Water Quality Assessment of Karnaphuli River of Bangladesh using CCME-WQI Method

ABSTRACT

Karnaphuli River is one of the largest recipients of industrial effluent among all the rivers in Bangladesh in the last couple of years. The main purpose of this study is to evaluate the suitability of the river water for irrigation, livestock and other uses and to identify the main pollutants affecting the river during its course through the city. Ten Sampling points along with the Karnaphuli river basin was selected for the WQI assessment. The sampling was conducted for a period of one year from May 2021 to April 2022. Canadian Council of Ministers of the Environment (CCME)-(WQI) Water Quality Index was applied for several water quality parameters namely pH, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Phosphate, Nitrate, Chloride, Total Hardness, Conductivity, Biological Oxygen Demand (BOD), Cd, Cu, Zn, Pb. Irrigation and livestock indices were analyzed based on Canadian Water Quality Guidelines (CWQGs). The study shows that the river water is mostly alkaline and the pH lies between 6.4 -7.8. The DO value varies from 1.8 to 6 ppm and BOD varies from 1.7 to 3.4 ppm. The concentrations of Cu, Cd, Pb and Zn are Cu- (0.108-0.743 ppm), Cd- (0.073-0.281 ppm), Pb- (0.017-0.699 ppm), Zn- (0.012-0.032 ppm) respectively. Based on the index values, the river water quality has been observed as poor and marginal.

Keywords: *Karnaphuli river basin, Heavy metals, CCME, Water Quality Index.*

1. INTRODUCTION

Our survival on planet Earth depends on three basic natural resources - water, air and soil. Of them, water is the most important component as it forms the basic medium for the origin of life. In our daily life water is used for drinking, irrigation and other purposes (1). The quality of drinking water is a very sensitive issue. The availability of water supply in terms of both quantity and quality is essential to human existence (2). Water quality is influenced both by natural and anthropogenic intervention where the former includes the local climate, geology etc. and the latter covers the construction works (3).

Rivers are the main inland water resources for domestic, industrial, irrigation and drinking purposes, which receive great amount of anthropogenic, land use and industrial dissolved contaminants from throughout the river basin. Karnaphuli River is the largest and most important river in first growing industrial city and port city Chattogram and Chattogram Hill Tracts (CHT), is a 667m (2188ft) wide river in the southeastern part of Bangladesh (4). Originating from Lushai Hills in Mizoram province of India, it flows 270Km (170 miles) west through Chattogram and Hill Tracts area into the Bay of Bengal.

The Karnaphuli River is the major source for supplying water to Chattogram though it is contaminated with organic pollutants mainly from domestic and industrial wastes. Liquid waste of the Karnaphuli Paper Mills, Thousands of tonnages of dirt and garbage from Chattogram municipal area and different Mills and Factories are dumped into the Karnaphuli River. There are more than 140 industries in Kalurghat, Patenga, Nasirabaad, Sholoshahar, Kaptai, Bhatiary, Barabkunda, Anowara, and Fauzderhaat in Chattogram. Chattogram has 19 Tanneries, 1 Rayon Mill, 26 Textile Mills, 1 Refinery, 2 Chemical, 1 TSP fertilizer, 5 Fish Processing, 2 Cement Factories, 5 Steel Mills, 2 Insecticide Factories, 4Dyeing Factories and about 75 other small Industries (5). Most of the industries are major contributor of toxic chemicals and trace metals in the river (6)- (8).

The water quality management of the Karnaphuli River is very important for the present and future economy of Bangladesh. Water quality is determined by comparing the physical, chemical and biological characteristics of a water sample with water quality guidelines (9)- (11).

Water Quality Index (WQI) is a tool to determine the quality of water by using physicochemical parameters of surface water, which can act as an indicator of water pollution (12)-(14). WQI provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters. The objective of water quality index is to turn complex water quality data into information that is understandable and usable by the public (15). WQI assessment is essential to prevent and control river pollution and to get reliable information on the quality of water for effective management. Different methods used for water quality index estimation, such as “The Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI), National Sanitation Foundation Water Quality Index (NSFWQI), Oregon Water Quality Index (OWQI) and Weighted Arithmetic Water Quality Index (WAWQI)" (16). CCMEWQI consists of three variances (Scope, Frequency and Amplitude) that combine to give a value between 0-100 that represents the water quality (17).

2. MATERIALS AND METHODS

2.1 Sampling site and study area

Karnaphuli River with its tributaries is the largest surface water source for Chattogram and the Chattogram Hill Tracts region. The river enters into Chattogram city in the south-west directions flows upto180 Km in the Chattogram region and then flows through Rangamati, Dhulia Chari, Kaptai (18) (19). In the present study samples were collected from main region, transitional region, meandering region to cover the Karnaphuli river basin.

Ten sample points were selected based on catchment characteristics, anthropological activities, land use practices, industrial discharges. Samples were collected in the middle month of three seasons Pre-monsoon (January-March), Monsoon (July-September), Post-Monsoon (October-December) of the hydrological year 2021-2022. A brief picture of study area is given in the Figure 1. Polyethylene terephthalate bottles were used to collect samples. pH and DO were analyzed by Hanna pH meter and Hanna DO meter (DO-5509) respectively, Turbidity was measured by Lovibond TB 250 turbidity meter, TDS and Electrical Conductivity were measured by a portable conductivity meter (model: HACH-Sension EC5) at the site itself. Winkler method was used to measure BOD_5. Alkalinity, Nitrates, Phosphates, Chlorides, Total Hardness were analyzed in the laboratory as per the standard procedures of APHA (20). Heavy metals were evaluated by Direct Reading Spectrophotometer (DR-2000). Atomic Adsorption Spectrophotometric method (iCE 3300 AAS) was used to analyze heavy metals (Cu, Cd Pb, and Zn) (21). Our study area consists of several polluted zones of Karnaphuli River. After the selection of sample points, the water samples were collected from Karnaphuli River to assess the water quality parameters discussed below. The study area is shown below in Table 1.

Table 1: Sample locations

Sample Point Number	Sample Point Location
S1	Near Sandwip Channel
S2	KAFCO Point
S3	Firingibazar Ghat Point
S4	Majhirghat Point
S5	Chaktai Canal Point
S6	Rajakhali Canal Point
S7	Ispahani Jetty Point
S8	Kalurghat Point (Near BSCIC)
S9	Karnaphuli Paper Mill
S10	Karnaphuli Halda Estuary

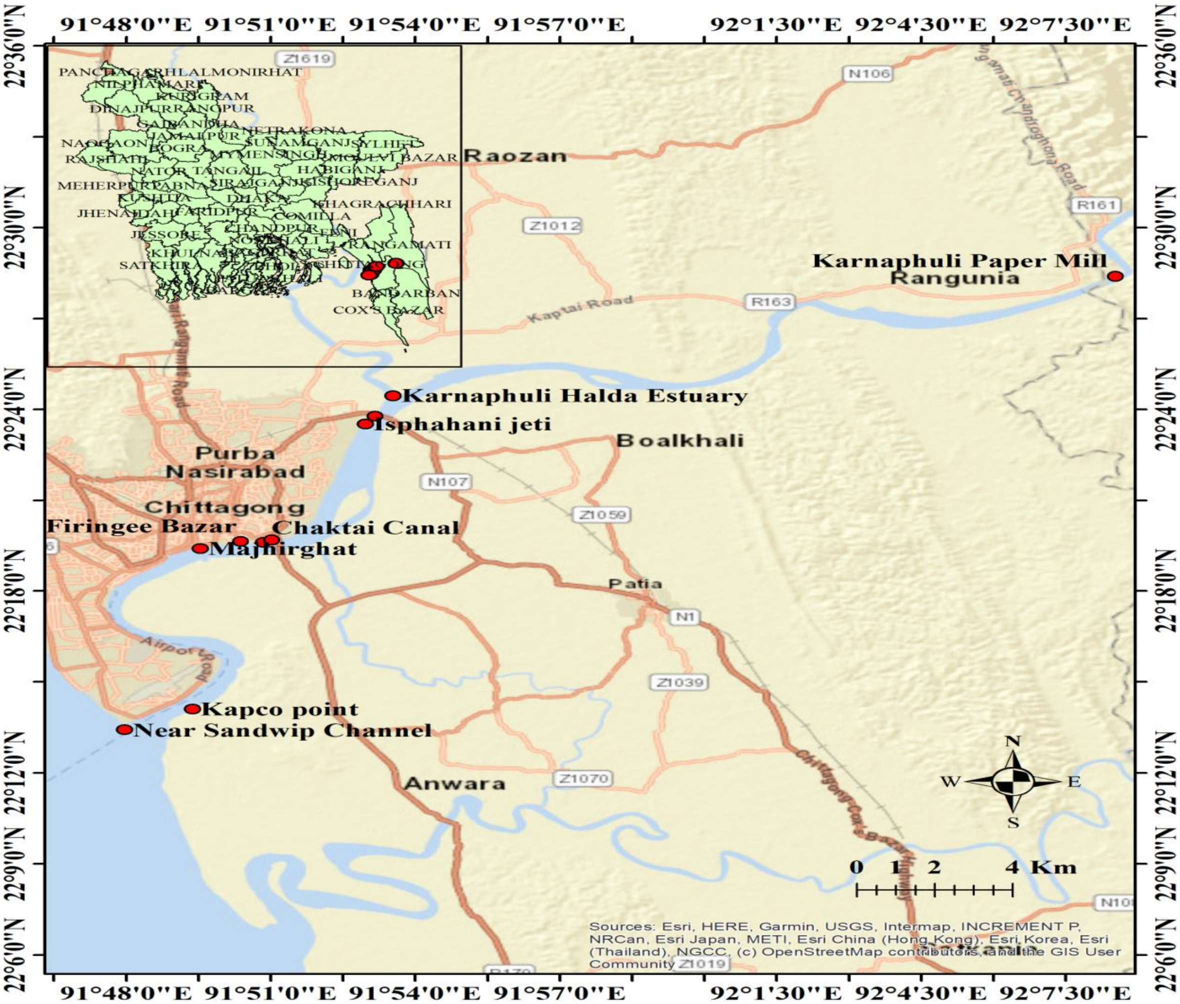


Fig 1: GPS location showing sampling sites

2.2 Sample digestion

For measuring heavy metal contents pre-treatment of samples were carried out by standard methods using APHA (22). 500 ml of the sample was taken into an evaporating disk, acidified with 5ml HNO_3 and evaporated on a steam bath to 15 to 20 ml. Then transferred to a 125 ml conical flask and 5ml HNO_3,10 ml H_2SO_4 and few glass beads (to prevent bumping) were added. Then, it was evaporated in hot plate until clear solution was observed. It was again cooled to room temperature and diluted to 50 ml and filtered with a porcelain filter crucible. The residue was washed with small amount of water. Then the filtrate was transferred to a 100 ml volumetric flask and made up to the mark with distill water. An aliquot of this solution were taken for the determination of the metals (23).

2.3 Calculation of CCME-WQI

After the body of water, the period of time, and the variables and objectives have been defined, each of the three factors that make up the index must be calculated. The calculation of F_1 and F_2 is relatively straightforward; F_3 requires some additional steps.

F_1 (Scope) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration ("failed variables"), relative to the total number of variables measured:

$$F_1 = \frac{\textbf{Number of failed variables}}{\textbf{Total number of variables}} \times 100$$

F_2 (Frequency) represents the percentage of individual tests that do not meet objectives (“failed tests”)

$$F_2 = \frac{\textbf{Number of failed tests}}{\textbf{Total number of tests}} \times 100$$

F_3 (Amplitude) represents the amount by which failed test values do not meet their objectives (“failed tests”). F_3 is calculated in three steps-

1) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed as excursion and is expressed as follows. When the test value must not exceed the objectives-

$$\textbf{Excursion}_i = \frac{\textbf{Failed test value}_i}{\textbf{Objectives}_j} - 1$$

2) The amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and diving by the total number of tests. This variable, referred to as the normalized sum of excursion, or nse, is calculated as-

$$\textbf{nse} = \frac{\sum_{i=1}^{n} \textbf{Excursions}}{\textbf{No.of tests}}$$

3) F_3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 to100.

$$F_3 = \frac{\textbf{nse}}{\textbf{0.01nse} + \textbf{0.01}}$$

Once the factors have been obtained, the index itself can be calculated by following equation.

$$\textbf{CCMEWQI} = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}$$

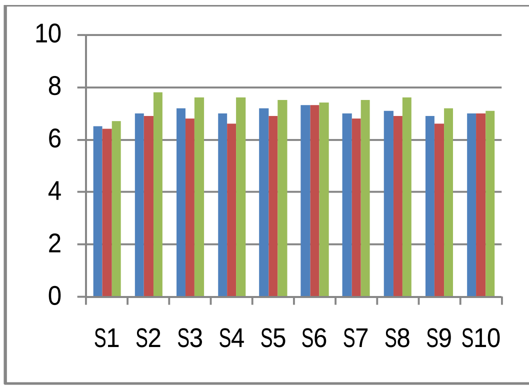
The divisor 1.732 normalizes the resultant values to a range of 0 to 100, where 0 represents the “worst” water quality and 100represent the “best” water quality. Once the CCME WQI value has been determined, water quality is ranked by relating it to one of the following categories (24) (25).

Table 2: CCME rankings for river water (26) (27)

Rank	WQI Value	Description
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels; these index values can only be obtained if all measurements are within objectives all the time.
Good	80-94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

3. RESULTS AND DISCUSSION

Laboratory analysis for different water quality parameters of Karnaphuli river water was performed according to standard methods. The test results varied in different sample points and also varied due to seasonal variation. pH is one of the important indicators of surface water quality. pH values vary between 6.4 and 7.8. Water from all the locations was not acceptable to drink throughout the period of the study. DO is the most important factor to support aquatic life as well as to assess the water quality. DO values vary between 1.8 and 6 ppm. Most of the locations have lower DO value than the standard value which indicates the water contains organic pollutants as well as chemicals that reduces DO value and increase BOD value.



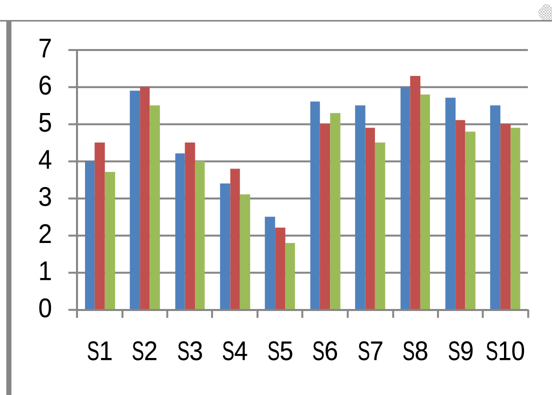
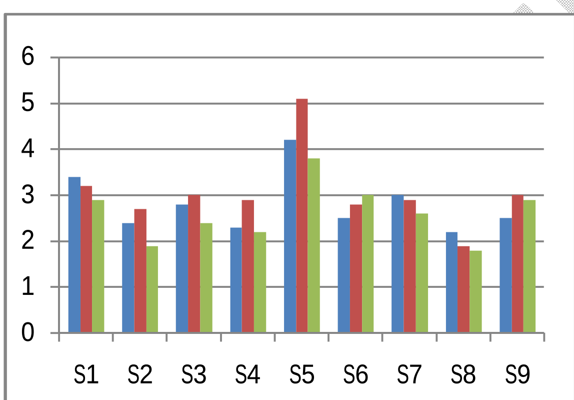


Fig 2: Seasonal variation of pH **Fig 3: Seasonal variation of DO (ppm)**

(Pre-Monsoon, Monsoon, Post-Monsoon)



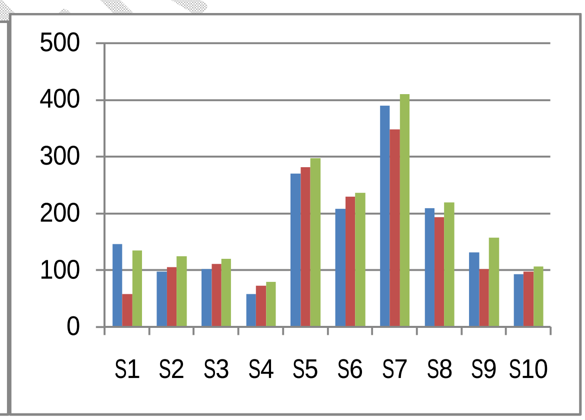


Fig 4: Seasonal variation of BOD (ppm) **Fig 5: Seasonal variation of TDS (ppm)**

TDS and Electrical Conductivity ranges between 94-390 ppm and 184-778 µS/cm. The main sources of TDS and EC are agricultural waste, domestic and municipal waste, runoff etc. The industrial wastes may also increase these parameters. Turbidity is also high due to high TDS.

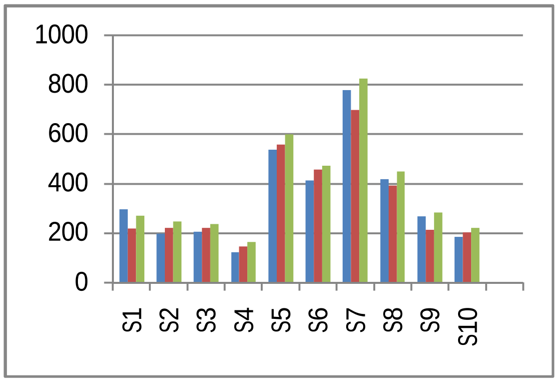


Fig 6: Seasonal variation of EC (µS/cm)

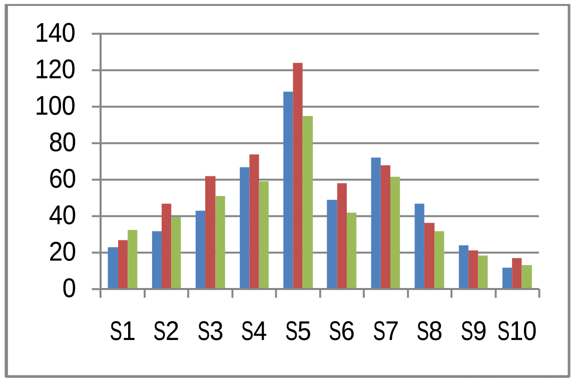


Fig 7: Seasonal variation of Turbidity (NTU)

Acceptable values of Alkalinity (34-123 ppm) and total hardness (74-177.8 ppm) were measured.

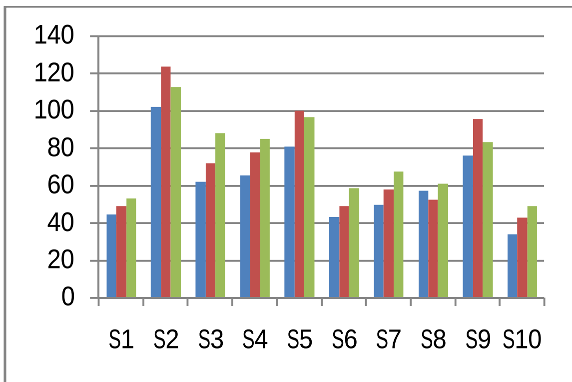


Fig 8: Seasonal variation of Alkalinity (ppm)

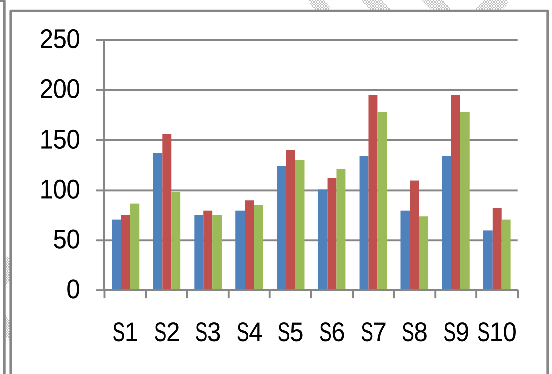


Fig 9: Seasonal variation of Total Hardness (ppm)

Almost all the sample points have higher Phosphate value than the standard which ranges from 0.03-2.5 ppm. Nitrate values (0.4-1.9 ppm) were within the standard except some points. Nitrates and phosphates come from fertilizer industries, municipal wastes, sewage, drainages etc.
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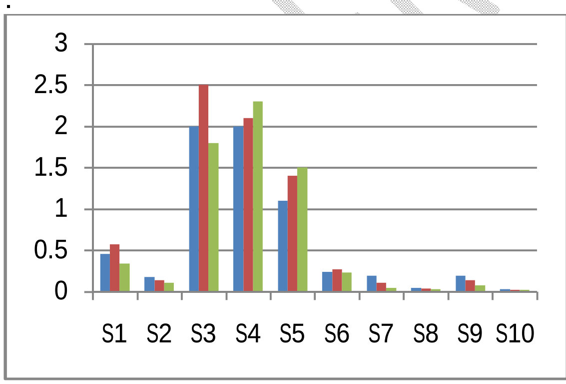


Fig 10: Seasonal variation of Phosphate (ppm)

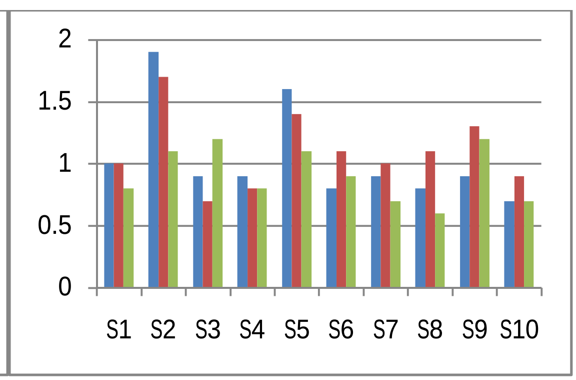
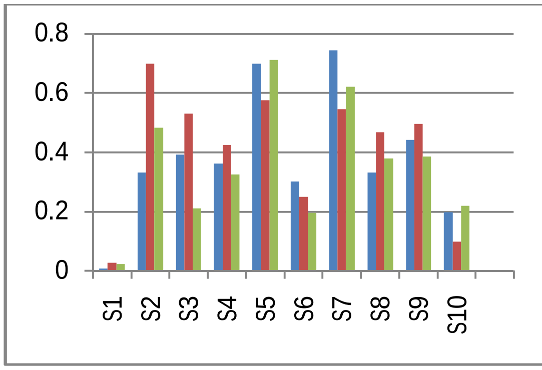


Fig 11: Seasonal variation of Nitrate (ppm)

Heavy metals (Cu, Cd, Pband Zn) were detected to exceed the standard value in all the sample location except Zn. The concentrations of Cu, Cd, Pb and Zn are Cu- 0.108-0.743ppm, Cd- 0.073-0.281 ppm, Pb-0.017-0.699 ppm, Zn- 0.012-0.032 ppm respectively. The main sources of heavy metals are untreated waste water from industries.



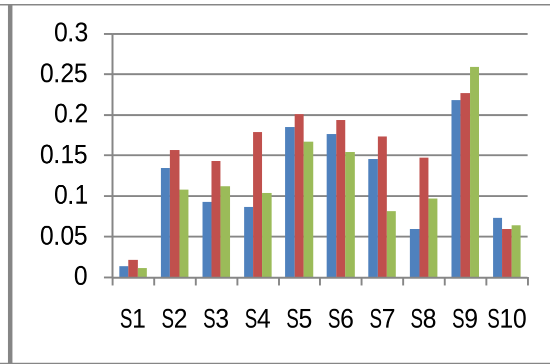
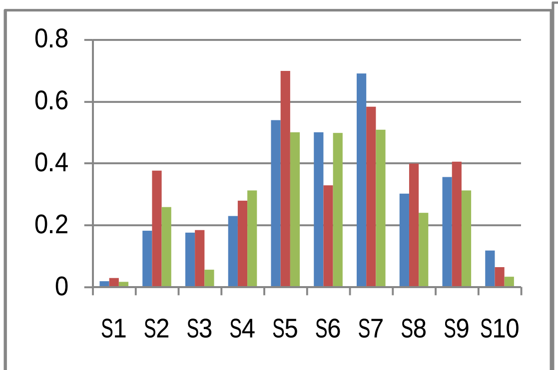


Fig 12: Seasonal variation of Cu (ppm)

Fig 13: Seasonal variation of Cd (ppm)



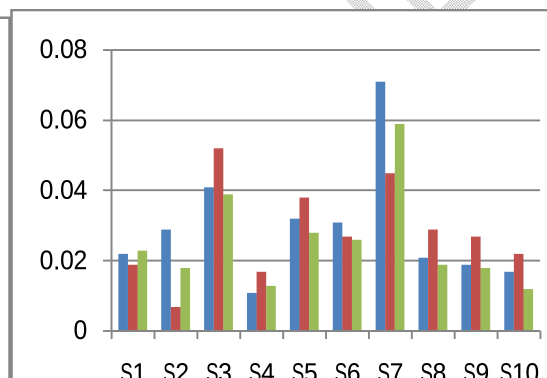


Fig 14: Seasonal variation of Pb (ppm)

Fig 15: Seasonal variation of Zn (ppm)

Chloride values ranges from 3.8-50 ppm and all the values were in acceptable range. Some sample points (S1, S2, S5, S6, S7) have high chloride values due to sea water intrusion, while the other sample points have low chloride values.

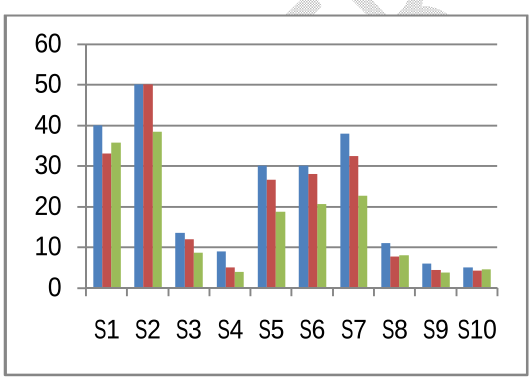


Fig 16: Seasonal variation of Chloride (ppm)

The WQI value is an indicator to identify the standard of water quality of surface or ground water and CCME-WQI method is used when seasonal variation is included. (28)-(30). Based on CCME-WQI model, WQI value for Karnaphuli River is found from 23.2 to 59.3 which indicate that water quality of this river is poor or marginal. The low level of WQI of Karnaphuli River is calculated by 15 numbers of variables. Applying the CCME equations on the results of water analysis, water quality of the different sampling points are determined. However, this method is used to assess the water quality for large scale calculations while this study is conducted on a limited scale in some selected points of Karnaphuli river basin. According to the range of CCME-WQI value given in Table-3, water quality of this river is threatened or impaired; conditions usually depart from natural or desirable levels (31)-(34).

Table 3: CCME-WQI Value and rankings of Karnaphuli river basin

Sample Point	CCME WQI	Category
Near Sandwip Channel	59.3	Marginal
KAFCO Point	37.9	Poor
Firingibazar ghat Point	37.5	Poor
Majhir ghat Point	38.8	Poor
Chaktai Canal Point	23.2	Poor
Rajakhali Canal Point	29.8	Poor
Ispahani Jetty Point	33.1	Poor
Kalurghat Point (Near BSCIC)	37.5	Poor
Karnaphuli Paper Mill Point	36.3	Poor
Karnaphuli Halda Estuary	45.5	Marginal

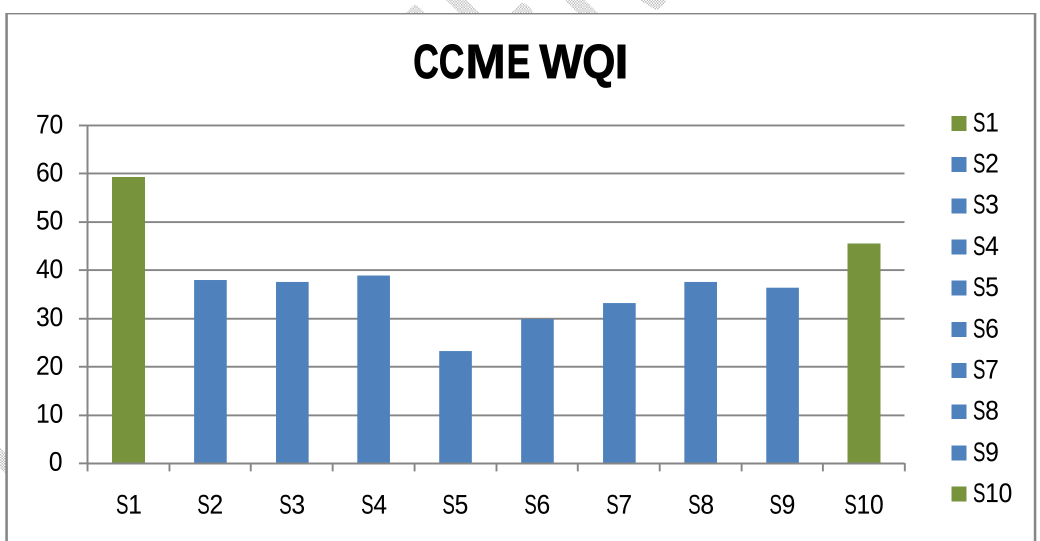


Fig 17: CCME-WQI Values
(Marginal Poor)

4. CONCLUSION

The WQI values indicate that the sample point 1 and 10 are less polluted but also near the marginal line of pollution. Other sample points are more polluted due to the industrial discharge, falling canals, municipal garbage, runoff etc. Untreated industrial wastes are the reason behind the high heavy metal content, municipal garbage increases the BOD value, fertilizers and nutrients used in agricultural fields inceases the nitrate and phosphate value. Most of the the water quality parameters exceeds the standard value given by CCME, so the river water is non-conducive for human use and aquatic life. As most of the sample points are below marginal line, the quality of this river water is not acceptable for drinking purpose and not good for irrigation and indutrial purpose also. As the water is widely used for irrigation, and in industries the pollution should be minimized by identifying the pollution sources.

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