ISSN 1022-8594
JUJS

Vol. 40, No. 2, pp.111-124

Phytoplankton Assemblage in Relation to Water Quality of the Wetland at National Monument of Bangladesh

A. K. M. Rashidul Alam
Department of Environmental Sciences, Jahangirnagar University, Dhaka 1342, Bangladesh

Abstract

Phytoplankton assemblage in relation to physical and chemical characteristics of water in wetland at National Monument of Bangladesh was assessed during March 2005 – January 2006. The sampling was performed during pre-monsoon (March – May), monsoon (July – September) and post-monsoon (November – January) seasons. Phytoplanktons in the wetland represented 69 identified taxa belonging to 4 major classes – Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae. On an average, Phytoplankton flora was dominated by Chlorophyceae (33.33%), followed by Bacillariophyceae (32.67%), Cyanophyceae (25.55%) and Euglenophyceae (8.47%). The average values of TDS, EC, pH, DO, BOD_5, nitrate-N, ammonium-N and dissolved-P in water were 68.25 mg/L, 75.75 µS/cm, 6.77, 7.5 mg/L, 8.67 mg/L, 3.79 mg/L, 5.64 mg/L and 62.48 mg/L, respectively. Chlorophyceae showed positive correlation with ammonium-N ($r = 0.719$). Bacillariophyceae and Cyanophyceae showed strong positive correlation with dissolved-P ($r = 0.904$) and ammonium-N ($r = 0.812$), respectively. Euglenophyceae exhibited similar correlation with pH ($r = 0.957$), DO ($r = 0.928$) and ammonium-N ($r = 0.823$) of water. Shannon-Weaver's diversity index H' ranged between 3.17 and 3.85 suggests clean water of the wetland.

Keywords: Phytoplankton, Shannon-Weaver's diversity index, Pollution, Water, Wetland, National Monument, Bangladesh.

Introduction

The growth and development of aquatic plants i.e. hydrophytes and phytoplankton are dependent on soil nutrient status, water quality i.e. physical and chemical natures and other meteorological and environmental factors [1]. The hydrogen ion concentration i.e. pH of water is one of the most important parameters for the aquatic ecosystem. The optimum pH range for aquatic life varied from 6.8 to 9.0 [2]. High value of water pH was due to blooming periods of phytoplankton [3]. Any alteration in water pH is accompanied by the changes in other physical and chemical

E-mail of correspondence: akmrashidulalam@yahoo.com

parameters. In aquatic ecosystem higher pH was generally found in summer and was closely correlated with the phytoplankton growth [4].

Nitrogen is one of the most important elements in aquatic ecosystem and together with phosphorus it is the most production stimulating nutrient [5,6]. When the blooms of *Microcystis* were observed in summer months, the values of nitrate-N were low in comparison to those of other seasons [7]. Significant correlation of nitrate-N with phytoplankton abundance was found in lagoons of Bangladesh [8]. Phosphorus plays an important role on the growth and abundance of phytoplankton [9]. The concentration of phosphorus was more during summer when the blooms of *Microcystis* were observed and the concentration of phosphorus and phytoplankton density were directly related with nitrate [10]. Blue-green algae increased their population even when nitrate and phosphorus were low. The abundance of diatoms in the ponds was found at higher concentrations of phosphorus, and diatoms showed their abundance in early summer periods when the concentration of phosphorus was low in comparison to those of rainy season [11,12].

The algae are reliable indicators of water pollution [11,12,13]. The alga like *Microcystis aeruginosa* could be used as the best single indicator of pollution and was associated with the highest degree of civic pollution [14]. In a wetland of greater Dhaka district, *Microcystis aeruginosa* grew with alkaline pH (7.73) of water during summer. Blue-green algae increased when the ammonium-N was high. Euglenoids showed abundance in a wetland where the amount of water soluble phosphorus was recorded to be in trace amount [15].

Diversity indices are used in water pollution research to evaluate impacts of pollution on species assemblages [16]. Alterations in environmental factors change diversity index [1]. A high value of diversity index suggests a good ecosystem health and a low diversity value indicates a less healthy or a degraded ecosystem [17,18]. With these backgrounds, this study was undertaken in order to investigate the phytoplankton assemblages in relation to physical and chemical characteristics of water in the wetland located nationally significant area i.e. the National Martyr's Memorial of Bangladesh, and to assess the status of pollution based on phytoplankton diversity index.

Methods and Materials

Study sites

The wetland located the National Martyr's Memorial of Bangladesh was selected for the investigation. The wetland was divided into four stations and designated as: station A = wetland of North-East corner of the monument, station B = wetland of South-East corner of the monument, station C = wetland of South-West corner of the monument and station D = wetland of North-West corner of the monument (Figure 1). The water characteristics of wetland was studied for three seasons namely pre-monsoon (March – May), monsoon (July – September) and post-monsoon (November – January) during March 2005 – January 2006.

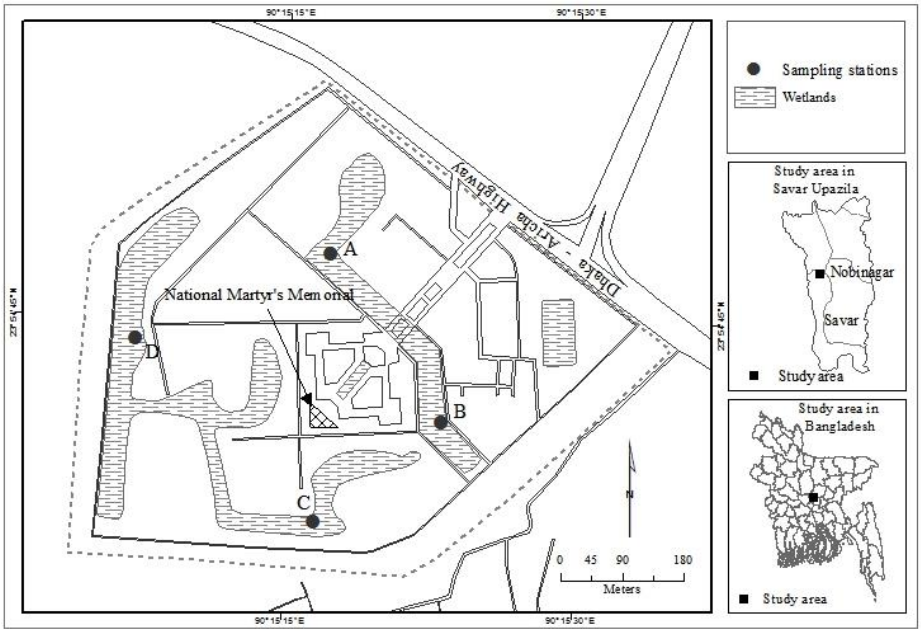

Figure 1. Map showing the sampling stations (A, B, C and D) located in wetland of the National Martyr's Memorial of Bangladesh.

Collection of water samples

To have a representative sample, 1.5 liter water sample was collected from each of the four stations of the wetland and all were mixed together. From

this composite sample 1 liter sample was fixed in Lugol's iodine solution in a glass bottle for phytoplankton sedimentation. Another 1 liter sample was acidified with HCl and used for the determination of nutrient parameters. However, fresh samples (unacidified) were used to determine water pH.

Analysis of phytoplankton

After sedimentation of plankton, water of the bottles was sucked out carefully keeping the sedimented layer of plankton undisturbed and the final volume was adjusted to 20 ml. For qualitative analysis, the plankton concentrate was observed under a compound microscope (Olympus CH-2) on a glass slide. For quantitative analysis, 1 ml of well shaken plankton concentrate was taken in a standard Sedgewick Rafter Counting Cell (SRCC; Model 50, Graticules Limited) and counted following the method of Boyd [19]. The phytoplankton specimens were identified at least up to generic level by consulting national and international literatures [20,21,22,23,24,25].

Determination of physical and chemical characteristics of water

Total dissolved solids (TDS) content of water were determined by gravimetric method. The pH of water was determined using a glass electrode pH meter (Griffin pH meter, Model No. 40). Electric conductivity (EC) of water was determined by EC meter (Bonnet 1, HI3291, ATC-Conductivity Probe). Biochemical oxygen demand (BOD_5) of water was measured by Winkler method [26]. Nitrate-N and Ammonium-N content of water were determined by Micro-kjeldhal distillation method as described by Jackson [27]. The water soluble phosphorus content was determined by ascorbic acid blue colour method [28].

Data Analysis

Evaluation of Shannon-Weaver's diversity index for phytoplankton assemblages

Phytoplankton assemblage was evaluated using Shannon-Weaver's diversity index [1]: $H' = -\sum (ni / N) \ln (ni / N)$, where ni = the abundance of phytoplankton species i, N = total number of individuals in phytoplankton community and ln = natural log. Shannon-Weaver's

diversity indices were calculated for phytoplankton assemblages in pre-monsoon, monsoon and post-monsoon seasons. The maximum diversity of a community occurs when available species are equally abundant or contribute equally to the total number of individuals. Maximum diversity is calculated using $H_{max} = \ln S$, where S = species richness. The evenness (E) of phytoplankton communities was calculated by comparing the actual diversity to the maximum diversity [1]: $E = H' / H_{max}$, where $H_{max} = \ln S$. The value of evenness ranges from 0 to 1 and the closer of the value to 1 is the more even distribution of phytoplankton [29].

Evaluation of the degree of pollution based on species diversity index

A relationship was proposed between species diversity and pollution status of a wetland as species diversity value > 3 = clean, 1 – 3 = moderately polluted and < 1 = heavily polluted [30]. In this study, the status of pollution for pre-monsoon, monsoon and post-monsoon seasons was evaluated based on Shannon-Weaver's diversity indices following Wilham and Dorris [30].

Statistical Analysis

Pearson correlation matrix [31] was used to measure the degree of linear relationship between phytoplankton assemblage and physicochemical characteristics of water.

Results and Discussion

Phytoplankton assemblages

Phytoplankton flora in the wetland of national monument area of Bangladesh represented 69 identified taxa belonging to 4 major classes i.e. Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae. Among phytoplankton Chlorophyceae was the most dominant group with 27 taxa, followed by Bacillariophyceae 25 taxa, Cyanophyceae with 15 taxa and Euglenophyceae with 2 taxa only. The dominant phytoplankton during pre-monsoon, monsoon and post monsoon in the wetland is mentioned in Table 1. The percentage composition of phytoplankton in wetland of national monument area during March 2005 – January 2006 is presented in Figure 2. In pre-monsoon, phytoplankton flora was dominated by Chlorophyceae (44.75%), followed by Cyanophyceae (30.57%),

Bacillariophyceae (18.38%) and Euglenophyceae (6.3%). In monsoon, Chlorophyceae was the most abundant class (33.29%). In post monsoon, the dominant phytoplankton in the wetland was Bacillariophyceae (54.45%), followed by Chlorophyceae (21.96%), Cyanophyceae (19.64%), and Euglenophyceae (3.95%). Nutrient enrichment along with seasonal fluctuations of abiotic variables in a wetland may influence the abundance of phytoplankton flora in different seasons [32,33].

Table 1: Dominant phytoplankton in wetland of National Monument during March 2005 – January 2006

Class	No. of Taxa	Dominant Taxa
Chlorophyceae	27	*Closterium toxon, Cosmarium depressum, Cylindrocystis brebisonii, Desmidium baileyi, Gonatozygon pilosum, Micrasterias alata, Pediastrum duplex, Scenedesmus acuminatus, Zygnema conspicuum,* etc.
Bacillariophyceae	25	*Eunotia, Fragilaria, Gomphonema, Melosira granulata, Navicula, Pinnularia, Synedra ulna,* etc.
Cyanophyceae	15	*Merismopedia, Microcystis areuginosa, Nostoc, Oscillatoria, Spirulina*, etc.
Euglenophyceae	2	*Euglena acus*

Phytoplankton assemblage varied spatiotemporally. In this study overall phytoplankton flora of the wetland of National Monument area of Bangladesh was dominated by Chlorophyceae (33.33%), followed by Bacillariophyceae (32.67%), Cyanophyceae (25.55%), and Euglenophyceae (8.47%). The dominance of Chlorophyceae, followed by Cyanophyceae > Bacillariophyceae > Euglenophyceae was reported [34] from which the present finding differs. Phytoplankton flora in wetlands of greater Dhaka district was dominated by Bacillariophyceae (40.81%) followed as Chlorophyceae (31.83%), Cyanophyceae (19.61%) and Euglenophyceae (7.75%) [35] from which the present findings showed

dissimilarity. In the wetland of Dhaka Export Processing Zone (DEPZ) that is located adjacent to the present study area, phytoplankton was dominated by Chlorophyceae (35.68%), followed by Bacillariophyceae (34.35%), Cyanophyceae (26.74%) and Euglenophyceae (3.21%) [36] to which the present finding corroborated. Phytoplankton composition in wetlands was dominated by Bacillariophyceae (39.81%), followed by Chlorophyceae (33.98%), Cyanophyceae (22.24%) and Euglenophyceae (3.96%) in both migratory birds visiting and non- visiting wetlands of Savar [37] to which the present finding showed similarity.

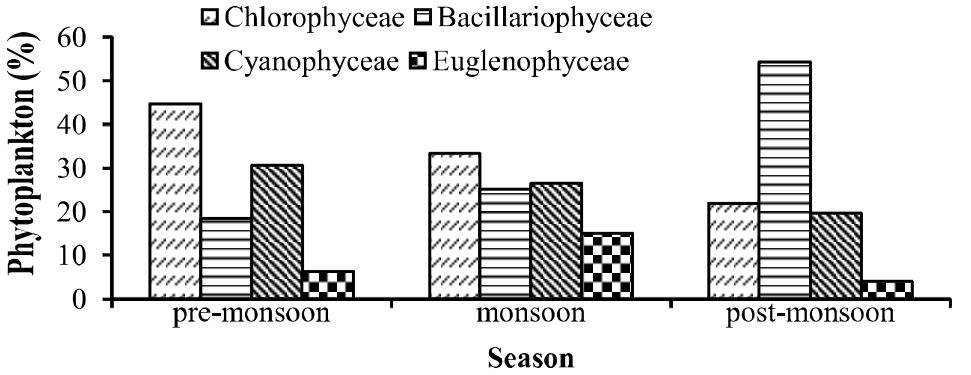

Figure 2: Percentage composition of phytoplankton in wetland located the National Martyr's Memorial of Bangladesh during March 2005 – January 2006.

Physical and chemical characteristics of water in the wetland of National Monument area during March 2005 – January 2006

Total dissolved solids (TDS) of water varied from 28 mg/L to 142 mg/L during three seasons at various stations of the wetland (Figure 3a). Average TDS was 90.5 mg/L, 59.75 mg/L and 54.5 mg/L during pre-monsoon, monsoon and post-monsoon seasons, respectively in the wetland. Electric conductivity (EC) ranged between 50 µS/cm and 120 µS/cm at different stations during the study period (Figure 3b). The average EC was 64.5 µS/cm, 88.5 µS/cm and 74.25 µs/cm during pre-monsoon, monsoon and post-monsoon seasons, respectively.

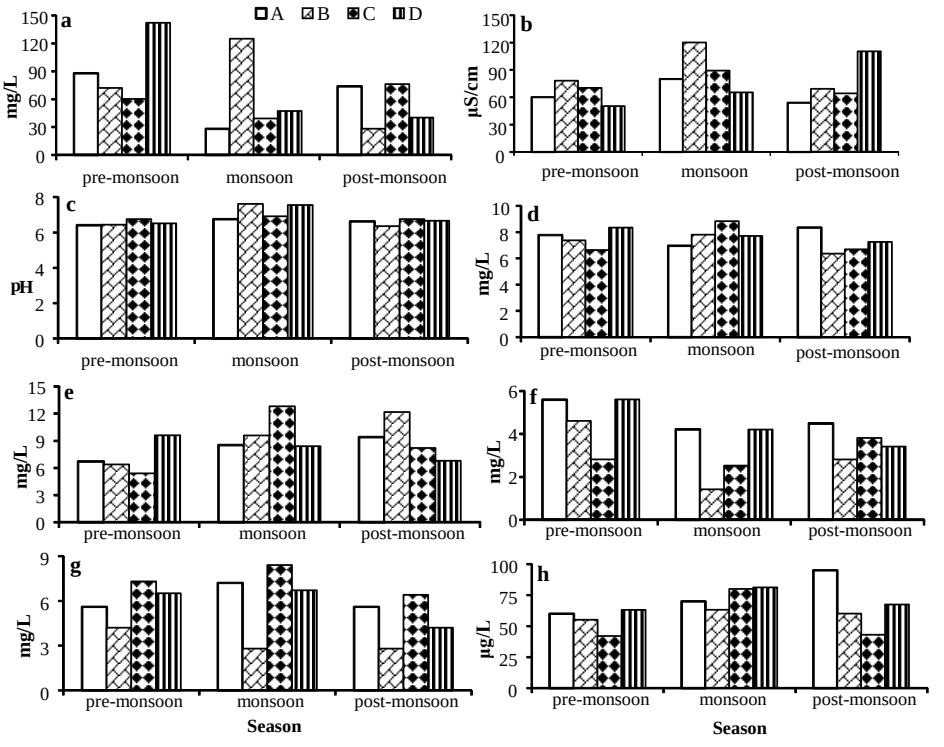

Figure 3: Seasonal physical and chemical characteristics of water in the wetland locating national monument area during March 2005 - January 2006 (a = total dissolved solids, b = electric conductivity, c = pH, d = dissolved oxygen (DO); e = biochemical oxygen demand (BOD_5); f = nitrate-N; g = ammonium-N and h = dissolved phosphorous); A, B, C and D are stations of the wetland.

The water pH ranged between 6.35 and 7.61 (Figure 3c). During monsoon the pH of water increased at all stations (6.75 – 7.61) in comparison to other seasons. Dissolved oxygen (DO) content of water ranged between 6.35 mg/L and 8.83 mg/L at four stations (Figure 3d). Average DO of water in the wetland were 7.52 mg/L, 7.82 mg/L and 7.15 mg/L during pre-monsoon, monsoon and post-monsoon seasons, respectively. Both the maximum and minimum amounts of biochemical oxygen demand (BOD_5) were recorded at station C during monsoon (12.8 mg/L) and pre-monsoon (5.4 mg/L), respectively (Figure 3e). Nitrate-N and ammonium-N content of water varied from 1.4 mg/L to 5.6 mg/L (Figure 3f) and 2.8 mg/L to 8.4

mg/L (Figure 3g), respectively in the studied wetland. Dissolved phosphorous ranged from 42 mg/L to 95 mg/L at various stations of the wetland (Figure 3h). The average dissolved-P during pre-monsoon, monsoon and post-monsoon were 55 mg/L, 73.56 mg/L and 58.88 mg/L, respectively.

Correlation between phytoplankton and physical and chemical properties of water

Phytoplankton assemblage varied from positive to negative along the gradients in physical and chemical properties of water [6, 38]. In this study, Chlorophyceae showed strong positive correlation with total dissolved solids (TDS) ($r = 0.927$) and ammonium-N ($r = 0.719$) (Table 2). Strong negative correlation of Chlorophyceae was recorded with BOD_5 ($r = – 0.728$) and dissolved-P ($r = –0.703$) content of water. Moderate positive correlation was reported for Chlorophyceae with DO ($r = 0.548$) and nitrate-N ($r = 0.643$). Bacillariophyceae showed a strong negative correlation with TDS ($r = – 0.743$), DO ($r = – 0.801$) and ammonium-N ($r = – 0.914$). Dissolved-P showed strong positive correlation ($r = 0.904$) with Bacillariophyceae. Moderate positive and moderate negative correlation was recorded for Bacillariophyceae with BOD_5 ($r = 0.450$) and nitrate-N ($r = – 0.342$), respectively. Ammonium-N showed strong negative correlation with Bacillariophyceae ($r = – 0.914$). Total dissolved solids (TDS) ($r = 0.863$) and ammonium-N ($r = 0.812$) were positively correlated with Cyanophyceae. Dissolved-P ($r = – 0.798$) had a strong negative correlation with Cyanophyceae i.e. the abundance of Cyanophyceae was inversely proportional with dissolved-P. Besides, moderately positive correlation was reported in the case of DO ($r = 0.663$) and nitrate-N ($r = 0.526$) with Cyanophyceae. Euglenophyceae showed strong positive correlation with EC ($r = 0.815$), pH ($r = 0.957$), DO ($r = 0.928$) and ammonium-N ($r = 0.823$) content of water. There was also strong negative correlation between Euglenophyceae and dissolved P ($r = – 0.836$). The degree of linear correlations between phytoplankton assemblages and TDS, EC, pH, DO, BOD_5, nitrate-N, ammonium-N, dissolved-P of water were not significant ($p > 0.05$).

Table 2: Pearson's correlation matrix for phytoplankton assemblages and physicochemical characteristics of water in the wetland of National Monument area, Bangladesh

Parameters	Chlorophyceae	Bacillariophyceae	Cyanophyceae	Euglenophyceae
TDS	0.927	– 0.743	0.863	– 0.186
EC	– 0.407	0.070	– 0.271	0.815
pH	– 0.097	– 0.249	0.047	0.957
DO	0.548	– 0.801	0.663	0.928
BOD_5	– 0.728	0.450	– 0.622	0.526
Nitrate-N	0.643	– 0.342	0.526	– 0.625
Ammonium-N	0.719	– 0.914	0.812	0.823
Dissolved-P	– 0.703	0.904	– 0.798	0.836

$p \leqslant 0.05$ was considered as the minimal level of statistical significance

Shannon-Weaver's diversity index for phytoplankton assemblages

In the studied wetland, for phytoplankton Shannon-Weaver's diversity indices $H' = 3.85$, evenness $E = 0.94$ in pre-monsoon, $H' = 2.75$ and $E = 0.72$ in monsoon, and $H' = 3.64$ and $E = 0.85$ in post-monsoon were observed. The maximum diversity remained relatively constant in pre-monsoon and post-monsoon as $H' = 3.85$ and $H' = 3.65$, respectively, but at monsoon it declined to 3.17. Low value of Shannon-Weaver's diversity index H' may be due to heavy rain during monsoon. The evenness 0.94 and 0.85 indicated more even distribution of phytoplankton species in community whereas the evenness 0.72 in monsoon suggested moderate variation of phytoplankton species in distribution.

Degree of pollution based on species diversity index

Species diversity index of any given wetland is used to find out the degree of pollution of that wetland because the level of pollution is always equal to the loss of species diversity [39]. In this study, Shannon-Weaver's diversity index H' ranged between 3.17 and 3.85 that indicate clean water of the wetland of National monument area [17, 30].

Phytoplanktons act as primary producer and food for variety of aquatic organisms. Phytoplanktons also act as efficient bioindicator to measure water quality [40]. A proper assessment of phytoplankton assemblages and

physicochemical characteristics of water is of vital importance to understand status of water quality in an aquatic habitat. So, the results of this study are of particular value for future monitoring and assessment of wetland pollution. The implications of the findings of this study may be integrated into the development of a sustainable wetland management. Future study should be performed to determine the relationship between soil nutrient and benthic organisms in the wetland located the National Martyr's Memorial of Bangladesh.

Acknowledgement

The authors wish to express gratefulness to Faculty of Mathematical and Physical Sciences, Jahangirnagar University (JU), Dhaka 1342, Bangladesh for providing financial support under JU Research Grant 2005 – 2006.

References

[1] H. G. Washington, Diversity, biotic and similarity indices. *Wat. Res.*, 1984, Vol. **18**, pp 653- 694.

[2] P. R. Trivedi and G. Raj, Environmental Water and Soil analysis. Akshdeep Publ. House, New Delhi, India. 1992, 72.

[3] S. Nazneen, Influence of hydrological factors on seasonal abundance of phytoplankton in Kinjhar lake, Pakistan. *Int. Rev. Ges. Hydrobiol.*, 1980, Vol. **65**(2), pp 269-282.

[4] H. K. Roy, Plankton ecology of the river Hooghly at Palta, West Bengal. *Ecology*, 1955, Vol. **36**, pp 169-175.

[5] M. Jansson, R. Andersson, H. Berggren and L. Leonardson, Wetlands and lakes as nitrogen traps. *AMBIO*, 1994, Vol. **23**(6), pp 320-325.

[6] W. Tian, H. Zhang, L. Zhao, F. Zhang and H. Huang, Phytoplankton diversity effects on community biomass and stability along nutrient gradients in a eutrophic lake. *Internat. J. of Environmental Res. and Publ. Health*, 2017, Vol. **14**(95), pp 1-15.

[7] S. N. Nandan and R. J. Patel, Ecological studies of algae. In: S.R. Mishra and D.N. Saksena (eds). *Aquatic Ecology*. Ashish Publ. House, India. 1992, pp 69-99.

[8] M. D. Gani, M. A. Alfasane and M. Khondker, Bloom forming phytoplankton and their comparative limnology in wastewater lagoons of Bangladesh. *Bangladesh J. Bot.*, 2017, Vol. **46**(1), pp 43-51.

[9] V. Kaul, D. N. Fotedar, A. K. Pandit and C. L. Trisal, A comparative study of plankton populations of some typical fresh water bodies of Jammu and Kashmir State. In: D. N. Sen and R. P. Bansal (eds). Environmental Physiology and Ecology of plants. Bishen Singh, M. Pal Singh, Dehra Dun. 1978, pp 249-269.

[10] B. A. Komarvosky, Comparative study of the phytoplankton of several fish ponds in relation to some of the essential chemical constituents of the water. *Buill. of Res.Council of Israel*, 1953, Vol. **2**(4), pp 379-400.

[11] M. T. Philipose, Freshwater phytoplankton of inland fisheries. *Proc. Sym. Algology* ICAR, 1960, pp 272-291.

[12] C. M. Palmer, A composite rating of algae tolerating organic pollution. *J. Phycol*. 1969, Vol. **5**, pp 78-82.

[13] M. Singh, Phytoplankton periodicity in a small lake near Delhi: Seasonal fluctuation of the physico-chemical characteristics of the water. *Phykos*. 1965, Vol. **41**, pp 61-68.

[14] A. K. M. R. Alam, A. B. M. E. Hossain and A. Aziz, Seasonal changes of phytoplankton flora of freshwater wetlands of greater Dhaka district, Bangladesh. *Bangladesh J. Env. Sci*. 2003, Vol. **1**, pp 33- 41.

[15] A. K. M. R. Alam, A. B. M. E. Hossain, A. Aziz and S. Hoque, Phytoplankton seasonality of some freshwater wetlands of greater Dhaka district in relation to water Chemistry, *Jahangirnagar University J. Sci*. 2004, Vol. **27**, pp 241-249.

[16] R. E. M. Archibald, Diversity in some South African diatom associations and its relation to water quality. *Wat. Res.*, 1972, Vol. **6**, pp 1229-1238.

[17] B. A. Whitton, River Ecology. Blackwell Scientific Publications, London. 1975.

[18] U. Sommer, Disturbance-diversity relationships in two lakes of similar nutrient chemistry but contrasting disturbance regimes. *Hydrobiologia*, 1993, Vol. **249**, pp 59-65.

[19] C. E. Boyd, Water quality in warm water fish ponds. Auburn Univ. Auburn. Albama, U.S.A., 1979, 359.

[20] J. G. Needham and P. R. Needham, A guide to the study of fresh water Biology (5th ed.). Holden-day Ine. Sun Francisco, Calif., U. S. A., 1966, pp 104-108.

[21] H. B. Ward and G. C. Whipple, Freshwater Biology (2nd ed.). John Wiley and Sons. New York. 1959, 803, 1240, 1248.

[22] G. W. Prescott, The Algae: A Review, 1984, Otto Koeltz Science Publ. Koenigstein, Germany.

[23] H. D. Kumar and H. N. Singh, A Text Book on Algae. Affiliated East-west Press Pvt. Ltd. New Delhi, India, 1971.

[24] A. K. M. N. Islam and K. M. Zaman, Limnological studies of the river Buriganga. (ii). Biological aspects. *J. Asiatic Soc. Bangladesh (Sci.)*, 1975, Vol. **1**(1), pp 45-65.

[25] K. M. Zaman, Baboharic Limnology O Mithapanir Jalaj Udvider Parichiti. Dhaka University, Dhaka, Bangladesh, 1997.

[26] A. K. De, Environmental Chemistry. New Age International Publ. Limited, India. 1993, 268 – 269.

[27] M. L. Jackson, Soil Chemical Analysis. Publ. Constable and Co. Ltd., London, U. K. 1973.

[28] J. Murphy and J. P. Riley, A modified single solution method for the determination of phosphorus in natural waters. *Anal. Chim. Acta.* 1962, Vol. **27**, pp. 31 – 36.

[29] E. C. Pielou, The measurement of diversity in different types of biological collections. *J. Theor. Biol.*, 1966, Vol. **13**, pp. 131 – 144.

[30] J. L. Wilham and T. C. Dorris, Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluents. *Amn. Midl. Nat.*, 1966, Vol. **76**, pp. 427 – 449.

[31] M.N. Islam, An Introduction to Statistics and Probability. Book World Publ. Company, Dhaka, 2001, 265.

[32] S.V. Rai and M. Rajashekhar, Seasonal assessment of hydrographic variables and phytolankton community in the Arabian Sea waters of Kerala, South West coast of India. *Brazili. J. Oceanogr.*, 2014, Vol. **62**(4), pp. 279 – 293.

[33] M.R. Mirzaei, F. Seraji, E. Erfanifar, T.A. Rad, Z. Aminikhoei and B. Azhang, Assessing phytoplankton community structure in relation to hydrographic parameters and seasonal variations (pre and post monsoon). *Biodiversitas*, 2017, Vol. **18**(2), pp. 507 – 513.

[34] K. K. Ahmed, M. K. I. Haque, G. C. Halder and S. B. Saha, Ecological studies on the planktonic organisms of Kaptai Lake. *Bangladesh J. Agri*., 1997, Vol. **22**, pp. 63 – 67.

[35] A. K. M. R. Alam, A. B. M. E. Hossain and A. Aziz, Seasonal changes of phytoplankton flora of freshwater wetlands of greater Dhaka district. *Bangladesh J. Env. Sci*., 2003, Vol. **1**, pp. 33 – 41.

[36] F. A**.** Khan, A. K. M. R. Alam and S. Hoque, Phytoplankton density in relation water quality of the wetland of Dhaka export processing zone. *Bangladesh J. Life Sci*., 2008, Vol. **20**(2), pp. 45 – 51.

[37] H. Momtaz, A. K. M. R. Alam and S. Hoque, A comparative study of phytoplankton diversity in relation to water quality of migratory birds visiting and non-visiting wetlands of Savar. *Bangladesh J. Environmental Res.*, 2010, Vol. **8**, 31 – 38.

[38] M. B. Devi, S. Gupta and T. Das, Phytoplankton community of lake Baskandi anua, Cachar District, Assam, North East India – an ecological study. Knowledge and Management of Aquatic Ecosystems, 2015, Vol. **417**(2), 1 – 9.

[39] J. You, H. Zheng and J. Duan, Research on Aquatic Ecology Indexes of three typical water areas in Tianjin. 2005, 4.

[40] T. K. Parmar, D. Rawtani and Y. K. Agrawal, Bioindicators: the natural indicator of environmental pollution. *Frontiers in Life Sci.*, 2016, Vol. **9**(2), pp. 110 – 118.