plant effluent untreated through two large size concrete made drains, which carry the wastewater up to a distance of about 300 meters from the mills, before the entry of the piped wastewater into a big underground cylindrical pipe. This underground transportation of wastewater culminates into a canal, known as Chhandan Mori, which is 4 km away from the mills and serves as the final disposal point for MSM wastewaters. This canal is 25-28 feet wide and 8-10 km long having a depth of 2-3 feet.

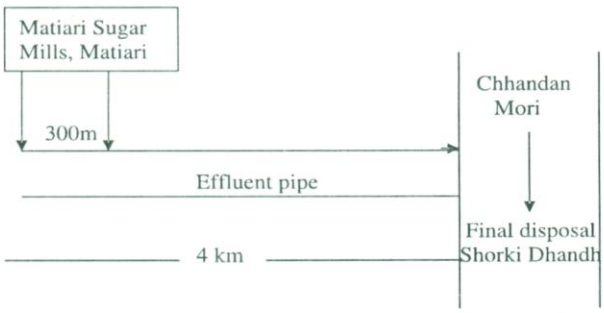

Figure 2: Wastewater disposal method for Matiari sugar mills, Matiari.

2.4 FAUJI SUGAR MILLS, TANDO MOHAMMAD KHAN (FSM)

Fauji sugar mills (FSM) is located within the city population of Tando Mohammad Khan, around 50 km away from Hyderabad. The wastewater of the mills is neither discharged to the ponds nor it is thrown away into any canal; rather, it is disposed of via a storm wastewater drain passing through the immediate vicinity of Mir Mumtaz agricultural lands. The drain water finally settles down in Tarai Nallah in Tarai village near Golarchi after bifurcating the Lakhat road. The wastewater disposal in case of FSM is schematically presented in Figure 3.

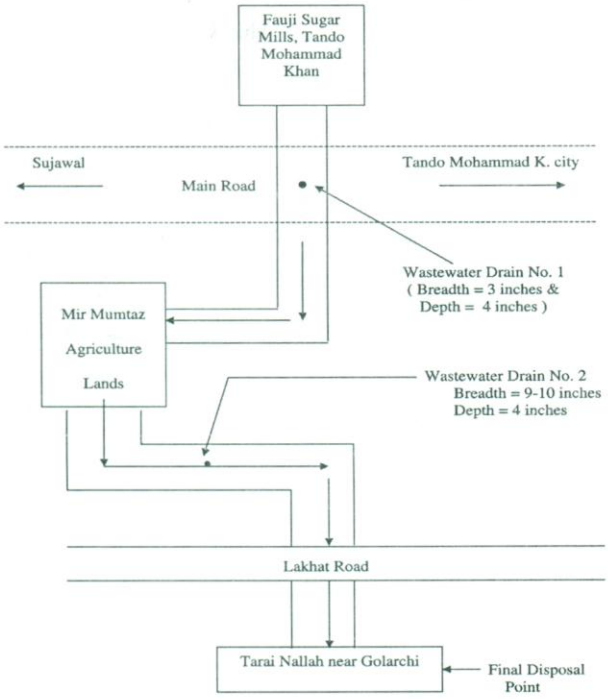

Figure 3: Wastewater disposal method for Fauji sugar mills, Tando Mohammad Khan.

2.5 WASTEWATER QUALITY COMPARISON OF THE SELECTED SUGAR MILLS

Each section of sugar mills generates wastewater with varying composition. Table 1 gives information about each section of the sugar mills along with the sources of wastewater generation and relevant parameters of concern within each section.

Table 1. ouse-wise wastewater characteristics in a sugar factory

Main Input	Unit house	Wastewater characteristics
Sugarcane	Mill House	Mostly contains suspended Solids and oil and grease contents. Also includes washing water used for floor cleaning, which contains sugar contents.
Sugar Juice	Process House	Washing of different omponents such as, Evaporator, Juice heater, Vacuum pan, clarifiers, generates aggressive effluents. Also includes manufacturing process water, which are high in BOD_5, COD concentrations.
Bagasse / Furnace oil	Boiler House	Wastewater from this unit has high pH, TDS and conductivity values

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 analyses was done *in-situ* (on site), while for chemical analyses, the samples had to be preserved by maintaining the sample container's inside temperature at 4^0C before being analyzed in the laboratory. Since sugar mills lie in category B of polluting industries by Pakistan Environmental Protection Act [7], the analysis of its effluents is comprised of five parameters namely pH, total suspended solids (TSS), BOD_5, COD and oils and greases. The sampling strategy for each parameters and point sources are given in Table 2:

2.6 ANALYTICAL PARAMETERS

Jenway direct reading pH meter was used to measure pH value. Oil contents were extracted from water by colorimetric extraction method using DR-2000 Spectrophotometer [8]. TSS were assayed via Photometric method using Hach's DR – 2000 Spectrophotometer. Whereas, BOD_5 test was carried out by making two diluted samples; one sample for the determination of its initial dissolved oxygen (DO_i) and the other sample was kept in incubator for five days at 20^0C. After five days the sample was tested for its final dissolved oxygen (DO_f) and with the help of following formula BOD_5 of the given sample was determined:

$$BOD_5 \text{ in mg/L} = \frac{DO_i - DO_f}{\text{Sample volume taken for dilution}} * \text{Total Volume of BOD bottle}$$

COD test was conducted by standard dichromate reflux method using the following equation [9]:

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

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)

Table 2: Wastewater sampling and analytical parameters.

Sample Point Source	EPA Prescribed Parameters	No. of samples from each sugar mill
Mill House	Oil and greases, pH, TSS	6
Process House	BOD_5, COD, pH, TSS	6
Combined or mix Effluent	TSS, pH, Oil and greases, BOD_5, COD	6

2.7 SURVEYING THE SEVERITY OF PROBLEMS IN THE VICINITY OF SUGAR MILLS

In order to know people's opinion about the problems caused by the disposal of wastewater into the surrounding environment, the people living nearby the vicinity of the mills were asked certain questions. The Specimen of the questionnaire is shown in Table 3:

Table 3: Specimen questionnaire for public opinion about sugar mills wastewater disposal effects.

Name of Industry :
Area / Locality :

Sr. #.	Name of Person and Age	Profession	Level of Impacts on				
			Human Health	Live-stock	Agricultural Lands	Odor Problem	Surface Or Ground Water
			A = 45% B = 55%	B =45% D =25%	C = 35% D = 45%	B = 55% D = 25%	A = 50% B = 50%

A = High / severe, B = Mild, C = Less, and D = No Problem

3. RESULTS AND DISCUSSIONS

3.1 WASTEWATER DISPOSAL BY SUGAR MILLS

All the three sugar mills namely Habib sugar mills (HSM), Fauji sugar mills (FSM) and Matiari sugar mills (MSM) discharge their wastewaters untreated, which can adversely affect the quality of receiving sources of water bodies or soils and agricultural lands. Major reported effects as obtained during environmental surveys of the three sugar mills were concerned with odors from settled untreated wastewaters, contamination of groundwater sources, soil erosion along with production of sludge from settled effluents with the passage of time. In case of FSM, it was noticed that the FSM effluent passing through Mir Mumtaz agricultural lands had rendered a portion of soil, parallel to the effluent drain, infertile and barren. The effects were apparent up to 100 m giving a blackish look to the soil. The area people also said that their animals were observed to fall ill especially after taking frequent dips into the sugar mills wastewater drain. While in case of HSM, the after effects of untreated wastewater disposal included contamination of groundwater resources, especially near the wastewater ponds. This information or observation was validated when a sample of groundwater was collected from the railway crossing hand-pump situated at about 600 m from the wastewater ponds for its physico-chemical analysis. In addition, the said hand-pump was reportedly not in use for the last two years due to poor quality of the water. The sample

analysis revealed that it had zero DO, pH 3.8, blackish color, undesirable smell and turbidity of > 500 NTU. It is more likely that the seepage or percolation of HSM wastewater might have caused the pollution of underground water reserves in the vicinity of unlined wastewater lagoons of HSM. Unlike surface water pollution, ground water contamination does not occur within a short time, but takes many years to contaminate the quality of ground water. This is because the mechanism of groundwater contamination is not direct and too slow as well, hence, its decontamination *in-situ* may also take long time in order to improve its quality [7, 8]. The children of the area were also seen splashing around in the stinking ponds of HSM making them susceptible to skin diseases such as acne and rash problems. When asked from a local Dermatologist about this, he said that since the wastewater of the ponds was highly organic in nature, therefore, children in this case were an easy target for skin diseases like darkening of skin and rashness, besides attracting many insects and flies towards their sugary skins. MSM wastewater was disposed of via a network of cylinders for its final settlement in the canal known as Chhandan Mori, which was a source of very pungent odor, as experienced beforehand. Moreover, the stagnant MSM wastewater was seemingly a breeding ground for mosquitoes, insects and other fliers. The data obtained from the survey questionnaire (Table 3) suggested that on average over 50% people were of the opinion that the sugar mills wastewater posed a direct or indirect effect on their health and on their livestock. They also complained of the odor nuisance caused by the stagnant wastewater in the ponds, as well as contamination of groundwater sources in the immediate vicinity of wastewater ponds.

3.2 WASTEWATER QUALITY COMPARISON OF THE SELECTED SUGAR MILLS

(a) Physical Analysis

The color of all the wastewater samples was juicy or brownish with a sugarcane juice-like smell. This implies towards the presence of sugar residues in the wastewaters. 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 may disturb the ecosystem of the receiving water bodies.

(b)Chemical Analysis

The wastewater pH for the three sugar mills is graphically shown in Figure 4. The pH results for process house and final effluent samples showed that HSM wastewater was more acidic in nature as it contained the lowest pH valued of 5. 15 and 3. 93 respectively, as compared to the other two samples. The lower pH values for HSM may likely be due to the difference in the nature of manufacturing process of each sugar mills, with HSM using Defecation Remelt Carbonation Sulphitation process in which derivative acidic compounds of both sulphur and carbon are formed, while FSM use Defecation Remelt Carbonation process without sulphitation factor. Secondly, HSM wastewater temperature was 45^{0}C as compared to 42^{0}C for FSM effluent, thus increasing the metabolic activity rate in the HSM wastewater, which would have resulted in the decrease of pH value. While pH of mill house samples of all the three sugar mills was found in alkaline range and within the specified limits of 6- 8.

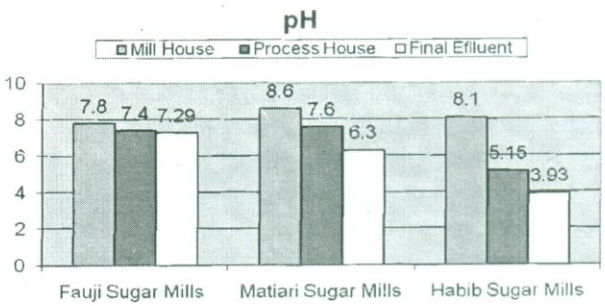

Figure 4: Wastewater pH for the three sugar mills.

Total suspended solids (TSS) were determined for the effluents of process house and combined mixture. TSS values were also found to be much higher than the standard value of 150 mg/L. TSS results suggested that MSM wastewater had the highest TSS of 300 mg/L from process house section as compared to other mills samples. This may largely be due to the lack of observation of in-plant control measures. Whereas, final effluent of HSM contained higher TSS value of 653 mg/L than those of the other two sugar mills, indicating higher cane crushing capacity of the industry and as a result producing large amounts of both fly ash and bottom ash and their subsequent possible presence in the effluent streams. In addition, the industry is also running a fiber plant within its premises 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. TSS results are graphically shown in Figure 5.

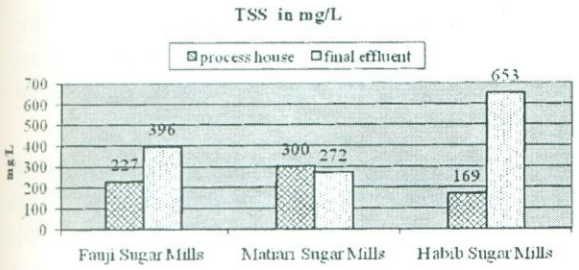

Figure 5: Total suspended solids of both process house and final combined effluents for the three sugar mills.

5-day biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) were analyzed for process house wastewater and final combined effluents and the results are shown in Figures 6 and 7 respectively. Like TSS, BOD_5 and COD values were also on the higher side as compared to their NEQS values. MSM final effluent had the highest BOD_5 and COD values of 673 mg/L 3673 mg/l in comparison to those of other two samples. While process house BOD_5 value of 365 mg/L for FSM was the highest among the process house BOD_5 values for 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_5 and COD values measured both for process and combined effluents i.e. 93 mg/L and 181 mg/L for BOD_5 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 [10].

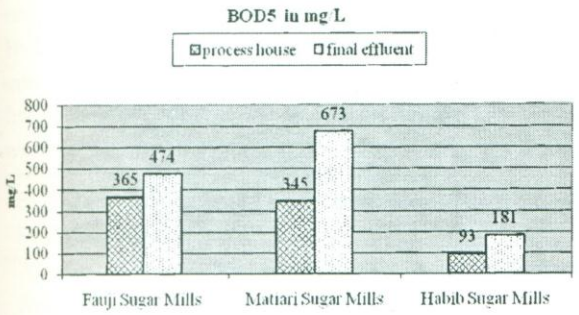

Figure 6: BOD_5 for process house and final combined effluents for the three sugar mills.

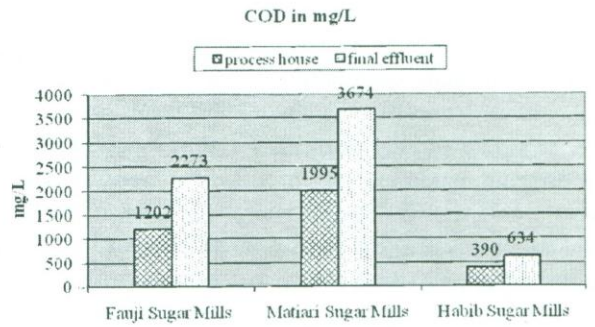

Figure 7: COD for process house and final combined effluents for the three sugar mills.

Oils and greases (OG) were determined for mill house samples, where oils and greases are particularly used, as well as for final effluent samples. Figure 8 show the results for oils and greases present in the wastewater samples from three sugar mills. These results show that OG were also present in wastewaters in higher quantities as against the set standard value of 10 mg/L. HSM effluent from mill house recorded the lowest value of OG i.e. 20 mg/L, while similar sample of FSM gave the value of 49 mg/L, which was the highest among the three samples. 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.

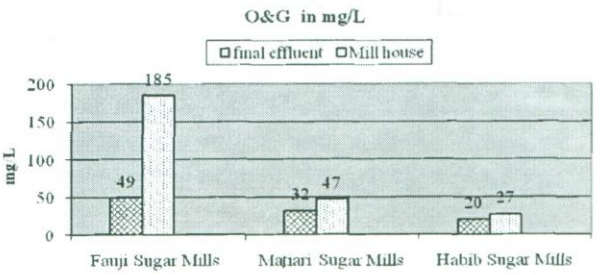

Figure 8: Oils and grease contents for mill house and final combined effluents for the three sugar mills.

4. CONCLUSIONS

From this research study, it was concluded via the conduct of environmental survey that people living in the vicinity of the selected sugar mills were being affected by the discharge of untreated sugar mills wastewater. In case of Habib sugar mills, Nawabshah, wastewater ponds built

outside the plant premises were the source of pungent and unpleasant odor that is bound to increase with time. In addition, this study has transpired that the groundwater quality in the immediate vicinity of HSM ponds has been affected severely to the extent that it is no longer in use for drinking purposes, which was also verified via laboratory analysis. The disposal of sugar mills wastewater in open pits is a source of ailments for humans, flora and fauna. While the wastewater seepage into soils may result in the loss of soil fertility. The effluent parameters such as pH, temperature, BOD_5, COD, TSS, Oils and greases were all found higher than the standard limits, which will be a source of further pollution with each passing day. Hence further work in this regard should focus on the treatment of sugar mills wastewater before their discharge into the environment.

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