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Cyanobacterial blooms and water quality in two urban fish ponds

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Abstract: The occurrence and abundance of cyanobacterial population was monitored monthly in two urban fish ponds in Rajshahi City Corporation area from January to December, 2006. The bloom was observed in March, August and September. Some environmental parameters such as water temperature, transparency, pH, Dissolved Oxygen(DO), free Carbon dioxide(CO_2), Biological Oxygen Demand (BOD), NO_2-N, NH_3-N, NH_4^+, toxic ammonia, Oxidation reduction Index (rH_2) were recorded and their relationship with the bloom formation by cyanobacteria are discussed. During the study period 23 species of cyanobacteria were identified. Among which *Microcystis*, *Anabaena*, *Planktothrix* were found to be the dominant genera. *Microcystis aeruginosa* was the most dominant species during the bloom period. At the peak bloom period, *Microcystis aeruginosa* comprised 81.64% and 83.24% of total cyanophyceae in pond-1 and pond-2, respectively. The initiation and persistence of natural bloom of cyanobacteria, especially *Microcystis* was found to be triggered by relatively high temperature (33.21-33.53^{o}C), alkaline pH (8.8), and nutrient enrichment especially high NO_2-N, NH_3-N, and NH_4^+ concentration.

Key words: Cyanobacterial bloom, nutrient, fish pond

Introduction

Cyanobacterial blooms occur in all freshwater systems, from man-made ponds and natural ponds to rivers, lakes and reservoirs. Though they tend to occur at the height of summer and early fall, some can persist well upto late fall or winter. Some cyanobacteria cause blooms under ice which can result in the build-up of toxins, and blooms may persist through spring ice-out. Blue-green algae need warm temperatures, light, phosphorus and nitrogen to produce. Phosphorus and nitrogen are commonly found in animal and human waste, and in fertilizers. Some common ways for phosphorus and nitrogen to enter into lakes and streams are from agricultural and garden runoff, improperly functioning septic systems, and erosion of nutrient-rich soils (NALMS Position Statement, 2007). Eutrophication is the result of uncontrolled human population growth and the discharge of urban, industrial and agricultural effluents into the aquatic ecosystem of several countries (Tundisi and Matsumura-Tundisi, 1992). One of the major consequences of eutrophication is the appearence of cyanobacterial blooms (Carmichael, 2001a; Falconer, 2001; Azevedo *et al*., 2002).

Some of the most serious effects of urban run-off on the aquatic habitat are reduction of water clarity and modification of its benthic substrate due to decomposition of huge quantities of sediments into the receiving water body. Unfortunately, sediment is not the only significant pollutant found in urban run-off. Urban run-off also can contain high concentrations of nutrients, oxygen-consuming wastes, pathogens and toxic substances such as pesticides, heavy metals and oils (Peterson *et al*., 1985). Concerns specially associated with urban waterbodies include the quantity and distribution of nuisance forming cyanobacteria. Cyanobacterial blooms in freshwater usually comprise both toxin and non-toxin producing species (Baker & Humpage, 1994). The main toxin producing cyanobacteria genera include *Anabaena*, *Aphanizomenon*, *Microcystis*, *Planktothrix*, *Lyngbya* and *Cylindrospermopsis* (Chorus & Bartran, 1999). Phytoplankton studies in some Greek lakes (Vegoritis, Volvi, Mikri Prespa, Doirani and Kastoria) have shown that prolonged cyanobacterial blooms upto 8 months can occur, which are dominated by known toxic species (Moustaka-Gouni & Nikolaidis, 1990, Moustaka-Gouni, 1993; Tryfon & Moustaka-Gouni, 1997, Temponeras *et al*., 2000; Vardaka *et al*., 2000). Cyanobacterial blooms can cause a variety of water quality problems, including dissolved oxygen depletion and subsequent fish kills, aesthetic nuisances (e.g. increased bad odours, algal scums, fish tainting, decreased aesthetic quality) and unpalatable, possibly even unsafe drinking water, (Carmichael, 2001b).

Cyanobacteria are known to produce a variety of toxins that can be lethal to livestock, pets, wildlife and humans following the ingestion of water contaminated with toxic cells, or toxins released from decaying cells (Codd, 1999; Azevedo *et al*., 2002). Certain species of *Anabaena* and *Aphanizomenon*, synthesize neurotoxic alkaloids, whereas species of *Anabaena*, *Microcystis*, *Nodularia* and *Planktothrix* generate mostly hepatotoxic peptides (Carmichael *et al*., 1990). Mammals and birds, in general appear to be more susceptible to such toxins than are aquatic invertebrates and fish. The death of fish during cyanobacterial blooms has been reported (Davidson, 1959; Koon, 1960; Ochumba, 1990; Servin-Reyssac & Pletiuosic; 1990 and Jewel *et al*., 2003). The fish farmer also reported that two goats died after drinking water from the same pond. This paper deals with the species composition, abundance of Cyanophyceae and the effect of various environmental factors that triggered the bloom of cyanobacteria in two urban fish ponds in the Rajshahi city corporation area.

Materials and Methods

Study area: The study was conducted in two urban ponds for a period of 12 months from January to December, 2006. Pond-1 was situated in Baliapukur and pond-2 in Hadirmor under Rajshahi City Corporation. Both the ponds were leased out to local people who were found to practice fish culture. Pond-1 was found to receive domestic wastes and decomposed organic nutrients through 2 drains while pond-2 from 5 drains in different sides of the pond. Three manholes were situated at the east side of pond-2. Both the ponds got over flooded during the rainy season.

Analysis of water quality: Surface water samples were collected once a month from 10 to11 am. Water samples were collected in black plastic bottles for the estimation of different chemical parameters. Plankton samples were collected by German plankton net of 55µm mesh size and preserved in 5% formalin.

Surface water temperature and transparency was measured using a Celsius thermometer and a Secchi disc. pH, NO_2-N, NH_3-N, NH_4^+ and toxic ammonia were measured using a HACH kit, model FF-2. Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) were estimated by Winkler's titration method (APHA, 1976). Free Carbon dioxide (CO_2) was measured by titration method of Welch (1948). Oxidation Reduction Index (rH_2) was calculated by using the formula given by Mukherjee (1996).

Phytoplankton Study: For species identification samples were gently shaken to resuspend all materials and were allowed to settle for one minute. Then 2-3 drops were removed from the middle of the sample and placed on a glass slide. Taxonomic determination of cyanobacteria was performed with a phase-contrast microscope Olympus, Japan (Skulberg *et al*., 1993, Anagonistidis & Komárek, 1985). The quantitative estimation of phytoplankton was done by Sedgewick-Rafter counting chamber (S-R cell) following the method described by Stirling (1985). Seasons were divided as: summer (June through August), autumn (September through November), winter (December through February) and spring (March through May).

Results and Discussion

Species composition: During the study period cyanobacterial bloom was observed twice in a year, one in March and the other in August in pond-1, while in March and September in pond-2. In pond-1, Cyanophyceae cell density was the highest (90.15×10^6 cells/L, 98.49%) in August, while that in pond-2 was (156.0×10^6 cells/L, 99.61%) in September (Fig 1).

In March Cyanobacteria bloom was also observed in both the ponds when the cell density was 79.8×10^6 cells/L (98.15%) and 134.68×10^6 cells/L (98.67%) in pond-1 and pond-2, respectively (Fig 1). Twenty three species of Cyanophyceae under 8 genera were identified (Table-1), of which *Microcystis* sp., *Anabaena* sp., *Planktothrix* sp., were the most dominant genera. *Microcystis* as a single genus contributed 83.07% and 85.09% to total Cyanophyceae in March and August, respectively in pond-1 while 85.15% and 87.16% in March and September, respectively in pond-2.

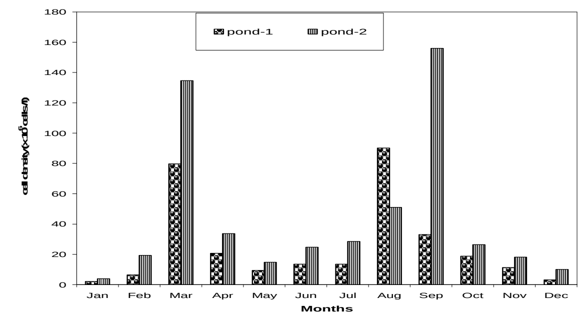

Fig. 1. Showing monthly variation in abundance of Cyanophyceae species in pond-1 and in pond-2 from January to December.

Table 1. The list of Cyanophyceae species observed among the two urban fish ponds during the study period.

Division Cyanophyta
Class Cyanophyceae
Order Hormogonales0
Family Nostocaceae
Genus *Anabaena* Bory

1. *Anabaena circinalis*
2. *Anabaena flosaquae*
3. *Anabaena spiroides*

Genus *Anabaenopsis* Morren

4. *Anabaenopsis arnoldii*

Order Chroococcales
Family Chroococcaceae
Genus *Aphanocapsa* Nägeli

5. *Aphanocapsa delicatissima*
6. *Aphanocapsa muscicola*
7. *Aphanocapsa crassa*
8. *Aphanocapsa koordersi*

Genus *Microcystis* Lemmermann

9. *Microcystis aeruginosa*
10. *Microcystis flosaquae*
11. *Microcystis botrys*
12. *Microcystis viridis*
13. *Microcystis natans*
14. *Microcystis wesenbergii*

Genus *Gleocapsa* Kutzing

15. *Gleocapsa calcarea*
16. *Gleocapsa magma*
17. *Gleocapsa granosa*

Genus *Merimopedia* Nägli

18. *Merismopedia elegans*
19. *Merismopedia minima*
20. *Merismopedia tenuissima*

Order Oscillatoriales
Family Oscillatoriaceae
Genus *Planktothrix* Anagnostidis and Komárek

21. *Planktothrix agardhii*
22. *Planktothrix rubescens*

Genus *Arthrospira* Stizenberge

23. *Arthrospira platensis*

Microcystis aeruginosa was the most dominant species 81.64% and 83.24% in pond-1 in August and in September in pond-2, respectively while 75.41% and 77.09% of total Cyanophyceae in March in pond-1 and pond-2, respectively (Fig 2) and the bloom forming species in both the ponds. Of three common species of Cyanophyceae, *Microcystis* was abundant throughout the study period, in pond-1 with maximum (82.76%) in summer and the second highest in spring (78.76%) while the same genera was most dominant in autumn (83.99%) and second highest in spring (80.57%). *Anabaena* and *Planktothrix* were highest (25.92% and 10.81%, respectively) in the winter in pond-1 while these showed dominance in winter (28.52% and 6.06% respectively) in pond-2 (Fig 3).

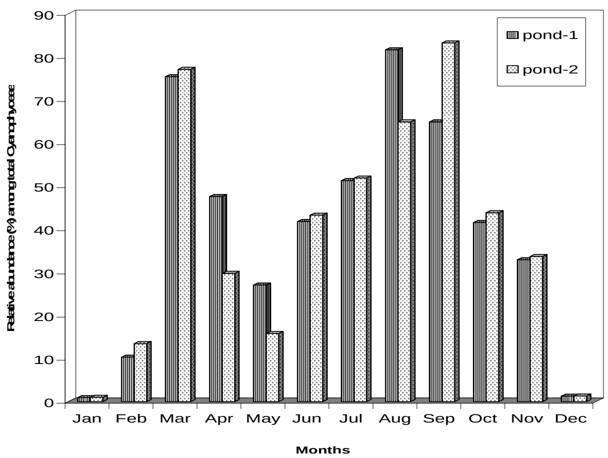

Fig. 2. Showing relative abundance (%) of *Microcystis aeruginosa* in pond-1 and pond-2 from January to December

Physico-chemical parameters

All the physico-chemical parameters were found to vary in dfferent months (Table 2). Temperature was found to increase from January and the increasing trend continued till September. The maximum and minimum rates were obtained in September and January in both the ponds. Transparency was the lowest (25.33cm) in August in pond-1 and in September (15.85cm) in pond-2 while the highest 57.63cm and 35.45cm in pond-1 and pond-2 respectively in June. Lowest value of pH (7.0) was observed in January in pond-1 while in December in pond-2 and highest (8.8) rate was observed in August and September in pond-1 and pond-2 respectively. DO was lowest in March and started to increase to highest level in July in both ponds. Free CO_2 was lowest (21.74mg/L) in February in pond-1 while in December (18.98mg/L) in pond-2. Highest levels of Free CO_2, 73.33mg/L and 79.84mg/L was observed in pond-1 and pond-2 respectively in October. Biological Oxygen Demand (BOD) was lowest in March and started to increase from April reaching the highest levels in July in both ponds. NO_2-N concentration was lowest 0.03mg/L and 0.15mg/L in pond-1 and pond-2 respectively in January, while highest levels (0.3mg/L) were observed in August in pond-1 and in September (0.5mg/L) in pond-2. Similarly, lowest concentration of NH_3-N was observed in January (0.3mg/L in pond-1 and 0.9mg/L in pond-2) while highest values were observed in August (2.0mg/L) in pond-1 and in September (3.0mg/L) in pond-2. Toxic ammonia was lowest in January in both ponds and highest in August (0.881mg/L) in pond-1 while in September (1.32mg/L) in pond-2. NH_4^+ was lowest in January and highest in March in both ponds. Lowest values of rH_2 were observed in August (24.72) in pond-1 while in September (24.64) in pond-2. Highest values of rH_2 was observed in January (29.62) in pond-1 while in December (29.94) in pond-2.

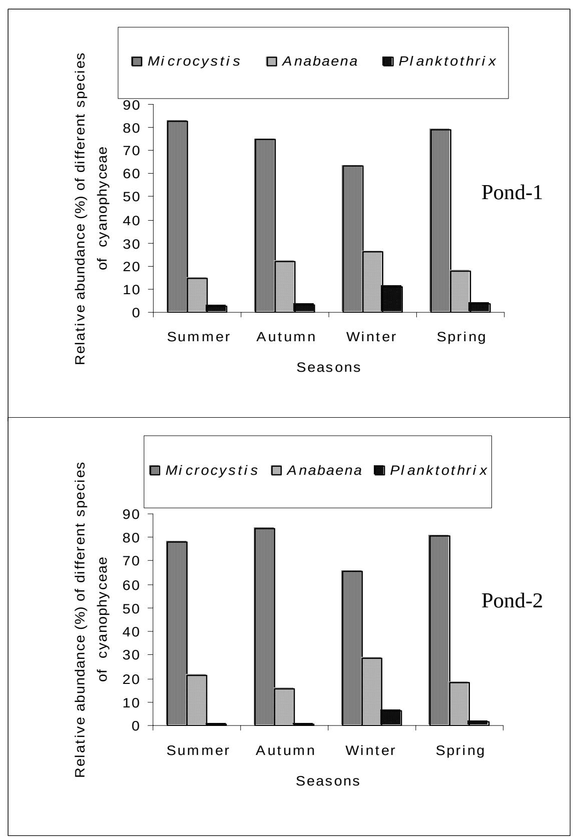

Fig 3. Showing seasonal relative abundance values of the three most common Cyanophyceae species (*Microcystis*, *Anabaena*, *Planktothrix*) in poind-1 (above) and pond-2. (below) Summer(Jun-Aug), Autumn(Sep-Nov), Winter(Dec-Feb) and Spring(Mar-May).

Table 2. Minimum, maximum, average ± SD of water quality parameters as recorded from the two experimental ponds during the study period.

Parameters	Pond-1			Pond-2		
	Min	Max	Average ±SD	Min	Max	Average ±SD
Water temperature (^oC)	16.51 Jan	33.53 Sept	27.95±6.23	16.50 Jan	33.50 Sep	27.91±6.23
Transparency (cm)	25.33 Aug	57.63 June	39.7±10.57	15.85 Sept	35.45 June	27.90±6.64
pH	7.00 Jan	8.80 Aug	7.93±0.52	7.00 Dec	8.80 Sept	7.91±0.57
DO(mg/L)	0.53 March	3.26 July	1.61±0.85	0.36 March	3.08 July	1.51±0.79
Free CO_2(mg/L)	21.74 Feb	73.33 Oct	43.82 ±15.37	18.98 Dec	79.84 Oct	45.66±18.31
BOD(mg/L)	0.53 March	3.0 July	1.46±0.86	0.36 March	3.08 July	1.44±0.78
NO_2-N(mg/L)	0.03 Jan	0.30 Aug	0.15±0.08	0.15 Jan	0.50 Sept	0.33±0.11
NH_3-N(mg/L)	0.30 Jan	2.00 Aug	1.22±0.51	0.90 Jan	3.00 Sept	2.09±0.64
ToxicAmmonia mg/L)	0.001 Jan	0.881 Aug	0.19±0.26	0.004 Jan	1.32 Sept	0.31±0.39
NH_4^+	0.39 Jan	2.03 March	1.38±0.49	1.17 Jan	3.02 March	2.38±0.57
rH_2	24.72 Aug	29.62 Jan	27.26±1.6	24.64 Sept	29.94 Dec	27.24±1.72

The observed water blooms due to cyanobacteria colonies in both experimental ponds during August and September ponds agree with the findings of Oberholster *et al*. (2006) who obtained the maximum abundance (1.66 x10 ^{9} cells/ml) of Cyanobacteria colonies in August. Relatively higher density of Cyanobacteria in pond-2 than pond-1 was probably due to the fact that pond-2 received sewage wastes from 5 drains that were found to bring large amount of nutrients in to the pond. Nutrients were also found to be accumulated from surface run-off, drains and ground seepage in both the ponds because of heavy rainfall in summer months. Relatively high temperature created more favorable condition for the growth of Cyanophyceae in August and September. Tilman *et al*. (1986) reported that Cyanobacteria have shown dominance at temperature higher than 20^{o}C which agrees with the findings of the present study. Alkaline pH, low dissolved oxygen concentration and comparatively higher nutrient concentration were observed during the bloom periods in both the experimental ponds. According to Hasan (2000) and Sreenivasan (1964) alkaline nature of water with a hypolimnion oxygen deficit and an occurrence of Cyanophyceae phytoplankton, especially *Microcystis* sp. are indicative of a eutrophic nature of a body of water. The observed lower values of rH_2 in August and September were found to coincide with higher organic loads in those months in both the ponds which agree with the findings of Mukherjee (1996) who reported that the low rH_2 value indicates high organic load when reduction prevails over oxidation in natural water bodies. He further added that anaerobic forms were found in the bottom with a low oxidation reduction index.

The coincidence of Cyanophyceae bloom with relatively higher temperature, pH and nutrient (NO_2-N, NH_3-N and NH_4^+) levels high in summer and in early autumn as observed in the present study more or less agree with the findings of Affan *et al*. (2005) who obtained blue-green algal (Cyanobacterial) abundance in the early autumn months. Jewel *et al*. (2006) reported that cyanobacteria especially *Microcystis* sp. was found to be controlled by relatively high temperature (>25^{o}C) and nutrient enrichment, especially high NO_3-N (3.8mg/l) concentration. High concentrations of nitrogen was found by May (1972), during heavy bloom of blue-green algae. Kolte & Goyal (1989) reported that blue-green algal cell density increased with increasing of nitrogen in media. Utkilen *et al*. (1996) reported that *Microcystis* population collapsed when NO_2-N concentration decreased. Eloff & VanDer (1981) reported that *Microcystis* grew well at temperature 27^{o}C to 29^{o}C in culture condition at pH value between 6.5 to 10.5. Low concentration of O_2 was found during Cyanophyceae bloom in March, August and September in the present study agree with the findings of Eloff (1977) who reported that removal of O_2 led to increased yield of *Microcystis aeruginosa*. Oudra *et al*. (1998) reported 95% of *M. aeruginosa* in a cyanobacterial bloom in eutrophic Lalla Takerkousta reservoir in Morocco. May (1981) reported that bloom of *Microcystis aeruginosa* and *Anabaena circinalis* were increasing due to increasing pollution of the water.

During the bloom of Cyanophyceae fish farmers reported that the people who bathed in the studied ponds suffered from skin rashes and eye and ear irritation. Turner *et al.* (1990) reported that 10 of 20 recruited army showed symptoms like vomiting, diarrhoea, central abdominal pains, blistering of the lips, sore throats after swimming and canoe training in water with a dense bloom of *Microcystis* sp. and two of the recruits developed severe pneumonia attributed to the aspiration of *Microcystis* toxin which was the indication of intoxication.

From the present study, it is suggested that further study on Cyanobacteria in relation to environmental factors as well as their harmful and noxious effects should be undertaken in different ponds, lakes, rivers and coastal water of Bangladesh.

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