Assessing the Impact of Sugar Mills Wastewater on the Surface Water Quality in Natore District

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Abstract. One of the most significant industrial sectors and largest agro-based industry in Bangladesh is the sugar industry. During production time, a large amount of wastewater produced on daily basis by sugar mills is hazardous. The poorly managed wastewater discharged in an open water body which causes water related environmental issues. In Bangladesh, surface water is the most widely used as domestic purpose, irrigation and fisheries. The availability of safe water is one of the major concerns as the quality of water is directly linked to human health. So, the study deals with the impact of sugar mills wastewater on the surface water quality in Natore district. Surface water samples were collected before and after sugar mill wastewater was discharged. It was found that the Sugar Mill wastewater increased the concentration of color, EC, iron, CO_2, hardness, alkalinity, chloride, COD ($p < 0.01$), and turbidity, BOD ($p < 0.05$) in surface water. Raw wastewater of the sugar mill was found in ECR 2023 standard limit. Before mixing, a strong positive correlation found between all parameters. After mixing, a strong positive correlation found pH with other parameters.

Keywords: Sugar mill, wastewater, surface water, impact.

1 Introduction

Assuredly, water is the most necessary resource not only for livelihood but also for the advancement of industry and economy [1]. At present, water resource management has taken on a chief role all over the world. Because Industrial development and the environment are confidentially connected. Developing countries are still discharging wastewater into numerous unlocked water bodies such as ponds, canals and rivers due to lack of awareness and strict disciplinary action. It is claimed that 70% of industrial waste in developing countries is discharged untreated into waterways, contaminating nearby water sources [2]. In Bangladesh, sugar industry is one of the most important industrial sectors which playing a vital role in its national wealth and development by the way of farming and creation of employment. Sugar industry is a seasonal industry which is run for four months in a year. Factories are consumers of vast amount of fresh water, wastewater contains peak level of contaminants including suspended solids, organic and inorganic substances and chemicals [3]. Most of the chemicals used in sugar

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mill for manufacturing process are toxic and if they are not properly handled, they may eventually find their course into streams, causing poor water quality [4]. The wastewater creates annoying odor throughout putrefaction.

In Bangladesh, most of the sugar mills are located in the western zone, where the concentration of growing sugar cane is high. There are 17 sugar mills in Bangladesh, all of them 15 sugar mills have been opened [5]. Most of the sugar mills were established in rural areas. There are two sugar mills in the Natore district. The first is the Natore Sugar Mill, situated in Natore Sadar upazila. The other is the North Bengal Sugar Mill, which is situated in Lalpur Upazila. These two sugar mills generate enormous amounts of wastewater throughout the manufacturing season, which they discharge into the environment. The wastewater from North Bengal Sugar Mill flows into a canal via an untitled open drain. It passes through several villages then falls into the 'Ichamati" river. The wastewater contaminated the surface water which may lead to major health problems [6]. Assessing the impact of sugar mills wastewater on the surface water quality is the goal of the study.

2 Materials and Methods

2.1 Study Area

The study was done in surrounding area of North Bengal Sugar Mills Ltd. which is situated at Lalpur Upazila in Natore District at the time of 1933. The study area is situated between longitude 24°12'54.1" to 24°13'27.5" and latitude 88°59'51.1" to 89°02'06.1". Location map of sampling point is shown in Fig. 1.

2.2 Sample Collection

Samples were collected in two terms. The North Bengal Sugar Mills only operates for four month a year (November to February). First sampling was done before starting manufacturing activity of the sugar mill. Second sampling was done after starting the manufacturing activity of the sugar mill. 9 sampling points were selected from non-tilted drains, canals and rivers to get before starting manufacturing activity of sugar mills samples. On the other hand, 13 sampling points were selected from non-tilted drains, canals and rivers to get after starting manufacturing activity of sugar mills samples. All surface water samples denoted as (S). During production time, a raw wastewater sample was collected from the main discharge pipe of sugar mill. The raw wastewater sample denoted as (D).

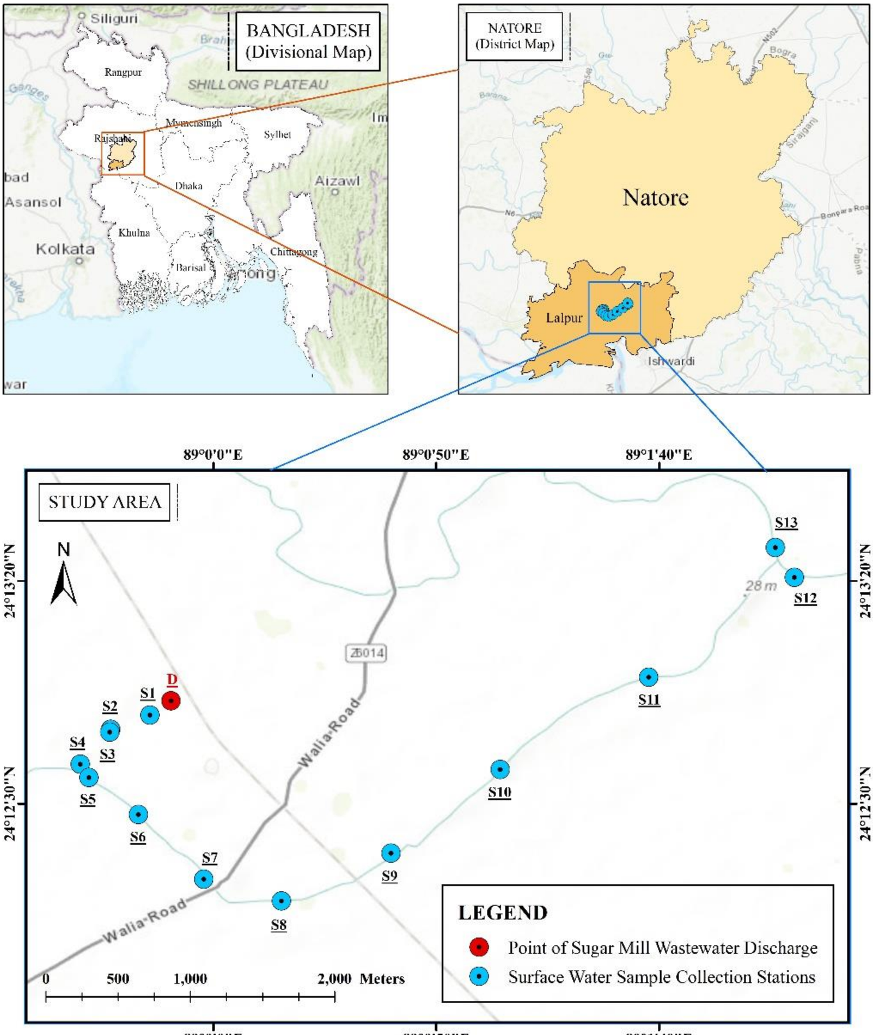

Fig. 1. Study Area Location Map

2.3 Tested Parameters

To know the water quality of the collected samples, they were brought in the Environmental Engineering Laboratory, Dept. of Civil Engineering, Bangladesh Army University of Engineering and Technology. The analyzed parameters were pH (Lutron Multimeter, WA-2015), Color (Spectrophotometer, HACH DR 3900), Turbidity (Turbidity Meter, TUB-430), EC (Lutron Multimeter, WA-2015), Alkalinity (HI 3812 Hardness Test Kit), Hardness (HI 3821), Chloride (HI 3815), CO_2 (Titrimetric method) Iron

(Spectrophotometer, HACH DR 3900). Also, TSS, TDS, BOD, and COD were measured through the APHA (2017) method [7].

Table 1. GPS Co-ordinates of Sample Stations

Station	GPS	
	N	E
D	24°12'54.1"	88°59'51.1"
S1	24°12'49.94"	88°59'45.75"
S2	24°12'46.68"	88°59'37.03"
S3	24°12'46.11"	88°59'36.81"
S4	24°12'38.88"	88°59'30.16"
S5	24°12'35.86"	88°59'32.07"
S6	24°12'27.58"	88°59'43.19"
S7	24°12'13.08"	88°59'57.85"
S8	24°12'8.22"	89°00'15.3"
S9	24°12'18.9"	89°00'39.9"
S10	24°12'37.7"	89°01'04.4"
S11	24°12'58.5"	89°01'37.7"
S12	24°13'20.8"	89°02'10.4"
S13	24°13'27.5"	89°02'06.1"

2.4 Data Analysis

Analysis is an important method for acquiring results from data collected. Data Collected from laboratory tests were processed and analyzed by using Microsoft Office Excel 2021 and IBM SPSS Statics version 27. Bangladesh Environment Conservation Rules (ECR) (2023) was used to compare results [8]. A statistical analysis was performed to examine the correlation and t-test. The physio-chemical parameters for the study area were analyzed by calculating Pearson's correlation coefficient value.

3 Result and Discussions

3.1 Raw Wastewater Characteristics

Sugar mills wastewater have intricated characteristics varying from mills to mills. The stages of growing, cutting, crushing and processing of sugarcane result in a range of sources of nutrient runoff and effluent wastewater being discharged into a drain. The daily sugarcane crushing capacity of North Bengal Sugar Mill is 1500 metric tons and the sugar mill generates 3000 metric tons liquid waste per day [9]. Typical sugar mills wastewater consists of COD; 1000-7000 mg/L, pH: 5-9, BOD: 800-2500 mg/L, total solids: 500-3000 mg/L [10]. Table 2 represents the physio-chemical characteristics of raw wastewater of North Bengal Sugar Mill. pH is the most important parameter of any kind of water. As per ECR 2023, pH value of sugar mill wastewater must be between 6 to 9. From Table 2, it was seen that pH was found in the standard range of ECR 2023. TSS are inorganic or organic particles that are suspended in the wastewater and can be removed by filtration. As stated by ECR 2023, TSS of sugar mill wastewater must be 100 mg/L. From Table 2, it was found that TSS was in the standard limit.

Table 2. Characteristics of Raw Wastewater

Parameter	Value
pH	8.703
EC (mS/m)	1.256
Color (Pt-Co)	910.67
Turbidity (NTU)	55.13
Iron (mg/L)	0.967
Chloride (mg/L)	51.67
Alkalinity (mg/L)	517
Hardness (mg/L)	620
TS (mg/L)	1.96
TDS (mg/L)	0.975
TSS (mg/L)	0.985
CO_2 (mg/L)	40.784
COD (mg/L)	1832

3.2 Surface Water Characteristics

The pH is one of the most dominant physiochemical parameters of surface water for aquatic life and microbial activity. According to the ECR 2023 inland surface water standard, the pH value should be 6 to 9. From Fig. 2 (a), it was seen that pH was found within the range of ECR 2023, which indicates pH would not pose any adverse impact on the surface water. Closer results were found by [11] in the same area. Before starting the manufacturing activity of the sugar mill, the value of pH varies from 7.69 to 8.57, which does maintain the standard value. After starting the manufacturing activity of the sugar mill, the pH range is 7.63 to 8.35 for the wastewater. Before mixing, a strong positive correlation of pH found with most parameters. After mixing pH had moderate positive correlation with hardness, alkalinity and pH had moderate negative correlation with EC. The maximum value of color was found in S9 in the after mix, which was 2729.33 Pt-Co, and the lowest was found in S12, which was 46.33 Pt-Co (Fig. 2 (b)).

After mixing, it was seen that the color was reduced from S1 to S8, which was justified as sugar mill wastewater was mixed with existing surface water and diluted and again increased at S9. However, before mixing at S6 and S7, color was slightly increased due to jute retting as reported by Ahmed and Akhter (2001) that the derogation process of jute produces smell and changes color concentration of the water used for jute retting [12]. The color concentration found significantly different ($p < 0.01$) before mixing and after mixing, which indicates that the sugar mill wastewater increased the concentration of the surface water. It was found that before mixing color had weak positive correlation with BOD, COD, TSS. After mixing color presented strong positive with turbidity, alkalinity, iron, CO_2. Before mixing, the turbidity was found to be very small (< 25 NTU). However, after mixing, turbidity was increased, which confirms that the sugar mill wastewater has an impact on surface water, as shown in Fig. 2 (c). After starting the wastewater of the sugar mill, the highest value of turbidity was 930.33 NTU, which is at station 2. Sunlight cannot pass through high turbid water and high turbid water isn't suitable for aquatic flora and fauna. However, the turbidity concentration showed significantly different ($p < 0.05$) before mixing and after mixing, which indicates that the concentration of the surface water was high. Before mixing turbidity had weak negative correlation with BOD and COD respectively.

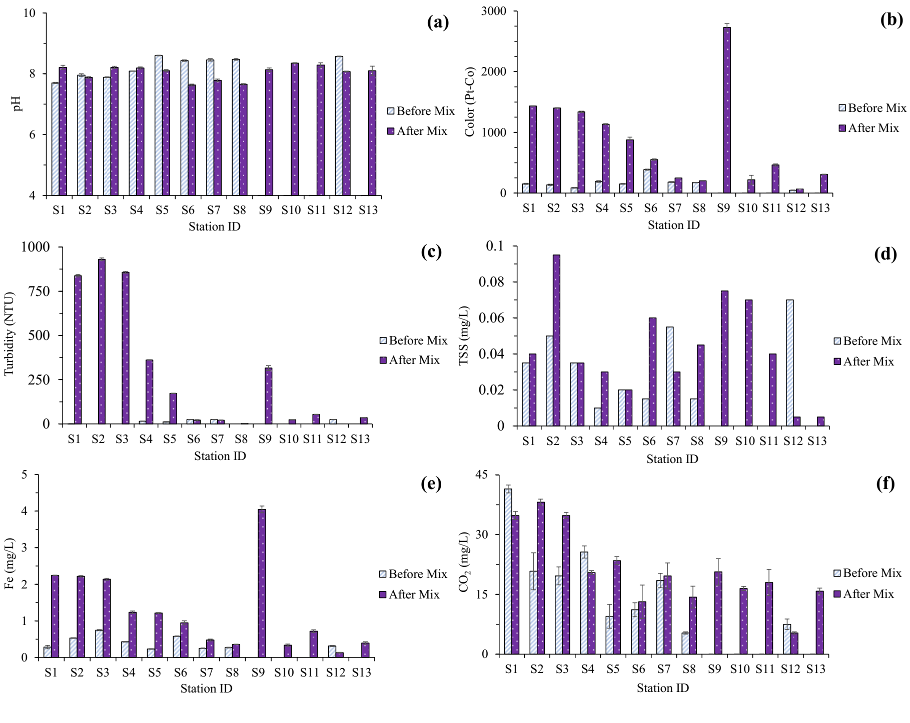

Fig. 2. Variations of surface water samples during before and after mixing of sugar mill wastewater (a) pH, (b) Color, (c) Turbidity, (d) TSS, (e) Iron, (f) CO_2

After mixing turbidity had moderate positive correlation with BOD, COD, TSS. As per the ECR 2023 inland surface water standard the TSS should be 100 mg/L. From Fig. 2

(d), it was seen that the TSS was high after mixing samples compared to before mixing samples except for S7 and S12. All samples TSS were within standard limit. There was only strong positive correlation of TSS with pH before mixing. After mixing TSS had weak negative correlation with pH and EC. According to the ECR 2023 inland surface water standard the Iron value should be maximum 3 mg/L. Before starting the manufacturing activity of the sugar mill the iron value varies from 0.23 mg/L to 0.75 mg/L, which does maintain the standard value as shown in Fig. 2 (e). After mixing starting the manufacturing activity of the sugar mill, when effluent mixed the iron value varies from 0.13 to 2.24 mg/L, which does also maintain the standard value. At S9 iron concentration suddenly increased during the after mixing period. Suddenly increased dissolved organic matter as the main driver behind the recent rise in iron concentration [13]. In terms of before mixing the sugar mill wastewater iron had weak positive correlation with turbidity and BOD. After mixing the sugar mill wastewater iron had strong positive correlation with CO_2, color, turbidity. But the iron concentration was found to be significantly different ($p < 0.01$) before mixing and after mixing, which indicates that the sugar mill wastewater increased the concentration of the surface water. The growth of aquatic plant life is contingent upon the presence of carbon dioxide and bicarbonates in water. Both microscopic phytoplankton, suspended in the water, and larger rooted plants engage in photosynthesis, utilizing carbon dioxide to produce various plant materials such as starches, sugars, oils, and proteins. The carbon constituting these materials originates from the dissolved carbon dioxide in water. The ECR 2023 does not set any limits for the presence of CO_2 in inland surface water. Before starting the manufacturing activity of the sugar mill, the value of CO_2 varies from 5.32 mg/L to 41.5 mg/L, and after starting, the CO_2 value varies from 5.32 mg/L to 38.12 mg/L of the effluent, as shown in Fig. 2 (f). The CO_2 concentration showed slightly different ($p < 0.01$), which indicates the contamination level of surface water. In case of before mixing CO_2 had strong positive correlation with most of the parameters. After mixing CO_2 had moderate positive correlation with hardness, BOD, COD and alkalinity.

In Fig. 3 (a), it was found that before mixing of the sugar mill effluent, the Hardness range is 123 mg/L to 455 mg/L. After mixing of the sugar mill wastewater the value of Hardness varies from 202 mg/L to 478 mg/L. The hardness concentration was found to be significantly different ($p < 0.01$) before and after mixing, which indicates that the sugar mill wastewater increased the concentration of the surface water. Before mixing there were strong positive correlation with most parameters of hardness. After mixing hardness had weak negative correlation with BOD and strong negative correlation with EC. Alkalinity is essential for fish and aquatic life by reason of it protects against swift pH changes. Large amount of alkalinity imparts bitter test in water. Before starting the manufacturing activity of the sugar mill, the alkalinity range is 144 mg/L to 427 mg/L, as shown in Fig. 3 (b). After starting the manufacturing activity of the sugar mill the alkalinity value varies from 225 mg/L to 559 mg/L. However, alkalinity concentration was found to be significantly different ($p < 0.01$) before mixing and after mixing, which indicates that the sugar mill wastewater increased the concentration of the surface water. Alkalinity showed strong positive correlation with most of the parameters during the before mixing period. In terms of after mixing alkalinity showed weak positive correlation with chloride, turbidity and COD.

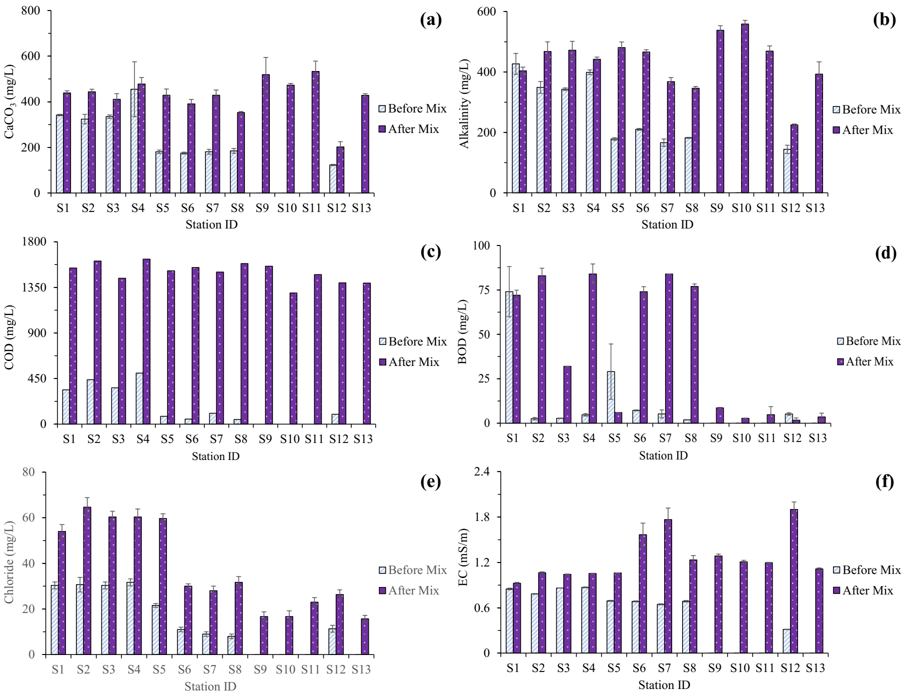

Fig. 3. Variations of surface water samples during before and after mixing period of sugar mill wastewater (a) Hardness, (b) Alkalinity, (c) COD, (d) BOD, (e) Chloride, (f) EC

COD is a principal indicator of drop of the water quality from discharging untreated industrial wastewater. According to the ECR 2023 inland surface water, the standard value of COD should be 200 mg/L. Fig. 3 (c), shows that, before starting the manufacturing activity of the sugar mill the COD range is 46 mg/L to 504 mg/L. The COD value varies from 339 mg/L to 504 mg/L in station 1 to station 4 apiece. The result showed that all of the values of stations 1 to 4 are greater than the standard value. The rest of the stations maintain the standard value. After starting the manufacturing activity of the sugar mill the COD value varies from 1295 mg/L to 1629 mg/L of the wastewater which much higher than the standard value. The COD concentration was found to be significantly different ($p < 0.01$) before mixing and after mixing, which indicates the concentration of the surface water increased due to the effluent. In terms of before mixing COD had weak positive correlation with TSS, color, BOD. After mixing COD had moderate negative correlation with pH and weak negative correlation with EC. Biological Oxygen Demand (BOD) is one of the most important parameters for aquatic life. As per the ECR 2023, the inland surface water standard value for BOD_5 should be 30 mg/l. Fig. 3 (d), shows that prior to commencing the manufacturing process in sugar mills, the wastewater typically exhibits a BOD range of 74.0 mg/L to 1.9 mg/L. At station 5, the BOD5 value is higher than at station 4. Because there was jute for degradation process at station 5. The degradation process of jute generates a high level of BOD_5 [14]. After starting the manufacturing activity of the sugar mill the BOD range is 1.7mg/L to 84 mg/L. The BOD concentration was found to be significantly different ($p < 0.05$) before mixing and after mixing, which indicates that the sugar mill wastewater contains highly concentrated BOD. Before mixing BOD showed strong positive correlation with CO_2 and alkalinity. After mixing BOD showed weak positive correlation with color, iron, TSS respectively. According to ECR 2023 inland surface water standard, Cl should be 600 mg/L. Before mixing effluent, Cl value found in the range of 8 mg/L to 31.66 mg/L, which maintains the standard value. After mixing effluent, the Cl varies from 16.67 mg/L to 64.66 mg/L, which maintains the standard value, as shown in Fig. 3 (e). The chloride concentration was found to be significantly different ($p < 0.01$) before mixing and after mixing, which indicates that the sugar mill wastewater increased the concentration of the surface water. Before mixing chloride had strong positive correlation with most parameters. After mixing chloride had weak positive correlation with hardness, alkalinity, TSS, pH. Fig. 3 (f), shows that before starting the sugar mills' manufacturing activity, the EC value varies from 0.314 mS/m to 0.86 mS/m. After starting the sugar mills' manufacturing activity, the EC value varies from 0.92 mS/m to 1.76 mS/m. The EC concentration was found to be significantly different ($p < 0.01$) which indicates that the sugar mill wastewater increased concentration of the surface water. Before mixing EC showed moderate positive correlation with TSS, BOD. In case of after mixing EC showed strong negative correlation with most parameters.

4 Conclusions

In conclusion, the investigation of surface water quality near North Bengal Sugar Mill Ltd. of Lalpur, Natore showed significant variability across different parameters. The raw sugar mill wastewater was found in standard limit. The surface water parameters were found in standard limit before sugar mill wastewater mixing as per ECR 2023 except BOD. Though the raw wastewater of the sugar mill was found in ECR 2023 standard. The sugar mill wastewater increased the concentration of color, EC, iron, CO_2, hardness, alkalinity, chloride, and COD of the surface water as the before-mixing and after-mixing concentrations were found to be significantly different ($p < 0.01$), and for turbidity and BOD significant level was $p < 0.05$. A strong positive correlation between these parameters specifies their habitual source, unwell treated sugar mill wastewater is accountable for the enrichment of these variables as they enter to the surface water and groundwater. Overall, from the study it is clear that the surface water becomes polluted due to sugar mill wastewater surrounding the canal area. Without proper treatment, the wastewater may cause serious health issues to people near the canal by using contaminated canal water. The fish of the canal are under menaces due to water contamination.

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