

Analysis of the Physicochemical Characteristics of Distillery Wastewater at Habib Sugar Mills, Nawabshah

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Abstract—The aim of this study is to perceive the level of significant physicochemical characteristics of Distillery Wastewater (DWW) at Habib Sugar Mills, Nawabshah, Pakistan. Five locations in the mill namely spent wash, digester tank, distillery, primary treatment, and secondary treatment were selected for analysis of pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and Chemical Oxygen Demand (COD) of the samples. The samples were taken on a weekly basis for four succeeding months, from January 2021 to April 2021 and the experiments were carried out in the laboratory by adopting standard procedures. The results revealed that the pH of the samples from spent wash was the lowest, whereas secondary treatment samples had the highest. On the contrary, the highest concentrations of TDS, TSS, and COD were found in the samples taken from the spent wash and the lowest from the secondary treatment. The pH values were found abruptly increasing in the digester tank due to the addition of calcium carbonate in the stream of wastewater after the spent wash. The COD concentration was found to rapidly decrease, from more than 106000mg/l in the spent wash to around 35000mg/l in the digester tank samples, and then to gradually decrease up to the final point of disposal. Overall, TDS, TSS, and COD values were higher during April, January, and February and lower during March. The level of pH was extremely low in the spent wash and did not meet the lower limits of standards and the other examined parameters exceeded the upper limits of WHO standards.

Keywords—chemical oxygen demand; distillery wastewater; sugar mill effluents; physicochemical characteristics

I. INTRODUCTION

Around 75% of the earth's crust is covered with water. About 97% of the total available water is saline, which is confined in oceans, 2% is entwined in glaciers, ice caps, mud

and air. The remaining less than 1% is usable freshwater for the general public [1, 2]. The quality and quantity of water has great importance as a basic need [3, 4]. The discharge of untreated effluents should be within the safety limits [5]. Water is used for many purposes such as drinking, washing, bathing, cooking, agriculture, industry, and generation of electricity. In average, global agricultural withdrawals of all freshwater sources is about 70%. Agricultural inputs, especially fertilizers, pesticides, and other chemicals used for increasing the production of crops deteriorate the quality of water [6, 7]. Moreover, industries and municipal sewage pollute water sources when discharged directly into the water bodies without treatment. Polluted water causes many ailments, which are either direct or indirect [8].

Sugar industries are quite common globally due to their availability in more than 65% of sovereign countries. They are processing cane to produce raw sugar [9]. These industries generate byproducts such as bagasse, press mud, molasses and wastewater [10]. The production of 1kg sugarcane crop requires about 210lt of water. Besides crop requirements, water is also needed to run different processes in sugar mills and generates varying quantities and qualities of wastewater. In the sugar industry, water is normally obtained during the cane processing and the refinery processes [11]. Sugarcane crop contains about 70–80% moisture and approximately 1m³ of wastewater is generated when 1 ton of sugarcane is processed in sugar industry [9, 12].

A. Distillery Industry

Sugar industries can be categorized into three main groups, namely those that produce only raw table sugar, those that produce only ethanol, and those that produce a combination of

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both [9, 13]. Approximately 90% of sugar industries belong to the third category, whereas, 7% produce only ethanol and 3% only sugar [14]. The increasing population has forced the enhancement of the development of distillery industry that produces ethanol, industrial chemicals, and bio-fuels. The processes used in distillery industry leads to the generation of Distillery Wastewater (DWW), stillage, or spent wash. On average, 1lt of alcohol production generates about 13lt of DWW depending on the used methods of distillation and waste treatment [15]. Thus, typical large distillery plants produce about 1950m³ of DWW.

B. Characteristics of Distillery Wastewater

The sugar mill DWW is highly polluted wastewater due to the presence of various organic compounds. It has dark color, low pH, high temperature, and extreme level of Chemical Oxygen Demand (COD), BOD, Total Dissolved Solids (TDS), sludge, press mud, and bagasse [16]. DWW has a pH of 4.0–4.6, BOD 25,000–35,000ppm TDS 85,000–110,000ppm and COD 85,000–110,000ppm [17]. Authors in [18] found the ratio of BOD and COD index in sugar industry to be 0.60 and 0.25. Authors in [10] found that DWW has a pH of 4.0 to 4.3 with high rates of BOD (52-58kg/m³), COD (92-100 kg/m³), and Total Suspended Solids (TSS) (2.0-2.5kg/m³). Authors in [19, 20] reported the characteristics of DWW as dark brown color, 5.4-4.5 pH, 40,000 to 50,000mg/L BOD, and 80,000 to 100,000mg/L COD. The high concentration of COD and BOD of DWW were attributed to the composition of input material used for the production of ethanol [21, 22]. High pollution load and the volume of DWW cause significant environmental issues [23] but now due to statutory restrictions, it cannot be used without meeting standards [24], as it may lead to alteration of the soil structure and can cause eutrophication of water bodies [21, 25, 26].

From the literature review, it is perceived that DWW is one of the most polluted waste materials and must be disposed of with care as it is of low pH, dark brown color, high content TDS, TSS, and COD. If DWW is disposed of without proper treatment, it can deteriorate the receiving water bodies and affect the general environment. This study was conducted in order to analyze the physicochemical characteristics of DWW and to check the level of pollutants in DWW and whether it meets standards or not.

II. MATERIALS AND METHODS

A. Study Area

Habib Sugar Mills was selected for this case study. It is located in the Nawabshah city. The sugarcane crushing capability of the mill is around 11,000ton per day. The refine productions of the mill are sugar and methanol, and the raw wastes are bagasse and molasses [27].

B. Sampling and Collection

A total of 5 wastewater sampling locations, namely spent wash, digester tank, distillery unit, primary treatment, and secondary treatment plant were selected in order to investigate the characteristics of sugar mill DWW. The samples were collected weekly for a period of four months. The samples were kept in cleaned plastic bottles. All bottles were washed

properly with distilled water. The capacity of each bottle was 5lt. The samples were collected from the exit points of each location. Precaution and standard protocols were adopted during the entire sampling period.

C. Analysis of the Physicochemical Characteristics of Sugar Mill Distillery Wastewater

Some physicochemical parameters of DWW were measured on the spot, while others were examined in the laboratory using the standard protocols. The instruments and methods used for the analysis of the physicochemical characteristics of DWW are tabulated in Table I.

III. RESULTS AND DISCUSSION

Four physicochemical parameters, namely pH, TDS, TSS, and COD of sugar mill DWW were analyzed as per ASTM standards from January 2021 to April 2021. The results obtained from the experimental work are presented in Figures 1-8.

TABLE I. METHODS USED FOR THE ANALYSIS OF PHYSICO-CHEMICAL CHARACTERISTICS OF DWW

S. No.	Parameter	Instrument	Method
1	pH	pH meter, HI 2211 pH/ORP meter	ASTM E70-19 ASTM D1293-18
2	TDS (mg/L)	TDS Digital meter	ASTM D5907-18 ASTM D5907-10
3	TSS (mg/L)	TSS Digital meter	ASTM D5907-18 ASTM D5907-10
4	COD (mg/L)	Titration method	ASTM D1252-06 (2020)

A. pH Level

The determined pH value of the samples taken from different locations and the monthly average values are presented in Figures 1 and 2. The pH value of spent wash wastewater samples was 4.3, 4.5, 4.3, and 4.3 for each month from January to April respectively with an average value of 4.3. Similarly, the pH value of digester tank was 7.6, 7.9, 7.8, and 7.6 with an average value of 7.7. Likewise, the pH level of distillery wastewater sample was 8.0, 8.0, 8.0, and 7.9 with an average of 7.9. The pH of the samples taken from primary treatment was 8.1, 8.1, 8.1, and 8.1 with an average of 8.1 and from secondary treatment it was 8.3, 8.2, 8.2 and 8.2 with an average value of 8.2. The maximum and minimum pH values of spent wash, digester tank, distillery wastewater, primary treatment and secondary treatment were 4.5 and 4.4, 7.9 and 7.6, 8.0 and 7.9, and 8.3 and 8.2 respectively. The mean monthly average values of pH from all sampling locations were 7.3, 7.3, 7.3, and 7.2 from January to April respectively. The maximum and minimum mean monthly average values of pH were 7.3 and 7.2 in February and April respectively. Overall, the maximum pH values were observed in the secondary treatment samples, and the minimum from the spent wash wastewater samples. It was observed that 4 wastewater samples were slightly closer to the upper limit of the standard and only 1 sample was highly acidic which was taken from the spent wash.

B. TDS Concentration

The levels of TDS in DWW samples are shown in Figure 3 and the monthly average in Figure 4. The TDS of spent wash wastewater was 34525, 34400, 34050, and 34675mg/l each month from January to April with an average of 34412mg/l. The TDS of the digester tank samples was 26775, 27150, 26890 and 27062mg/l respectively with an average of 26969mg/l. Similarly, the TDS concentration of distillery wastewater was 20675, 21962, 21420 and 21825mg/l with an average of 21470mg/l and from the primary treatment 14637, 14837, 14550, and 14887mg/l with an average of 14728mg/l. The TDS concentration of the samples taken from the secondary treatment was 11775, 11250, 11230, and 11362mg/l with an average value of 11404mg/l. The maximum and minimum TDS concentration of spent wash, digester tank, distillery wastewater, primary treatment, and secondary treatment was 34675 and 34050, 27150 and 26775, 21962 and 20675, 14887 and 14550, and 11775 and 11230mg/l respectively. The monthly mean values of TDS from all sampling locations were 21677, 21920, 21628, and 21962mg/l from January to April respectively.

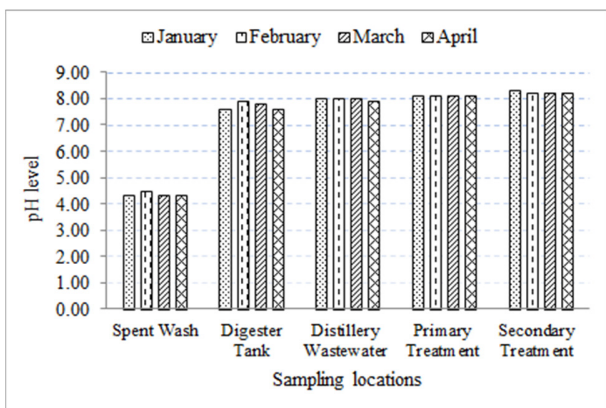


Fig. 1. pH values.

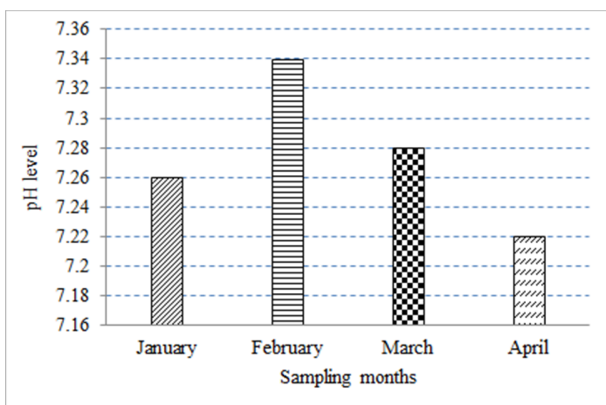


Fig. 2. Average monthly pH level.

The monthly maximum average value of TDS was 21962mg/l during April and the minimum was 21628mg/l in March. The higher TDS values were shown in spent wash samples and the lower values in secondary treatment water

samples. All wastewater samples were higher than the WHO standards.

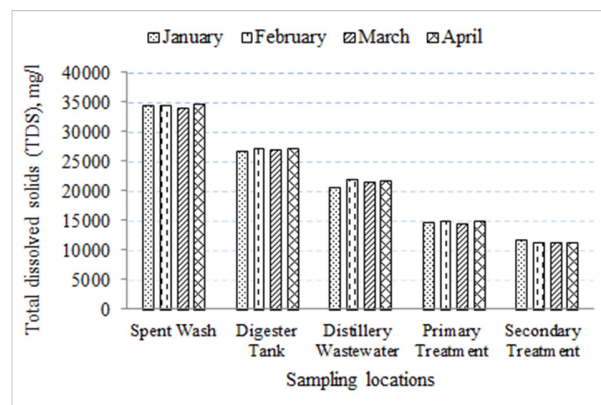


Fig. 3. TDS values of all samples from different locations.

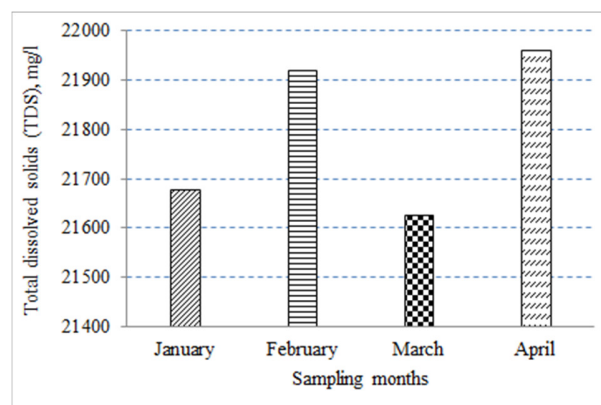


Fig. 4. Average monthly level of TDS in different months

C. Total Suspended Solids Concentration

The concentrations of TSS in the samples taken from different locations are given in Figure 5 and their average monthly level is displayed in Figure 6. The level of TSS in spent wash wastewater samples was 11630, 11370, 11246, and 11315mg/l for each months from January to April respectively with an average of 11390mg/l. The respective TSS level of digester tank samples was 8292, 8337, 8264, and 8305mg/l with a monthly average of 8300mg/l. The TSS concentration of distillery wastewater samples was 6822, 6852, 6808, and 6695mg/l with an average of 6794 mg/l. Similarly, the primary treatment samples had TSS level of 2917, 2970, 2968, and 2990mg/l with a monthly average of 2961mg/l. The TSS level in the samples taken from the secondary treatment was 1892, 1872, 1854, and 1847mg/l with an average of 1866mg/l. The higher and lower TSS concentrations of spent wash, digester tank, distillery wastewater, primary treatment, and secondary treatment were 11630 and 11246, 8337 and 8264, 6852 and 6695, 2990 and 2917, and 1892 and 1847mg/l respectively. The monthly mean values of TSS from all sampling locations were 6311, 6280, 6228, and 6230mg/l from January to April respectively. The highest observed monthly mean of TSS was 6311mg/l in January and the lowest was 6228mg/l in March. Overall, the higher TSS concentrations were found in spent

wash samples and the lower in the samples taken from the secondary treatment location. It was also observed that all examined samples showed higher values than the WHO standards.

D. COD Concentration

The levels of COD in the examined samples are shown in Figure 7 and their average monthly values in Figure 8. The COD value of spent wash samples for the months from January to April were 104763, 108370, 106052, and 106112mg/l respectively with an average of 106324mg/l. The COD values of the samples taken from the digester tank were 36250, 34448, 34510, and 34375mg/l respectively with an average of 34896mg/l. The monthly values of the samples taken from the distillery were 23175, 23225, 22640, and 23750mg/l respectively with an average of 23197.50mg/l. Likewise, the primary treatment samples values were 14012, 13982, 14270, and 14700mg/l respectively with an average of 14241mg/l. Correspondingly, the COD of secondary treatment samples for the months from January to April were 8400, 8705, 8320, and 8375mg/l respectively with an average of 8450mg/l.

average value of COD was 37746mg/l in February and the minimum 37158.4 mg/l in March. Generally, it was found from the analysis that the spent wash samples showed the highest COD concentration, whereas the samples taken from secondary treatment location displayed the lowest values. However, all examined samples showed higher COD values than the WHO standards.

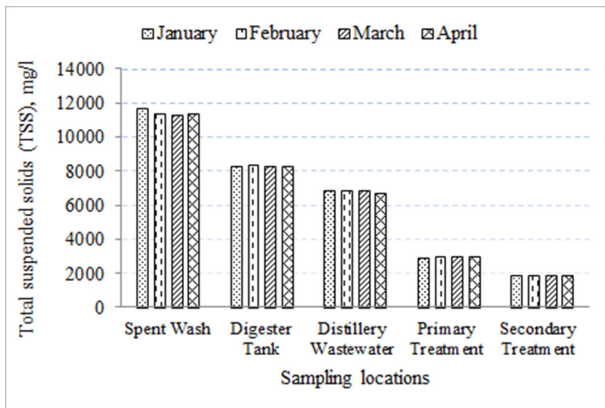


Fig. 5. TSS values of all samples.

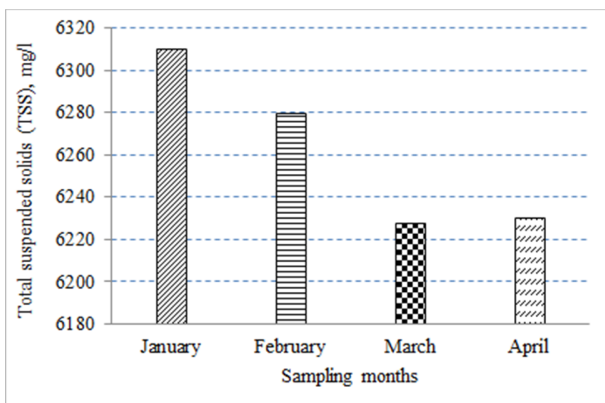


Fig. 6. Average monthly level of TSS.

The maximum and minimum COD concentration in spent wash, digester tank, distillery wastewater, primary treatment, and secondary treatment were recorded as 108370 and 104763, 36250 and 34375, 23750 and 22640, 14700 and 13982, and 8705 and 8320mg/l respectively. The maximum mean monthly

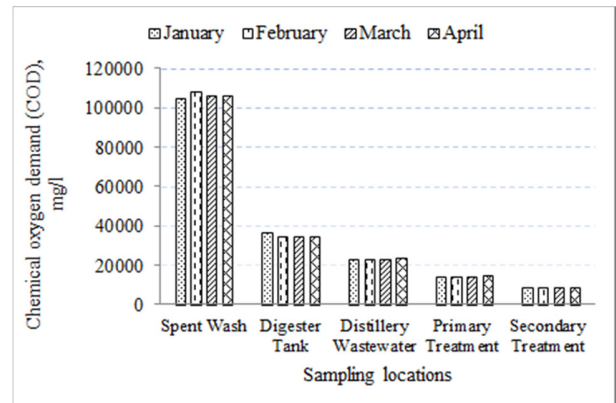


Fig. 7. COD values of all samples.

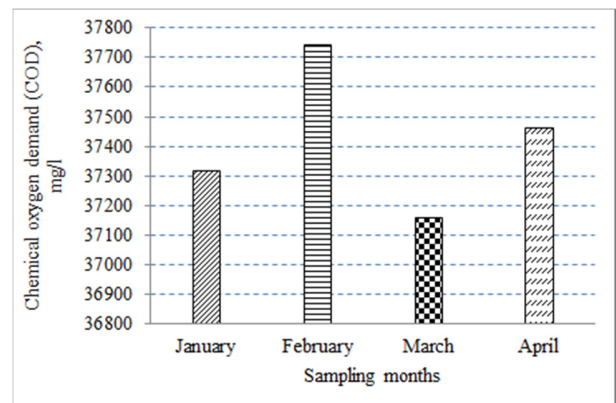


Fig. 8. Average monthly level of COD.

IV. CONCLUSION

Weekly samples of sugar mill DWW were taken from 5 locations, namely spent wash, digester tank, distillery wastewater, primary and secondary treatment, and analyzed for four consecutive months from January 2021 to April 2021 by observing 4 physicochemical characteristics, namely pH, TDS, TSS, and COD. It was found from the analysis that the pH values of spent wash samples were the lowest, whereas the values from the secondary treatment samples were the highest. The highest concentrations of TDS, TSS, and COD were found from the samples taken from the spent wash and the lowest from the secondary treatment location. The authorities of Sugar Mill add calcium carbonate to increase the level of pH up to standards, thus its values were sharply increased in the next sampling place, i.e. in the digester tank, and then were slowly increasing up to the final disposal point. The concentration of COD was found to quickly decrease from 106000mg/l in the spent wash samples to around 35000mg/l in the next sampling

location, and then gradually decreased up to the final disposal point. Overall, TDS, TSS, and COD values were found lower in March and higher during the other months. The levels of almost all examined parameters were higher than WHO standards, except from pH which was extremely low in the spent wash.

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