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Physicochemical and Biological Monitoring of Water Quality of Halda River, Bangladesh

Mohammad Ayub Parvez [1], M. Main Uddin [2], Md. Kamrul Islam [1*], Md. Manzoorul Kibria [3]

[1] *Research Associate, Institute of Forestry and Environmental Sciences University of Chittagong, Chittagong 4331, BANGLADESH*
[2] *Assistant Professor, Institute of Forestry and Environmental Sciences University of Chittagong, Chittagong 4331, BANGLADESH*
[3] *Professor, Department of Zoology, University of Chittagong, Chittagong 4331, BANGLADESH*

* CORRESPONDENCE: ✉ islamkamrul1120@gmail.com

ABSTRACT

The tidal river Halda that serves as a natural breeding ground for major Indian carps and sources of other aquatic resources is of special interest. This study was conducted to monitor the water quality using physicochemical and biological parameters of the river in three different sampling stations namely Gorduara, Sattarghat and Kalurghat. Eight physicochemical parameters of water - temperature, P^H, transparency, EC, DO, TDS, SS, salinity and plankton communities were considered for monitoring water quality in three stations. All the physicochemical parameters were within the pollution standard except DO (4.5 mgL^{-1}) at Kalurghat station. In case of biological monitoring, zooplankton populations consisting of four classes were identified where 13 zooplankton genera under these 4 classes showing the dominancy. The abundance of zooplankton was higher at Gorduara station (2042 No./ L) followed by Sattarghat (1906 No./ L) and Kalurghat (1610 No./ L) respectively. On the basis of Identifying 11 genera of algal genus, six genera were used to prepare 'Palmer pollution index' which identified Kalurghat station as highly polluted zone. The study also explored the correlation of physicochemical parameters and the zooplankton abundance.

Keywords: biological, dissolved oxygen, Halda River, monitoring, physicochemical, zooplankton

INTRODUCTION

River water is one of the most important and widely distributed natural resources, considered as supplemental resource to meet the domestic, agricultural and industrial requirements (Vugteveen *et al*., 2006; Wei *et al.,* 2009). Contamination of river water results in poor drinking water quality, loss of water supply, high cleanup cost and potential health hazards (Mobin *et al*., 2014). Of the environmental elements, water is the most affected due to the setting up of industries and other establishment on the river banks which yields the toxicity and harmful effluents into the rivers (Sarwar *et al.,* 2010). The environmental pollution created by the industries has now become a burning issue of the nation (Noel and Rajan, 2015) as they discharge toxic waste into river causing deleterious effect in flora and fauna and other aquatic organisms (Bashar *et al*., 2015).

However, quality of water is determined by its physical, chemical and biological factors (Mustapha, 2008). Changes in the river water quality accompanying anthropogenic pollution are a cause of growing concern and require monitoring of the surface waters (Uddin *et al*., 2014). The condition of the river is typically assessed by regularly monitoring a variety of physical and chemical indicators (Bhatnagar *et al*., 2013). The biota of an ecosystem gives an insight of the conditions existing in an aquatic ecosystem (Ahmed *et al.,* 2003). In unpolluted streams, the flora and fauna is represented by a significant number of species. A progressive

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decrease in the number of individual is generally indicates the increase of pollution. Again, the numbers of taxa present and their abundance relative to one another, the population's diversity of organisms is a measure of pollution (Bhatnagar *et al.*, 2013). Presently, biological monitoring has become an inseparable part of water quality assessment and forms part of many water pollution studies (Thakur *et al.,* 2013).

Biological monitoring are evaluations of the condition of water-bodies using surveys and other direct measurement of resident biological organisms (planktons, macro-invertebrates, fish and plants) (EPA, 2016). Biological communities can be accurate indicators of overall environmental conditions, providing an accurate account of general 'health' of an aquatic ecosystem (Crofford and Avenont-Oldewage, 2009). Planktons are accepted the most useful biological indicators of water quality of running water ecosystems (Kazanc *et al*., 2010).

However, the Halda is the third major river after the Karnaphuli and the Sangu in Chittagong, Bangladesh. The river is the sole source of fertilized eggs of major Indian carps such as *Catla catla, Labeo rohita, Cirrhimus mrigala and Labeo calbasu* in the world, as it provides favourable physicochemical factors for the spawning during monsoon between April and June. Besides, the river also provides navigation, supplies drinking water, and generates sizeable employment opportunities for the local fishing and farming communities (Kabir *et al*., 2015a).

A great deal of research work has been done on the ecology and population of the phytoplankton and zooplankton, and physicochemical assessment of water quality of different districts of Bangladesh including Ronald and Azadi, 1987; Chowdhury *et al*., 2008; Mamun *et al*., 2009; Roy *et al.,* 2010; Ahsan *et al*., 2012; Shil *et al.,* 2013; Bashar *et al*., 2015; Biswas and Panigrahi, 2015; Rahi *et al.,* 2015 and Flura *et al*., 2016. But still there is a dearth of information on plankton community of different rivers of Bangladesh. Besides, the study using Palmer's Algal Genus Index for the evaluation of organic pollution hasn't been used in our country and particularly there is no detailed works were found on the biological assessment of water quality of Halda River using plankton organisms. Thus, there is a research gap that needs to be bridged. Considering these facts, present investigation was carried out in the Halda River, Chittagong, which was polluted by sewage and industrial effluents (Akter and Ali, 2012). The aim of the present study is to monitor the water quality of the Halda River by assessing its physicochemical parameters along with the plankton community in terms of its diversity, abundance, evaluation of organic pollution using Palmer's Algal Genus Index and the relationship between zooplanktons and physicochemical parameters of the river water.

METHODS

Reconnaissance Survey and Selection of the Study Area

The Halda River is located in South-East region of Bangladesh which is a major tributary of the river Karnaphuli in Chittagong district originated from the hilly Haldachora fountain at the Patachara hill ranges of Ramgarh in the Khagrachari hill (Akter and Ali, 2012; Kabir *et al*., 2015b). It flows through Fatickchari Upazila, Hathazari Upazila, Raozan Upazila and Chandgaon Thana of Chittagong metropolitan that finally meets with the Karnaphuli River near Kalurghat bridge at latitude 22°25'13" N and longitude 91°52'33" E (Alam *et al*., 2013a). The total length of this river is about 98 km (Kabir *et al*., 2014), where a 29 km reaches up to Nazirhat navigable by big boats throughout the year and small country boats sailing 16–24 km further upstream to Narayanhat. The river is also famous for breeding pure Indian major carps (www.haldariver.org). The area of the present study is located at the down-stream of the river Halda.

First of all, a reconnaissance survey was conducted to observe the whole downstream of the Halda River. After reconnaissance survey, three important stations (**Table 1**) were selected purposively for primary data collection depending on the accessibility to the river for collecting both water and plankton samples.

Table 1. Three stations of the study area with GPS locations

Station No.	Name of stations	GPS Locations	
		Latitude	Longitude
S1	Sattarghat	N-22° 30' 49"	E-91° 50' 44"
S2	Gorduara	N-22° 30' 10"	E-91° 52' 7"
S3	Kalurghat	N-22° 23' 59"	E-91° 53' 17"

Data Collection

Sampling was done primarily by means of field observation. Data was analysed in the laboratory to identify the status of planktons (phytoplankton and zooplankton) and to assess the water quality parameters of the Halda River. Water and plankton samples were collected fortnightly from selected three sampling stations over the period of 3 months (April 2016 to June 2016). The secondary data were collected from internet, journal articles, books and different departments and institutes of the University of Chittagong (Institute of Forestry and Environmental Sciences, Department of Zoology, Institute of Marine Science and Fisheries).

Primary data source

After conducting a reconnaissance survey, the plankton and water samples were collected over the period of three months (April – June 2016). In case of plankton, each sample was collected after each 15 days. For each sample of the plankton, the plankton net was used for five times in the upper layer of the river water. The total of six samples from each of the stations in the study area was collected over the period of three months. Therefore, 18 samples of plankton for monitoring biological quality of the water were taken into consideration. In case of water sample, 250 ml of plastic bottles was used for collecting each sample after each 15 days and hence 6 samples for water were considered from each station. Therefore, 18 samples were also taken into consideration for physicochemical monitoring of water quality.

Secondary data source

The secondary data were collected from a range of secondary sources such as internet, published articles in peer reviewed national and international journals, books and seminar proceedings, etc.

Sampling Procedure for Primary Data Collection

Collection of water samples

The accurate assessment of the concentration of different chemical parameters in water primarily depends upon the samples drawn for the analysis. The following procedures were followed for collection of samples.

1. Plastic bottles were thoroughly cleaned with distilled water.
2. Sample was collected manually at 50 cm depth of water to avoid debris.
3. The water samples were collected in a plastic bottle and filled the total volume of the container and cap was locked sufficiently so the no air space can be remained inside to minimize the chemical changes.
4. Proper labeling was made in each sample by mentioning the name, location of the sample site, date and time of collection.

Measurement of physicochemical parameters

The physicochemical parameters were measured in the IFESCU and DoE (Chittagong) laboratory over the period of three months. The important parameters considered for monitoring water quality are water temperature, P^H, Total Dissolved Solids (TDS), Suspended Solids (SS), Electrical Conductivity (EC), transparency, Dissolved Oxygen (DO) and salinity. Water temperature, p^H, TDS, EC of the collected samples were measured by Digital water proof p^H, EC/ TDS and temperature meters (HANNA instruments, model: HI 98129. HI 98130). DO and salinity of the collected samples were measured by HACH (HQ30d) Portable Multi-parameter Meter. SS was measured by the DR/2400 Portable Spectrophotometer. Transparency of water was recorded by Sacchi disc method.

Water temperature

Procedure: The following steps are involved in the measurement.

1. The protective cap was removed and turned on the meter.
2. The instrument was standardized against known buffer solution at ambient temperature.
3. After the standardization had been done, the electrode of the instrument was taken out from the buffer solution.
4. Then the electrode was washed by the distilled water and wiped thoroughly and carefully with soft tissue paper.
5. After that, the electrode was put on the water sample.

6. The temperature key was pressed on the key pad.
7. Then the instrument displayed on the water temperature value in degree (°).
8. As soon as the reading became stable, it was noted down in the note book.

P^H

Procedure: The following steps are involved in the measurement.

1. The protective cap was removed and turned on the meter.
2. The instrument was standardized against known buffer solution at ambient temperature.
3. After the standardization had been done, the electrode of the instrument was taken out from the buffer solution.
4. Then the electrode was washed by the distilled water and wiped thoroughly and carefully with soft tissue paper.
5. After that-, the electrode was put on the water sample.
6. The P^H key was pressed on the key pad.
7. Then the instrument displayed the P^H value.
8. As soon as the reading became stable, it was noted down in the note book.

Dissolve Oxygen (DO)

Procedure: The following steps are involved in the measurement.

1. The protective cap was removed and turned on the meter.
2. The instrument was standardized against known buffer solution at ambient temperature.
3. After the standardization had been done, the electrode of the instrument was taken out from the buffer solution.
4. Then the electrode was washed by the distilled water and wiped thoroughly and carefully with soft tissue paper.
5. Then 200 ml of sample was taken in a 250 ml conical flask and the electrode was put on it.
6. The key was pressed on the key pad.
7. Then the instrument displayed on the DO value in mg/L.
8. As soon as the reading became stable, it was noted down in the note book.

Electric Conductivity (EC)

Procedure: The following steps are involved in the measurement.

1. The protective cap was removed and turned on the meter.
2. The instrument was standardized against known buffer solution at ambient temperature.
3. After the standardization had been done, the electrode of the instrument was taken out from the buffer solution.
4. Then the electrode was washed by the distilled water and wiped thoroughly and carefully with soft tissue paper.
5. After that, the electrode was put on the water sample.
6. The EC key was pressed on the key pad.
7. Then the instrument displayed the EC value in $\mu S\ cm^{-1}$.
8. As soon as the reading became stable, it was noted down in the note book.

Total Dissolve Solid (TDS)

Procedure: The following steps are involved in the measurement.

1. The protective cap was removed and turned on the meter.
2. The instrument was standardized against known buffer solution at ambient temperature.

3. After the standardization had been done, the electrode of the instrument was taken out from the buffer solution.
4. Then the electrode was washed by the distilled water and wiped thoroughly and carefully with soft tissue paper.
5. After that, the electrode was put on the water sample.
6. The TDS key was pressed on the key pad.
7. Then the instrument displayed the TDS value in ppm.
8. As soon as the reading became stable, it was noted down in the note book.

Suspended Solid (SS)

Procedure: The following steps are involved in the measurement.

1. At first, the meter was turned on and selected program for suspended solids (SS) measurement.
2. A clean sample cell was filled to the 25 ml mark with de-ionized water (the blank).
3. Then the blank sample was placed into the cell holder.
4. If the 'Read' key was pressed, result would display: 0.0 mg/L SS (for calibration).
5. The supplied water sample was swirled to remove any gas bubbles and uniformly suspend any residue.
6. After that, another clean sample cell was poured to the 25 ml mark with the supplied water sample.
7. The cell with the water sample was placed into the cell holder.
8. Then the instrument displayed on the SS value in mg/L after the 'Read' key was pressed.
9. As soon as the reading became stable, it was noted down in the note book.

Transparency

Transparency or light penetration in water was measured with secchi disc. It is inversely proportional to the turbidity, which in turn is directly proportional to the amount of suspended organic and inorganic matter.

Materials

It was devised by an Italian scientist, A. Secchi in 1865. It is a metallic disc of 20 cm diameter with four quadrants on the upper surface painted black and white alternately. It has a hook in the centre of upper part, to which a graduated cord is tied. On lower surface it has a centrally placed weight which facilitates the sinking of the disc in proper position.

Method

It was dipped into the water on a calibrated line until it disappeared. The depth at which it disappeared and also the depth at which it reappeared when two readings was recorded. The average of these two readings is called secchi disc reading.

Calculation

The following formula was used to calculate transparency (Bashar *et al.*, 2015).

$$\text{Secchi disc reading (cm)} = \frac{A+B}{2}$$

where,

A=depth at which secchi disc disappears (cm)

B=depth at which secchi disc reappears (cm)

Salinity

Procedure: The following steps are involved in the salinity measurement.

1. The protective cap was removed and turned on the meter.
2. The instrument was standardized against known buffer solution at ambient temperature.
3. After the standardization had been done, the electrode of the instrument was taken out from the buffer solution.

4. Then the electrode was washed by the distilled water and wiped thoroughly and carefully with soft tissue paper.
5. Then 200 ml of sample was taken in a 250 ml conical flask and the electrode was put on it.
6. The salinity key was pressed on the key pad.
7. Then the instrument displayed on the salinity value.
8. As soon as the reading became stable, it was noted down in the note book.

Collection of plankton samples

Plankton samples were collected from the surface water of the river Halda from three stations (**Table 1**). Each sample was collected by filtering through (mesh size 50µm) plankton net. The net was thrown to the desired distance and allowed to reach the desired depth (approx.) of the sampling station from the bank. Then the throne rope with net was pulled quickly toward the bank for the collection of samples. The water was passed down through the net and the plankton condensed at the lower end of the plankton net then it was collected into a glass test tube and fixed firmly (Shil *et al*., 2013). The net was pulled 5 times. The plankton samples were preserved in plastic bottles.

Preservation

The plankton samples were preserved in 5% formalin in the plastic jars immediately after collection and were carried to the laboratory. For laboratory analysis, the samples were allowed to settle and overlying water containing floating particles were then taken out by decantation. The preserved samples were taken to the laboratory of the Department of Zoology, University of Chittagong for further study.

Quantitative analysis (counting)

The quantitative enumeration of the planktons was carried out with the help of a Sedgwick-Rafter (S-R) counting cell which is 50 mm long, 20 mm wide and 1 mm deep (Rahi *et al*., 2013). To identify the planktons, the preserved samples were gently shaken to re-suspend all materials and allowed to settle for one minute. Then, 1 ml sub-sample was examined using S-R cell and a compound microscope. The S-R cell is equally divided into 1000 fields, each having a volume of 0.001 ml. By moving the mechanical stage, the entire bottom of the slide area was examined carefully. To achieve a random sampling, 5 fields for each time were examined for each sample and an average of the counts was recorded. The organisms thus counted were expressed as No. of species per liter of the sample. Number of planktons in the S-R cell was derived from the following formula according to (Roy *et al*., 2010; Flora *et al*., 2016).

$$\text{No. of species /Liter} = \frac{C \text{ x } 1000 \text{ mm3}}{L \text{ x D x W x S}}$$

where,

C = Number of organisms counted

L = length of each field (S-R cell) in mm

W = width of each field (S-R) cell in mm

D = depth of each field (S-R cell) in mm and

S = number of fields counted.

For counting plankton five comprehensive steps were followed which has been enumerated below

Step 1: Plankton net has been thrown to the desired distance and depth, waited for 2-3 minutes than plankton have been collected which process has been replicated for five times

Step 2: The collected samples were preserved in a plastic bottle with 5% formalin

Step 3: After a gentle shake 1ml subsample counting chamber where 15 minutes were allowed to settle the plankton

Step 4: Whole chamber floor were counted at magnification of 40×, 100×, or 200× depending on plankton cell size.

Step 5: Five fields for each sample were examined in the counting cell than final counting result have been calculated

Identification

The sorted zooplankton and phytoplankton were identified up to genus level according to – Edmondson (1959); Bhouyain and Asmat, (1992); Hoq (1993) and Vashishta (2005).

Data Analysis

Abundance

Abundance of a species is defined as the number of individuals per quadrate and is calculated as follows.

$$\text{Abundance} = \frac{\text{Total number of individuals of the species}}{\text{Number of quadrats in which they occurred}}$$

Palmer's Pollution Index

The pollution tolerant genera and most pollution tolerant species of algae were recorded from each of the three stations. Algal pollution indices of palmer, based on genus were used in rating water samples for high organic pollution. A list of all significantly occurring algae in the samples was made for all stations from where 20 most frequent genera were taken into account. A pollution index factor was assigned to each genus by determining the relative number of total points scored by each algae for rating of water samples as high or low and organically polluted observations were made according to Palmer (1969).

The following numerical values for individual zone have been followed.

0 – 10 suggest lack of organic pollution.

10 – 15 indicate moderate pollution.

15 – 20 indicate probable high organic pollution;

20 or more indicate high organic pollution

Statistical analysis

The statistical analysis of different physicochemical and biological parameters were carried out manually and by using desktop software such as MS Excel to plot graphs for dissemination of the results.

The abundance and percentage analysis of the zooplanktons in all stations were used to observe the percentage distribution of each species between samples of the three months. The correlation between total zooplanktons and physicochemical parameters of water quality was done by using MS Excel of office 2013 version.

RESULTS

Physicochemical Monitoring of Water Quality

A total of 8 parameters for assessing water quality of the three stations were considered to monitor the physiochemical water quality (**Table 2**). The water temperature (in ˚C) was recorded as 28.9, 29.1 and 29.3 for Sattarghat, Gorduara and Kalurghat respectively (**Table 2**). Transparency depends on zooplankton abundance and other organic particles. The transparency of productive water bodies should be 40cm or less (Islam *et al.,* 2012). In all stations, transparency was within the standard limit (**Table 2**). The p^H of a water body is very important in determination of water quality since it affects other chemical reactions such as solubility and metal toxicity (Flora *et al*., 2016). In Sattarghat and Kalurghat, the p^H was higher than 7.0 showing slightly alkaline in nature (**Table 2**). Kalurghat station was the confluence point of the Halda River with the river Karnaphuli. So, Saline water intrusion was observed from recorded data. During the study, the DO levels were 5.8 at Sattarghat, 5.7 at Gorduara and 4.5 at Kalurghat respectively.

The lowest value of DO was observed at Kalurghat. This lower level was observed due to industrial effluents and enrichment by nutrients. TDS is an important chemical parameter in water indicating the presence of various minerals including ammonia, nitrite, nitrate, phosphate, alkalis, some acids, sulphates etc., which are comprised both colloidal and dissolved solids in water (Islam *et al.,* 2012). The TDS concentrations were 65.5 at Sattarghat, 63.2 at Gorduara and 87.3 at Kalurghat respectively TDS concentrations in three stations were not exceeded the standard limit of 165 ppm. A positive relation was found between EC and TDS where the EC value increased with increasing the TDS concentration. The EC in Halda River was comparatively better than Dhaleshwari River where the standard limit of EC is 700 µS/ cm (Islam *et al*., 2012).

Table 2. Physicochemical parameters used for monitoring water quality in three stations

Physicochemical Parameter	Sattarghat	Gorduara	Kalurghat	Standard (Islam *et al.*, 2012)
Water temperature (°C)	28.9 (± 1.6*)	29.1 (±1.6)	29.3 (±1.2)	20 – 30
Transparency (cm)	26.3 (±8.1)	27.9 (±4.5)	24.2 (±6.8)	40 or less
p^H	7.1(±0.2)	7.0 (±0.2)	7.2 (±0.1)	6.5 – 8.5
DO (mgL^{-1})	5.8 (±0.3)	5.7 (±0.4)	4.5 (±0. 7)	5.0
EC ($\mu S\ cm^{-1}$)	130.8 (±38.7)	127.3 (±31.7)	175.3 (±76.0)	700
TDS (ppm)	65.5 (±19.0)	63.2 (±15.7)	87.3 (±37.7)	165
SS (mgL^{-1})	154.0(±104.4)	123.5 (±80.1)	434.8 (±217.0)	-
Salinity (%)	0.06 (±0.02)	0.06 (±0.02)	0.09 (±0.04)	-

*Value in the parenthesis indicates standard deviation of the mean

Table 3. Biological monitoring of water quality evaluating zooplankton groups found in the study area

Class	No. of genera	Name of genera identified
Copepoda	3	*Cyclops sp., Mesocyclops sp., Diaptomus sp.*
Rotifera	5	*Brachionus sp., Keratella sp., Filinia sp., Lucane sp., Platyias sp.*
Cladocera	4	*Daphnia sp., Ceriodaphnia sp., Moina sp., Bosmina sp.*
Crustacean larvae	1	*Shrimp larvae*

Table 4. Abundance of zooplanktons in three stations of the river Halda ((No. / L)

Stations	Copepoda	Cladocera	Rotifera	Crustacean larvae	Others	Total zooplankton
Sattarghat	867	400	433	100	106	1906
Gorduara	567	300	667	367	141	2042
Kalurghat	467	300	567	200	76	1610

Biological Monitoring of Water Quality

Biological monitoring by zooplankton populations

In case of biological monitoring for assessing water quality in the Halda River, zooplankton populations consisting of four classes - Copepoda, Rotifera, Cladocera and Crustacean larvae were identified (**Table 3**). A total of 13 zooplankton genera under these 4 classes were also recorded from three stations considered for this study. Among the identified zooplankton, the class of Rotifera was dominant with 5 genera followed by Copepoda (3), Cladocera (4) and crustacean larvae (1) respectively.

Abundance and of zooplankton

Abundance of zooplankton in the Halda River is shown in **Table 4**. In the three stations of the study area, Copepoda was the highest (867 No./L) at the Sattarghat station followed by Rotifera (667 No./L) at Gorduara, Cladocera (500 No./L) at Sattarghat and crustacean larvae (141 No./L) at Gorduara respectively.

Percentage distribution of zooplankton under different classes at three stations

In case of Sattarghat station, zooplankton population was mainly dominated by the class of Copepoda (45%) followed by Rotifera (23%), Cladocera (21%), Crustacean larvae (5%) and others (6%) (**Table 5**). Copepoda was mainly represented by both common genera like, *Cyclops, Diaptomus* and dominated over other groups during the investigation period.

In case of Gorduara station, zooplankton population was mainly dominated by the class of Rotifera (34%) followed by Copepoda (28%), Cladocera (12%), Crustacean larvae (19%) and others (7%).

In case of Kalurghat station, zooplankton population was mainly dominated by the class of Rotifera (35%) followed by Copepoda (28%), Cladocera (19%), Crustacean larvae (13%) and others (5%) (**Table 5**). Rotifera was mainly represented by both common genera like, *Brachionus, Keratella.* and dominated over other groups during the investigation period.

Table 5. Percentage distribution of zooplankton under different classes at three stations

	Percentage distribution under different classes of zooplankton				
Stations	**Copepoda (%)**	**Cladocera (%)**	**Rotifera (%)**	**Crustacean larvae (%)**	**Others (%)**
Sattarghat	45	21	23	5	6
Gorduara	28	12	34	19	7
Kalurghat	28	19	35	13	5

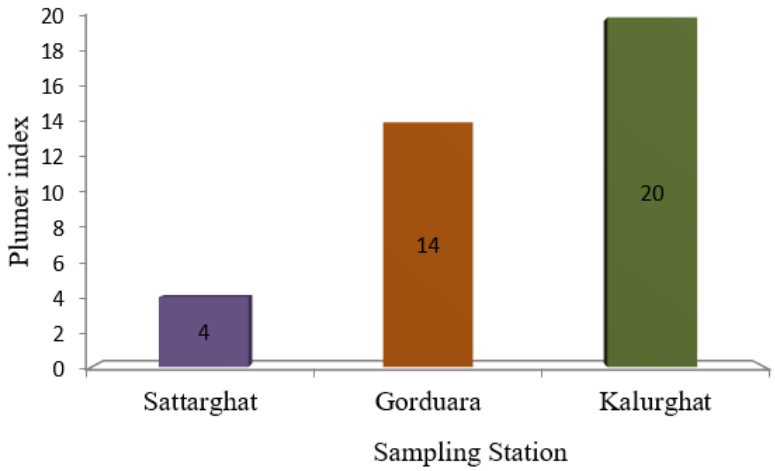

Figure 1. Pollution index score of algal genera at selected sampling station of Halda River

Evaluation of organic pollution by Palmer's Algal Genus Index

The results showed that the presence of planktons indicates the pollution status of water bodies and is a reliable tool for assessment of fresh water bodies. By using Palmer's index of pollution for rating of water samples as high or low organically polluted at three stations of river Halda were tested. The total score of Algal Genus Pollution Index of station Sattarghat, Gorduara and Kalurghat were 4, 14 and 20 respectively (**Figure 1**).

It was observed that the higher score for Palmer's index at Kalurghat indicated high organic pollution. While the total scores of Gorduara was less than 20 indicating moderate pollution. On the other hand, the Sattarghat showed an index of 4 which indicated no organic pollution. In case of algal genus, a total 11 genera was identified from the stations where six genera such as *Cyclotella, Oscillatoria*, *Navicula*, *Nitzschia*, *Stigeoclonium* and *Melosira* were recorded repeatedly and considered as indicators of pollution in referenc of Palmer pollution index (Kshirsagar, 2013).

The Co-efficient of Correlation (r) between Total Zooplankton and Physicochemical Parameters

The co-efficient of correlation (r) between total zooplankton and physicochemical parameters in the Halda River are given by **Table 6**. Total zooplankton was positively correlated with water temperature, dissolved oxygen and transparency while negative correlations were found with p^H, electrical conductivity, total dissolved solids, suspended solids and salinity in the Halda River.

Water temperature is one of the most outstanding and biologically significant phenomena of aquatic environment; it has the relationship on zooplankton variation. Zooplankton abundance showed positive correlation (r=+0.178) with water temperature (**Table 6**). These results have similarity with the findings of Shil *et al.* (2013) and Bashar *et al.* (2015). They worked in semi intensive prawn farm of Bagerhat district and Kaptai Lake, Bangladesh respectively.

Zooplankton abundance showed negative relationship with water pH (r=-0.320). This result is varied in comparison to Shil *et al.* (2013) and Bashar *et al.* (2015). They reported positive relationship with pH. Zooplankton abundance showed positive relationship with dissolved oxygen in Halda River (r = +0.740). On the other hand zooplankton showed direct relationship with dissolved oxygen in such finding resembles the works of Ghosh *et al.* (2011) and Bashar *et al.* (2015). Zooplankton abundance showed negative relationship with electrical conductivity (r= -0.635). Total dissolved solids and suspended solids showed inverse

Table 6. The co-efficient of correlation (r) between total zooplankton and physicochemical parameters

	Water temp.(° C)	PH	DO (mg/ l)	EC (µS cm-1)	TDS (ppm)	SS (mg/ l)	Transparency (cm)	Salinity (%)	Total zooplankton
Water temp. (° C)	1	0.04	-0.27	0.20	0.19	0.02	-0.30	-0.39	0.18
PH	0.04	1	-0.38	0.77	0.77	0.46	-0.67	0.60	-0.32
DO (mg/ l)	-0.27	-0.38	1	-0.52	-0.53	-0.46	0.30	-0.24	0.74
EC (µS cm-1)	0.20	0.77	-0.52	1	0.20	0.35	-0.88	0.38	-0.64
TDS (ppm)	0.19	0.77	-0.53	0.20	1	0.35	-0.88	0.38	-0.65
SS (mg/ l)	0.02	0.46	-0.46	0.35	0.35	1	-0.47	0.83	-0.58
Transparency(cm)	-0.30	-0.67	0.30	-0.88	-0.88	-0.47	1	-0.35	0.50
Salinity (%)	-0.39	0.60	-0.24	0.38	0.38	0.83	-0.35	1	-0.50
Total zooplankton	0.18	-0.32	0.74	-0.64	-0.64	-0.58	0.50	-0.51	1

relationship with zooplankton abundance (r = -0.643 and r =-0.576) respectively (**Table 6**). Zooplankton abundance showed positive relationship with transparency (r = +0.497) (**Table 6**). These results have dissimilarity with the findings of Ghosh *et al.* (2011) and Shil *et al.* (2013). They reported inverse relationship (r=-0.327 and r=-0.693) between zooplankton abundance and water quality parameter in semi intensive prawn farm of Bagerhat district, Bangladesh. Zooplankton abundance showed negative relationship with water salinity in the Halda River (r = -0.509). This finding was supported the results of Ghosh *et al.* (2011) and Shil *et al.* (2013).

CONCLUSION AND RECOMMENDATIONS

The Halda River plays a vital role as a source of freshwater in Bangladesh, has attained a very special identity and is frequently referred as a natural heritage by being the breeding ground for major Indian carps. Its water is used for irrigation, navigation, fisheries, dumping of domestic and industrial waste and recreational purposes. Thus, intensive investigation of both physicochemical and biological factors will allow us to understand more about plankton diversity and distribution in the freshwater ecosystems and it further provides support as to why plankton species are good indicators of environmental change. This study explored the current status of water quality at the Halda River using physicochemical and biological parameters considering three stations – Sattarghat, Gorduara and Kalurghat as the sampling stations. All the eight parameters considered for physicochemical monitoring of water quality showed the standard level except the Dissolved Oxygen (DO) at Kalurghat stations. On the basis of Palmer's algal genus index, river water in Kalurghat station was highly polluted than other two stations. The probable reasons discharge of pollutant from industries of surrounded area. The physicochemical parameters and the zooplankton abundance showed some interrelationships. However, more studies are required to make a complete list of available zooplankton as well as their impact on water quality of the Halda River of Chittagong, Bangladesh.

Based on the findings of the present study, we have come up with the deduction that the river need regular monitoring by the responsible authority like, Department of Environment (DoE) along with other related departments should monitor the water quality of the Halda River regularly at the Kalurghat station. In case of monitoring water quality by physicochemical parameters, all the parameters were within the limit, except DO at Kalurghat station. So, continuous monitoring should require for checking the water quality of the river. Again, as pollution also traced by Palmer's Pollution Index, this pollution index should be adapted for identifying the pollution level by biological monitoring which will ultimately control the pollution. Even if possible, biotic communities in the Halda River should be regularly monitored as indications of condition of the river water as complementary to routine chemical quality control. Direct discharge of effluents and other wastes should be stopped at Kalurghat station. More important thing is that as water in the Halda River at the Kalurghat station receives a load of nutrients from surrounding areas e.g., industrial effluents as well as from anthropogenic activities, bathing and washing that led to severe contamination followed by eutrophication. Hence it is suggested to exercise all the necessary precaution before the water is used for drinking and other purposes, otherwise, it may lead to much adverse effect on fish resources along with health condition of the local community.

The present study suggests for conducting further research to assess the overall physicochemical and biological status impacting water quality especially at Kalurghat station of the Halda River. On the basis of physicochemical parameters of water quality and Palmer's Algal Genus Index, the present study revealed that the river water at the Kalurghat station is more polluted than other two stations. Since the current study is

only limited to three months. Therefore, it is necessary to do further research work considering seasonal variations to prove that Kalurghat is the polluted zone.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Mohammad Ayub Parvez – Research Associate, Institute of Forestry and Environmental Sciences University of Chittagong, Chittagong 4331, Bangladesh.

M. Main Uddin – Assistant Professor, Institute of Forestry and Environmental Sciences University of Chittagong, Chittagong 4331, Bangladesh.

Md. Kamrul Islam – Research Associate, Institute of Forestry and Environmental Sciences University of Chittagong, Chittagong 4331, Bangladesh.

Md. Manzoorul Kibria – Professor, Department of Zoology University of Chittagong, Chittagong 4331, Bangladesh.

REFERENCES

Ahmed, K. K. U., Ahamed, S. U., Hossain, M. R. A., Ahmed, T., & Barman, S. (2003). Quantitative and qualitative assessment of plankton: some ecological aspect and water quality parameters of the river Meghna, Bangladesh. *Bangladesh Fish. Res.,* 7(2), 131-140. Retrieved from http://aquaticcommons.org/17745/1/BJFR7.2_131.pdf

Ahsan, D. A., Kabir, A. N., Rahman, M. M., Mahabub, S., Yesmin, R., Faruque, M. H., & Naser, M. N. (2012). Plankton composition, abundance and diversity in hilsa (Tenualosa ilisha) migratory rivers of Bangladesh during spawning season. *Dhaka University Journal of Biological Sciences,* 21(2), 177–189. Retrieved from https://www.banglajol.info/index.php/DUJBS/article/view/11516

Akter, A., & Ali, M.H. (2012). Environmental flow requirements assessment in the Halda River, Bangladesh. *Hydrological Sciences Journal, 57*(2), 326–343.

Alam, M. S., Hossain, M. S., Monwar, M. M., & Enamul, M. (2013a). Assessment of fish distribution and biodiversity status in Upper Halda River, Chittagong, *Bangladesh. International Journal, 5*(6), 349–357. Retrieved from https://academicjournals.org/journal/IJBC/article-abstract/0BCB07D10739

Bashar, M. A., Basak, S. S., Uddin, K. B., Islam, A. S., & Mahmud, Y. (2015). Seasonal variation of zooplankton population with reference to water quality of Kaptai Lake, Bangladesh. *Bangladesh Research Publications Journal, 11*(2), 127–133. Retrieved from https://s3.amazonaws.com/academia.edu.documents/37772948/1410071.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1557135593&Signature=YYk5fkRBjlZUvOgcrcAqJ%2FZLM9s%3D&response-contentdisposition=inline%3B%20filename%3DSEASONAL_VARIATION_OF_ZOOPLANKTON_POPULA.pdf

Bhatnagar, A., Chopra, G., & Malhotra, P. (2013). Assessment of water quality of river Yamuna in Yamunanagar, India with reference to planktons and macrozoobenthos. *Sch. Jr. Eng. Tech, 1*(4), 204–213.

Bhouyain, A. M., & Asmat, G. S. (1992). Freshwater zooplankton from Bangladesh, Dhaka: Ghazi Publishers, pp. 32-151.

Biswas, B. C., & Panigrahi, A. K. (2015). Ecology and Zooplankton Diversity of a Wetland at Jhenidah District Bangladesh. *International Journal for Innovative Research in Science and Technology, 1*(9), 246–249. Retrieved from http://www.ijirst.org/articles/IJIRSTV1I9038.pdf

Chowdhury, M. M. R., Mondol, M. R. K., & Dewan, S. (2008). Seasonal dynamics of plankton in relation to some environmental factors in a Beel ecosystem. *University Journal of Zoology, Rajshahi University, 27*, 55–58. https://doi.org/10.3329/ujzru.v27i0.1955

Crofford, D., & Avenont-Oldewage, A. (2009). Application of a fish health assessment index and associated parasite index to Clarias gariepinus in the Vaal River System, South Africa. *African Journal of Aquatic Science, 34*(3), 261-272. https://doi.org/10.2989/AJAS.2009.34.3.8.984

Edmondson, W. T. (1959). *Fresh-water biology* (2nd edn.). New York & London: John Wiley & Sons, Inc.

Environmental Protection Agency (EPA) (2016). *Water: monitoring & assessment*. Retrieved from http://water.epa.gov/type /watersheds/monitoring/bioassess.cfm (accessed 20 June 2016).

Flura, M. A. A., Nima, A., Begum, M., & Tanu, M. H. K. (2016). Physico-chemical and biological properties of water from the river Meghna, Bangladesh. *International Journal of Fisheries and Aquatic Studies, 4*(2), 161-165. Retrieved from http://www.fisheriesjournal.com/archives/2016/vol4issue2/PartC/4-1-110.pdf

Ghosh, A. K., Saha, S. K., Islam, M. R., & Rahaman, S. M. B. (2011). Abundance and diversity of zooplankton in semi-intensive shrimp (*Penaeus monodon)* farm. *International Journal of Life Sciences*, *5*(1), 1-11. https://doi.org/10.3126/ijls.v5i1.5286

Haldariver.org (2016) Halda River. Retrieved on 14 March, 2016 from http://www.haldariver.org/about%20halda.html

Hoq, M. F. (1993). *Limnology and oceanography*. Bangla Acadmy, Dhaka.

Islam, M. S., Meghla, N. T., Suravi, Al Mamun, S., & Islam, M. (2012). Status of water quality in the Dhaleshwari River and its effect on aquatic organism. *Journal of Environmental Science and Water Resources*, *1*(8), 192–201.

Kabir, H., Kibria, M., Jashimuddin, M., & Hossain, M. M. (2015a). Conservation of a river for biodiversity and ecosystem services: the case of the Halda–the unique river of Chittagong, Bangladesh. *International Journal of River Basin Management*, *13*, 333–342. https://doi.org/10.1080/15715124.2015.1012514

Kabir, M. H., Kibria, M. M., & Hossain, M. M. (2015b) Indirect and non-use values of Halda River-a unique natural breeding ground of Indian carps in Bangladesh. *Journal of Environmental Science and Natural Resources, 6*(2), 31–36. https://doi.org/10.3329/jesnr.v6i2.22092

Kabir, M. H., Kibria, M. M., Russell, I. A., & Hossain, M. M. (2014). Engineering activities and their mismanagement at Halda: a unique river for natural spawning of Major Indian carps. *International Journal of Surface and Groundwater Management, 1*(1), 59-66.

Kazanc, N., Ekingen, P., Turkmen, G., Ertunc, O., Dugel, M., & Gultutan Y. (2010). Assessment of ecological quality of Aksu Stream (Giresun, Turkey) in Eastern Black Sea Region by using Water Framework Directive (WFD) methods based on benthic macroinvertebrates, *Review of Hydrobiology*, *3*(2), 165-184. Retrieved from https://www.researchgate.net/profile/Ozge_ertunc_Basoren/publication/235933645_Assessment_of_ecological_quality_of_Aksu_Stream_Giresun_Turkey_in_Eastern_Black_Sea_Region_by_using_Water_Framework_Directive_WFD_methods_based_on_benthic_macroinvertebrates/links/546b79a90cf20dedafd5318c.pdf

Khanam, M. R. M., Naser, M. N., & Ali, S. (2014). Population dynamics of planktonic rotifers in the southern coastal area of Bangladesh. *International Journal of Natural and Social Sciences*, *1*(2), 53-60. Retrieved from http://ijnss.org/wp-content/uploads/2014/11/IJNSS-V1I2-08-pp-53-60.pdf

Kshirsagar, A.D. (2013). Use of algae as a bioindicator to determine water quality of river Mula from Pune city, Maharashtra (India). *Universal Journal of Environmental Research & Technology, 3*(1), 79-85.

Mamun, M. M., Sarower, M. G., Ali, M. A., Rahman, S. M. B., & Huq, K. A. (2009). Abundance and distribution of plankton in the Sundarbans mangrove forest. *Journal of Innovation and Development Strategy*, *3*(3), 43–54.

Mobin, M. N., Islam, M. S., Mia, M. Y., & Bakali, B. (2014). Analysis of physicochemical properties of the Turag River water, Tongi, Gazipur in Bangladesh. *J. Environ. Sci. & Natural Resources, 7*(1), 27-33. https://doi.org/10.3329/jesnr.v7i1.22140

Mustapha, M. K. (2008). Assessment of water quality of Oyun reservoir, Offa, Nigeria, using selected physico-chemical parameters. *Turkish Journal of Fisheries and Aquatic Sciences*, *8*, 309-319. Retrieved from https://s3.amazonaws.com/academia.edu.documents/30576321/309_319.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1557137200&Signature=E6yxV6lJ79%2BpNcjJU8SOwtNpm7U%3D&response-content-disposition=inline%3B%20filename%3DAssessment_of_the_water_quality_of_Oyun.pdf

Noel, S. D., & Rajan, M. R. (2015). Evaluation of organic pollution by Palmer's Algal Genus Index and physico-chemical analysis of Vaigai River at Madurai, India. *Natural Resources and Conservation, 3*(1), 7-10.

Palmer, C. M. (1969). A composite rating of algae tolerating organic pollution. *Journal of Phycology, 5*, 78–82. https://doi.org/10.1111/j.1529-8817.1969.tb02581.x

Rahi, M. L., Mahfuj, S. E., Islam, S. S., Islam, S. S., & Sabbir, W. (2015). Assessment of the abundance and species composition of phytoplankton of Moiur river, Khulna. *Journal of Bio-Science, 21*, 27–34. https://doi.org/10.3329/jbs.v21i0.22516

Ronald, W. R. P., & Azadi, M. A. (1987). Ecological studies on the planktonic organisms of the Halda River, Chittagong, Bangladesh. *Bangladesh Journal of Zoology, 15*(2), 109-123.

Roy, U., Shaha, B. K., Mazhabuddin, K., Haque, M. F., & Sarower, M. G. (2010). Study on the diversity and seasonal variation of zooplankton in a brood pond, Bangladesh, *Marine. Res. Aqua., 1*(1), 30-37.

Sarwar, M. I., Majumder, A. K., & Islam, M. N. (2010). Water quality parameters: a case study of Karnafully River Chittagong, Bangladesh. *Bangladesh J. Sci. Ind. Res., 45*(2), 177-181. https://doi.org/10.3329/bjsir.v45i2.5722

Shil, J., Ghosh, A. K., & Rahaman, S. B. (2013). Abundance and diversity of zooplankton in semi intensive prawn (Macrobrachium rosenbergii) farm. *SpringerPlus*, *2*, 183. https://doi.org/10.1186/2193-1801-2-183

Thakur, R. K., Jindal, R., Singh, U. B., & Ahluwalia, A. S. (2013). Plankton diversity and water quality assessment of three freshwater lakes of Mandi (Himachal Pradesh, India) with special reference to planktonic indicators. *Environmental Monitoring and Assessment, 185*, 8355–8373. https://doi.org/10.1007/s10661-013-3178-3

Uddin, M. N., Alam, M. S., Mobin, M. N., & Miah, M. A. (2014). An assessment of the river water quality parameters: a case of Jamuna River. *J. Environ. Sci. & Natural resources, 7*(1), 249-256.

Vashista, B. B. (2005). *Botany for Degree students (part- 1) Algae,* S. Ramnagar, New Delhi: Chand & Company Ltd.

Vugteveen, P., Leuven, R. S. E. W., Huijbregts, M. A. J., & Lenders, H. J. R. (2006). Redefinition and elaboration of river ecosystem health: perspective for river management. *Hydrobiologia*, *565*, 289–308. https://doi.org/10.1007/s10750-005-1920-8

Wei, M., Zhang, N., Zhang, Y., & Zheng, B. (2009). Integrated assessment of river health based on water quality, aquatic life and physical habitat. *Journal of Environmental Sciences, 21*, 1017–1027.