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Assessment of water quality in Halda River (the Major carp breeding ground) of Bangladesh

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ABSTRACT: The present study has been conducted to assess the surface water quality of Halda River from September 2015 to March 2016. DO, BOD_5, COD, pH, EC, Chloride, Alkalinity, and Hardness concentrations in water samples have been found to range within 0.93-5.15 mg/L, 30-545 mg/L, 43-983 mg/L, 6.3-7.3, 110-524 uS/cm, 12-56 mg/L, 35-67 mg/L, and 38-121 mg/L, respectively. Multivariate statistical analyses, such as Principal Component Analysis (PCA) as well as Correlation Matrix (CM) have revealed significant anthropogenic pollutant intrusions in water. Cluster Analysis (CA) has indicated decent results of rendering three different groups of resemblance between the two sampling sites, reflecting the different water quality indicators of the river system. A very strong positive linear relation has been found between COD and BOD (1.000), hardness and EC (0.993), pH and DO (0.979), hardness and COD (0.929), hardness and BOD (0.924), EC and COD (0.922), and EC and BOD (0.916) at a significance level of 0.01, proving their common origin entirely from industrial effluents, municipal wastes, and agricultural activities. River Pollution Index (RPI) has indicated that the water from rivers at Kalurghat and Modhunaghat varied from low to high pollution, which is due to the former area's being mostly industrial zone with some domestic sewage, while the latter underwent less industrial activities. On the contrary, lots of agricultural activities have been found in Modhunaghat. Use of river water can pose serious problems to human health and aquatic ecosystem via biological food chain. The present research suggests special preference for proper management of the river with eco-friendly automation along with development of the country's sustainable economic.

Keywords: chemical parameters, Halda River, industrialization, river pollution index, water quality.

INTRODUCTION

Bangladesh, basically known as land of rivers, is filled with 700 rivers including tributaries (Chowdhury, 2001). Halda River, being the only tidal river of Bangladesh, serves as a natural source of fertilized carp eggs (Saimon et al., 2016). Indian Major Carps are spawn naturally in Halda River in Bangladesh, making this river a unique heritage of the country (Tsai et al., 1981; Patra & Azadi, 1985; Kabir et al., 2013). Generally, Indian Major Carp, i.e. Rohu (*Labeo rohita*), Katla (*Gibelion catla*), and

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Mrigal (*Cirrhinus cirrhosus*), are collected by fishermen from Halda River that hugely support their daily lives (Tsai et al., 1981). Water is the most essential and important compound for all living creatures that form ecosystems (Kataria et al., 2011; Manjare et al., 2010) and river water is used for innumerable rural and urban communities and livestock, fish culture, recharge of ground water, control of floods etc. (Gurunathan & Shanmugam, 2006). However, water quality is being degraded unceasingly due to haphazard industrialization (Manjare et al., 2010). Chemicals, produced from industries, are a major source of water pollution that, carried through geological materials, may cause problems (Kataria et al., 2011). Most of the industries are major contributor of trace metals with the rivers playing the vital role in carrying off municipal and industrial wastewater (Singh et al., 2004; Singh et al., 2005; Wang et al., 2007). Chemical, physical, and biological contaminants from anthropogenic activities pollute surface water. River pollution is a matter of concern all over the world (May et al., 2006; Noori et al., 2010a; Ouyang et al., 2010). At first polluted river affect its chemical quality of water, then to destroy the community structure steadily, disrupting the subtle food web (Joshi et al., 2009). Most probably the effects of industrialization are in the state of beggar description on both aquatic biota and human being. According to WHO, up to 80% of all illnesses and ailments in the world is triggered by poor sanitation and contaminated water (Budhathoki, 2010). Bangladesh is facing serious problems with water contaminations from different industries, domestic wastes, and agrochemicals (Venugopal et al., 2009; Islam et al., 2015a, b). Water quality can be assessed by its physical, chemical, and biological properties (Manjare et al., 2010). RPI has been used in analyses of water quality (Chen et al., 2012; Lai et al., 2013; Hoseinzadeh et al., 2014; Rim-Rukeh, 2016). Moreover, many scholars have used CA, PCA, and Factors Analysis (FA) to evaluate and categorize water quality. Wang et al. (2014) used these statistical analyses for correct interpretation of the water chemistry. Furthermore, Singh et al. (2004), Kowalkowski et al. (2006), Qadir et al. (2007), Venkatesharaju et al. (2010), Noori et al. (2011), Wang et al. (2012), Selle et al. (2013), Jiang-Qi et al. (2013), and Talukder et al. (2016) stated that multivariate statistical methods can be very effective tools to interpret the complex data sets easily and clearly, recognizing pollution factors and assessing water quality parameters with spatio-temporal deviation.

Therefore, trustworthy information on the characteristics of water quality is direly needed so as to control pollution effectively and manage sustainable water resources. As a consequence, it is really necessary to assess river water. The present study has been conducted to assess the water quality and provide the baseline data of the area, which will be useful to measure any anthropogenic pollution level.

MATERIALS AND METHODS

Water samples were collected form the two sites of Kalurghat and Modhunaghat along Halda River (Fig. 1). Sampling procedures were performed in three phases: first in September 2015 (rainy season), second in January 2016 (winter season), and third in March 2016 (pre-monsoon).

After selecting the sampling sites, a total of 12 water samples were collected, six from Kalurghat and six from Modhunaghat. Two liters of surface water sample were regularly collected in the morning, between 10 to 11am, in polythene bottle for every seasons. Immediately after collection, water sample were transferred to the laboratory of Bangladesh Council of Scientific and Industrial Research (BCSIR), Chittagong, where pH and dissolved oxygen were measured.

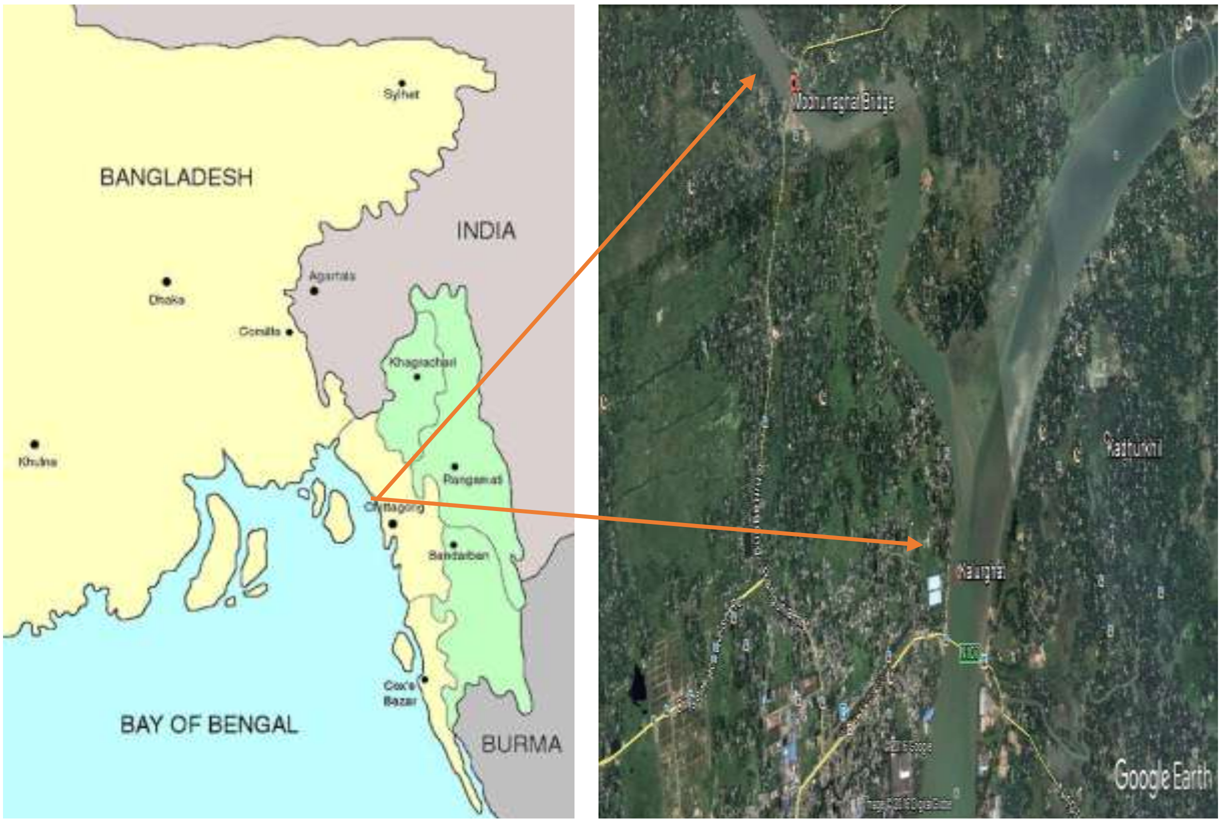


Fig. 1. Map showing the sampling sites of the study area

The value of Hydrogen-ion-Concentration (pH) of water was determined by using Hanna pH meter, while chloride was measured by Volhard Method, hardness by Compleximetric Method, alkalinity by Titrimatric, EC by Hanna EC meter, Dissolve Oxygen (DO) by DO meter (Hanna DO meter, HI-9146), Bio-chemical Oxygen Demand (BOD) by Modified Winkler Method (1988), and Chemical Oxygen Demand (COD) by Dichromate Reflux Method stated by APHA (2005).

One Way Analysis of Variance (Post-hoc LSD test) was done to show the variations in concentrations of water parameters in terms of seasons and sites, using SPSS (v.22). According to Dreher (2003), Principal Component Analysis (PCA) was performed on the original data set (without any weighting or standardization). PCA was executed to sort out the principle features of variations in dataset with simplification and classification of raw data. Noori et al. (2008) used principal component analysis (PCA) technique with the SVM to forecast the weekly generated waste in the city of Mashhad, reporting that it was a potential tool to predict waste generation. Noori et al. (2010a) used PCA technique to analyze surface water quality of the Karoon River, Iran. And Noori et al. (2010b) used PCA to predict monthly stream flow of the river.

PCA delivers strategies on spatial and temporal distribution of resultant factors. Cluster Analysis (CA) is an effective tool to find out the similarity and dissimilarity of the influencing factors on different data sets (Wang et al., 2014). Moreover, CA is an important tool for characterization and simplification of datasets, based on their behavior. According to Singh et al. (2004). Pearson's product moment correlation matrix was done to identify the relation among parameters to strengthen the results from multivariate analysis. CA (Dendogram) was performed to show the similarity among the variables and identify their sources of origin, using PRIMER (v.6).

Each water quality variable used to determine River Pollution Index (RPI) was changed to one of four index scores (S_i= 1, 3, 6, or 10). Particularly, RPI referred to arithmetic average of these index scores, with respect to water quality.

The River Pollution Index (RPI) is computed, using the following equation (Liou et al., 2006).

$$RPI = 1/4\sum_{i=1}^{4} Si$$

where S_i represents the index scores and RPI value ranges from 1 to 10.

RESULTS AND DISCUSSION

Dissolved Oxygen (DO) is the amount of oxygen, dissolved in the water (Effendi et al., 2015). Both in natural and waste water; the physical, chemical, and biological activities regulate DO levels (Huq & Alam, 2005). Natural water bodies demonstrate high levels of oxygen which vary depending on temperature, salinity, water turbulence, and atmospheric pressure (Effendi, 2003). Cold water hold more oxygen than warm one (Said et al., 2004). Various biological life forms are greatly influenced by the DO level (Saksena et al., 2008). The survival of aquatic organisms largely depends on the oxygen dissolved in water. The low DO directs high demand for oxygen by the microorganisms (Ott, 1978). In the present study, the dissolve oxygen was found between (0.93-5.15) mg/L in sampling site. The highest DO was recorded 5.15 mg/L at Kalurghat during post-monsoon and the lowest was recorded 0.93 mg/L during monsoon at Modhunaghat (Table 2). More or less, similar observations have also been recorded by Effendi et al. (2015), Gasim et al. (2007), Alam et al. (1996), Jashimuddin and Khan (1993), Hossain and Khan (1992), Islam and Khan (1993), Hossain et al. (1988), Bhuyian (1979), Khan et al. (1976), and Mahmood and Bhuyian (1988).

Table 1. River Pollution Index (RPI) Chart (Chen et al., 2012; Liou et al., 2006)

Items/ ranks	Good	Less polluted	Moderately polluted	Highly polluted
DO (mg/L)	>6.5	4.6-6.5	2.0-4.5	<2.0
BOD_5 (mg/L)	<3.5	3.0-4.9	5.0-15	>15
SS (mg/L)	<2.0	20-49	50-100	>100
NH_3-N (mg/L)	<0.5	0.5-0.9	91.0-3.0	>3.0
Index scores (Si)	1	3	6	10
Sub-index	<2	2.0-3.0	3.1-6.0	>6.0

Table 2. Chemical parameters of water at two sampling points during the three seasons

Parameters/ Sites	Seasons	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	pH	EC (uS/cm)	Chloride (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)
Kalurghat	Pre-Monsoon	5.10	31	43	7.1	110	35	63	43
Modhunaghat		4.7	32	59	7.2	123	12	65	40
Kalurghat	Monsoon	1.03	339	595	6.3	189	15	35	58
Modhunaghat		0.93	545	983	6.4	524	56	67	121
Kalurghat	Post- Monsoon	5.15	30	50	7.2	112	36	65	46
Modhunaghat		4.90	35	65	7.3	125	15	67	38

Biochemical Oxygen Demand (BOD) is the amount of oxygen used by microbes to decay carbon-based materials in water within a five-day period (APHA, 2005). Low BOD in water indicates that the riverside is free from organic pollution (Saksena et al., 2008) while high BOD is detrimental as it reduces the DO (Fatoki et al., 2005). Paul (1999) mentioned that, river water with a BOD rate above 10mg/L is considered to be moderate, while above 20 mg/L is considered highly-contaminated water.

The BOD in Halda River ranging 30-545 mg/L was relatively high (Table 2). Lower amount of BOD has been observed by Kataria et al. (2011) at Bhopal city water and by Sikder et al. (2016) at the Turag River.

Chemical Oxygen Demand (COD) is a reliable factor for judging the pollution degree in water (Loomer & Cooke, 2011). Higher COD is harmful to all aquatic living organisms, which increase pollution in water bodies (Nian et al., 2007). COD in pure water must be below 20 mg/L, whereas water bodies with a COD above 200 mg/L is considered contaminated (Effendi et al., 2015).

COD varied from 43 to 983 mg/L in the present study (Table 2), which is far above the results, found by Sikder et al., (2016), Ahmed and Nizamuddin (2012), and Miah (2012).

Roy (1955), Moore (1972), APHA (2005), Mahmood and Bhuyian (1988), Sarma et al. (1982), and Campbell (1978) stated that industrial or municipal waste materials played a significant role in increasing or decreasing pH of the adjacent water body, into which waste materials had been dumped. Moreover, activities like bathing, washing, and latrines along water bodies related to pH fluctuations (Effendi et al., 2015). Air temperature is the primary responsible factor for changing the pH of water. Furthermore, bio-chemical and chemical reactions are influenced by the pH (Manjare et al., 2010). This report is thoroughly in accord with the study by Farshad and Venkataramana (2012).

In the present study, results indicate that the water of the river was slightly alkaline (6.3-7.3) in nature (Table 2). In surface water the standard value of pH ranged within 6.5-8.5 (ECR, 1997). Ahmed and Rahman (2000) mentioned that in most raw water sources, pH lies within the range of 6.5- 8.5.

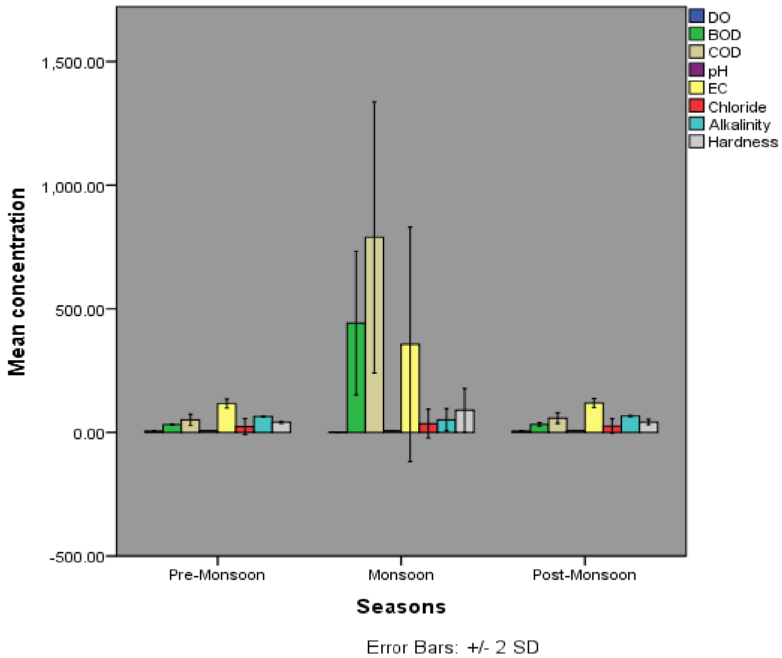


Fig. 2. G-graph showing the concentrations of water quality parameters during different seasons

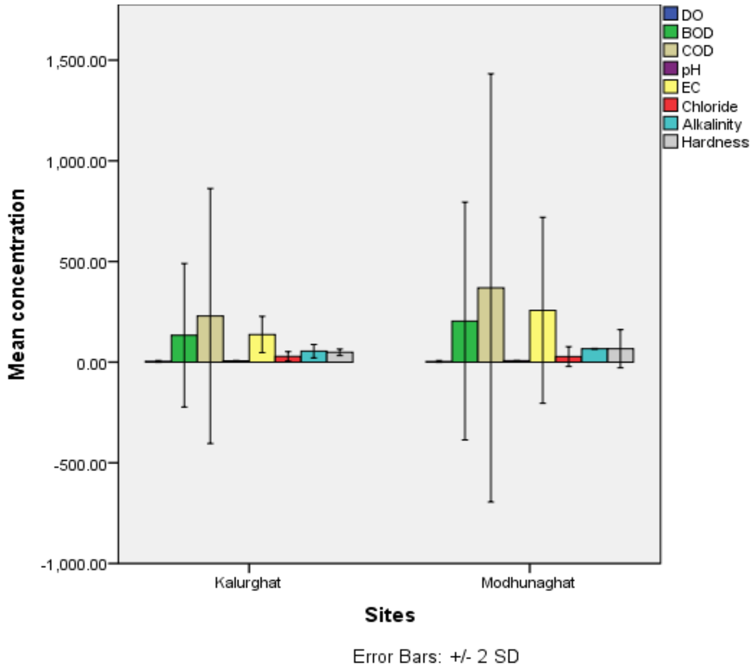


Fig. 3. G-graph showing the concentrations of water quality parameters at different sites

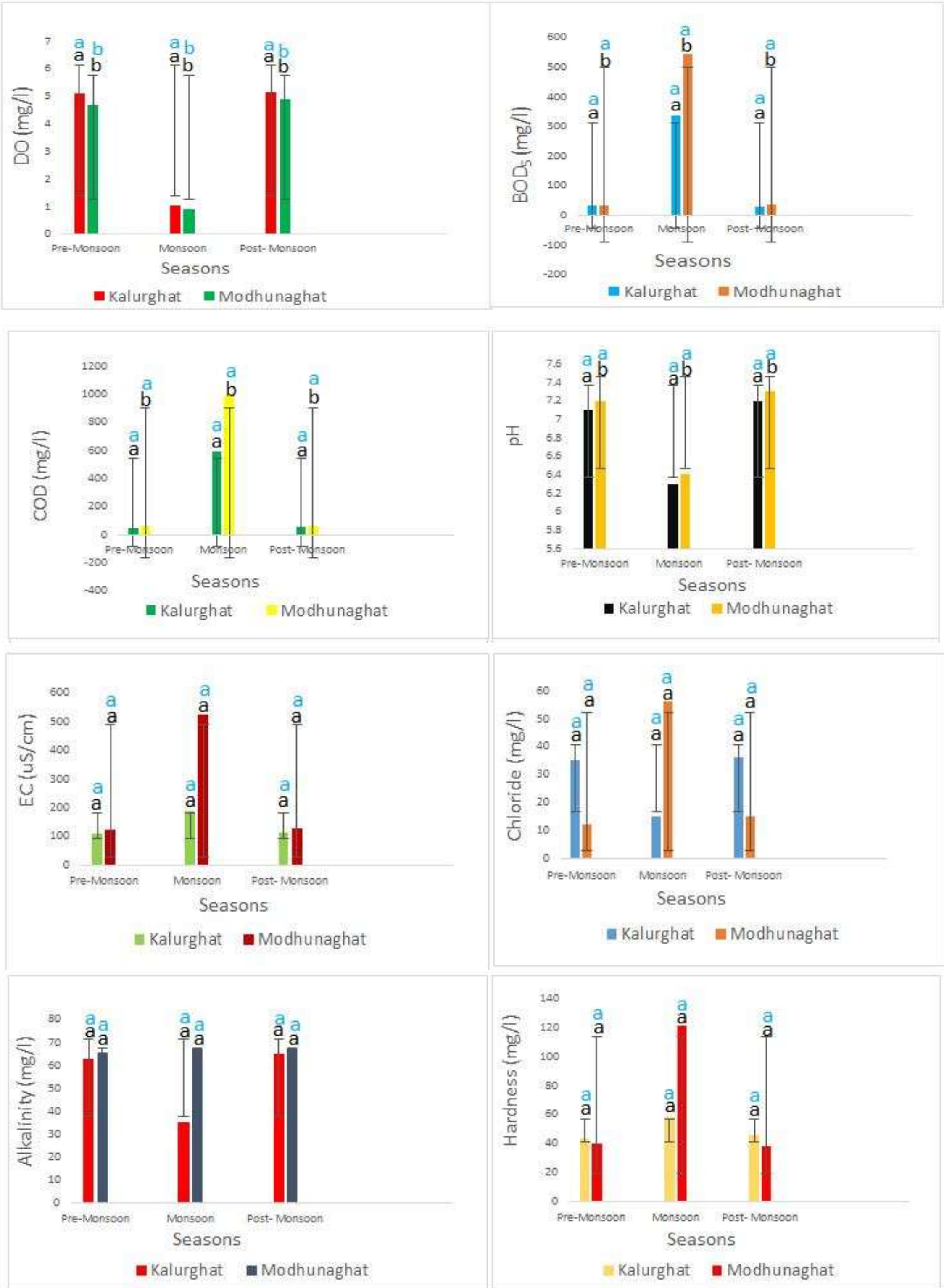
Electrical Conductivity (EC) is usually used to indicate the total concentration of ionized constituents of water (Huq & Alam, 2005). A higher conductivity reflects higher water pollution (Florescu et al., 2010). Typical EC value is 300 µS/cm (De, 2007). In the present study, EC ranged between 110 and 524 uS/cm. The highest value (524 uS/cm) was found at Modhunaghat during monsoon, while the lowest one (110 uS/cm) was recorded at Kalurghat during pre-monsoon (Table 2). Hoque et al. (2012) recorded the mean values of EC to be 452.4 µs/cm in monsoon and 901 µS/cm in winter, in the Bansi River**.** Florescu et al. (2010) found 237 µS/cm (on Arges River) and 960 µS/cm (on Olt River) from southern Romania.

Generally, chlorides are not injurious to public health, though the sodium part of Nacl salt is connected to heart and kidney diseases (Florescu et al., 2010). Sodium chloride (Nacl) may render a salty taste at 250 mg/L. Elevated concentrations of dissolved salts in water compromise its use for domestic or agricultural purposes. Excessive amount of Cl- in inland water is usually regarded as an index of pollution and can be found across hygienic and industrial waters (Florescu et al., 2010).

In the present study the concentrations of chlorides were recorded between 12 and 56 mg/L, with the maximum amount found at Modhunaghat during monsoon and the minimum value (10 mg/L) at Modhunaghat during pre-monsoon (Table 2).

In the present study alkanity ranged from 35 to 67 mg/L. The highest concentration (67 mg/L) belonged to Modhunaghat during monsoon and post-monsoon, whereas the lowest amount (35 mg/L) was found at Kalurghat during monsoon (Table 2). Hoque et al. (2012) reported that the value of alkalinity in monsoon and winter seasons were 50.4 mg/L and 146.5 mg/L in the Bansi River, respectively.

Hardness depends on the presence of Mg and Ca ions in water. The richness of Ca relies on its natural occurrence in the earth's crust. River waters usually contain (1-2) mg/L calcium, but in lime river zones water can contain as high as 100 mg/L calcium. Ca ion exerts great influence on aquatic organisms, enhancing metal toxicity in their gills (Florescu et al., 2010). In the present study hardness was recorded



Black a & b= Variation with seasons, Blue a & b= Variation with sites

Fig. 4. Variations (Mean±SD) of water quality parameters. Bars with the same letter are statistically indifferent.

between 38 and 121 mg/L. Maximum concentration of hardness (121 mg/L) was found at Modhunaghat during monsoon and minimum concentration of this parameter (38 mg/L) was recorded at Modhunaghat during post-monsoon season (Table 2). Joshi et al. (2009) recorded higher hardness in the monsoon season (120.62 mg/L) and lower in the winter season (87.55 mg/L) in the River Ganga.

Significant variations were found for DO, BOD, COD, and pH in terms of seasons ($P<0.05$); however, Chloride, Alkalinity, Hardness, and EC showed nothing of this sort with seasons ($P>0.05$). BOD, COD, pH, Chloride, Alkalinity, Hardness, and EC exhibited no prevalent variations with sites ($P>0.05$), with the exception of DO ($P<0.05$, Fig. 4).

Different multivariate statistical analyses viz. CA, PCA, and Factors Analysis (FA) act as fruitful guides for eloquent explanation of spatio-temporal parametric data.

CA was carried out, using square root and Bray Curtis Similarity, to show the similarity among the parameters that hugely contribute to water pollution. From the output of the cluster analysis, three clusters were found during different seasons: Cluster 1, including DO and pH; Cluster 2, including EC, COD, and BOD_5; and Cluster 3, including Chloride, Alkanity, and Hardness (Fig. 5). DO and pH represent a strong connection with minimum cluster distance, indicating that these parameters are influential during seasonal variations. Parameters are grouped together in less distance have higher affinity with similar identical behavior, during temporal variations. They also exert a probable effect on each other. Furthermore EC, COD, and BOD_5 also have strong linkage, though lesser than cluster 1. However, they contribute largely to the environmental process. Chloride, Alkanity, and Hardness are under the group of cluster 3 with minimum distance, compared to cluster 1 and cluster 2. Nonetheless they affect the environment. Impacted site is the effluent-discharged area of the river, highly influenced by untreated industrial effluents, agricultural inputs, and domestic wastes.

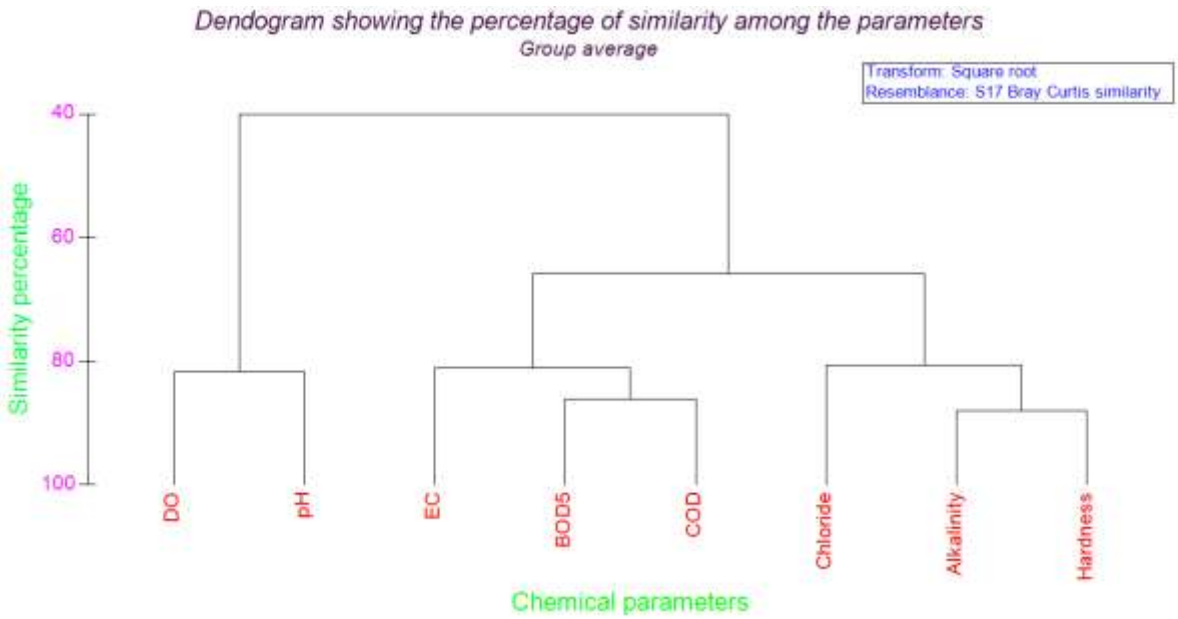


Fig. 5. Dendogram showing the percentage of similarity among water parameters during different seasons (BOD= Bio-chemical oxygen demand; COD= Chemical oxygen demand; EC=Electrical conductivity; and DO= Dissolve oxygen)

In river water environment, the inter-linkage among water parameters deliver noteworthy information as well as pathways for parameters. Results of correlation between water parameters fully consented with those, obtained by PCA and CA, that approve some new associations among the variables. A very strong positive linear relation was found between COD vs BOD (1.000), Hardness vs EC (0.993), pH vs DO (0.979), Hardness vs COD (0.929), Hardness vs BOD (0.924), EC vs COD (0.922), and EC vs BOD (0.916) at a significance level of 0.01 (Table 3).

Strong positive correlations were recorded between Hardness vs Chloride (0.769) and Chloride vs EC (0.718) at the significance level of 0.05 (Table 3). The very strong and strong correlations indicate that the parameters were originated from similar sources, particularly from industrial effluents, domestic wastes, and agricultural inputs. Besides, strong negative correlations were found between DO vs BOD (-0.958), COD vs DO (-0.954), pH vs BOD (-0.922), and pH vs COD (-0.915) in river water.

Subsequently Principal Component Analysis (PCA) was carried out, in which the components were regarded as principal components whose Eigen values were above 0.5. Principal component highlighted the most vital factors that affect the water quality of the study area. PC1 had an initial Eigen value of 7.948 and a total variance of 99.349%, with strong positive loading of DO, pH, Chloride, and Alkalinity that resembled the loading of pollution, mainly caused by untreated organic load with crucial anthropogenic effect (Table 4). PC 1 had high negative loading of BOD, COD, EC, and Hardness. It can be represented as the effect of geological changes on environmental parameters. From the present PCA study, it may be concluded that the source of PC 1 can originate from a mixed source of anthropogenic inputs, particularly from industrial wastes and agricultural actions in the study area.

Table 3. Correlation matrix of chemical parameters in river water

	DO	BOD	COD	pH	EC	Chloride	Alkalinity	Hardness
DO	1							
BOD	-0.958	1						
COD	-0.954	1.000	1					
pH	0.979	-0.922	-0.915	1				
EC	-0.768	0.916	0.922	-0.698	1			
Chloride	-0.297	0.532	0.534	-0.323	0.718	1		
Alkalinity	0.561	-0.314	-0.299	0.643	0.091	0.381	1	
Hardness	-0.777	0.924	0.929	-0.728	0.993	0.769	0.054	1

Table 4. Component matrix of factors model with strong loadings in river water

Component Matrix	
Eigen value (0.5)	**Component1**
DO	1.000
BOD	-1.000
COD	-1.000
pH	0.995
EC	-1.000
Chloride	0.999
Alkalinity	0.998
Hardness	-0.982
Eigen value	7.948
% Total variance	99.349
Cumulative %	99.349

Recently, the simple method of River Pollution Index (RPI) has been used concurrently by different organization, like Taiwan EPA, to assess the surface water quality. This method comprises with concentration level of four parameters, namely DO, BOD, SS, and NH_3-N. Pollution status is calculated using four-state of each parameter.

The current study compared the concentrations of DO and BOD_5 with those of RPI table, in order to weigh the status of particular water variables (Table 1). Average DO in the Kalurghat turned out to be 1.03 mg/L during monsoon season, indicating that the water was highly polluted in comparison with RPI. The water of Modhunaghat contained 0.93 mg/L DO, indicating that the water was highly polluted, too.

Averages DO in the Kalurghat was recorded 5.15 mg/L during post- monsoon season which can be treated as less polluted zone according to RPI index, while 4.90 mg/L DO was found from the Modhunaghat, suggesting the area was less polluted. During pre-monsoon the average DO concentration was 5.1 mg/L at Kalurghat, which designated less pollution in this area, according to RPI table, where 4.7 mg/L was found from Modhunaghat area, also indicative of an area, characterized with less pollution.

Average amount of BOD_5 were found between 31 and 545 mg/L for all seasons at Kalurghat and Modhunaghat, indicating that the water of the river was highly polluted, according to Table 1.

CONCLUSION

Findings of this study indicate that the water of the river is being polluted gradually. Unplanned industrialization, urbanization, and agricultural activities are the prime responsible factors for continuous pollution of river water. River water cause great harm to human beings if it is used for domestic, irrigation, and pisciculture purposes. Moreover, the excessive concentrations of some water parameters can pose great risk to fish and human communities, dwelling in and adjacent to Halda River. Finally, this research gives special focus to water quality assessment for better management of the river water to protect the health of aquatic ecosystem of the river.

Acknowledgements

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