

Assessment of Water Quality of Most Polluted Area of Karnaphuli River, Bangladesh, Using Multivariate Analysis and Pollution Evaluation Indices.

ABSTRACT

Aims: The Karnaphuli River is one of polluted River of Chittagong originating from the Lushai Hills in India which is being polluted recently by various industries located around it. The primary objectives of this study is to determine the water quality status of the most polluted area of Karnaphuli River and along with the root causes of pollution.

Methodology: The study involved the determination of physical parameters like Temperature, Color, Electrical Conductivity, Odor, Turbidity and chemical parameters like Potential of Hydrogen (pH), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) etc. of the most polluted zone of Karnaphuli River. On the basis of water quality parameters, evaluation of water quality is done on the basis of Standard Water Quality Index (WQI) and Comprehensive Pollution Index (CPI). Principal Component Analysis (PCA) is used to extract the parameters that are most important in assessing variation in water quality.

Results: The WQI value indicates that around 40% of the sampled stations water quality is bad whereas about 40% of water quality is low. But CPI values indicates that all of the sampling station water is severely polluted. Three Principal Components were identified as responsible for the data structure explaining 89.24% of the total variance of the dataset.

Conclusion: The samples sites are highly polluted with different wastes generated from various industries situated in the bank of Karnaphuli River.

Keywords: Karnaphuli River; Water Quality Parameters; Water Quality Index; Comprehensive Pollution Index; Geostatistical Analysis.

1. INTRODUCTION

Water quality deterioration, due to the anthropogenic, natural activities and its immense utilization in various sector, is considered as a great concern throughout the world because these activities ultimately leads to the scarcity of readily usable water [1-3]. Both the quantity and the quality of surface and ground water supplies are already uneven, and the incidence of pollution and of scarcity is on the rise. Today, nearly 40 percent of the world's food supply is grown under irrigation, and a wide variety of industrial processes depends on water [4]. But These Rivers are easily polluted because of their critical roles in transporting municipal and industrial pollution and runoff from agricultural land [5].

Bangladesh is a land of rivers. Around 230 rivers flow through the country including 53 international rivers. Urbanization is the main reason of pollution for these rivers and other water bodies because in developing countries the water bodies usually act as the final reservoir of various industrial and sewage effluents [6]. Several studies showed that surface water quality of the rivers of the country is highly polluting day by day [6-8]. In Chittagong the Karnaphuli is the biggest river and considered as the heart because for centuries it has shaped the lives of the people living along its banks [9]. But urban population generates greater loads of urban waste, and the industries around the river are throwing out their effluents directly or indirectly into Karnaphuli River [10-11]. Industrial wastes are creating ecological imbalances to the water body by changing its quality parameters [11]. The effluents of different industries contain organic matter along with pathogens which occurs life killing diseases. A lot of study was conducted across the Karnaphuli River but no study was found along the most heavily industrial zone between the Kaloorghat Bridge and Patenga estuary for determining water quality on the basis of quality indexes. [12-13]. This area has a lot of industry and all of these industries discharge their untreated toxic waste water directly into the river Karnaphuli [9, 10, 11, 14]. That's why, water quality evaluation of this zone is important for pollution control, resource management and implement future protective measure.

The water quality index (WQI) method has been widely used in water quality assessments of both groundwater and surface water, particularly rivers, and it has played an increasingly important role in water resource management [15-17]. WQI methods combine multiple water quality parameters and

effectively convert them into a single value reflecting the overall status of water quality. Thus, instead of comparing the various parameters results, the WQI method provides integrated information regarding overall quality of water necessary for find out appropriate treatment technique to meet the concerned issue [16]. Beside WQI, Comprehensive Pollution Index (CPI) is also used to evaluate the water quality which is also

Thus the study involved determination of physical and chemical parameters of surface water at different points of most polluted zone of Karnaphuli River to analyze some of the most common water quality parameters. This research work also includes the utilization of WQI method and CPI index to assess the water quality and its spatial variations in Karnaphuli River. Our study was based on a data set of 17 parameters measured three times at 15 sampling sites that covered the entire basin. The primary objectives of this study were to determine the water quality status and its spatial variation across the five major site of the river along with their root causes.

2. MATERIAL & METHODOLOGY

2.1 Study Area Description:

River Karnaphuli, originating from South Lushai Hills is the largest surface water source for Chittagong and the Chittagong Hill Tracts region. The Karnaphuli river enters into Chittagong region in the west and south-west directions and flowing upto 180 km, it passes the city on its right bank [9]. Prior to that, it also flows through Rangamati, Dhuliachhari and the Kaptai at a zigzag manner. At the time of its flowing through Chittagong, it ensures the demand of water supply to industrial, agriculture, fishing, household and navigational infrastructure sectors. Now it is under a great threat, as the natural water characteristics is adversely changing day by day [7].

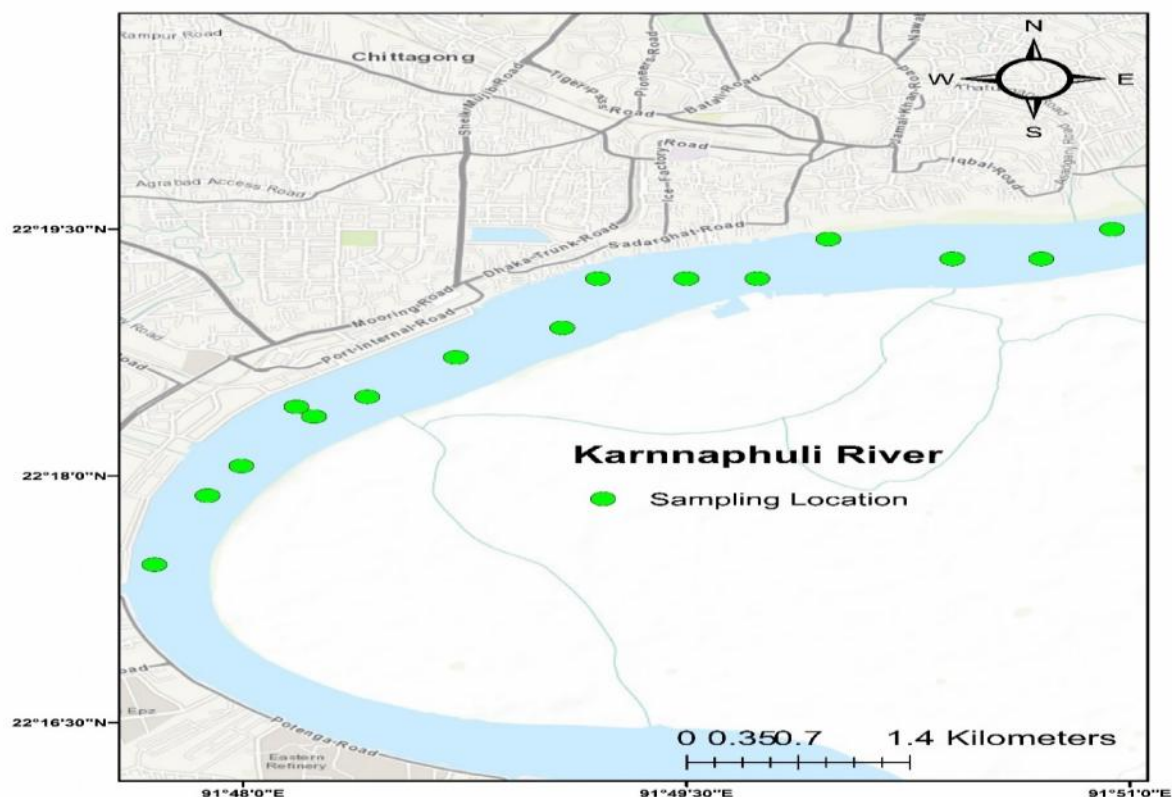


Fig. 1 Sampling area with identification

2.2 Sample Collection and laboratory Analysis:

Water samples were collected from the Karnnaphuli River during summer season in 2016, and tested for physical qualities and chemical contents. The sample location are indicated in fig. 1 and site location (GIS Coordinates) and condition are shown in Table 1. Two (2) liter polypropylene bottles were used for water sample collection. Prior to sample collection, all bottles were washed with dilute acid followed by distilled water and were dried in an oven. Before taking final water samples, the bottles were rinsed three times with the water to be collected. The sample bottles were labeled with date, time and sampling source. Five major sampling points (Three for each) were selected within 6 km of Karnnaphuli River and samples were collected from river in the distance of about at least 20 meter from one sample to another for each sampling site. pH was calculated by pH meter which was standardized by distilled water and buffer solution [18]. Electrical Conductivity (EC), Total Dissolved Solid (TDS) and Temperature readings were collected from TDS meter [10] whereas Dissolved Oxygen was determined by DO meter which was

also standardized by distilled water and buffer solution [18]. BOD and COD were determined Winkler's Azide method and Dichromate method respectively whereas sulphate and chloride were by spectrophotometric and titrimetric method respectively [19]. For heavy metal determination the sample water were digested using concentrated nitric acid (HNO_3) and concentration of Zinc (Zn), Iron (Fe), Manganese (Mn), Nickel (Ni) and other metals were measured with S series atomic absorption spectrophotometer (AAS) [7]. The entire chemicals used were reagents grade. QA and QC meant to make certain that reliable data were produced consistently with a minimum of error for carrying out research study.

Table 1. The sampling locations and its tidal condition

Sample ID	Sampling Sites(Longitude/Latitude)	Conditions
S-1	91.810204°/ 22.310346°	Low Tide
S-2	91.812573°/ 22.312224°	Low Tide
S-3	91.817053°/ 22.315515°	Low Tide
S -4	91.826208°/ 22.319719°	Low Tide
S -5	91.841579°/ 22.322430°	Low Tide

2.3 Assessment Methodologies:

2.3.1 Assessment Based on Water Quality Index (WQI):

Water quality index (WQI) is a tool for assessing water quality through the determination of physico-chemical parameters of surface water which efficiently give the overall water quality of a specific area water source [20]. The equation (1) was used to calculate the WQI:

$$EQI = \frac{\sum_{i=1}^n q_i w_i}{\sum_{i=1}^n w_i} \quad (1)$$

where: W_i is weightage factor (equation 2); K is a constant value and it is calculated using the following formula $K=1/\sum(1/S_i)$; S_i is the standard value of the i th water quality parameter; n is the total number of water quality parameters; q_i is the quality rating for the i th water quality parameter and is calculated using the equation (3).

$$w_i = \frac{K}{s_i} \quad (2)$$

$$q_i = \frac{V_a - V_i}{s_i - V_i} \times 100 \quad (3)$$

V_a represents the value of the *i*th water quality parameter determinate experimentally, V_i is the ideal value of the *i*th water quality (V_i for pH = 7, for OD is 14.6 mg/L and for the other parameter the V_i value is 0 [21-22]. The WQI ranges from 0 and 100, with high values representing good water quality conditions. The water quality was classified into five grades based on the WQI scores: excellent (91–100), good (71–90), moderate (51–70), low (26–50), and bad (0–25) [23].

2.3.2 Assessment Based on Comprehensive Pollution Index (CPI):
It is the most trustworthy method used to assess the overall water quality status in a water body followed by classification of water based on definite numerical value range [24]. Drinking water quality standard prescribed by DPHE of Bangladesh and WHO 2011 was used for calculating CPI [25]. In the present study, the evaluation of CPI has been done based on the physiochemical parameters data, which were obtained during chemical analysis of the collected water samples. It is mathematically expressed in equation 3 and 4:

$$PI_i = \frac{C_i}{s_i} \quad (3)$$

$$CPI = \frac{1}{n} \sum_{i=1}^n PI \quad (4)$$

Where, PI denotes the pollution index of *i*th parameter; C_i represents the measured concentration of the *i*th parameter; S_i is standard value of the *i*th parameter; and n denotes the total number of parameters. The CPI gives the precise result of overall water quality status in a water body in classification range 0-2 as: 0-0.20 (excellent); 0.21-0.4 (good); 0.41-1.00 (slightly polluted); 1.01-2 (moderately polluted); ≥2.01 (severely polluted) [26].

2.4 Analytical Methods:

2.4.1 Statistical Method

All statistical analyses were computed by using SPSS version 16. Tukey HSD test was applied to compare results of various parameters collected from 5 different stations in Karnaphuli River. Multivariate statistics like PCA analysis was also done by SPSS and cluster analysis was done by PAST software.

2.4.2 Geostatistical Methods

The inverse distance weighted (IDW) method was applied to understand the spatial distribution of WQI and CPI values in the river water surface. The IDW interpolation calculates the cell values for the unmeasured site by averaging the sampled data in the target site. The more weight is observed when the measured point is close to the center of prediction cell. ArcGIS 10.2.2 was used for analysis. Power of two and the number of 20 neighboring samples were chosen to show both spatial variation of the WQI/CPI values. We made a polygon very similar to sampling area and used this polygon for interpolation. Total RMS error was maintained below 1 (0.001-0.002) to ensure the proper interpolation of data.

3. RESULTS AND DISCUSSIONS:

3.1 Water characteristics

Table 2 shows the descriptive statistics of determined water quality parameters of five different sampling zone of Karnaphuli River. From the table it is clear that all of the parameters are significantly varied among the sampling stations except for Temperature and heavy metal content. From the apparent test three stations were mostly polluted as its color and odor was also in the worst condition as compared to other stations (Table 2). The highest pH values was observed at station 2 followed by station 1, 3 4 and 5. The mean turbidity was found of 40.48 NTU, with the highest value at station 4 and a significant difference was observed with other stations except for station 1 (48 NU).

The highest Do was observed at station 1 while the lowest value was observed at station 5 which is higher than the standard limit (4 mg/L) for sustaining aquatic life [26]. Both the BOD and COD value at station 5 were highest among all sampling stations and they were significantly higher than the other stations also ($P < 0.001$). Highest TS value was observed at station 3 followed by station 2 and 1, however TS value at station 4 and 5 were significantly lower from the highest concentration ($P < 0.001$). TS value

165 ranges from 2517 to 15782 mg/L whereas Standard value for TS recommended for Bangladesh is about
 166 1000-1200 mg/L [27]. Both the TDS and TSS value in all sampling station were higher than the
 167 recommended standard value of 1000ppm and 150 ppm respectively [10-11].

168

169 **Table 2. Environmental variables summarized as the mean and standard deviation for the 5**
 170 **stations of Karnaphuli River.**

Parameter	River station					p
	Station 1	Station 2	Station 3	Station 4	Station 5	
Odor	Odorless	Odorless	Slightly pungent	Odorless	Objectionable	
Color	Nearly colorless	Colorless	Slightly Muddy	Colorless	Very light green	
pH	7.4 ± 0.01 ^a	7.9 ± 0.17 ^a	6.9 ± 0.05 ^a	6.8 ± 0.11 ^{ab}	6.6 ± 0.05 ^b	<0.001
Temperature (°C)	26 ± 1.64 ^a	26.7 ± 0.64 ^a	28 ± 1.74 ^a	27 ± 1.16 ^a	25.5 ± 0.70 ^a	0.359
Turbidity (NTU)	48 ± 1.74 ^a	38.22 ± 0.02 ^b	35.63 ± 0.01 ^c	58.54 ± 0.02 ^c	22.00 ± 1.16 ^d	<0.001
Dissolved Oxygen (DO) (ppm)	5.20 ± 0.01 ^a	2.50 ± 0.02 ^b	3.90 ± 0.01 ^c	2.80 ± 0.01 ^{cd}	1.50 ± 0.02 ^d	<0.001
Biochemical Oxygen Demand (BOD) (ppm)	168 ± 0.58 ^a	215 ± 1.16 ^b	185 ± 1.16 ^c	324 ± 0.58 ^{cd}	380 ± 1.16 ^d	<0.001
Chemical Oxygen Demand (COD) (ppm)	420 ± 1.16 ^a	425 ± 1.16 ^b	322 ± 0.58 ^c	600 ± 1.16 ^c	765 ± 0.58 ^c	<0.001
Total Dissolved Solid (TDS) (ppm)	11920 ± 1.74 ^a	13325 ± 1.16 ^b	15262 ± 1.16 ^c	1963 ± 0.58 ^d	3981 ± 1.74 ^e	<0.001
Total Suspended Solid (TSS) (ppm)	430 ± 0.58 ^a	520 ± 1.74 ^b	320 ± 0.58 ^b	242 ± 1.16 ^c	425 ± 0.58 ^d	<0.001
Total Solid (TS) (ppm)	12431 ± 1.74 ^a	13965 ± 0.58 ^b	15782 ± 1.16 ^c	2517 ± 1.16 ^d	4522 ± 0.58 ^e	<0.001
Electrical Conductivity (EC) (µs/cm)	18340 ± 1.74 ^a	20500 ± 1.16 ^b	23480 ± 0.58 ^c	3020 ± 1.16 ^d	6125 ± 1.74 ^e	<0.001
Hardness (ppm)	165 ± 1.16 ^a	220 ± 0.58 ^b	84 ± 1.74 ^{bc}	146 ± 0.58 ^c	128.6 ± 0.18 ^d	<0.001
Iron (ppm)	0.05 ± 0.02 ^a	0.04 ± 0.02 ^a	0.60 ± 0.15 ^a	0.11 ± 0.04 ^a	0.1 ± 0.01 ^a	<0.05
Manganese (ppm)	0.01 ± 0.01 ^a	0.02 ± 0.02 ^a	0.01 ± 0.01 ^a	0.08 ± 0.03 ^a	0.03 ± 0.02 ^a	<0.05
Nickel (ppm)	0.06 ± 0.03 ^a	0.09 ± 0.04 ^a	0.08 ± 0.03 ^a	0.13 ± 0.02 ^a	0.11 ± 0.03 ^a	<0.05
Zinc (ppm)	0.02 ± 0.02 ^a	0.08 ± 0.03 ^a	0.03 ± 0.02 ^a	0.02 ± 0.01 ^a	0.03 ± 0.02 ^a	<0.05
Chloride (ppm)	41.35 ± 0.05 ^a	25.96 ± 0.07 ^b	13.88 ± 0.12 ^c	37.22 ± 0.22 ^d	32.85 ± 0.42 ^d	<0.001
Sulphate (ppm)	2.65 ± 0.02 ^a	2.10 ± 0.15 ^{ab}	1.35 ± 0.22 ^{bc}	1.27 ± 0.05 ^c	3.55 ± 0.1 ^c	<0.001

171

172 Results are represented as mean ± SD. Men with different letters in rows (a, b, c, d, e) are significantly
 173 different (P<0.05)

174 The electrical conductivity at station 4 and 5 are significantly lower than the station 1, 2 and 3 respectively
 175 (P<0.001). The mean value found 14293 µs/cm ranging from 3020 to 23480 µs/cm, whereas Bangladesh

Standard for EC in terms of inland surface water is 1200 $\mu\text{S}/\text{cm}$ [11]. Higher EC value is a clear indication of river water pollution, presence of inorganic dissolved solids as well. Metal content of Karnnaphuli River water was found in very trace amount. Mean value of Fe, Mn, Ni, and Zn was found 0.2, 0.043, 0.094 & 0.036 mg/L respectively. All of them were found below the harmful level.

3.2 Evaluation of Water quality Indices:

The well-known indices like WQI and CPI were evaluated using the parameters data obtained during laboratory analysis, to classify the overall water quality status of Karnnaphuli River. WQI and CPI values are represented by means of prediction map in fig. 2. Prediction map usually helps to know the predicted values in the untested location based on the determined value at sampled location. The prediction map clearly defines the distribution of various parameters where red color indicates the highest concentration and green color signifies the lowest concentration. From the figure it is clear that, in general 40% of the sampling area of Karnnaphuli River had bad quality water and 40% sampling area had low quality water. One of five sapling station had good quality water. Overall, the water quality of the five stations of Karnnaphuli river systems was classified in "Low" status, whereas the WQI values differed significantly among these systems. The lowest value was observed in station 1(17.54) and station 3 (17.91) whereas the highest was observed at station 4 (131.52) followed by station 5 (49.74). From the CPI value prediction map it is clear that, more than 60% of the sampled location water were severely polluted in Karnnaphuli River. More specifically the station 2 and 3 were more polluted as compared to the station 1. On the other hand, water at station 4 and station 5 water were moderately polluted.

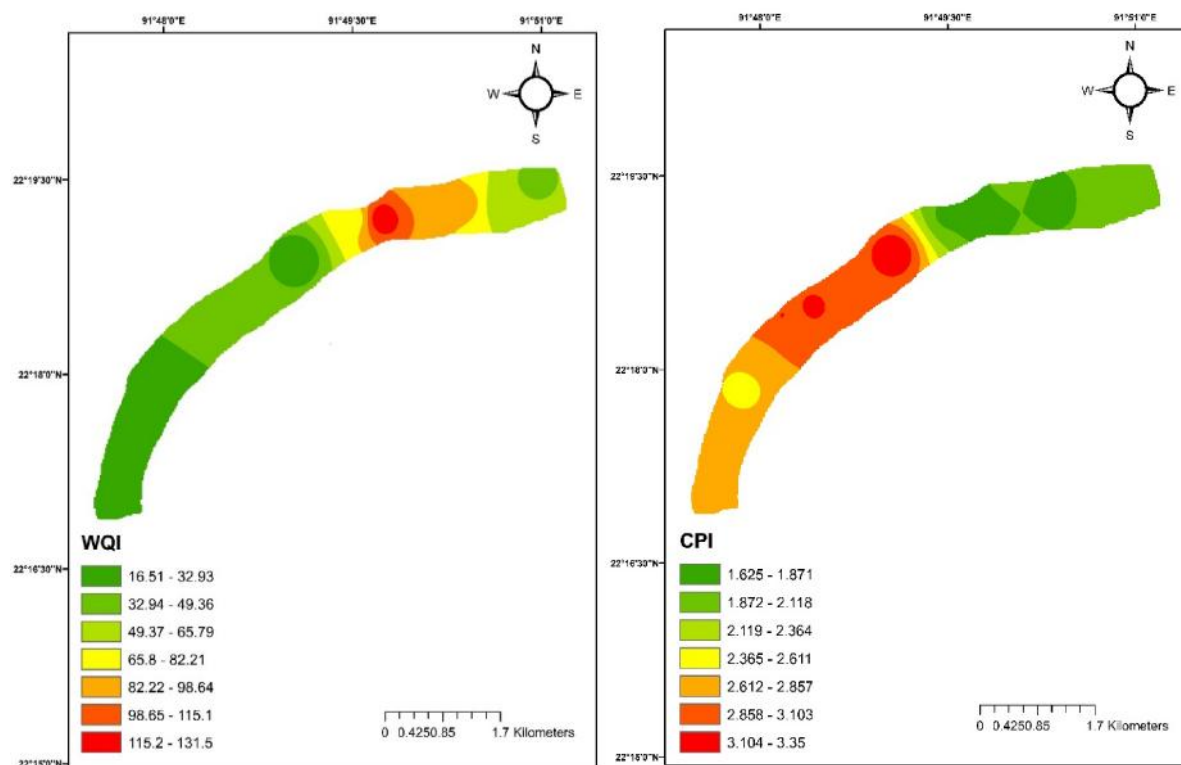


Fig. 2 Spatial distribution of WQI and CPI values in Karnaphuli River

3.3 Relationships between the water quality parameters:

The inter-parameter interactions signify the dependency and common sources of pollutant that alter the concentration of different water quality parameters in a water body. The Pearson correlation values (r) obtained PCA analysis was summarized in Table 4. From the correlation data it is very clear that, both BOD and Cod had strong positive correlation (0.957) but both BOD and COD had a strong negative correlation (-0.827 & -0.724 respectively). The negative correlation of BOD and OCD with indicate the significant impact of local anthropogenic pollution like industrial and domestic wastes in the river [28]. The positive correlation of pH with Fe and Ni indicates that their availability in water is somehow controlled by pH whereas negative correlation pH with Mn and Zn indicates that there are some other factors responsible for their accumulation in water body. The negative correlation of DO with BOD and COD signifies that water is not suitable for aquatic life [28].

3.4 Source Identification:

PCA is a powerful tool for classification, modeling, and other aspects of data evaluation [29]. To make the results more easily interpretable, PCA with varimax normalized rotation also was applied.

Table 3. Rotated component matrix (Varimax with Kaiser Normalization) for various parameter

Variables	Component 1	Component 1	Component 1
pH	.840	.442	.270
Temperature	.355	.677	-.595
Turbidity	.000	.874	.337
DO	.756	.277	.082
BOD	-.968	-.237	-.078
COD	-.905	-.395	.114
EC	.959	-.044	-.115
Hardness	.065	.060	.910
TDS	.958	-.044	-.115
TSS	.373	-.613	.543
TS	.957	-.042	-.111
Fe	.360	.147	-.921
Mn	-.816	.567	.080
Zn	-.933	.271	-.115
Ni	.228	-.071	.335
Chloride	-.949	.120	.152
Sulfate	-.182	-.922	.312
Eigen values	8.796	3.997	2.379
% of variance	51.74	23.51	13.99
Cumulative %	51.74	75.25	89.24

level in Karnnaphuli River. (Factor with >0.5 loading are indicated by bold letter)

Table 3 shows the factor loading along with eigenvalues of three major component along with their total variance. The 3D plot of PCA (Fig. 3) shows that three component counted for 89.24% of total variance. Component 1 (51.74% of total variance) is highly loaded with) EC, TDS, TS and pH having an eigenvalue of 8.796. The second component (PC2) explained 23.51% of the total variance with an eigenvalue of 3.997 and high values of temperature, turbidity and Mn. The third component is highly loaded with hardness and TSS with 13.99% of the total variance. The correlation values (Table 4) shows that there is

227 strong positive correlation among the high factor loading parameter of principle component 1 ensuring
228 that these parameter

229 **Table 4. Correlation matrix of the water quality parameters obtained from the PCA**

230

	pH	Temperature	Turbidity	DO	BOD	COD	EC	Hardness	TDS	TSS	TS	Fe	Mn	Zn	Ni	chloride	Sulfate
pH	1.000																
Temperature	.397	1.000															
Turbidity	.534	.304	1.000														
DO	.874 ^b	.262	.476	1.000													
BOD	-.945 ^a	-.447	-.247	-.827 ^b	1.000												
COD	-.888 ^b	-.683	-.271	-.724	.957 ^a	1.000											
EC	.714	.443	-.167	.553	-.898 ^b	-.890 ^b	1.000										
Hardness	.263	-.377	.217	-.097	-.132	-.021	.060	1.000									
TDS	.714	.443	-.167	.553	-.898 ^b	-.890 ^b	1.000	.060	1.000								
TSS	.119	-.498	-.506	-.099	-.240	-.078	.434	.658	.434	1.000							
TS	.713	.443	-.167	.548	-.897 ^b	-.890 ^b	1.000	.066	1.000	.438	1.000						
Fe	.114	.783	-.191	.221	-.311	-.493	.452	-.794	.452	-.443	.448	1.000					
Mn	-.400	.027	.551	-.406	.646	.532	-.837 ^b	.021	-.837 ^b	-.644	-.835 ^b	-.286	1.000				
Zn	-.728	-.027	.125	-.762	.856 ^b	.702	-.839 ^b	-.065	-.839 ^b	-.486	-.836 ^b	-.184	.889 ^b	1.000			
Ni	.106	.060	-.269	-.354	-.193	-.235	.418	.685	.418	.707	.425	-.210	-.273	-.081	1.000		
Chloride	-.743	-.284	.068	-.818	.888	.803	-.868 ^b	.184	-.868 ^b	-.237	-.864 ^b	-.456	.834 ^b	.952 ^a	.053	1.000	
Sulfate	-.455	-.909 ^b	-.652	-.287 ^b	.365	.580	-.206	.161	-.206	.607	-.207	-.493	-.338	-.145	.003	.076	1.000

231

232 a P<0.01

233 b P<0.05

are strongly correlated with each other and their abundance also strongly controlled by them. The obtained PCA results are very much similar to the indication of correlation coefficient results. From the cluster analysis (Fig. 4) it is clear that, there have two main cluster. Cluster 1 comprise of two subset where station 1, 2 is in one subset and station 3 is in another one. This is indication that the pollutant of station 1, 2 are almost same and the pollutant from same sources are responsible for water pollution. On the other hand, pollutant from the first and second station also contributed to the major pollution in station 3 although it has some other point source for pollution. Cluster 2 consists of Station 4 and 5 and have more or less similar sources of pollutants.

We have selected five different zone to investigate the contribution of different activities beside Karnaphuli River responsible for major water pollution along with the effect of these point sources on water quality. For this reason we have kept our discussion on the basis of sources.

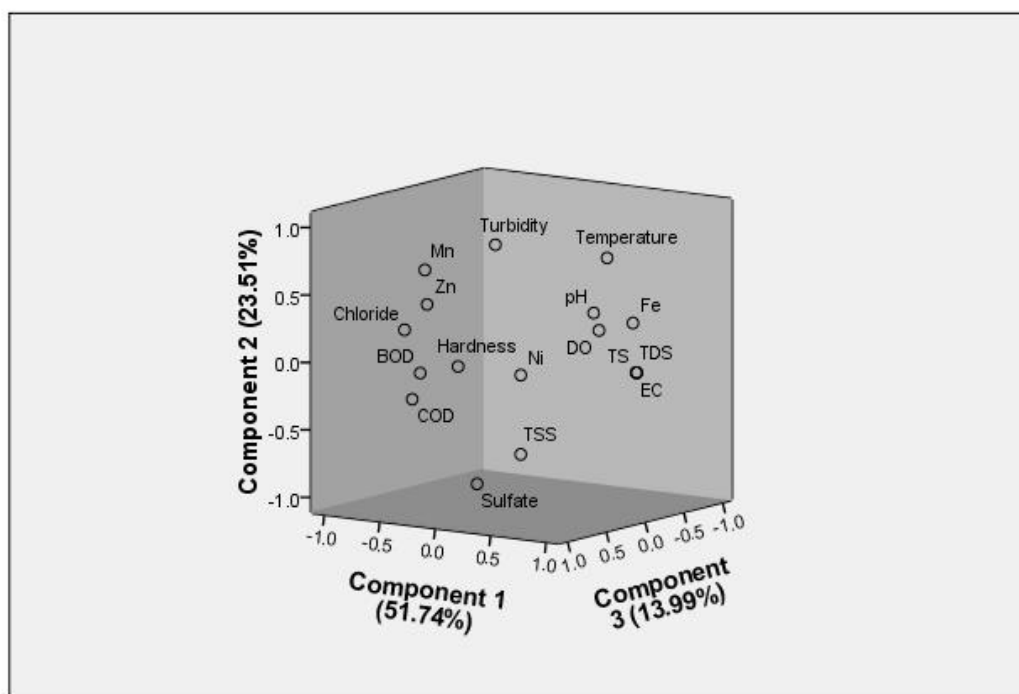


Fig. 3 The result of PCA Analysis

3.4.1 Cement Industry Zone (Station 1 & 2):

In cement manufacturing process, the main four components are dicalcium silicate, tricalcium silicate, tricalcium aluminate and tetracalcium aluminoferrate as a mixture called clinker which is cooled, powered and mix with 3 % Gypsum [30]. Due to the alkaline nature of these chemical the

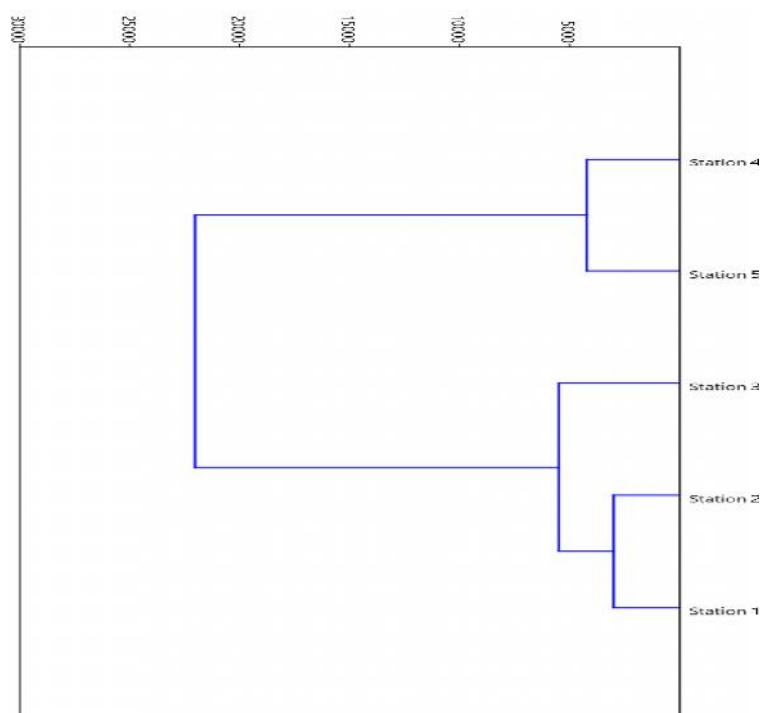


Fig. 4 Cluster analysis representing as Dendrogram Using Euclidian Distance Method.

water sample from two station are slightly alkaline because a huge amount of water is necessary in cement industry having possibility to mix with river water. The calcium salt compounds contributed to the excess TDS, TSS, TS and hardness of the river water in station 1 and 2. Higher turbidity of station 1 and 2 may leads to the growth problem of aquatic livings with a great possibility of microorganism growth [31]. Although the chloride content of station 1 and 2 is higher than standard limit, but it is much lower than other cement industry area of Bangladesh like Surma River (Chattok Cement Factory). Sulphate content is lower than the both standard limit and s compared to Surma River. The high concentration of chloride content and even sulphate concentration can leads to the corrosion of various river side or inside

construction like bridges [32-33]. The higher value BOD, COD and lower value of DO indicated that a huge amount of organic /inorganic waste are deposited from these industrial area as well from municipal area as well. Chlorine content of station 1 and 2 is higher than other stations due to the sea water intrusion.

3.4.2 Sugar Industry Zone (Station 3):

Sugar producing industries or mills are producing thousands liter of waste liquid. The effluents discharge from sugar industry constitute a number of chemical pollutants such as oil, grease, carbonate, bicarbonate, nitrite, phosphate, sulphate in addition to total suspended solid, dissolved solid, volatile solid along with some others organic or inorganic pollutants (sand, mud, debris etc.) from washing of different equipment [34-36]. Calcium hydroxide is used for clarification may also increase pH of river water. Due to presence of carbonate, bicarbonate, nitrite, phosphate either in colloidal dispersion or as dissolved in water TSS, TDS and TS value deviated from standard value.

3.4.3 Fish Processing Zone (Station 4):

Bangladesh is a riverine country, its economy largely depends on marine resources especially on fish. There have about 20 fish processing plant beside Karnaphuli river [7]. Either for home uses or export, the fish should be carefully processed especially the preservation. Drying preservation process is very cheap and easy but the unusual residue of fishes is drained to the nearest water sources [37]. Fish processing activities generate potentially large quantities of organic waste like blood, tissue, and dissolved protein and by-products from inedible fish part which drastically alters the water quality parameters especially increases the turbidity. It also reduces DO, increases BOD, COD and dissolved or undissolved solid. The higher amount of chloride content at station 4 may be due to the using of calcium hypochlorite in fish industry [38]. This is the only zone where water quality is excellent as compared to the other sampling station. The WQI values as well as color and odor test ensure the quality of station 4. This is because fish processing industries basically use huge amount of ice with minimal amount of other chemical for fish preservation.

3.4.4 Industrial Zone (Station 5):

Fisheryghat is a heavy industrial zone in Chittagong. This area constitutes following ice factory, cement factory, food industry, nearest CPI (Chemical Processing Industry) etc. The industrial waste can be classified as-Waste water for process and wash, Waste for cooling and sanitary waste. The wastewater generated from food processing operations has distinctive properties that set it apart from usual municipal wastewater: it is biodegradable and non-toxic, but has high concentrations of biochemical oxygen demand (BOD) and suspended solids. The high sulphate content in station 5 may be due to use of various sulphate compounds in metal processing and paint industry present near the Fisheryghat.

Above observation ensure that the water of Karnnaphuli River is in worst condition very close to the estuary zone. This is because this area is downstream area where water flow rate of river also decreased due to the high flow rate seawater and higher level as well. This phenomena accelerates the possibility of accumulation of various water impurities in river water. Based on our finding and considering the present scenario, necessary steps should be taken as early as possible to minimize water pollution of Karnnaphuli River.

4. CONCLUSIONS:

Karnnaphuli is an important river for Chittagong and feeding the city in many ways and plays an important role in the communication system of the whole region. From our observation Karnnaphuli River water turned into toxic and poisonous under the huge industrial effluents discharging into it, most of the wastes coming from the industries and factories like small ship yard, paper industry, textile industry, salt and sugar industry, cement industry, fish processing factory etc. The river with blackish green and black water, is constantly receiving tons of industrial wastes and other toxics and poisonous solid and liquid wastes without any measures and treatment from surrounding industries, growth center and settlements. The industrial wastes, chemical pesticides, land fill leakages and other human garbage mixed with the river water by the forces of rain water, drain, canals, lake and flood etc. Proper treatment of ETP should be taken by the authority and flow capital dredging is needed in the river. Industries and any others factories which have built up on the bank of the river illegally should be stopped and evicted immediately and finally People should be more aware about water pollution as well as environment. Proper policy should be formulated from the government side.

REFERENCES:

1. Vorosmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C.A., Liermann, C.R., Davies, P.M., 2010, Global threats to human water security and river biodiversity. *Nature*, 467, 555–561
2. Pekey H, Karaka D, Bakoglu M ,2004, Source apportionment of trace metals in surface waters of a polluted stream using multivariate statistical analyses. *Mar Pollut Bull*, 49, 809–818.
3. Venkatramanan S, Chung SY, Lee SY, Park N, 2014, Assessment of river water quality via environmentric multivariate statistical tools and water quality index: a case study of Nakdong river basin, Korea. *Carpath J Earth Environ Sci*, 9, 125–13
4. BCAS, 2000, Pollution Study, Management of Aquatic Ecosystem through Community Husbandry (MACH) (Dhaka, Bangladesh).
5. Singh, K.P., Malik, A., Sinha, S., 2005, Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques - a case study. *Anal. Chim. Acta*, 538, 355–374.
6. Bhuiyan M A H, Dampare S B, Islam M A & Suzuki S.,2015,Source apportionment and pollution evaluation of heavy metals in water and sediments of Buriganga River, Bangladesh, using multivariate analysis and pollution evaluation indices, *Environ Monit Assess*, 187:4075
7. Chakraborty, C., Huq, M. M., Ahmed, S., Tabassum, T. and Miah M. R. , 2013, Analysis of the causes and impacts of water pollution of Buriganga River: A critical study, *International Journal of Scientific and Technology Research*, 2(9), 245-252.
8. Kamal M M, Hansen A M and Badruzzaman A. B. M., 1999, Assessment of pollution of the river Buriganga, Bangladesh, using a water quality model, *Water Science and Technology*, 40(2), 129-136
9. Ali M M, Ali M L, Islam M S, Rahman M Z, , 2016, Preliminary assessment of heavy metals in water and sediment of Karnaphuli River, Bangladesh, *Environmental Nanotechnology, Monitoring & Management*, 5: 27-35

10. Hossain and Khanb Y. S. , 2002, An environmental assessment of metal accumulation in the Karnaphuli estuary, Bangladesh; presented at APN/ Karnaphuli estuary, SASCOM/LOICZ Regional Workshop, Negombo, SriLanka. 8-11 Dec, 2002
11. Majid M. A. and Sharma S. K., 1999, A study of the water quality parameter of the Karnaphuli River, J.Ban. Chem. Soc., 12(1), 17-24.
12. Sarwar M I, Majumder A K and Islam M N, 2010, Water Quality Parameters: A Case Study of Karnafully River Chittagong, Bangladesh, Bangladesh J. Sci. Ind. Res. 45(2), 177-181.
13. Banglapedia. ,2008, Sources of water pollutant in the Karnafuli River. National Encyclopedia of Bangladesh. Asiatic society of Bangladesh.
14. Islam, M.R., Das, N.G., Barua, P. et al., 2017, Environmental assessment of water and soil contamination in Rajakhali Canal of Karnaphuli River (Bangladesh) impacted by anthropogenic influences: a preliminary case study, Appl Water Sci (2017) 7: 997.
<https://doi.org/10.1007/s13201-015-0310-2>
15. Shah K A, Joshi G S. , 2017, Evaluation of water quality index for River Sabarmati, Gujarat, India, Appl Water Sci. 7:1349–1358, DOI 10.1007/s13201-015-0318-7
16. Zhaoshi Wu, Xiaolong Wang, Yuwei Chen, Yongjiu Cai, Jiancai Deng. , 2018, Assessing river water quality using water quality index in Lake Taihu Basin, China, Science of the Total Environment, 612, 914–922.
17. Tyagi S, Sharma B, Singh P, Dobhal R , 2013, Water quality assessment in terms of water quality index. Am J Water Resour 1(3):34–38
18. Halder J.N, Islam M.N., 2015, Water Pollution and its Impact on the Human Health. Journal of Environment And Human; 2(1); 36-46
19. Kangabam R D, Bhoominathan S D, Kanagaraj S, Govindaraju M., 2017, Development of a water quality index (WQI) for the Loktak Lake in India. Appl Water Sci; 7:2907–2918
20. Pesce, S.F., Wunderlin, D.A., 2000, Use of water quality indices to verify the impact of Cordoba City (Argentina) on Suquia River. Water Res. 34, 2915–2926.
21. Yisa, J., Jimoh, T. , 2010, Analitical studies on water quality index of river Landzu, American Journal of Applied Science, 7 (4), 453-458.

22. Iticescu, C., Georgescu, L.P., Topa, C.M. , 2013, Assessing the Danube water quality index in the city of Galati, Romania, *Carpathian Journal of Earth and Environmental Sciences*, 8 (4), 155-164.
23. Jonnalagadda, S.B., Mhere, G., 2000. Water quality of the Odzi River in the eastern highlands of Zimbabwe. *Water Res.* 35, 2371–2376.
24. Zhao, Y., Xia, X.H., Yang, Z.F., Wang, F. , 2012, Assessment of water quality in Baiyangdian Lake using multivariate statistical techniques. *Procedia Environmental Science*, 13, 1213– 1226.
25. Water Quality Parameters Bangladesh Standards & WHO Guide Lines, 2011, http://dphe.gov.bd/index.php?option=com_content&view=article&id=125&Itemid=1 (Accessed March 2018)
26. Dalakoti H, Mishra S, Chaudhary M & Singal S K , 2017, Appraisal of Water Quality in the Lakes of Nainital District through Numerical Indices and Multivariate Statistics, India, *International Journal of River Basin Management*, DOI: 10.1080/15715124.2017.1394316
27. Pardo, R., Vega, M., Debán, L., Cazorro, C., & Carretero, C., 2008, Modelling of chemical fractionation patterns of metals in soils by two-way and three-way principal component analysis. *Analytica Chimica Acta*, 606, 26–316.
28. Sharma K, 2006, *Industrial Chemistry*. India, Krishna Prakashan Media.
29. Mackie, A. L., & Walsh, M. E., 2012, Bench-scale study of active mine water treatment using cement kiln dust (CKD) as a neutralization agent. *Water Research*, 46, 327–334. <https://doi.org/10.1016/j.watres.2011.10.030>
30. Karikari, A. Y., & Ansa-Asare, O. D., 2006, Physico-chemical and microbial water quality assessment of Densu River of Ghana. *West African Journal of Applied Ecology*, 10(1). DOI: <http://dx.doi.org/10.4314/wajae.v10i1.45701>
31. Ipeaiyeda A.R., Obaje G.M. , 2017, Impact of cement effluent on water quality of rivers: A case study of Onyi river at Obajana, Nigeria, Ipeaiyeda & Obaje, *Cogent Environmental Science* (2017), 3, 1319102. DOI: <https://doi.org/10.1080/23311843.2017.1319102>
32. Kushawaha J.P., ,2013, A review on sugar industry wastewater: sources, treatment technologies and reuse. *Journal of Distillation and Water Treatment.*, 53(2), 309-318.

- 396 33. Poddar P.K., Sahu O. ,2017, Quality and management of waste water in sugar industry. Applied
397 water science, 7(1), 461-468.
- 398 34. Ahmed A.U. and Reazuddin, M.,2000, Industrial pollution of water systems in Bangladesh , In
399 Rahman, A. A., Huq, S. and Conway, G. R. (Ed). Environmental system of surface water
400 systems of Bangladesh, University Press Limited, (pp 175-178), Dhaka, Bangladesh.
- 401 35. FAO, 2005, Waste management of fish and fish products. Fisheries and Aquaculture
402 department, Rome.
- 403 36. Islam M S, Khan S, Tanaka M., 2004, Waste loading in shrimp and fish processing effluents:
404 potential source of hazards to the coastal and nearshore environments, Marine Pollution Bulletin
405 49,103–110.
- 406 37. Alam, M. M., M. A. Islam, S. Islam and S.Z. Haider., 1996, Surface water quality of various
407 polluted locations. J Bangladesh Chemi. Soci, 8, 129-137.
- 408 38. Ahmad S, Mahmoud, T.A., 1982, Wastewater from a sugar refining industry, Water Res. 16,
409 345–355.