

LIMNOLOGY OF A CONSERVED MAN-MADE LAKE IN BANGLADESH. I. PHYSICAL AND CHEMICAL FACTORS

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Abstract

Limnological investigation on a conserved man-made lake located in the Safipur Ansar and VDP Academy, Gazipur district has been carried out between July, 2008 and May, 2009. Thirteen limnological parameters were measured mostly at fortnight intervals and their annual and seasonal fluctuations were observed. The lake water was slightly alkaline in nature having a monthly mean pH range 7.26 - 7.91. The water temperature varied from 18 - 32°C. Soluble reactive phosphorus, soluble reactive silicate and nitrate nitrogen ranged from 9.22 - 154.57 µg/l, 2.52 - 17.06 and 0.17 - 187 mg/l, respectively.

Introduction

Conservation of freshwater resources has now become an issue of global concern because water is one of the vital resources to the modern society. Bangladesh, because of its geographical location holds adequate reserves of freshwater but due to excessive population pressure very few of her water bodies retain good water quality and aquatic biodiversity. A number of limnological investigations have been carried out in some man-made lakes situated in and around Dhaka metropolis⁽¹⁻⁴⁾ to evaluate their water quality and biodiversity. Urban based man-made lakes are usually created for meeting the demands of emergency water supply and to fulfil aesthetic and environmental needs. Most of these created lake waters are abused so strongly by dumping solid wastes, discharging waste water and sewages that hardly any emergency water requirement need can be met with this water. On the other hand, those water bodies could not be enjoyed as a place for human recreation. A conservation strategy is usually suggested for the reclamation of those lakes.

Man-made lakes are vulnerable towards the disposal of organic matter and sewage inflows which makes the lake water very rich in organic matter and to support a luxuriant algal bloom almost all over the year. This nuisance actually hampers the main goal of creating such a water body. Beyond this, a very few man-made lakes are protected against this kind of contamination through strong administrative measures. Limnology in respect to the water quality, phytoplankton quality and quantity and terminal production must be different in these two categories of man-made lakes.

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The present lake, in concern, is situated in the Safipur Ansar and VDP Academy in Gazipur district. The lake has been created to increase the beauty of the locality and also for meeting the needs of emergency water supply. The lake is conserved against any external input of pollutants and to keep its water free of hazardous elements. Routine aquaculture is also being practiced in the lake water. The aim of the present research is to study the diversity of phytoplankton and limnology of such a conserved lake.

Materials and Methods

The studied lake is situated 30 km north east of Dhaka Metropolis within the campus of Bangladesh Ansar and VDP Academy, Gazipur district. The geolocation being 24°00' - 24°15' N and 90°15' - 90°30' E. The lake was excavated in 1985 on agricultural land. Its area is 1.25 ha and the depth ranged from 2.0 - 2.5 m. It is perennial and rain fed. A permanent station was set up for carrying out routine sampling. The sampling was done mostly at 15 days interval between July, 2008 and May, 2009 and altogether a total of 23 samples were collected. On each sampling occasion the lake was reached around 09:00 a.m. and the sampling began from the fixed station. Air and water temperature was measured with the help of a graduated mercury centigrade thermometer. From 10 cm depth 5 liter water sample was collected by a black canister. Duplicate BOD bottles (125 ml cap.) was filled by the same water and fixed *in situ* by adding each of 1 ml of manganous sulfate and Winkler's reagent. pH, TDS and conductivity of water was measured *in situ* (Griffin pH meter, Model-50, UK; Hanna HI 9034, Hanna, HI 9033, Singapore). All the collected and fixed samples were transported to the Hydrobiology and Limnology Laboratory, Department of Botany, University of Dhaka within the next one and half an hour.

Two hundred fifty ml well mixed sample water was filtered through a Sartorius filtration device using a vacuum pump and Whatman GF/C filter paper (circle dia. 47 mm). After filtration the filtrate was used for nutrient analysis. Sub-samples of filtrate were used to determine SRP, SRS and NO₃-N⁽⁵⁻⁷⁾. Alkalinity was determined by using unfiltered sample⁽⁸⁾ and DO by using the samples fixed *in situ*⁽⁶⁾. Monthly data were pulled to mean values and plotted (Fig. 1A-F).

Results and Discussion

All physicochemical data measured in the present investigation have been presented in Table 1 and Fig. 1. Air and water temperature ranged from 17.5 - 33.5 and 18 - 32°C, respectively. pH of water ranged from 7.26 - 7.91, conductivity from 106.75 - 372.00 µS/cm and TDS from 55.00 - 114.75 mg/l. Whereas, the alkalinity ranged from 1.25 - 4.10 meq/l and DO from 4.98 - 9.66 mg/l (Table 1). The SRP and NO₃-N concentrations in the beginning of the study i.e, July, 2008 were very high, 154.57µg/l and 187.54 mg/l, respectively (Table 1). Without this exceptional concentration, SRP showed a fluctuating

trend from 5.12 - 31.71 µg/l. NO₃-N concentrations in the lake water were always in the lowermost ranged from 0.02 - 0.58 mg/l. Silicate concentration ranged from 2.52 - 17.06 mg/l.

The lake is almost free from any external pollution sources except via precipitation and seepage. The lake was not previously investigated limnologically. So, the present limnological investigation highlights some of the water quality parameters in the lake for the first time.

Table. 1. Physical and chemical variables of the water sample.

Month		Air temp. (°C)	Water temp. (°C)	pH	Cond. (µS/cm)	TDS (mg/l)	Alkalinity (meq/l)	DO (mg/l)	SRP (µg/l)	SRS (mg/l)	NO ₃ -N (mg/l)
July 2008	A	29.00	28.00	nd	372.00	62.00	1.50	8.13	31.71	16.88	*187.54
	B	29.00	28.50	nd	221.00	73.00	1.35	7.22	18.71	14.16	0.27
	C	28.50	27.00	nd	150.00	70.50	1.30	4.98	*154.57	13.08	0.00
Aug. 2008	A	28.00	26.50	7.58	153.00	71.50	3.00	9.66	9.22	12.54	0.39
	B	24.00	23.00	7.48	162.25	76.25	1.45	5.69	7.41	14.28	0.02
Sept. 2008	A	24.00	23.00	7.46	136.33	64.25	1.60	7.42	9.48	12.64	0.07
	B	22.00	21.00	7.26	128.63	60.75	1.75	5.59	19.87	15.40	0.04
Oct. 2008	A	22.50	21.00	7.51	128.00	61.25	1.60	6.61	0.00	13.24	0.10
	B	21.00	20.00	7.37	106.75	55.00	1.60	8.84	17.92	13.20	0.10
Nov. 2008	A	22.50	20.00	7.72	115.25	60.50	1.80	8.03	12.98	10.61	0.12
	B	18.00	19.50	7.48	123.00	66.25	1.50	7.72	13.34	10.46	0.08
Dec. 2008	A	18.00	19.00	7.89	116.5	61.50	1.40	7.22	5.89	9.60	0.14
	B	17.00	18.50	7.71	117.50	61.25	1.25	8.13	6.10	10.69	0.00
Jan. 2009	A	17.00	18.00	7.91	115.00	62.00	1.70	8.13	7.11	11.04	0.10
	B	20.00	20.00	7.79	128.50	69.50	1.45	7.42	6.87	15.51	0.09
Feb. 2009	A	20.50	22.00	7.26	141.00	86.00	2.30	7.83	13.89	17.06	0.15
	B	25.50	24.50	7.34	153.50	95.75	1.80	7.01	6.94	15.25	0.17
Mar. 2009	A	28.00	26.50	7.31	166.75	95.00	1.90	7.52	5.12	12.02	0.42
	B	30.00	28.00	7.60	189.25	104.75	2.00	5.38	7.70	8.31	0.33
Apr. 2009	A	30.50	29.00	7.86	214.75	114.75	2.10	6.61	0.00	6.01	0.13
	B	30.50	29.00	7.61	199.5	109.25	2.20	5.69	15.61	2.52	0.23
May 2009	A	32.00	30.00	7.90	210.50	108.25	4.10	7.22	5.74	5.61	0.06
	B	33.50	32.00	7.80	192.25	97.00	3.80	5.99	9.87	6.54	0.07
Mean value		24.83	24.09	7.59	162.65	77.66	1.93	7.13	10.52	11.59	0.14

*Values not included in the annual mean calculation. (A = 1st fortnight, B/C = 2nd fortnight, n = 23), nd = not determined.

This lake is shallow in nature ($Z_{\max} = 2.0 - 2.5$ m) and in Bangladesh thermal stratification is not possible with a water depth lesser than 10 m⁽⁹⁾. So, it indicates that the principle of wind induced mixing in shallow water is strictly working here. Regarding surface water temperature it followed the general seasonal pattern i.e. lower water

temperature during the winter month (December 18.75°C) which is usual for other man-made lakes so far studied in Bangladesh i.e., ~20°C⁽¹⁰⁻¹²⁾. Annual mean water temperature is also closer to other man-made lakes of Bangladesh (Table 4).

Table 2. Monthly mean values of different limnological parameters from the lake.**

Parameters	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Air temp. (°C)	28.83	26	23	21.75	20.25	17.50	18.5	23	29	30.5	32.75
Water temp. (°C)	22.83	24.75	22	20.5	19.75	18.75	19.00	23.25	27.25	29.00	31.00
pH	nd	7.53	7.36	7.44	7.60	7.80	7.85	7.30	7.46	7.74	7.85
Cond (µS/cm)	247.67	157.63	132.48	117.38	119.13	116.88	121.75	147.25	178.00	207.13	210.38
TDS (mg/l)	68.5	73.88	62.5	58.13	63.38	61.38	65.75	90.86	99.88	112.00	102.63
Alkal. (meq/l)	1.38	2.22	1.68	1.60	1.65	1.33	1.58	2.05	1.95	2.15	3.95
DO (mg/l)	6.78	7.68	6.51	7.73	7.88	7.68	7.78	7.42	6.45	6.15	6.61
SRP (µg/l)	*25.21	8.32	14.67	8.96	13.16	5.99	6.99	10.42	6.41	7.81	7.81
SRS (mg/l)	14.70	13.41	14.02	13.22	10.54	10.15	13.28	16.16	10.27	4.27	6.08

** (n = 2, except July, 2008, where n = 3), nd = Not determined.

Table 3. Average value of different limnological parameters in four distinct seasons of Bangladesh.

Parameters	Unit	Winter (Late November- February)	Summer (March - May)	Monsoon (June - Early October)	Autumn (Late October - early November)
Air temp.	(°C)	19.42 ± 3.00	30.08 ± 1.86	25.88 ± 3.03	21.75 ± 1.06
Water temp.	(°C)	20.22 ± 2.28	29.08 ± 1.86	24.75 ± 3.09	20.0 ± 0
pH		7.62 ± 0.26	7.86 ± 0.22	7.46 ± 0.12	7.54 ± 0.25
Conductivity	µS/cm	127.82 ± 14.5	195.5 ± 17.2	181.40 ± 81.6	111 ± 6.01
TDS	mg/l	71.75 ± 13.69	104.83 ± 7.58	67.44 ± 6.06	57.75 ± 3.89
Alkalinity	meq/l	1.63 ± 0.35	2.68 ± 0.99	1.69 ± 0.55	1.7 ± 0.14
DO	mg/l	7.63 ± 0.44	6.49 ± 0.86	6.91 ± 1.53	8.44 ± 0.57
SRP	µg/l	8.59 ± 3.46	7.34 ± 5.22	*13.78 ± 1.52	15.45 ± 3.49
SRS	mg/l	12.80 ± 3.02	6.84 ± 3.16	14.03 ± 1.49	11.91 ± 1.83
NO ₃ -N	mg/l	0.11 ± 0.06	0.21 ± 0.15	*0.14 ± 0.06	0.11 ± 0.02

The range of variation in pH was from 7.25 - 7.90. Similar narrow fluctuation has also been recorded by Khondker and Parveen⁽²⁾ and Kabir⁽⁹⁾. The average pH value is approximately near about to that recorded for Dhanmondi lake, Banani lake and Gulshan lake^(11,13,14). Mean annual pH of the present lake (7.59) is similar to that recorded for Dhanmondi lake (7.58). Slightly lower value was recorded for Banani and Gulshan lake (Table 4). Annual mean pH 7.59 ± 0.22 qualifies the water as slightly alkaline in nature. This is quite normal for most surface waters of Bangladesh with a few exceptions (Table 4).

The annual average conductivity of this lake showed a minimal value (162.65 $\mu\text{S}/\text{cm}$) than Dhanmondi lake (565.42 $\mu\text{S}/\text{cm}$), Gulshan lake (196.1 $\mu\text{S}/\text{cm}$) and Banani lake (337.23 $\mu\text{S}/\text{cm}$) (340.10 $\mu\text{S}/\text{cm}$).^(2,11,14) The conductivity value of this lake is closer to Crescent lake (158.57 $\mu\text{S}/\text{cm}$) and Gulshan lake (196.1 $\mu\text{S}/\text{cm}$) (Table 4). In the present investigation the highest conductivity value was obtained in summer (Table 3), which indicates that the highest free ionic load occurs during this period. This may be a result of crucial breakdown of organic and inorganic matters in the water body and this was followed by high phytoplankton densities in dry months.

Table 4. A comparative limnology of different man-made lakes (data indicate average value).

Parameters	Unit	Present investigation (n = 23)	DL (Khondker and Rahim 1990) (n = 22)	CL (Mukhtar 1993) (n = 22)	BL (Rahman 1993) (n = 22)	GL (Chowdhury 1993) (n = 22)
Water temp.	$^{\circ}\text{C}$	24.09	28.48	27.19	25.87	26.32
pH		7.59	7.58	9.14	7.30	7.40
Conductivity	$\mu\text{S}/\text{cm}$	162.65	565.42	158.57	337.23	196.1
TDS	mg/l	77.66	-	-	-	-
Alkalinity	meq/l	1.93	3.62	1.09	2.25	1.28
DO	mg/l	7.13	11.57	14.16	3.91	5.04
SRP	$\mu\text{g}/\text{l}$	10.52*	780	370	390	47.34
SRS	mg/l	11.59	30.55	42.61	33.68	24.16
$\text{NO}_3\text{-N}$	mg/l	0.138*	0.21	0.73	0.008	0.23

SL = Safipur Lake, Safipur Anser VDP Academy, Safipur, Gajipur, Dhaka; DL = Dhanmondi Lake, Dhaka (Hyper-eutrophic); CL = Crescent Lake, Sher-E-Bangla Nagar, Dhaka (Mesotrophic); BL= Banani Lake, Dhaka; GL = Gulshan Lake, Dhaka. *Mean has been calculated excluding the value of one very high record.

TDS load in the pelagic water of this lake varied from 55.00 - 114.75 mg/l (Table 1). The data could not be compared with other man-made lakes because of its absence in them. However, a study from some pond ecosystems of the southern part of Bangladesh indicates a range of 5.13 - 2165 mg/l ⁽¹⁵⁾ for this parameter. Compared to this result the TDS load of the present lake shows a lower scale.

Table 4 depicts the comparative analyses of alkalinity values from different other man-made lakes of Bangladesh. In this comparison the annual mean alkalinity fall in a third highest category compared to Dhanmondi and Banani lake (Table 4). Alkalinity values of two other lakes, namely Crescent and Gulshan lake are lower than the present lake (Table 4).

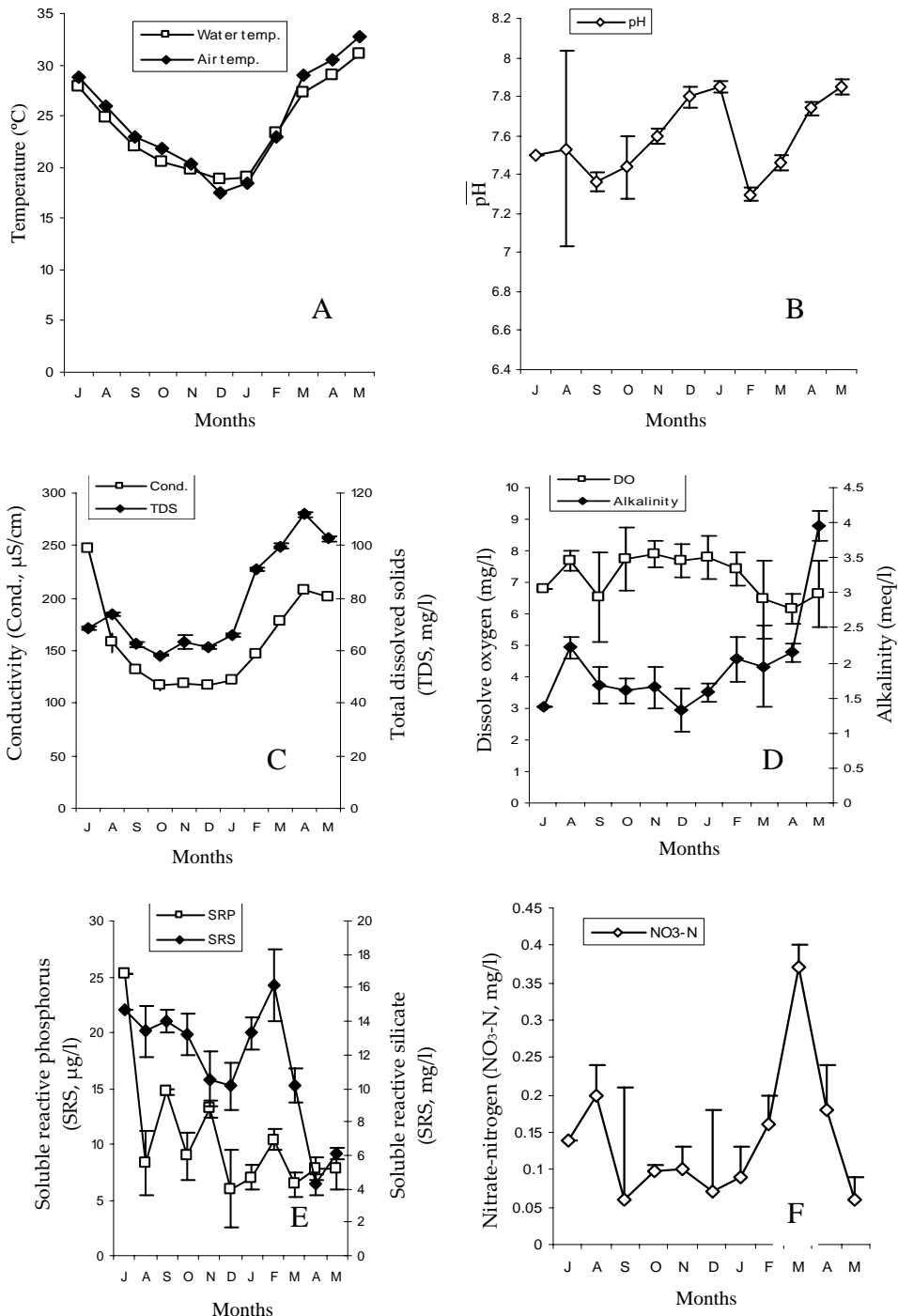


Fig. 1A-F: Monthly fluctuation of different physicochemical factors of the lake. A. Water and air temperature. B. pH. C. Conductivity and total dissolved solids. D. Dissolved oxygen and alkalinity. E. Soluble reactive phosphorus and soluble reactive silicate. F. Nitrate-nitrogen.

There is not very high fluctuations in the concentration of dissolved oxygen (DO) content in the lake, which might be due to temperature, rainfall, absence of macrophytes and the plankton population of the lake. Lower oxygen content (4.98 mg/l) was obtained in monsoon and this value is near about two-fold less than the highest value. The annual average DO of the lake is 7.13 mg /l, which is half compared to Crescent lake and less than Dhanmondi lake⁽²⁾ but greater than Banani and Gulshan lake (Table 4). Extremely low value as indicated in the Gulshan and Banani lake (3.91 - 5.40 mg/l) and high value as indicated in Dhanmondi and Crescent lake (11.57 - 14.16 mg/l) are all indicators of eutrophicated water. The mean DO (7.13 mg/l) as recorded in the present investigation indicates a good water quality.

The highest concentration of soluble reactive phosphorus (SRP) was measured in monsoon and lowest in summer (Table 3). The average SRP concentration in the lake was 10.52 µg/l. SRP concentration reported for some eutrophic lakes of other regions, namely Suraha lake⁽¹⁶⁾, reservoir and lakes of south Holland⁽¹⁷⁾ are 60, 90 and 500 µg/l, respectively. Compared to these water bodies the SRP concentration is much lower. Annual mean phosphorus concentration of some man-made lakes of Bangladesh, namely Dhanmondi, Crescent and Banani lakes show values of 780, 370 and 390 µg/l. These are also very high values compared to Safipur lake (10.52 µg/l). Since phosphorus is considered to be a key nutrient to trigger phytoplankton biomass so, in terms of mean SRP concentration the present lake shows a better water quality. A very high SRP was recorded in July which might have resulted because of lake fertilization for aquaculture.

The silicate content of Safipur lake is the lowest compared to all other studies carried out on man-made lakes in Bangladesh (Table 4). Actually silica metabolism is associated with diatom population. According to Welch⁽¹⁸⁾ much of the dissolved silicate becomes utilized by diatoms resulting in the lower concentration of silicate in water. The present lake is very poor in diatom population, Bacillariophyceae was represented by 5.75% of the total population.

Very low seasonal fluctuation of nitrate (NO₃-N) was observed in the selected lake of Safipur except the value of 3 July, 2008. Table 4 shows a comparative analysis of this data with some other man-made lakes. The mean nitrate concentration for most of the periods for Safipur lake was much lower than Dhanmondi, Crescent and Gulshan lakes (Table 4). Banani lake has shown a very low mean nitrate concentration (0.008 mg/l). The extremely high value for Safipur lake which was recorded in July, 2008 might be due to fertilization of the lake for aquaculture. A moderate effect of temperature on the nitrate (NO₃-N) content was found in the mean seasonal value (Table 4).

The present limnological study on Safipur lake shows a good water quality of the lake as it has been indicated by annual mean values of some key limnological parameters such as water temperature (24.9°C), pH (7.59), alkalinity (1.93 meq/l), DO

Table 5. Matrix of product moment correlation coefficient (r) among different physico-chemical and biological variables recorded from the sampling station.

		Water temp.	pH	Conductivity	TDS	Alkalinity	DO	SRP	SRS	NO ₃ -N
Water temp.	Pearson correlation	1.000	0.108	0.898	0.802	0.673	-0.784	0.262	-0.480	0.302
	Sig. (2-tailed)	.	0.766	0.000	0.003	0.023	0.004	0.436	0.135	0.367
	N	11	10	11	11	11	11	11	11	11
pH	Pearson correlation	0.108	1.000	0.200	0.130	0.284	0.023	-0.550	-0.649	-0.327
	Sig. (2-tailed)	0.766	.	0.580	0.721	0.426	0.949	.099	0.042	0.357
	N	10	10	10	10	10	10	10	10	10
Conductivity	Pearson correlation	0.898	.200	1.000	0.589	0.361	-0.704	0.622	-0.294	0.666
	Sig. (2-tailed)	0.000	0.580	.	0.056	0.276	0.016	0.041	0.381	0.025
	N	11	10	11	11	11	11	11	11	11
TDS	Pearson correlation	0.802	0.130	0.589	1.000	0.652	-0.683	-0.212	-0.619	-0.161
	Sig. (2-tailed)	0.003	0.721	0.056	.	0.030	0.021	0.531	0.042	0.637
	N	11	10	11	11	11	11	11	11	11
Alkalinity	Pearson correlation	0.673	0.284	0.361	0.652	1.000	-0.362	-0.283	-0.522	-0.265
	Sig. (2-tailed)	0.023	0.426	0.276	0.030	.	0.273	0.399	0.100	0.431
	N	11	10	11	11	11	11	11	11	11
DO	Pearson correlation	-0.784	0.023	-0.704	-0.683	-0.362	1.000	-0.186	0.467	-0.192
	Sig. (2-tailed)	0.004	0.949	0.016	0.021	0.273	.	0.584	0.147	0.573
	N	11	10	11	11	11	11	11	11	11
SRP	Pearson correlation	0.262	-0.550	0.622	-0.212	-0.283	-0.186	1.000	0.343	0.988
	Sig. (2-tailed)	0.436	0.099	0.041	0.531	0.399	0.584	.	0.302	0.000
	N	11	10	11	11	11	11	11	11	11
SRS	Pearson correlation	-0.480	-0.649	-0.294	-0.619	-0.522	0.467	0.343	1.000	0.295
	Sig. (2-tailed)	0.135	0.042	0.381	0.042	0.100	0.147	0.302	.	0.379
	N	11	10	11	11	11	11	11	11	11
NO ₃ -N	Pearson correlation	0.302	-0.327	0.666	-0.161	-0.265	-0.192	0.988	0.295	1.000
	Sig. (2-tailed)	0.367	0.357	0.025	0.637	0.431	0.573	0.000	0.379	.
	N	11	10	11	11	11	11	11	11	11
Chl-a	Pearson correlation	0.728	0.322	0.473	0.953	0.720	-0.662	-0.347	-0.789	-0.298
	Sig. (2-tailed)	0.011	0.364	0.141	0.000	0.012	0.027	0.296	0.004	0.374
	N	11	10	11	11	11	11	11	11	11
Phaeo-pigment	Pearson correlation	0.782	0.440	0.549	0.711	0.902	-0.562	-0.132	-0.741	-0.098
	Sig. (2-tailed)	0.004	0.203	0.080	0.014	0.000	0.072	0.698	0.009	0.775
	N	11	10	11	11	11	11	11	11	11
Phyto-plankton	Pearson correlation	0.714	0.480	0.489	0.773	0.836	-0.572	-0.217	-0.799	-0.185
	Sig. (2-tailed)	0.014	0.160	0.127	0.005	0.001	0.066	0.522	0.003	0.586
	N	11	10	11	11	11	11	11	11	11

(7.13 mg/l), conductivity (162.65 μ S/l), TDS (77.55 mg/l), SRP (10.52 μ g/l), SRS (11.59 mg/l), NO₃-N (0.14 mg/l). After comparison of the collected data with other man-made

lakes, it could be said that Safipur lake is not eutrophicated. Its water is not sufficiently enriched with nutrients. N and P fertilization has been practiced in the lake one time throughout the year which enhanced plankton for purely a temporary basis. Because of heavy grazing by stocked planktivorous fishes such as silver carp, common carp and tilapia macro-plankton are mostly eliminated and for this reason the lake's phytoplankton population is purely a micro-plankton dominated one. Results of the correlation analysis also support the dependency of phytoplankton biomass on water temperature, pH and conductivity. Because of high population density (~800 ind/km²) and an extensive agricultural practice the allochthonous nutrient input in most surface water of Bangladesh is a common phenomenon. This process deteriorates water quality very quickly and makes those unsuitable for human use. However, if the water bodies are managed properly and conserved against all sorts of nutrient input of anthropogenic origin, eutrophication could be easily controlled.

Multiple correlation analysis was done among the recorded variables versus (vs) phytoplankton show significant positive correlation with water temperature, pH, conductivity, TDS, and alkalinity. On the other hand it showed a negative correlation with DO, SRP, SRS and NO₃-N (Table 5). The levels of significance varied from 1-5% level in the analysis.

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