ENVIRONMENTAL IMPACT OF SUGAR INDUSTRY - A CASE STUDY ON KUSHTIA SUGAR MILLS IN BANGLADESH

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Abstract

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The study was conducted at the adjacent area of Kushtia Sugar Mill to determine the physico-chemical properties of effluent of Kushtia sugar Mills and Gorai Khal water to know the pollution load on environment. For the present study, sampling of water effluents was conducted before and after starting the sugar mill at different stations. The samples were then analyzed and it is found that the effluent of Kushtia Sugar Mills does not maintain the Department of Environment (DoE) Standard and Surface Water Quality Standard. A wide variation is found in the water quality of before and after starting the mill. The EC and TDS values of the effluent and the neighboring water vary from 612 to 1306 µS/cm and 430 to 927ppm respectively. High TDS, low DO content, high BOD, COD and conductivity values with high Cl^-, K^+, Ca^+, Mg^+, SO_4^{2-}, PO_4^{3-}, NO_3^- content indicates a highly polluted condition of water. It is true that sugar mill plays an important role but adversely affect the environment simultaneously. Proper way of operation and imposing laws and regulations and maintaining those strictly, can reduce pollution level. Improving technology may be the best strategy in the context of reducing pollution level and environmental damage.

Key word: Sugar industry, effluent and environmental impact, pollution

INTRODUCTION

Sugar industry plays an important role in the economy of Bangladesh by way of farming and creation of employment. The by-products of sugar mills are also used as raw materials in different industry. However sugar mill have a great environmental impact upon the surrounding environment. The change of water chemistry is the main associated environmental impact of discharging sugar mill's effluent on an open water body. The effluents are causing odor nuisance during decomposition. Wastewater from sugar mills with its high Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) rapidly deplete available oxygen supply when discharged into water bodies endangering fish and other aquatic life and also creates septic conditions, generating foul-smelling hydrogen sulfide, which in turn can precipitate iron and any dissolved salts, turning the water black and highly toxic for aquatic life. Suspended solids reduce light penetration capability and, as a result, plant production in the receiving water body is diminishing through increasing turbidity that also clog fish gills. Discharge of water with a high Total Dissolved Solids (TDS) level would have an adverse impact on aquatic life, render the receiving water unfit for drinking and domestic purposes, reduce crop yields if used for irrigation, and exacerbate corrosion in water systems and pipe (ETPI, 2001).

Highly colored water, besides being aesthetically unpleasing, limits light penetration, reducing production of phytoplankton and, by association, zooplankton, and fish and dissolved oxygen supply. Effluents with a high temperature can be of concern because high temperatures deplete dissolved oxygen levels in the water body. Effluents also change the natural pH level of the receiving water body to some extent. Such changes can tip the ecological balance of the aquatic system, excessive acidity particularly; can result in the release of hydrogen sulfide. Dermatitis, skin disease or other water born diseases is a major health complaint resulting from domestic uses of eutrophied water (Nadia and Mahmood, 2006).

The study was done in Kushtia Sugar Mill, which is situated at Jogoti in Kushtia district in Bangladesh in 2006-2007.

Objectives of the Study

- To determine the physico-chemical characteristics of the effluents of the sugar mill;
- To develop a management system regarding effluents of the sugar mill.

MATERIALS AND METHODS

The study was done by a comprehensive study through primary data collection and secondary literature survey for secondary data collection. First of all the study area was selected and a reconnaissance survey took place. Then to obtain basic ideas of the quality, characteristics and chemical composition of the effluent of sugar mill,

five samples were collected before and after starting the production activity of the mill. This sampling method involves purposive or deliberate selection of particular units of the sampling area for constituting a sample, which represent the universe. The samples were collected along the flow path of the effluent i.e., the drain and Gorai Khal. A questionnaire survey was also held to assess the health condition and collect opinions of the inhabitants of the surrounding.

For physical and chemical analysis of those effluent samples a number of sophisticated instruments were used and standards methods were followed. To measure the effluent quality of the collected sample the following analysis were performed in the laboratory of Environmental Science Discipline of Khulna University. The analyzed parameters are given in the Table 1.

Table 1. The analyzed parameters for the study

Physical Parameters	Chemical Parameters	Physico-chemical Parameters
pH, EC, TDS, Temperature	Sodium (Na^+), Potassium (K^+), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Chloride (Cl^-), Carbonate (CO_3), Bicarbonate (HCO_3^-), Dissolve silica ($H_4SiO_4^{2-}$), Ortho-Phosphate ($H\text{-}PO_4^{3-}$), Sulphate (SO_4^{2-}), Nitrate-Nitrogen (NO_3-N)	DO, COD, BOD

RESULTS AND DISCUSSION

The impact of pollution on the environment can be estimated through checking out the pollution level in the affected environment. In this study the physico-chemical characteristics of sugar mill's effluent was determined and compared with the Department of Environment (DoE) standard and surface water standard. The concentrations of different parameters are given in Table 2.

Table 2. The Physico-chemical Characteristics of the effluent of Kushtia Sugar Mill and Gorai Khal water before and after operation

Parameters	Station 1		Station 2		Station 3		Station 4		Station 5	
	Before	After	Before	After	Before	After	Before	After	Before	After
Temperature(ºC)	31	39	29.3	38.66	30	36	29.9	38.1	30.5	38
pH	7.11	7.7	7.05	6.95	7.18	5.42	7.9	5.59	7.7	5.73
TDS	383	927	374.4	789	301	430	365	540.4	350	529
EC (µs/cm)	819	1306	803	1306	712	1212	777	1298	761	1279
DO (mg/l)	-	-	-	-	1.2	1.2	1.4	-	1.9	-
BOD (mg/l)	73	88	67	79	33	59	42	64	39	61
COD (mg/l)	943.2	1631.2	727.2	1291	631.2	612	823.2	1198	712.7	1179
Na^{2+} (mg/l)	17.80	22.5	15.40	23	14.80	17	15.80	24	15	18.3
K^+ (mg/l)	15.2	96	8.4	91	7.3	38	7.4	77	7	63
Ca^+ (mg/l)	90	160	96	147	90	123	94	134	92	129
Mg^+ (mg/l)	24	55	19.2	51	25.2	32	21.6	46	23.1	40
Cl^- (mg/l)	8.4	440	7.7	425	8.2	565	7.7	585	7.9	575
HCO_3^- (mg/l)	437	16.2	401	15	419	13	408.5	14.46	403	14.03
SO_4^{2-} (mg/l)	8.2	23.75	6.7	22.70	5.8	7.2	6.7	21.7	6.5	20
PO_4^{3-} (mg/l)	13.65	50	11.8	56	10.6	60	11.5	59	9.5	52
NO_3^- (mg/l)	0.65	23	0.60	21.5	0.50	18.3	0.55	17	0.53	13.7

Source: Laboratory analysis, 2006-2007.

Discussion of the Parameters

pH: According to the DoE standard the pH of the effluent should be in range of 6-9 at discharge point. Before starting the mill the pH at the discharge point was 7.11 and after starting the mill the pH range is 5.42 to 7.07 which do not maintain the standard.

Total dissolved solid: According to the DoE standard the TDS of the effluent should be in range of 2,100 mg/L. Before starting the mill the effluent contains 383 ppm total dissolved solid. After starting the operation the effluent at station 1 and 2 contains total dissolved solid of 927 and 789 ppm respectively.

***Electrical conductivity*:** According to the DoE standard the EC of the effluent should be 1200 μs/cm. The effluent from Kushtia Sugar Mills before starting the mill contains 819 μs/cm and after starting the mill at station 1 and 2 contains EC 1526 and 1306 μs/cm. All of the values are greater than the standard value.

Dissolved oxygen: Dissolved oxygen (DO) in water body is very good indicator of water quality. According to the DoE standard the Dissolved Oxygen of the effluent should be within the range of 4.5 to 8. Before starting the mill the DO is absent in the waste discharge point. After starting the mill the station 1, 2,4and 5 contains 0mg/l dissolved oxygen. Only station 3 contains 1.2 mg/l DO. This result shows that the lake water is highly loaded with organic pollutants.

***Biological oxygen demand (BOD)*:** According to the DoE standard the BOD of the effluent should be 50 mg/L. Before starting the mill the BOD is 21.65mg/L in the effluent. After starting the mill the effluent of sugar mill contains 73.2 and 67.7 mg/L BOD in station 1 and 2 respectively. This high level of BOD refers that large amount of organic matter present in water at the station 1 and 2. Here the effluent BOD level doesn't maintain the DoE standard.

Chemical oxygen demand (COD): COD indicates the toxic condition and the presence of biologically resistant organic substances. According to the DoE standard the COD of the effluent should be 200mg/L. Before starting the mill the industrial effluent contains 943.2 mg/L COD. After starting the mill the effluent contains 1631.2 mg/L and 1146.4 mg/L in station 1 and 2 respectively. This result shows that the effluent from sugar industry releasing large amount of oxygen demanding chemicals. As the effluent mix with lake water the COD level reduces to 1079.6 mg/L and 975.2 mg/L at station 4 and 5 respectively. All of the values are greater than the standard value.

Sodium (Na^+): According to surface water standard the Na^+ in fresh water should be 6.3 mg/L (Garrels and MacKenzie, 1971). But the sugar mill effluent before starting the mill contains Na^+ 17.80.mg/L at the discharge point and after starting the mill the effluent of sugar mill contains 22.5, 23, 21, 17 and 18.3 mg/L at station 1, 2, 3, 4 and 5 respectively.

Potassium (K^+): According to surface water standard the K^+ in fresh water should be 2.3 mg/L. (Garrels and MacKenzie, 1971). But the sugar mill effluent before starting the mill contains 15.2 mg/L K^+ and after starting the mill the effluent of sugar mill contains 96 and 91 mg/L in station 1 and 2 respectively. As the effluent mix with lake water the K^+ concentration reduce to 77 and 63 mg/L at station 4 and 5 respectively.

Calcium (Ca^{++}): According to surface water standard the Ca^{2+} in fresh water should be 15 mg/L (Garrels and MacKenzie, 1971). But the sugar mill effluent before starting the mill contains 90 mg/L Ca^{2+} and after starting the mill the effluent contains 160 and 147mg/L in station 1 and 2 respectively. As the effluent mix with lake water the Na^+ concentration reduces to 134 and 129 mg/L at station 4 and 5 respectively.

Magnesium (Mg^{2+}): According to surface water standard the Mg^{2+} in fresh water should be 4.1mg/L (Garrels and MacKenzie, 1971). But the sugar mill effluent before starting the mill contains 24mg/L Mg^{2+} and after starting the mill the effluent of sugar mill contains 55 and 51 mg/L in station 1 and 2 respectively.

Chloride (Cl^-): According to surface water standard the Cl^- in fresh water should be 7.8 mg/L (Garrels and MacKenzie, 1971). But the sugar mill effluent before starting the mill contains Cl^- 8.4 mg/L and after starting the mill the effluent of sugar mill contains 23 and 21.5 mg/L in station 1 and 2 respectively.

Bicarbonate (HCO_3^-): According to surface water standard the HCO_3^- in fresh water should be 58.4 mg/L (Garrels and MacKenzie, 1971). But the sugar mill effluent before starting the mill contains 437 mg/L HCO_3^- and after starting the mill the effluent of sugar mill contains 440 and 425 mg/L in station 1 and 2 respectively. As the effluent mix with lake water the HCO_3^- concentration increase to 585 and 575 mg/L at station 4 and 5 respectively.

Sulphate (SO_4^{2-}): According to surface water standard the SO_4^{2-} in fresh water should be 11.2 mg/L (Garrels and MacKenzie, 1971). The sugar mill effluent before starting the mill contains 8.2 mg/L SO_4^{2-} and after starting the mill the effluent contains highest concentration of SO_4^{2-} 16.2 and 15 mg/L in station 1 and 2 respectively.

Ortho-Phosphate (PO_4^{3-}): The sugar mill effluent before starting the mill contains 13.65 mg/L PO_4^{3-} at the discharge point and after starting the mill the effluent of sugar mill contains PO_4^{3-} 23.75 and 22.70 mg/L in station 1 and 2 respectively. Other sampling points become less in concentration.

Nitrate (NO_3^-): The DoE standard mentions 10mg/L as a standard of NO_3^- the effluent should contain. The sugar mill effluent before starting the mill contains 0.65mg/L NO_3^-. After starting the mill the effluent of sugar mill contains NO_3^- 5.3 and 4.85mg/L in station 1 and 2 respectively. As the effluent mix with lake water the NO_3^- concentration reduced to 4.9 and 4 mg/L at station 4 and 5 respectively. The NO_3^- concentration in lake water at station 3 is 3.65mg/L.

Table 3. Comparison the Kushtia Sugar Mill's Effluents with Waste Discharge Quality Standards

Parameter	Unit	Standard	Kushtia Sugar Mill's Effluents	Remark
pH	-	6-9	7.7	Within the standard
TDS	mg/L	2,100	927	Maintain the standard
EC	µs/cm	1,200	1306	Doesn't maintain the standard
BOD	mg/L	50	73	Doesn't maintain the standard
COD	mg/L	200	1631	Much grater than the standard
NO_3^-	mg/L	10	5.3	Within the standard

(Source: DoE, 2002)

Table 4. Comparison the Kushtia Sugar Mill's Effluents with Surface Water Standards

Parameter	Unit	Standard	Kushtia Sugar Mill's Effluents	Remarks
Na^+	mg/L	6.3	22.5	Does not maintain the standard
K^+	mg/L	2.3	96	Much grater than the standard
Mg^{2+}	mg/L	4.1	55	Much grater than the standard
Ca^{2+}	mg/L	15	160	Much grater than the standard
Cl^-	mg/L	7.8	23	Does not maintain the standard
SO_4^{2-}	mg/L	11.2	16.2	Does not maintain the standard
HCO_3^-	mg/L	58.4	440	Much grater than the standard

(Source: Garrels and MacKenzia, 1971), Lab analysis, 2006-2007

Recommendations for Water Pollution Minimization Option

Monitoring and Maintenance

- Prevention or minimization of spills and leaks through regularly inspecting and repairing various units (pumps, conveyors, pipes, and etc) and handling and storing molasses properly.
- Monitoring of quantity and quality of incoming and outgoing water at the mill with flow meters by measuring the flow.

Process Modifications

Minor changes in the sugar production and waste handling process can produce substantial reductions in wastewater volume and pollutant load:

- Mills should be operated at optimum capacity and with minimum stoppages because raw water consumption per ton of cane crushed increases when crushing lower than the optimum capacity and when hot water production is suspended during halts in operations (cleaning, restocking, and breakdowns).
- For maximum sugar sucrose recovery, condensate hot water should be used for imbibitions. For optimum recovery, imbibitions water should be maintained around 25-30% of cane used.
- The TSS level of the wastewater is much less when the sugar cane is manually harvested.
- Water conservation and sugar recovery can be improved by avoidance of overloading evaporators and vacuum pans, boiling at excessive rates, or operating at incorrect liquid levels

- Dirt and large particles in effluents can be minimized by allowing suspended particles in filter cloth washings to settle in a holding tank before being mixed with other effluents and screening wastewater before emitting to remove refuse, dirt, and remnants of the cane
- Caustic wastes from the cleaning equipment should be separated from the rest of the wastewater and gradually released into furrows and blended with the other effluents.
- The recycling of water is the primary factor in reducing wastewater volume.
- Effluents from sugar mills are often used for irrigation and this is considered an apt measure if the wastes are first treated to remove oil and suspended particles and to correct the pH value.

Policy Recommendation

- It is necessary to strengthen research and development activities in the Kushtia Sugar Mill. The aim should be to develop an idea to use nutrient rich effluent in the form of fertilizer to the agriculture field.
- Kushtia Sugar Mill should have the pretreatment process within the plant boundary and thus waste generated from the plant can treat to reduce the level of BOD, COD, TDS, K^+, Ca^{2+}, Mg^{2+}, PO_4^{3-} etc.
- Kushtia Sugar Mill should also analyze the physico-chemical properties of Gorai Lake to know its assimilation power and to control the environmental contamination of the lake water and vicinity.
- Regular monitoring of air quality should be performed and disclosed to the people and setting a limit on the total amount of pollution produced by sugar mill.
- Making existing laws more stringent
- The awareness program is to be initiated by the NGO's and the DOE to discourage the investors to invest in polluting technology.

CONCLUSIONS

Kushtia Sugar Mill is one of the largest industries among all operating industries in Kushtia region. Though this industry is seeking to increase government revenue and employment opportunities the rampant discharge of untreated effluents causing severe environmental degradation. The present investigation has been carried out to assess the physico-chemical characteristics of effluent from Kushtia Sugar Mill. From the result of physico-chemical analysis of effluent of Kushtia Sugar Mill it has been concluded that it does not always maintain DoE standard for industrial effluent as well as the surface water quality standard. It is to be concluded that it maintains DoE standard for pH, BOD, TDS while discharging its effluent. The standard of BOD and COD are also very low in comparison to the discharged effluent. Discharges of such nutrient containing effluent directly affect the water quality of lake and the stream that should be prevented.

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