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COMPARATIVE WATER QUALITY ASSESSMENT OF THE RIVER BURIGANGA NEAR DHAKA METROPOLIS[1]

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Abstract

Physicochemical and biological water quality data from a reference study station of the river Buriganga measured fortnightly during 1994 - 1995 have been presented and compared with the results of other studies carried out during 1972 - 1973, 2003 - 2005, 2011 and 2012 - 2013 by different authors. During 1994 - 1995, a total of 10 dominant species of phytoplankton were quantified from the River Buriganga in different seasons. *Melosira granulata* (Ehrenberg) Ralfs (5-10400 × 10^3 ind/l), *Oscillatoria chalybea* (Mertens) Gomont (8 - 2660 × 10^3 ind/l) and *Spirulina platensis* (Nordst) Gomont (2 - 7480 × 10^3 ind/l) were present throughout the year. The other seven species which occurred sporadically were *Cryptomonas obovata* Czosnowski (423 - 3520 × 10^3 ind/l), *Actinastrum hantzschi* Lagerheim (123 - 119000 × 10^3 ind/l), *Closterium limneticum* Lemmermann (202 - 2300 × 10^3 ind/l), *Ankistrodesmus falcatus* (Corda) Ralfs (226 - 7140 × 10^3 ind/l), *Scenedesmus dimorphus* (Turp.) Kuetz. (7-2780 × 10^3 ind/l) and *Euglena acus* (Mueller) Ehr. (38 - 700 × 10^3 ind/l). The summer population was supported by high densities of *M. granulata*, *O. chalybea*, *S. platensis* and *C. meneghiniana* having larger bio-volumes compared to its winter counterparts (*C. obovata*, *A. hantzschi* and *Ank. falcatus*). Seasonal mean values of the planktonic potential primary productivity of the river ranged from 15-120 µgC/l/h with a chlorophyll *a* concentration of 2-142 µg/l. The maximum phytoplankton primary productivity in the river Buriganga was 4.92 times lesser than the River Padma at Mawa Ghat. Maximum assimilation rate (P/B) was found nearly double the greater than River Turag. The population density of zooplankton was almost same as that reported for Turag. Comparative analysis reveals no change in the water temperature and pH of the river water during 1972-2013. However, for the recorded maximum of each parameter, a reduction in the Secchi depth, NO_3-N, DO, phytoplankton species number and density was observed by factors of 3.5, 36.33, 3.5, 1.67 and 675.89, respectively. Alkalinity, TDS, SRS, SRP were increased by factors of 1.34, 3.49, 2.06, 2 and 12.57, respectively. During the period concerned, data on phytoplankton biomass as chlorophyll *a* was available only on two occasions i.e., during 1994 - 1995 and 2003 - 2005, which showed 1.13 times higher in the latter study. Enhanced eutrophication with reduced light climate as well as a shift in phytoplankton diversity has been found prevalent in the reference station of the river.

Introduction

The city of Dhaka is 400 years old and so to say with the name of the river Buriganga attached to it. How the city of Dhaka and its adjacent river Buriganga looked like four centuries before from now, can be depicted in a recent publication titled 'Dhaka: In the Eyes of Painters 1789 - 1947' (Rahman 2012). But the question, about the water quality of the river Buriganga at that time could not be answered, excepting a mere guess, by looking to those century old paintings on the river. Buriganga is said to be the 'pulse of Dhaka' is true, because the panoramic view of the river and its water use for trade, commerce, industries and household purposes was a common subject in the paintings drawn between 1789 and 1947 (Rahman 2012). Regarding water quality of that time, subject of two paintings could be quoted here. One shows (Part of Dacca from Dholai Khal, 1 September 1826, Charles D'Oyly) that people are taking peaceful bath in the Dholai Khal

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area of the river and another one (The city of Dacca viewed from the River Buriganga, 12 May 1861, Frederick William Alexander De Fabeck) showing 10 boats and 20 people on a clean bank of the river Buriganga which is free of garbage and drains. A painting of 1814, shows the clumps of floating macrophytes in the river. Though, all these do not bear any scientific merit, but could tell us that the water quality of the River Buriganga was pretty safe and sound and supporting also components of aquatic biodiversity.

About 40 years back from now, in 1972 a small limnological team visited river Buriganga with a boat and a few water and plankton collecting gears and this was possibly the first attempt to carry out a limnological investigation there (Islam *et al.* 1974, Islam and Zaman 1975). Two more studies related to the physicochemical and biological water quality of the pelagic zone of the River Buriganga were also followed later on (Zerin 1995 and Islam and Moniruzzaman 2011).

At present, the fluvial segment of the River Buriganga adjacent to Dhaka Metropolis has grown tremendous limnological interests (GOB 1993, Ahmed 1993, Bari and Badruzzaman 2007). The reason for this is the increasing urban anthropogenic threshold imposed upon the water quality as well as the biodiversity on this segment. The trend of limnological follow up on the River Buriganga from 1972 until recently casts no hope on the improvement of the water quality rather shows a deepening crisis to an irrecoverable condition (Islam *et al*. 1974, Islam and Zaman 1975, Islam and Moniruzzaman 2011, Saifullah *et al*. 2012, Sarkar *et al*. 2015).

Phytoplankton community interrelates with the physicochemical factors of water over the season and reflects the ecosystem condition. So, analysis on the dynamisms in the community pattern and productivity by phytoplankton can be considered as a tool for the water quality assessment of any aquatic ecosystem. Such analysis, dealt with historical data can reveal valuable information on the dynamic characteristics of water quality. Important limnological investigations on the adjacent fluvial segment of the river Buriganga near Dhaka metropolis were carried out during 1972 - 1973, 1994 - 1995 and 2003 - 2005 by Islam *et al*. (1974), Islam and Zaman (1975), Zerin (1995) and Islam and Moniruzzaman (2011). Zerin (1995) studied 20 different physicochemical and biological parameters collected at 15 days intervals for one year during 1994-1995 and presented the data in her M.Sc. thesis. The results of the study however, could not be published in time because of some unavoidable reasons. Other limnological researches carried out between 2007 and 2015 on the River Buriganga, mostly dealt with a few selective physicochemical parameters (Rahman and Hossain 2008, Saifullah *et al*. 2012, Ferdous *et al*. 2012, Sarkar *et al*. 2015). Raknuzzaman (2006) studied the relationship of zooplankton abundance and physicochemical parameters in two different stations of the River Buriganga.

In the present paper the research results of Zerin (1995) has been presented, discussed and compared with other studies to see the sequential changes over a period of nearly four decades in respect of the River Buriganga (Islam *et al*. 1974, Islam and Zaman 1975, Islam and Moniruzzaman 2011, Saifullah *et al*. 2012, Sarkar *et al*. 2015).

Materials and Methods

The data presented in Zerin (1995) were collected from a permanent station located in the mid-part of the main navigation channel situated North West of Bangladesh-China Friendship Bridge of the River Buriganga (Fig. 1). Detailed description of this fluvial segment of the river can be obtained from Islam *et al*. (1974) and Islam and Moniruzzaman (2011). Collection of samples was made fortnightly from July, 1994 to June, 1995 during 23 visits. A manually driven country boat was used to reach the sampling point where a Schindlers sampler (5 l capacity, 50 cm long) was dipped to collect a 50 cm integrated surface water sample of the river. The temperature of the water was recorded from the mercury thermometer housed in the sampler. At once, BOD bottles in triplicate (Pyrex, 120 ml cap.) were filled and fixed for determination of dissolved oxygen by Winkler's method (Wetzel and Likens 1979). A field conductivity meter (AL 52) was used to measure the conductivity of water. Secchi depth and water current were measured by using a Secchi disc and a Pitot tube, respectively (Welch 1948). A black canister of 5 liter capacity was filled with the river water and brought to the laboratory along with all other samples. Daily radiation was measured from sunrise to sunset at hourly intervals using the LI-190SB sensor and radiometer. Methodologies followed for carrying out measurements of all other parameters have been mentioned in Khondker and Abed (2013). Physicochemical and biological variables measured during the period of investigation have been presented in Table 1. Seasonal mean values (±Sd) of the data with their maximum and minimum values have been presented in Table 2. For comparison, relevant research results were obtained from Islam *et al*. (1974), Islam and Moniruzzaman (2011), Saifullah *et al*. (2012) and Sarkar *et al*. (2015).

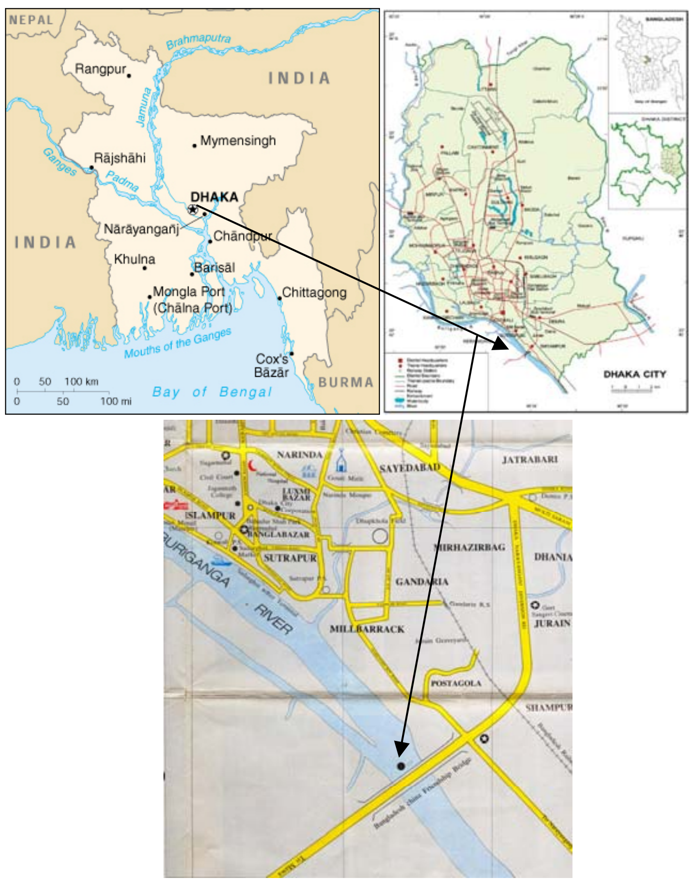

Fig. 1. Map of the study site (•) of the River Buriganga adjacent to Dhaka metropolis (Modified after: https://www.google.com and Parjatan Corp. Bangladesh).

Principal component analysis (PCA) (Primer 6: Clarke and Gorley 2006) was applied to environmental variables to specify the reduced set of variables explaining a percentage of the variability in the ordination of samples in space and later on regression analysis (Statistica 6) was used with PC1 and PC2 scores and abundance of different phytoplankton species (log (x+1) transformed). Prior to PCA analysis water temperature and pH were standardized while rest of the environmental variables were log (x+1) transformed. Only components (PCs) with Eigen values > were interpreted. The scores of the first two PCs were used for plotting samples on a 2-d PC plot. Variables with a significant correlation, higher than |0.3|, reflecting their contribution to each axes, were represented by vectors in the same plot.

Results and Discussion

Table 1 presents the physicochemical and biological data of the River Buriganga during the study period of 1994-1995. Since the data were collected almost every 15 days interval, it gives a closer look to the water quality of the study station. Phytoplankton biomass as chlorophyll *a* (chl *a* µg/l), its degraded product as phaeopigment (phaeo. µg/l), rate of potential primary productivity both as carbon (PP µgC/l/h) and oxygen values (PP O_2 mg/l/h) and assimilation rate (P/B µgC/µg chl *a*/h) have been presented in Table 1. Ahmed and Alfasane (2004) studied the net phytoplankton productivity of the river Padma at Mawa Ghat where the productivity ranged from 0.13 - 0.54 mgO_2/l/h. In the river Buriganga, range of this parameter was 0.03 - 0.32 mgO_2/l/h. Primary productivity as carbon value (converted) for Padma and Buriganga were 105.0 - 592.5 h and 15 - 120 µgC/l/h, respectively (Ahmed and Alfasane 2004). In the river Turag, the phytoplankton density and productivity were 1 - 800 × 10^3 and 6.22 - 199.7 µgC/l/h, respectively (Khondker and Abed 2013). The phytoplankton standing crop in the River Buriganga during 1994 -1995 varied from 36 - 133152 × 10^3 (Table 1), while in the River Padma it ranged from 12 -867 × 10^3 (Ahmed and Alfasane 2004). From this comparison it appears that though Padma at Mawa Ghat and the river Turag at Mirpur contains almost identical maximum phytoplankton density, the primary productivity of the former is nearly five times higher than the latter. On the otherhand, the river Buriganga shows a maximum plankton density by the order of 166 times more than the former two rivers, despite its production is low (Table 1). PO_4-P showed direct relationship with the planktonic chlorophyll in Turag (Khondker and Abed 2013). This parameter ranged for the River Turag and Buriganga from 50 - 800 and 38 - 508 µg/l, respectively. Occurrence of a very high (maximum) phytoplankton cell density in the River Buriganga shows the presence of algal bloom. In terms of primary productivity, Padma was found optimum compared to Turag and Buriganga (Ahmed and Alfasane 2004, Khondker and Abed 2013). In the latter two rivers the impact of strong pollution might be a factor to reduce the primary productivity.

On a seasonal scale (Rashid 1991), water temperature in the River Buriganga varied from 21.9-30.4°C of which the highest being recorded in monsoon and the lowest in winter (Table 2). Secchi depth, alkalinity, conductivity, pH, PO_4-P, chl *a*, and total zooplankton concentration of the river showed a clear trend of increase starting from monsoon up to summer via autumn and winter (Table 2). Phytoplankton standing crop showed an increasing seasonal trend from monsoon to autumn and then to winter. Its density however, reduced to one third in summer compared to its winter maximum (Table 2). Water current, DO and P/B showed a declining trend starting from monsoon to summer via autumn and winter (Table 2). The rate of primary productivity was similar in both the monsoon and winter seasons. It dropped one third in autumn compared to its monsoon value. The mean primary productivity of the river water was reduced by nearly 27% compared to the value of the previous adjacent summer season (Table 2).

Secchi depth was high in summer (60.83 cm) than in monsoon (27.75 cm). In autumn and winter the Secchi depth were 44 and 59.33 cm, respectively. The reason is during monsoon the river water carried more particles compared to the other seasons. Water current was higher in monsoon (0.76 m/sec) and lower in summer (0.56 m/sec).

Table 1. Water quality variables of the River Buriganga measured on different dates during the period 1994 to 1995.

	1994											
Parameter	Jul. 21	Jul. 28	Aug. 11	Aug. 25	Sep. 8	Sep. 22	Oct. 10	Oct. 20	Nov. 3	Nov. 15	Dec. 15	Dec. 28
Water temp. °C	29.7	31.2	30.3	29.6	30.8	30.7	29	29	28.8	27.8	22	21.5
Secchi depth cm	20	46	22	17	32	32	33	33	55	53	95	62
Alkal. meq/l	1.14	1.36	1.25	1.1	1.19	1.22	1.12	1.38	1.76	2.6	4.04	3.48
Cond. µS/cm	110	115	120	110	120	140	135	140	200	280	440	500
pH	6.98	7.33	7	6.9	7.1	6.9	7.1	7.1	7.1	7.2	7.6	6.8
Water curr. m/s	0.75	0.82	0.92	0.92	0.64	0.70	0.64	0.67	0.76	0.74	0.61	0.61
DO mg/l	9.7	8.6	9.5	11.2	12.1	12.8	2.7	2.8	1.8	1.8	1.8	1.8
PO_4-P µg/l	55.6	38	57.0	46.1	40.6	49.4	44.2	57.7	120	126	221	348
NO_3-N µg/l	43.4	59	71.5	47.3	59.3	139	91.9	72.8	74.5	134	108	86.2
Silicate mg/l	7.89	7.1	8.1	7.8	7.8	9.4	15.9	11.4	16	23	32	36
Tot ppl.×1000 ind/l	1043	679	73	40	440	312	336	356	472	370	2230	3993
Chl *a* µg/l	2.98	3.84	2.66	1.97	2.98	2.66	3.98	5.32	6.24	9.25	9.62	10.84
Phaeo. µg/l	1.17	1.14	0.96	0.1	1.65	1.07	1.9	1.33	2.3	3.23	1.82	5.79
Tot zoopl. ind/l	9	7	6	8	9	44	6	7	59	75	48	62
PP O_2 mg/l/h	0.22	0.04	0.06	0.08	0.2	0.32	0.05	0.03	0.06	0.04	0.06	0.14
PP µgC/l/h	82.5	15	22.5	30	75	120	18.75	11.25	22.5	15	22.5	52.5
P/B µgC/µg chl *a*/h	27.68	0.25	8.45	15.22	25.16	45.11	4.71	2.11	3.6	1.62	2.33	4.84
PAR µE/m^2/s	586	880	555	261	482	731	512	802	440	845	701	533
Incub temp. °C	29.3	31.7	28.6	27.9	28.8	31.4	28.1	29.5	28.1	28.5	26.2	26
BOD_5 mg O_2/l	0.5	0.75	2.25	2.25	3	0.25	0.25	0.25	1	0.5	1.25	1.5

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1995										
Jan. 12	Jan. 29	Feb. 2	Feb. 16	Mar. 16	Mar. 30	Apr. 18	Apr. 27	May 4	May 25	Jun. 22
20.3	19.7	19.8	22.2	25.5	28.5	29.5	30.8	31.5	30.6	29
45	48		53	53	62	70	50	60	70	20
2.02	4.41	4.48	4.86	4.46	3.36	2.43	2.33	3.78	2.24	1.06
520	565	580	610	640	430	360	385	280	330	120
7.4	7.35	8.1	7.36	7.5	7.52	7.74	7.68	7.63	7.63	6.93
0.61	0.50	0.57	0.55	0.53	0.50	0.53	0.55	0.54	0.72	0.72
1.7	1.6	0.8	0.4	0.6	0.5	0.3	0.7	0.7	0.6	1.6
284	292	410	487	508.6	169	254	259	171	196	56.3
83.6	123.5	108	104	727	522	237	163	150	183	1090
34	37	38	19	18	3.04	5.34	3.78	4.09	10.3	19.9
6094	133152	28546	10669	17412	1337	18287	6741	3685	576	36
8.88	96.2	81.4	72.52	142.05	13.31	40.25	60.18	40.84	46.17	1.47
2.56	35.88	43.4	21.89	41.37	5.87	6.93	3.08	1.79	6.86	0.8
14	261	2590	4831	2986	693	866	907	525	1252	3
0.125	0.14	0.09	0.12	0.18	0.04	0.06	0.08	0.06	0.12	0.04
46.8	52.5	90	45	67.5	15	22.5	30	22.5	45	15
5.27	0.545	1.1	0.62	0.47	1.12	0.55	0.49	0.55	0.97	10.2
178	888	698	621	1166	1208	1200	1408	1118	1050	1316
23.2	27	26	26.3	31.4	29.8	33	32	32.2	30.1	29.9
3.2	3.25	2.75	2.5	3	1.5	0.5	1.75	1.5	1.75	2

Table 2. Seasonal mean (± Sd), minimum (min.) and maximum (max) of different physicochemical and biological variables of the river Buriganga during 1994 to 1995.

Parameters	Monsoon				Autumn			
	Mean	Sd	Min.	Max.	Mean	Sd	Min.	Max.
Water temp. °C	30.04	0.84	29	31.2	28.9	0.14	28.8	29
Secchi depth cm	27.75	9.75	17	46	44	15.55	33	55
Water curr. m/sec	0.76	0.11	0.639	0.923	0.71	0.06	0.67	0.75
Alkal. meq/l	1.18	0.09	1.06	1.36	1.57	0.26	1.38	1.76
Cond. µS/cm	121.25	10.94	110	140	170	42.42	140	200
pH	7.03	0.14	6.9	7.33	7.1	0	7.1	7.1
DO mg/l	8.53	4.18	1.6	12.8	2.3	0.70	1.8	2.8
PO_4-P µg/l	48.35	7.47	37.65	57.04	88.75	43.91	57.69	119.8
NO_3-N µg/l	200.24	361.00	43.36	1090.4	73.65	1.23	72.78	74.52
Silicate mg/l	10.48	4.75	7.11	19.91	13.89	3.53	11.39	16.39
Tot phyt.×1000 ind\l	370	352	36	1043	414	82	356	472
Chl *a* µg/l	2.82	0.85	1.47	3.98	5.78	0.65	5.32	6.24
Phaeopig. µg/l	1.09	0.54	0.1	1.9	1.82	0.68	1.33	2.3
Tot zoopl. Ind/l	11.50	13.28	3	44	33	36.76	7	59
PP O_2 mg/l/h	0.13	0.11	0.04	0.32	0.05	0.02	0.03	0.06
PP µgC/l/h	47.34	39.83	15	120	16.88	7.95	11.25	22.5
P/B µgC/µg chl *a*/h	17.09	14.76	0.25	45.11	2.86	1.05	2.11	3.6
PAR µE/m^2/sec	665.38	319.11	261	1316	621	255.97	440	802
Incub temp. °C	29.46	1.44	27.9	31.7	28.80	0.98	28.1	29.5
BOD_5 mg O_2/l	1.40	1.08	0.25	3	0.63	0.53	0.25	1

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Winter				Summer			
Mean	Sd	Min.	Max.	Mean	Sd	Min.	Max.
21.9	2.79	19.7	27.8	29.4	2.18	25.5	31.5
59.33	18.40	45	95	60.83	8.35	50	70
0.59	0.07	0.49	0.74	0.56	0.07	0.495	0.715
3.69	1.05	2.02	4.86	3.1	0.91	2.24	4.46
499.28	111.89	280	610	404.16	126.11	280	640
7.40	0.39	6.8	8.1	7.61	0.09	7.5	7.74
1.41	0.57	0.4	1.8	0.56	0.15	0.3	0.7
309.56	119.33	126.3	487.28	259.55	128.16	168.95	508.52
106.82	18.25	83.64	134.13	330.33	238.74	149.74	726.93
31.71	7.34	19.85	38.24	7.38	5.71	3.04	17.76
26436	48000	370	133152	8006	7926	576	18287
41.24	40.01	8.88	96.2	57.13	44.29	13.31	142.05
16.36	17.45	1.82	43.4	10.98	15.03	1.79	41.37
1125.85	1882.10	14	4831	1204.83	905.80	525	2986
0.10	0.03	0.04	0.14	0.09	0.05	0.04	0.18
46.32	24.27	15	90	33.75	19.41	15	67.5
2.33	1.96	0.54	5.27	0.69	0.27	0.47	1.12
637.71	236.58	178	888	1191.66	121.07	1050	1408
26.17	1.58	23.2	28.5	31.41	1.24	29.8	33
2.13	1.06	0.5	3.25	1.66	0.80	0.5	3

Alkalinity and conductivity related directly and showed their highest values in winter and lowest in monsoon (Table 2). A slight increasing trend was observed in case of pH from monsoon to summer via autumn and winter (Table 2). Mean DO was higher in monsoon (8.53 mg/l) which gradually decreased through autumn, winter and summer (Table 2). In monsoon and autumn PO_4-P concentration was lower (48.35 and 88.74 µg/l, respectively) compared to their values recorded in winter and summer (309.56 and 259.55 µg/l). The concentration of NO_3-N in the river water was higher in summer (330.33 µg/l) and monsoon (200.24 µg/l) while in autumn and winter the values were 73.65 and 106.82 µg/l, respectively. Dissolved silicate showed higher mean value in winter (31.72 mg/l). Its concentration during monsoon, autumn, winter and summer was 10.48, 13.89, 31.89 and 7.38 mg/l, respectively.

The study of the River Turag and Buriganga was carried out at the same time and when the mean values of different water quality parameters are compared, exceptions were found in cases of Sechhi depth: 46.86 and 29.87 cm, water current: 0.67 and 0.58 m/sec, DO: 3.74 and 4.16 mg/l, NO_3-N: 194.74 and 219.37 mg/l, total zooplankton: 664 and 348 ind/l and primary productivity: 40.84 and 3.77 µgC/l/h, BOD_5: 1.45 and 1.38, respectively for the River Buriganga and Turag (Khondker and Abed 2013). The River Buriganga was found to be relatively better productive at that time compared to Turag, since the light climate of Turag was bad as indicated by a lower Sechhi depth.

In the River Buriganga, the density of phytoplankton increased gradually from monsoon (370 $\times 10^3$ ind/l) via autumn (414 $\times 10^3$ ind/l) and reached a peak during winter (26436 $\times 10^3$ ind/l). A decreasing trend in the density of phytoplankton has been observed in summer (8006 $\times 10^3$ ind/l). The concentration of chl *a* showed a clear increasing seasonal trend from monsoon to summer (Table 2). The summer population was supported by high densities of phytoplankton (*Melosira granulata* (Ehrenberg) Ralfs, *Oscillatoria chalybea* (Mertens) Gomont, *Spirulina platensis* (Nordst) Gomont and *Cyclotella meneghiniana* Kuetz.) having larger bio-volumes compared to its winter counterparts (*Cryptomonas obovata* Czosnowski, *Actinastrum hantzschi* Lagerheim and *Ankistrodesmus falcatus* (Corda) Ralfs). The degraded product of chl *a* the phaeophytin concentration also showed similar trend. Winter and summer biomasses of phytoplankton supported the higher concentration of zooplankton in the river water (Table 2). The productivity was low in summer (33.75 µgC/l) and in autumn (16.88 µgC/l). But a different picture was evident in respect to the P/B values. Higher P/B was recorded during autumn and lowest in summer (Table 2).

The phytoplankton community of the river was represented by 28 algal genera belonging to Cyanophyceae (33.06%) followed by Bacillariophyceae (27.2%), Chlorophyceae (22.81%), Euglenophyceae (11.37%) and Cryptophyceae (5.38%). Of these, the density of 10 phytoplankton species could be quantified routinely. *Melosira granulata* (Ehrenberg) Ralfs (5 - 10400 $\times 10^3$ ind/l) and *Oscillatoria chalybea* (Mertens) Gomont (8 - 2660 $\times 10^3$ ind/l) were present throughout the period of study showing the highest density in March for the former and April for the latter species. Their minimum density was recorded in December and July, respectively. *Spirulina platensis* (Nordst) Gomont (2 - 7480 $\times 10^3$ ind/l) thrived in the community almost in the same pattern except in late June. The highest population density of this species was recorded in April and the lowest in July. *Cyclotella meneghiniana* Kuetz. (342 - 4700 $\times 10^3$ ind/l) was first recorded in the community in December which continued until early May, showing a peak growth in April and lowest density in March. In the community, *Cryptomonas obovata* Czosnowski (423 - 3520 $\times 10^3$ ind/l) was present from December to April. *Actinastrum hantzschi* Lagerheim (123 - 119000 $\times 10^3$ ind/l), *Closterium limneticum* Lemmermann (202-2300 $\times 10^3$ ind/l), *Ankistrodesmus falcatus* (Corda) Ralfs (226 - 7140 $\times 10^3$ ind/l) and *Scenedesmus dimorphus* (Turp.) Kuetz. (7 - 2780 $\times 10^3$

ind/l) and *Euglena acus* (Mueller) Her. (38 - 700 × 10^3 ind/l) prevailed in the community for 3 - 4 months.

PCA analysis resulted five statistically significant (Eigen values >1.0) principal components (PCs). The first two PCs explained 87.5% of the total variance (Fig. 2). PC1 correlated negatively to pH (r = -0.562), chl *a* (r = -0.351) and total zooplankton (r = –0.625). PC2 correlated negatively to total phytoplankton (r = 0.354) and positively to water temperature (r = 0.811). Samplings conducted during winter and summer was ordinated on the negative side while, monsoon and autumn samplings were positioned on the positive side of PC1. Regression analysis between PC1, PC2 and phytoplankton species abundance showed that *Cryptomomas* (r = –0.999120; p < 0.05), *Cyclotella* (r = –0.995282; p < 0.05), *Euglena* (r = –0.997295; p<0.05), *Actinastrum* (r = –0.965956; p < 0.05), *Monoraphidium* (r = –0.987080; p < 0.05) and *Scenedesmus* (r = –0.982395; p < 0.05) were correlated with PC1 scores and found that during winter and summer they were abundant and during monsoon and autumn they were less abundant or absent. Mainly pH, chl *a* and total zooplankton were responsible environmental parameters for the species abundance/absence as these parameters correlated to PC1 (Fig. 2) and during summer and winter, the value of pH, chl *a* and total zooplankton was greater in comparison to autumn and monsoon.

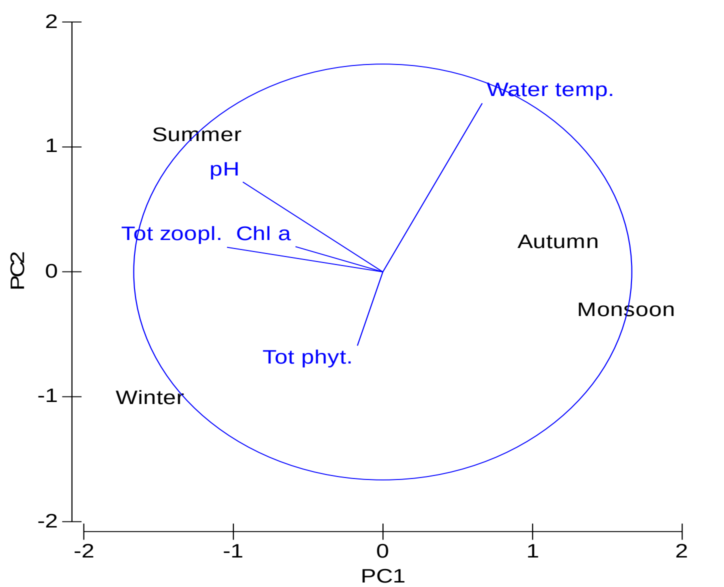

Fig. 2. Principal component analysis (PCA) plot of the first two PC axes on the transformed environmental data (Water temp. = Water temperature, Tot zoopl = Total zooplankton & Tot phyt. = Total phytoplankton). The length of the vectors in this plot reflects the significance of each variable contribution to each axis. If the vector reaches the circle, then none of that variable's coefficients differ from 0.

Table 3 reveals a comparative analysis of the water quality parameters of the River Buriganga at a reference station (near Bangladesh-China Moitry Bridge) measured at different times between 1973 and 2015. Data show that the water temperature did not change throughout this period. However, the transparency of water decreased as it is evident by the data of Secchi depth. It shows a 68 cm reduction in the visibility of water between 1995 and 2011 (Table 3). pH shows slightly acidic compared to its previous values. Alkalinity, conductivity, SRS and SRP rose significantly in their concentration between the periods as mentioned earlier (Table 3). Nitrate concentration dropped drastically in the recent time in the river water. It might be due to the increasing denitrifying capacity of the water. The upper limit of the DO of the river water seems unaltered, however the lower limit decreased to a value closer to zero (Table 3). The concentration of chl *a* increased slightly in the recent years compared, but the quality and quantity of the phytoplankton remained variable (Table 3). Comparative analysis reveals no change in the water

Table 3. Comparison of some physicochemical and biological variables from the River Buriganga measured over five different periods between 1972 and 2013.

	Air temp. (°C)	Wat. temp. (°C)	Zs (cm)	pH	Alkal. (meq/l)	Cond. (µS/cm)	TDS (mg/l)	SRS (mg/l)
1	29-34	26 - 32	nm	6.9 - 7.8	nm	nm	nm	nm
2	nm	20 - 30	17-95	6.8 - 8.1	1-4.9	110 - 640	nm	3 - 38
3	15-35	20 - 33	17-60	6.7 - 6.9	1-6.6	115 - 915	55 - 394	4 - 76
4	nm	17 - 30	18-27	6.4 - 7.2	nm	1520 - 2236	150 - 641	nm
5	nm	22 - 31	nm	6.7 - 7.8	nm	146 - 1223	97 - 814	nm

Table contd. right side

SRP (µg/l)	NO_3 (mg/l)	DO (mg/l)	Chl *a* (µg/l)	Total genera	Total spp.	Major phytoplankton group	Phytopl. $\times 10^3$ ind/l
5 - 126	nm	2.4 - 9.57	nm	70	137	Green algae 62%	0.10 - 10000
38 - 508	0.4 - 10.9	0.3 - 12.8	2 - 142	28	nm	BGA 33%	36 - 133152
34 - 1584	0 - 0.3	<0.02 - 9.4	2 - 160	60	82	Green algae 41%	1 - 197
nm	nm	2.6 - 5.8	nm	nm	nm	nm	nm
nm	nm	1.5 - 3.7	nm	nm	nm	nm	nm

1 = 1972-1973 (Islam *et al*. 1974), 2 = 1994-1995 (Zerin 1995), 3 = 2003-2005 (Islam and Moniruzzaman 2011), 4 = 2011 (Saifullah *et al*. 2012); 5 = 2012-2013 (Sarkar *et al*. 2015). nm = not measured, BGA = Blue green algae.

temperature and pH of the river water during 1972 - 2013. However, for the recorded maximas of each parameter, a reduction in the Secchi depth, NO_3-N, DO, phytoplankton species number and density was observed by factors of 3.5, 36.33, 3.5, 1.67 and 675.89, respectively. Alkalinity, TDS, SRS, SRP increased by factors of 1.34, 3.49, 2.06, 2 and 12.57, respectively. During the period concerned, data on phytoplankton biomass as chlorophyll *a* were available only on two occasions i.e., during 1994 - 1995 and 2003 - 2005, which showed 1.13 times higher in the latter study. Enhanced eutrophication with reduced light climate as well as a change in the phytoplankton diversity has been found prevalent in the reference station of the river.

References

Ahmed MF 1993. The effect of bio-degradable organic pollutants on aquatic ecosystem of the River Buriganga. *In*: Hypertrophic and Polluted Freshwater Ecosystems: Ecological bases for water Resources Mangagemnt (Tilzer MM and Khondker M eds). Proc. Int. Symp. Limnol., Botany Dept. Dhaka Univ., Bangladesh. pp. 97-108.

Ahmed A and Alfasane MA 2004. Ecological studies of the River Padma at Mawa Ghat, Munshiganj II. Primary productivity phytoplankton standing crop and diversity. Pak J. Biol. Sci. **7**(11): 1870-1875.

Bari MF and Badruzzaman ABM 2007. Water quality mapping around Dhaka city. www. assess_hkh.at/downloads/meeting5/session3_BD_river_quality_map_Badruzzaman.pdf

Ferdous Z, Akter S, Hasan M, Begum RA and Shahajahan RM 2012. Phytoplankton diversity and abundance in relation to pollution levels in the Hazaribagh tannery effluent sewage water of the river Buriganga. Bangladesh J. Zool. **40**(1): 121-128.

GOB 1993. Government of the People's Republic of Bangladesh. Water quality data of rivers Buriganga, Meghna, Balu, Sitalakhya, Jamuna (1981-90). Dept. Env. Dhaka. pp. 313.

Islam AKMN and Zaman KM 1975. Limnological studies of the River Buriganga. III. Biological aspect. J. Asiatic Soc. Bangladesh (Sci.) **I**(1): 45-65.

Islam AKMN, Haroon AKY and Zaman KM 1974. Limnological studies of the River Buriganga. I. Physical and chemical aspects. Dhaka Univ. Stud. B, **22**(2): 99-111.

Islam and Moniruzzaman 2011. Limnology of one of the worst affected rivers in Bangladesh: Phytoplankton diversity, its seasonality and pollution status in one of the affected river in Bangladesh. Lap. Lambert Acad. Publ. pp. 180.

Islam AKMN and Zaman KM 1975. Limnological studies of the river Buriganga III. Biological aspect. J. Asiatic Soc. Bangladesh (Sc.). **1**(1): 45-65.

Khondker M and Abed G 2013. Seasonality of phytoplankton productivity of the River Turag of Dhaka in relation to its water quality. Bangladesh J. Bot. **42**(2): 287-294.

Rahman SA 2012. Dhaka in the eyes of painters 1789-1947. Prathama Prakashani. Dhaka, Bangladesh. pp. 140.

Rahman S and Hossain F 2008. Spatial assessment of water quality in peripheral rivers of Dhaka city for optimal relocation of water intake point. Wat. Res. Mang. **22**: 377-391.DOI10.1007/s11269-007-9167-y.

Raknuzzaman M 2006. Comparative studies on physico-chemical variables and zooplankton abundances in polluted waters of Buriganga river. Thre CDR J. **1**(2): 99-106.

Rashid HER 1991. Geography of Bangladesh. 2nd Edn. Univ. Press Ltd. Dhaka. pp. 364.

Saifullah ASM, Kabir MH, Khatun A, Roy S and Sheikh MS 2012. Investigation of some water quality parameters of the Buriganga river. J. Env. Sci. Nat. Res. **5**(2): 47-52.

Sarkar M, Rahman AKM, Islam JB, Ahmed KS, Uddin MN and Boumik NC 2015. Study of hydrochemistry and pollution status of the Buriganga river, Bangladesh. Bangladesh J. Sci. Ind. Res. **50**(2): 123-1334.

Welch PS 1948. Limnological Methods. McGraw-Hill Book Co. Inc., New York. pp. 381.

Wetzel RG and Likens GE 1979. Limnological analysis. WB Saunders Co., Philadelphia. pp. 357.

Clarke KR, Gorley RN 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth, U.K. pp. 190.

Zerin L 1995. Potamoplankton of River Buriganga near Dhaka metropolis, its seasonality and primary productivity. M.Sc. thesis. Unpupl. Dept. Bot., Univ. Dhaka. pp. 74.

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