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Environmental Assessment of Industrial Wastewater in Chittagong City-Bangladesh

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ABSTRACT

The paper presents the quality of the wastewater of different industrial discharges in Chittagong City by finding out the values of various target parameters through analytical methods, i.e., pH, temperature, electrical conductivity (EC), percent sodium chloride (% NaCl), total hardness, alkalinity, total dissolved solids (TDS), total suspended solids (TSS), chloride, sulphate, phosphate, nitrite, nitrate, BOD, COD, and dissolved oxygen. The assessment revealed that the wastewater sample from Heliads Fashion Ltd. (S8) reported to be most polluted comparing all other samples. This industry is located in Basic Industrial area of the Baizid Industrial Zone. The study found the highest values of 10 major parameters i.e., temperature (ºC), pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), percent sodium chloride (%NaCl), dissolved oxygen (DO), alkalinity, chloride ions (Cl^-), and nitrate ion (NO_3^-) from the samples of this industry. The average value of pH found from wastewater samples was above 7, which was alkaline in nature. KDS Accessories Ltd. (S4) sample wastewater of Nasirabad Industrial area reported lowest values of temperature, total suspended solids, and nitrite ions. On the other hand, highest values of total hardness and sulphate ions were found in this industrial effluent. Finally, highest BOD and COD values were reported in the samples of Quality Garments Ltd. (S9) at the Basic Industrial area. In summary, high volumes of different parameters were found in the industrial wastewater samples of Basic Industrial area as compared to Nasirabad area. Therefore, the assessment study found that the effluent of the industries of Basic Industrial area was more polluted than those of Nasirabad Industrial Area.

Keywords: *Chittagong City, Wastewater, Pollution, Analytical Methods, Target Parameter.*

1. INTRODUCTION

Water is the basis and origin of life on Earth. All of the earliest civilizations were established around water resources. In addition, water is a substantial element in civilization's development. Nowadays, accessing water resources is an important factor to achieve sustainable development. In fact, water plays a key role in underpinning all aspects of sustainable development [1]. Water also has a major impact on all social and economic activities and development, healthy ecosystems and human survival itself [1, 2]. In 2015, the population of the world was roughly 7.3 billion people [3], but the world's population will reach over 9 billion people in 2050 [4]; thus, population growth and other factors such as climate change, food and energy security policies, industrial growth, increasing farming, macro-economic processes and urbanization will create critical challenges, such as a growing water shortage for water supply systems [1, 5-9].

Wastewater is any water which has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture and can encompass a wide range of potential contaminants and concentrations. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources [10]. Wastewater can be broadly classified depending upon the source it is obtained from i.e., Domestic or Municipal Wastewater and Industrial Wastewater. The domestic wastewater is obtained directly from residential buildings. It includes waste water obtained from toilets (human waste), sinks bathing and laundry etc. It might contain intestinal disease organisms [11]. The industrial wastewater discharged directly from different industries such as electroplating, steel manufacturing, small scale industries, dye casting, garments and textile industries, food production industries etc. This is discharged by manufacturing processes and commercial enterprises [12]. Process wastewater can contain rinse waters including such things as residual acids, dye casting, and toxic chemicals. The sources of municipal wastewater are human waste, cesspit leakage, septic tank discharge, sewage treatment plant discharge, washing water (personal, clothes, floors, dishes, etc.), also known as grey water or sullage, rainfall collected on roofs, yards, hard-standings, etc. (generally clean with traces of oils and fuel), groundwater infiltrated into sewage, surplus manufactured liquids from domestic sources (drinks, cooking oil, pesticides, lubricating oil, paint, cleaning liquids, etc.), urban rainfall runoff from roads, car parks, roofs, sidewalks, or pavements (contains oils, animal faeces, litter, fuel or rubber residues, metals from vehicle exhausts, etc.), seawater ingress (high volumes of salt and micro-biota), direct ingress of river water (high volumes of micro-biota), direct ingress of manmade liquids (illegal disposal of pesticides, used oils, etc.), highway drainage (oil, de-icing agents, rubber residues), storm drains (almost anything, including cars, shopping trolleys, trees, cattle, etc.), black water (surface water contaminated by sewage). The industrial wastewater contains industrial site drainage (silt, sand, alkali, oil, chemical residues, heavy metals), Industrial cooling waters (biocides, heat, slimes, silt), Industrial process waters, organic or bio-degradable waste, including waste from abattoirs, creameries, and ice cream manufacture, organic or non-biodegradable/difficult to treat waste (pharmaceutical or pesticide manufacturing), extreme pH waste (from acid/alkali manufacturing, metal plating), toxic waste (metal plating, cyanide production, pesticide manufacturing, etc.), solids and emulsions (paper manufacturing, foodstuffs, lubricating and hydraulic oil manufacturing, etc.), agricultural drainage, direct and diffuse [13,14].

WASTE WATER CHARACTERISTICS

The selection and design of treatment plants for industrial effluent is based on the study of the physical, chemical and biological characteristics of wastewater, the quality that is to be maintained in the environment to which the wastewater is to be discharged or quality that is to be maintained for its reuse and standards for its discharge. The important and principal physical characteristics of wastewater are its color, solid contents, its odor and temperature and chemical properties include organic compounds, inorganic compounds, pH, alkalinity, hardness, and temperature [15].

Color

Color is a qualitative characteristic that can be used to assess general condition of Wastewater. Wastewater that is light brown in color is less than 6 h old, while a light-to-medium grey color is characteristic of wastewaters that have undergone some degree of decomposition or that have been in the collection system for some time. If the color is dark grey or black, the wastewater is typically septic, having undergone extensive bacterial decomposition under anaerobic conditions [16].

Total Solids

The total solids in a wastewater consist of the insoluble or suspended solids and the soluble compounds dissolved in water. Between 40 and 65 % of the solids in an average wastewater are suspended. Settle-able solids, expressed as milliliters per liter, are those that can be removed by sedimentation. Usually about 60 % of the suspended solids in a municipal wastewater are settle-able.

Temperature

Temperature is not a critical issue below 37 °C if waste water is to receive a biological treatment. Most industries waste tends to be on the warmer side. It is possible to operate thermophilic biological wastewater treatment systems up to 65 °C with acclimated microbes. Low temperature operations in northern climates can result in very low temperatures and slow reaction rates for both biological treatment systems and chemical treatment system. Increased viscosity of waste waters at low temperatures makes solid separation more difficult. Efforts are generally made to keep operating temperatures between 10 °C and 30 °C.

Organic Compounds

Organic compounds create most of the pollution problems as a result of their effect on oxygen resources in the environment. The low-molecular weight water soluble organics tend to be biodegraded by bacteria and fungi with utilization of oxygen. Solubility and biodegradability decrease with the complexity of organic molecules. The total COD (Chemical Oxygen Demand) of organic compounds in waste water is measured by dichromate Cod test. A 2- hour reflux with concentrated sulphuric acid and potassium dichromate with silver sulphate and mercuric sulphate catalyst is adequate for complete oxidation of all but a few aromatic organic compounds.

Inorganic Compounds

The inorganic compounds in most industrial wastes are the direct result of inorganic compounds in the carriage water. Soft water sources will have lower inorganic compounds than hard water or salt water sources. In a few instances, industrial processes add inorganic compounds to the waste water. While domestic waste water has a balance industrial processes add inorganic compounds to the waste water. While domestic waste waters have balance in organic compounds and inorganic compounds, many process waste waters from industry are deficient in specific inorganic compounds. Biodegradation of organic compounds requires adequate nitrogen, phosphorus, iron and trace salts. Ammonium salts or nitrate salts can provide the nitrogen, while phosphate supplies the phosphorus. Either ferrous or ferric salts or even normal steel corrosion can supply the needed iron. Other trace elements needed for biodegradation are potassium, calcium magnesium, cobalt, molybdenum, chloride and sulphur. Carriage water or demineralized waste waters or corrosion products can supply the needed trace elements for good metabolism. Occasionally, it is necessary to add specific trace elements or nutrient elements.

pH and Alkalinity

Waste water less than pH less than 6 are corrosive in nature and those having pH more than 9 will cause some of the metal ions to precipitate as carbonates or hydroxides.

Total Hardness

Total hardness is determined by the multivalent cations concentrations present in water. These cations have a positive charge that is higher than 1+. Typically, cations have a charge of 2+. The most common cations present in hard water are Mg^{2+} and Ca^{2+}. Recommendations have been made for the maximum and minimum levels of calcium (40–80 mgL^{-1}) and magnesium (20–30 mgL^{-1}) in drinking water, and a total hardness expressed as the sum of the calcium and magnesium concentrations of 2–4 $mmolL^{-1}$.

Dissolved Oxygen

Dissolved Oxygen is present in water which is an essential element for the working of aerobic bacteria in the biological treatment systems. It is important that the waste water have maximum DO level, when these are discharged. Oxygen is a poorly soluble gas in water, having a solubility of 9.1 mgL^{-1} at 20°C. DO is minimum when the BOD rates are maximum.

Chlorides, sulphates, pH and alkalinity are determined to assess the suitability of reusing treated wastewater and in controlling the various treatment processes. Trace elements, which include some heavy metals, are not determined routinely, but trace elements may be a factor in the biological treatment of wastewater. All living organisms require varying amounts of some trace elements, such as iron, copper, zinc and cobalt, for proper growth. Heavy metals can also produce toxic effects; therefore, determination of the amounts of heavy metals is especially important where the further use of treated effluent or sludge is to be evaluated. Many of the metals are also classified as priority pollutants.

2. MATERIALS AND METHODS

In this research, 10 samples of industrial wastewater were taken from 10 different industries in the summer of 2015. These factories are located in two different industrial areas of Chittagong City. It is noted that all the industries from where samples were collected are located in the two different areas of the Baizid Industrial Zone namely, Nasirabad Industrial Area and Bscic Industrial Area. The samples were subjected to physical, chemical and biological tests. The physical and chemical parameters were: pH, alkalinity, electrical conductivity (EC), percent sodium chloride (% NaCl), total hardness, total dissolved solids (TDS), total suspended solids (TSS), chloride, BOD, and COD. After collecting the samples, they were transferred to the laboratory of the Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka to be quantified. Then, physical, chemical and biological analyses were conducted on the collected data.

3. SAMPLING METHOD AND EQUIPMENT

The samples were taken from the underground reservoirs according to the procedure outlined in the standard methods of water and wastewater examinations [17]. To determine pH, TDS, and EC, a digital meter was used. To measure the Hardness, Ethylene-Diamine-Tetraacetic Acid (EDTA) titration was applied. To obtain the temperature, a digital thermometer with desirable accuracy was employed. To measure several chemical parameters such as Chloride, Sulfate, Phosphate, an Ion Chromatography (Dionex ICS-5000) was used. Alkalinity was determined by titration with Sulfuric Acid, and TSS was specified by oven dry method. To determine the parameters of Nitrite, Nitrate, a Spectrophotometer was employed [18]. The biological tests were carried out in BCSIR Laboratory under guided methods [17]. Note that to retrieve the water, the temperature and pH measurements were performed on location. In addition, the samples were collected in special test tubes and secured in a bag.

3.1. Sampling area

Wastewater samples were collected from different locations in the vicinity of different industries at Chittagong City. Locations from where wastewater was collected and the type of industries in that area are shown in Table 1.

Table 1: Location of the Industries in different areas of Baizid industrial Zone

Name of the Sample	Name of Industry	Location
S1	KDS Fashion Ltd.	Nasirabad Industrial Area.
S2	KDS Garments Ltd.	Nasirabad Industrial Area.
S3	Clifton Textile & Apparels Ltd.	Nasirabad Industrial Area.
S4	KDS Accessories Ltd.	Nasirabad Industrial Area.
S5	Jakir Hossain Re-rolling Mills Ltd.	Nasirabad Industrial Area.
S6	Mars Apparels Ltd.	Bscic Industrial Area.
S7	Hoque Industrial Enterprise Ltd.	Bscic Industrial Area.
S8	The Heliads Fashion Ltd.	Bscic Industrial Area.
S9	Quality Garments Ltd.	Bscic Industrial Area.
S10	Fulkoli Food Products Ltd.	Bscic Industrial Area.

4. RESULTS AND DISCUSSION

The physical, chemical, and biological characteristics of the wastewater 10 industries were summarized in Table 2.

Table 2: Analysis of different water quality parameters

Sl No.	Parameter	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
1	Temperature (^{0}C)	29.28	29.08	28.20	24.90	29.08	25.10	29.60	29.60	25.20	25.20
2	P^H	9.46	7.36	9.54	10.19	7.12	6.80	2.85	10.21	9.65	9.80
3	EC (µScm $^{-1}$)	1125	5110	487	1217	6225	3120	868	25150	1821	6540
4	TDS(mgL^{-1})	561	2500	233	611	3120	1560	443	12570	911	3270
5	TSS (mgL^{-1})	100.00	220	40.00	16	440	257	38	480	120.00	154
6	%NaCl	2.20	10.00	1.00	2.30	12.20	3.7	1.70	48.80	3.60	4.6
7	DO (mgL^{-1})	3.20	0.10	0.20	1.30	0.10	2.10	1.10	3.60	3.10	2.40
8	BOD (mgL^{-1})	107.29	12.40	82.67	117.00	136.00	46	197.60	276.90	416.00	164
9	COD (mgL^{-1})	145.47	327.31	509.15	164.75	172.74	184	752.94	282.43	1854.61	682
10	Alkalinity (mgL^{-1})	617.88	666.66	634.14	869.33	504.06	32.02	13.42	3995.50	900.60	1184.5
11	Hardness (mgL^{-1})	40.00	9.20	40.00	192	108.00	116.00	120.00	100	10.00	45.00
12	Chloride (mgL^{-1})	201	1199.31	22.35	995.05	1670.55	546.23	184.78	10533.6	30.35	643.56
13	SO_4^{2-} (mgL^{-1})	183.68	154.51	14.79	400.25	338.45	36.32	39.58	389.92	95.37	12.46
14	$PO_4{}^{3-}$ (mgL^{-1})	105.97	10.33	253.96	5.31	5.30	14.92	36.24	10.02	24.23	5.53
15	NO^{2-} (mgL^{-1})	0.35	0.09	0.16	BDL	0.10	0.11	0.06	0.06	0.07	0.09
16	NO^{3-} (mgL^{-1})	0.56	1.23	BDL	2.41	BDL	2.41	1.56	3.83	BDL	1.76

*BDL = Below Detection Limit

Temperature

The temperature of the industrial wastewater in Chittagong City was in the range of 24.9 ºC and 29.6 ºC which was below the range of BECR guideline of 40 ºC to 45 ºC [19].

pH

The pH level describes the amount of alkalinity or acidity of water, and is one of the important parameters in drinking water treatment. The variations of pH in the wastewater were from 2.85 to 10.21. Although the average value (8.3) was within the acceptable range of BECR between 6 and 9 [19], the characteristics of wastewater does not allow to drink without extensive treatment.

EC, TDS, and Chloride

The parameter of EC is an indication of the concentration of TDS and major ions in a given water body. The EC of the samples was between 487 and 25150 µScm^{-1}. According to BECR guideline, the maximum value of EC is 1200 µScm^{-1}. The values of EC of only 3 industrial effluents (S1, S3, and S7) were lower compared to the standards. On the other hand, the high value of EC in some wastewater was due to the high amount of TDS in the water. The parameter of TDS refers mainly to inorganic substances dissolved in water. The principal constituents of TDS are % NaCl, Chloride, Sulfates, Phosphate, Nitrate, and Nitrite. The values of TDS in the wastewater were between 233 and 12570 mgL^{-1}. Six industrial effluents (S1, S3, S4, S7, and S9) showed a TDS level less than 2100 mgL^{-1} which is commonly considered to be desirable before discharging in to surface water bodies. The relationship between the parameters of TDS and EC is shown in the following formula [20, 21]:

$$- TDS = (0.48 \text{ to } 0.51) EC \quad (1)$$

The values of Chloride were in the range of 22.35-10533.6 mgL^{-1}. These chloride of 5 samples of the industrial wastewater fell within the acceptable range of BECR standards (maximum 600 mgL^{-1} [19]). The relationship among electrical conductivity (EC), total dissolved solids (TDS), and Chloride is shown in the Figure 1.

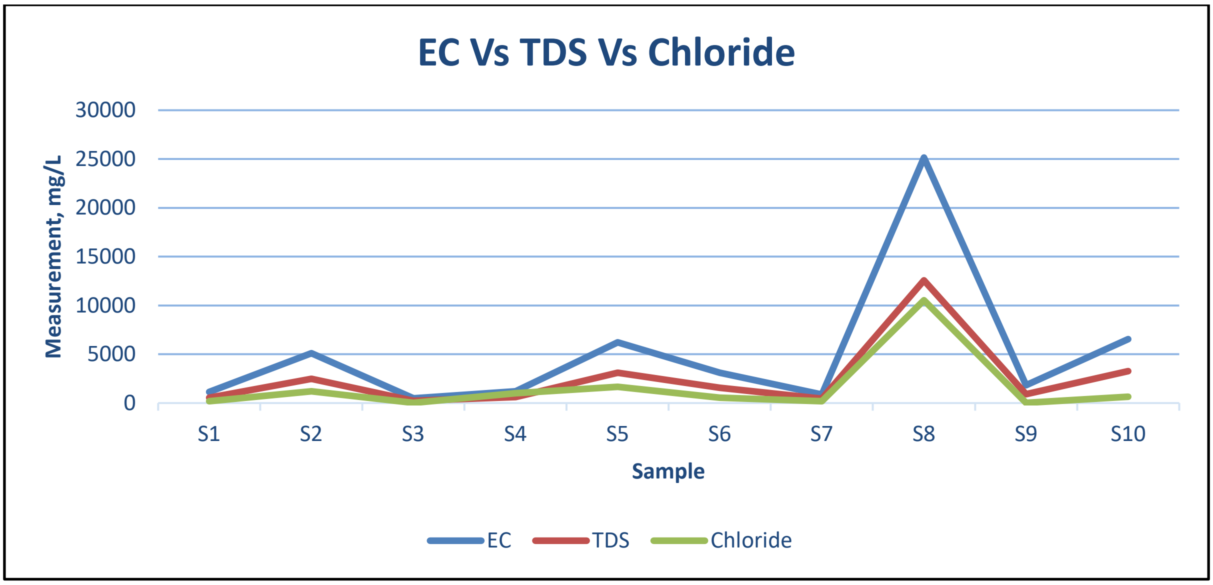

Figure 1: Comparative measurement of EC, TDS, and Chloride

TSS

The amount total suspended solids (TSS) found in the industrial discharges indicated that the wastewater was mainly filled with suspended solids. It was undoubtedly observed that samples from 5 industries (S2, S5, S6, S8, and S10) had suspended solids above Bangladesh Standard (150 mgL^{-1}).

Alkalinity and Hardness

The alkalinity is defined as the quantitative ability to react with (neutralize) a known quantity of standard acid. Also, alkalinity is a measure of the amount of alkaline substances in the water. The amount of alkalinity was in the range of 13.42-3995.50 mgL^{-1} as $CaCO_3$. On the other hand, the values of hardness as represented in the form of total hardness were in the range of 9.2-192 mgL^{-1} as $CaCO_3$ so that the average value was 135.86 mgL^{-1} as $CaCO_3$ which was below BECR range of 200 mgL^{-1} as $CaCO_3$. So, the wastewater fell in between soft to moderately hard in terms of hardness. The relationship between alkalinity and hardness is shown in Figure 2.

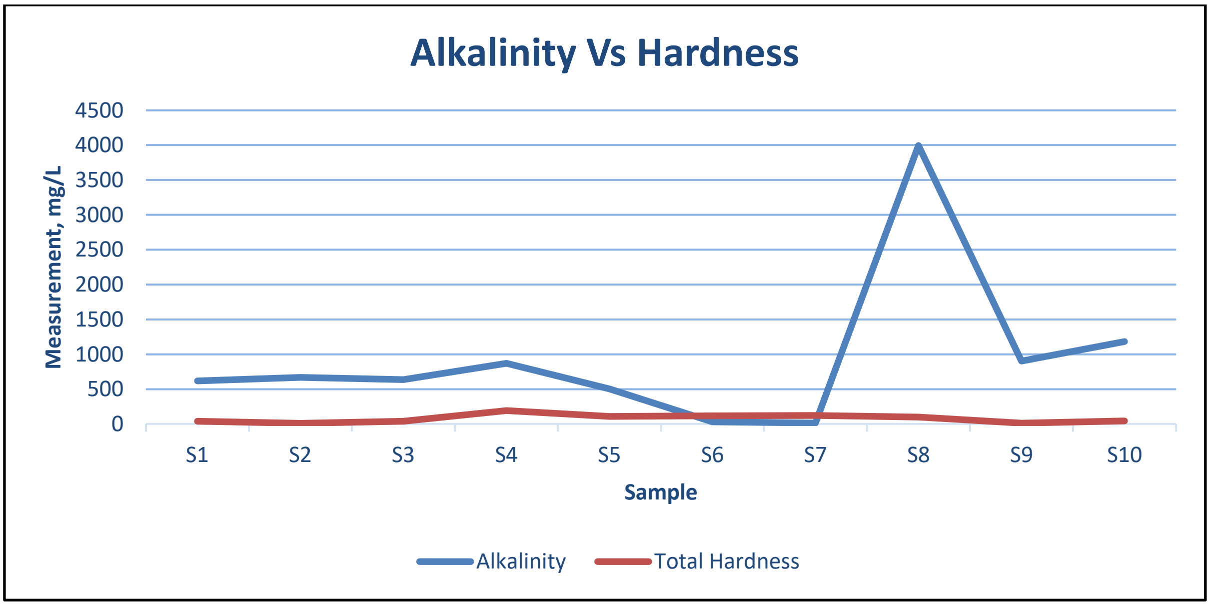

Figure 2: Comparative measurement of alkalinity and hardness

Sulfate and Phosphate

The amount of Sulfate was between 14.79 and 400.25 mgL^{-1}, and so the average amount was 166.5 mgL^{-1}. Almost all of these amounts were under the range of BECR Standard value which is up to 400 mgL^{-1}. Compared to sulphate content, almost all the samples reported the phosphate content to well above BECR Standard (8 mgL^{-1}) and the highest value of 253.96 mgL^{-1} was found in the sample of Clifton Textile & Apparels Ltd. (S3). The comparative relationship between sulphate and phosphate is presented in Figure 3.

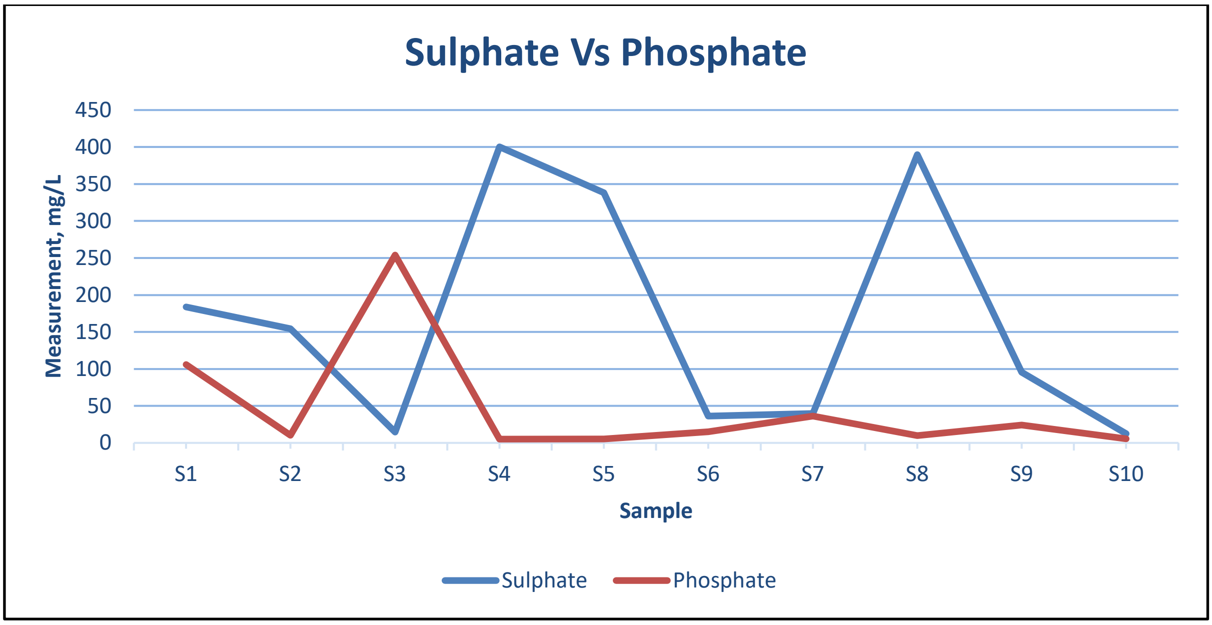

Figure 3: Comparative measurement of sulphate and phosphate

Nitrite and Nitrate

The amounts of Nitrite were between 0.06 and 0.35 mgL^{-1} as NO^{2-}, and so the average amount was 0.024 mgL^{-1}. These amounts were acceptable, since the maximum allowable value is 1 mgL^{-1} for BECR standard. The values of Nitrate were from 0.56 to 3.83 mgL^{-1} as NO^{3-}, and so the average value was within the range of BECR Standard which is 10 mgL^{-1}. The amount of Nitrate concentration in the samples was variable, and the high Nitrate concentration in most wastewater was owing to the use of chemical reagents in industrial production. Figure 4 shows typical relationship between nitrite and nitrate ions in wastewater samples.

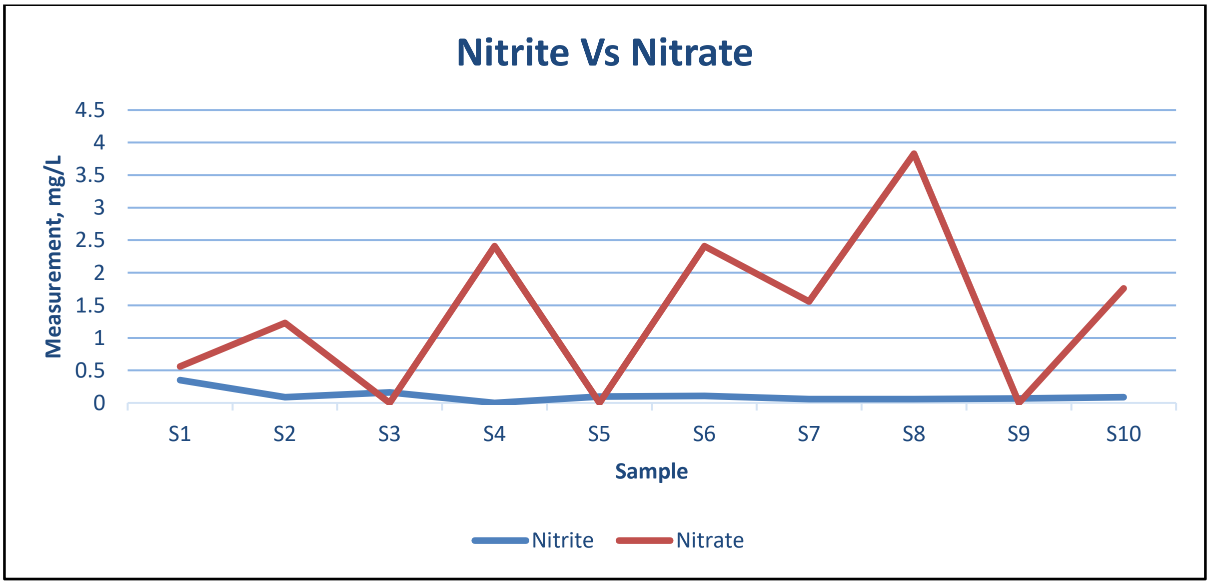

Figure 4: Comparative measurement of nitrite and nitrate ions

DO, BOD, and COD

All the industrial samples had dissolved oxygen less than the BECR standard value of 4.5 to 8 mgL^{-1}. So, it is assumed that wastewater from all the industries has high level of biodegradable matter and microorganisms. The BOD_5 observed in the wastewater to be much higher than the acceptable BECR standard which is 50 mgL^{-1}. The maximum values of BOD_5 and COD were found to be 416 mgL^{-1} and 1854.61 mgL^{-1}, respectively in the samples of Quality Garments Ltd. (S9). The comparative relationship of DO, BOD, and COD is shown in Figure 5.

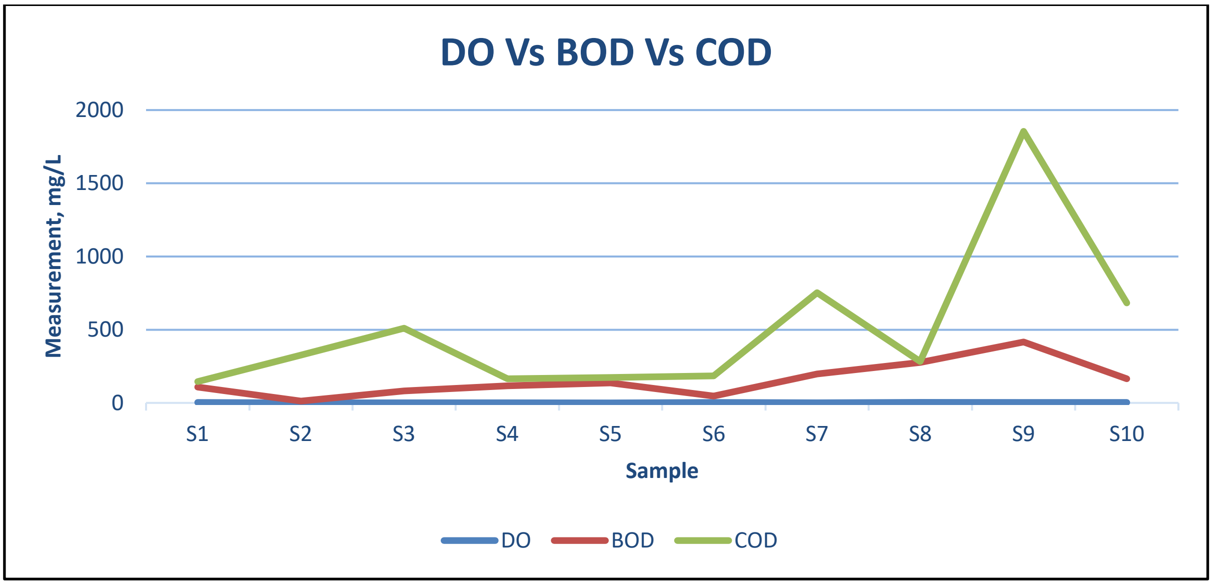

Figure 5: Comparative measurement of DO, BOD, and COD

The ratio of COD to BOD is calculated for all the samples of the industries and it was found that all the samples had high level of biodegradability. The samples of KDS Garments Ltd. (S2) in Nasirabad Industrial area reported highest amount of non-biodegradable organic matters whereas samples of KDS Fashion Ltd. (S1), KDS Accessories Ltd. (S4), Jakir Hossain Re-rolling Mills Ltd. (S5), and The Heliads Fashion Ltd. (S8) reported very few non-biodegradable matters. The ratio is summarized in Table 3 and represented in Figure 6.

Table 3: Ratio of COD and BOD

Sample	COD : BOD_5	Degree of Biodegradability
S1	1	High
S2	26	Very High
S3	6	Very High
S4	1	High
S5	1	High
S6	4	Very High
S7	4	Very High
S8	1	High
S9	4	Very High
S10	4	Very High

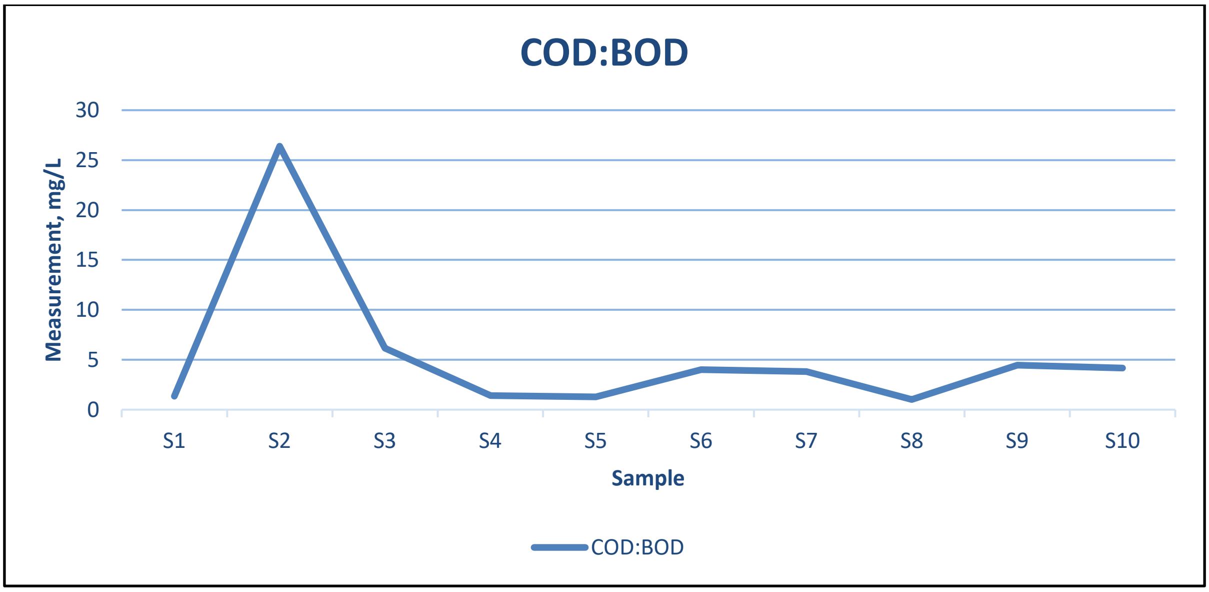

Figure 6: Ratio of COD to BOD

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The physical, chemical, and biological tests showed that some parameters such as Temperature, Hardness, percent Sodium Chloride, Sulfate, Nitrite, and Nitrate were within an acceptable range of BECR standards. However, several other parameters, including pH, TDS, TSS, EC, Chloride, Phosphate, BOD, COD, and DO were outside the acceptable range of the standard. All these parameters can be controlled through wastewater treatment by using several different methods.

5. CONCLUSION

The wastewater samples were collected from different locations existing in the Baizid Industrial Zone of Chittagong City. The maximum pH of 10.21 was reported in Heliads Fashion Ltd. (S8) and the least pH of 2.85 was reported from Hoque Industrial Enterprise Ltd. (S7). The low pH of this sample (S7) and high pH in Heliads Fashion Ltd. (S8) may be due to the various raw materials used including chemicals and integrated processing techniques adopted in the production of cloths and garments. In the rest of the industries, pH varied between these two extreme values and majority of them were alkaline in nature (pH>7). The temperatures of all the industries of both Nasirabad and Basic Industrial areas recorded well below the standard values. This was because of most of samples were collected from the garment industries in the Baizid Industrial zone. The least alkalinity was reported in the sample of Hoque Industrial Enterprise Ltd. (S7) and it was 13.42 mgL^{-1} as $CaCO_3$. The possible reasons can be release of certain acidic compounds in the industrial wastewater. The highest alkalinity value of 3995.5 mgL^{-1} as $CaCO_3$ was reported from Heliads Fashion Ltd. (S8). It could be because of the discharge of certain alkalis from garments industry existing in the Basic Industrial area. The highest total hardness level of 192 mgL^{-1} as $CaCO_3$ was reported from KDS Accessories Ltd. (S4) in Nasirabad Industrial area. This may be due to the presence of high volume of calcium and magnesium ions released from industrial discharge. Again the lowest total hardness value (9.20 mgL^{-1} as $CaCO_3$) was reported from sample of KDS Garments Ltd. (S2) at Nasirabad Industrial area. The total hardness levels ranged between 40 to 120 mgL^{-1} as $CaCO_3$ at most of the places which are accepted hardness values of wastewater according to BECR standard for discharging in to surface water. The highest value of chloride concentration of 10533.6 mgL^{-1} was reported from Heliads Fashion Ltd. (S8) in Basic Industrial area. This can be due to the presence of sodium chloride (% NaCl) in wastewater and various other chloride salts being used in industrial production in this area. This supposition was attributed by the analysis of percent sodium chloride in the wastewater samples and it was found that maximum amount was reported from the same industrial effluent (S8). The analysis revealed that 5 industries (S1, S3, S6, S7, and S9) which had chloride concentration below the BECR standard values of 600 mgL^{-1}. Only 2 industries (S2 and S6) had BOD_5 values under the prescribed BECR standard (50 mg/L). The highest BOD_5 value of 416 mgL^{-1} was reported at Quality Garments Ltd. (S9) in Basic Industrial area. This is because of the high level of micro-organisms present in the samples of that industrial effluent. Similarly, same industry also reported highest COD value of 1854.61 mgL^{-1}. The lowest value of COD was recorded to be 145.47 mgL^{-1} at KDS Fashion Ltd (S1) in Nasirabad Industrial area. All 5 industries from Nasirabad Industrial area reported COD values below the BECR guideline whereas only 2 industries from Basic Industrial area provided this record. The outcome of the analysis of industrial effluent revealed that the industries selected from Basic Industrial area release extremely polluted wastewater than those of Nasiarabad Industrial area. Therefore, effluent of the industries in Basic Industrial area needs a thorough treatment before discharge it on to a surface water body.

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