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Seasonal nutrient status of Banjara lake, Hyderabad

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Abstract. Seasonal and diel variations of nutrients viz. nitrate, nitrite, ammonia, soluble reactive phosphorus and silica in Banjara lake (identified by Andhra Pradesh Fisheries Department for pisciculture) during August 1986 to July 1987 were reported. Nitrate, nitrite and ammonia reached highest concentrations in March ($3{\cdot}76 \pm 1{\cdot}74$ mg l^{-1}), July (575 ± 77 $\mu g\, l^{-1}$) and April ($404{\cdot}6 \pm 127$ $\mu g\, l^{-1}$) respectively. However, fish kills through nitrite toxicity was not observed at the reported nitrite concentrations. Ammonia decreased during summer mainly due to utilization by phytoplankton blooms. The highest value of soluble reactive phosphorus was observed in April (956 ± 44 $\mu g\, l^{-1}$) attributed to sewage, domestic effluents and also release from sediments. Silica was at a maximum in October and decreased during diatom blooms in December. Clear pattern of diel variation was not observed for nitrate, nitrite and phosphorus. However, ammonia showed diel variation having higher concentrations at 6 h than 12, 18 and 24 h due to its slower uptake by phytoplankton during nights. Chlorophyll *a* was at a maximum in May (32 mg m^{-3}) at N/P ratio of 5·3 with the dominance of cyanophyceae and chlorophyceae.

Keywords. Nitrogenous nutrients; soluble reactive phosphorus; silica; seasonal changes; Banjara lake.

1. Introduction

Nitrogenous and phosphorus nutrients are abundant in water receiving substantial inputs of sewage, domestic waste and agricultural leachouts. However, smaller amounts may be due to leaching from the sediments and bacterially mediated decomposition of organic matter (Lukatelich and McComb 1986; Ravera *et al* 1986; Uehlinger 1986).

Lakes and fish ponds in and around Hyderabad have been studied to a considerable extent for water quality, plankton and trophic status (Zafar 1964, 1967; Munawar 1970; Seenayya 1971, 1972; Rao 1971; Mohan 1987). Banjara is a small lake with an area of about 0·046 km^2 located in Banjara hills, a posh residential area of Hyderabad (figure 1). Other important lakes in and around Hyderabad are Osman sagar, Himayat sagar (oligotrophic); Hussain sagar (hyper eutrophic); Mir alam and Faukk's sagar (mesotrophic). Banjara has been classified as eutrophic on the basis of total nitrogen (3·07 mg l^{-1}), phosphorus (0·15 mg l^{-1}) nutrients and calcium (94 mg l^{-1}; Johnson 1983). Urbanisation has been growing rapidly during past 3–5 years surrounding the lake for its picturesque scene due to hillocks. The Banjara hotel is located on the south bank of the lake. The lake is used for pisciculture, water source for cattle, recreation area with anthropic activity (washing cloths and vehicles) and it serves as a receptacle for domestic wastes. Andhra Pradesh State Fisheries Department is keen in keeping this lake pollution free since it generates a revenue of about Rs. 60,000–80,000 per year through fish production. Banjara hotel

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management also concerned about its management and keen to develop the lake as an aesthetic and recreation resort. So far seasonal and diel nutrient status of Banjara lake has not been studied. The only available reports are: mineral accumulation in water hyacinth (Satyakala *et al* 1986) and trophic status (Johnson 1983). Hence, the objective of present study is to investigate the diel variations and to provide information regarding the seasonality of nitrogenous nutrients, phosphorus and silica in the lake and to review the lake trophic status.

2. Materials and methods

Banjara lake is situated in Hyderabad at an altitude of 1722 ft (latitude 17° 22′ 30″ N; longitude 78° 25′–78° 27′30″ E). It is a shallow lake with surface area of about 0·046 km^2 having an effective length and width of 0·57 and 0·22 km respectively. The total volume of the lake is $0{\cdot}52 \times 10^6$ m^{-3}. It has a shoreline of about 1·8 km. The inflow and outflow is seasonal mainly due to rainfall. The dominant macrophyte is *Eichhornia crassipes* and is periodically removed by Banjara hotel management.

Surface water samples were collected in polyurethane cans every month from 3 sites viz. (A) close to road, where anthropic activity is common, (B) near to outlet and (C) near to inlet of the lake at 6, 12, 18 and 24 h from August 1986 to July 1987. Samples were analyzed on the same day. Nutrients were estimated after filtration through GF/C filters. All spectrophotometric absorbency measurements were made on a Hitachi 150–20 model Spectrophotometer. Methods followed for

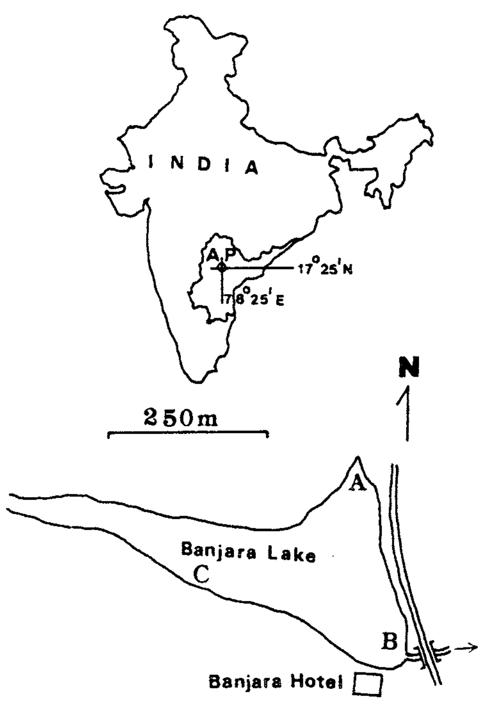

Figure 1. Map showing the location of lake and sampling sites (A, B and C).

analysis of nutrients are ammonia by nesslerization (Michael 1984); nitrate by nitrate-brucine complex, nitrite by sulphonilamide-NED diazotization (Nicholas and Nason 1957); soluble reactive phosphorus (SRP) by molybdenum blue method (APHA 1985; Michael 1984); silica by molybdosilicate method (APHA 1985; Saad and Abbas 1985) and chlorophyll by extraction in 90% acetone (Parsons and Strickland 1965).

3. Results

The synoptic data of the seasonal and diel variations of nutrients at sites A, B and C for the period of one year (August 1986 to July 1987) are presented in figures 2, 3 and table 1.

Nitrate, nitrite and ammonia exhibited diel variation but no clear pattern emerged. However, higher concentration of ammonia were observed at 6 h in all months. Diel and seasonal variations of the 3 forms of nitrogen are shown in figure 2. Nitrite was undetectable during 5 months i.e. August, September, January, February and May. The minimum and maximum amounts of nitrite were $35 \cdot 8 \pm 17 \cdot 6$ (SE) μgl^{-1} in April, 515 ± 132 μgl^{-1} in July respectively. The minimum and maximum nitrate values were $0 \cdot 56 \pm 0 \cdot 09$ mgl^{-1} in November, $3 \cdot 76 \pm 1 \cdot 4$ mgl^{-1} in March respectively. The minimum and maximum values of ammonia were 63 ± 9 μgl^{-1} in January and $404 \cdot 6 \pm 127$ μgl^{-1} in April respectively.

There was a seasonal change in nitrogenous nutrients. In March the form in highest concentration was nitrate ($3 \cdot 76 \pm 1 \cdot 4$ $mg\,l^{-1}$) followed by nitrite

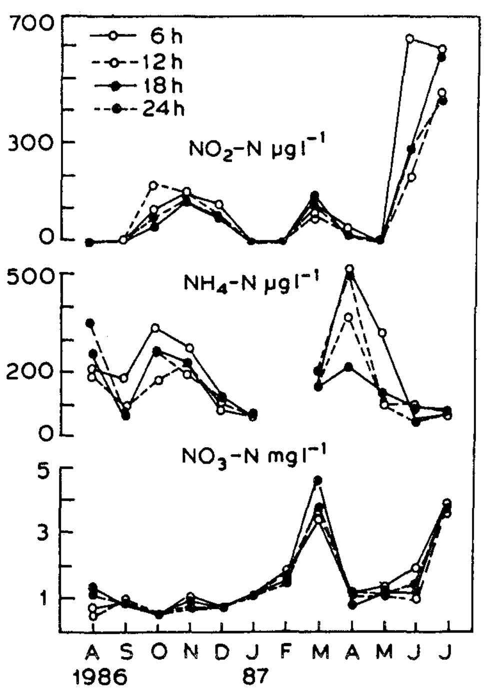

Figure 2. Seasonal and diel variations of nitrate, nitrite and ammonia (average of 3 sites).

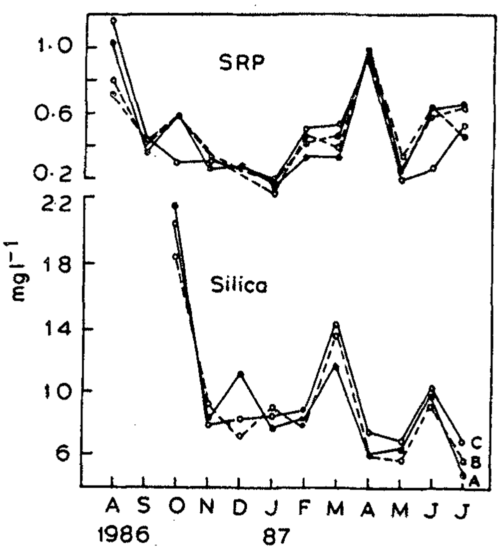

Figure 3. Seasonal variations of soluble reactive phosphorus and silica in sites A, B and C at 12 h.

Table 1. Monthly mean concentrations of ammonia, nitrate, nitrite, SRP and Chl. *a*.

Month	Ammonia ($\mu g l^{-1}$)	Nitrate ($mg l^{-1}$)	Nitrite ($\mu g l^{-1}$)	SRP ($\mu g l^{-1}$)	Chl. *a* ($mg m^{-3}$)
1986					
Aug	255·8 ± 77·8	0·84 ± 0·5	Absent	868·5 ± 167·0	NE
Sep	98·7 + 65·0	0·88 + 0·14	Absent	408·0 ± 64·6	8·6
Oct	260·8 ± 67·0	0·56 ± 0·09	95·2 ± 68·0	545·0 ± 85·0	9·7
Nov	232·0 ± 48·0	0·83 ± 0·27	132·8 ± 25·0	307·0 ± 61·0	NE
Dec	109·5 ± 24·4	0·74 ± 0·14	86·3 ± 28·0	280·0 ± 35·0	19·7
1987					
Jan	63·0 ± 9·0	1·07 ± 0·09	Absent	171·0 ± 53·0	20·2
Feb	NE	1·65 ± 0·48	Absent	480·0 ± 101·0	25·5
Mar	164·4 ± 32·0	3·76 ± 1·4	118·7 ± 47·0	407·0 ± 57·0	30·1
Apr	404·6 ± 127·0	1·04 ± 0·36	35·8 ± 17·6	956·0 ± 44·0	28·1
May	171·0 ± 107·0	1·16 ± 0·3	Absent	247·0 ± 59·0	32·0
Jun	73·8 ± 39·2	1·39 ± 0·46	331·4 ± 214·0	495·0 ± 176·0	27·0
Jul	69·1 ± 37·0	3·84 ± 0·19	515·0 ± 132·0	575·0 ± 77·0	25·8

NE. Not estimated.

(118·7 ± 47 $\mu g l^{-1}$) and ammonia (171 ± 107 $\mu g l^{-1}$). In April nitrate (1·04 ± 0·36 $mg l^{-1}$), nitrite (35·8 ± 17·6 $\mu g l^{-1}$) were at lower concentrations, and ammonia (404·6 ± 127 $\mu g l^{-1}$) reached its highest concentration. In May a slight increase in nitrate (1·16 ± 0·3 $mg l^{-1}$) and decrease in ammonia (171 ± 107 $\mu g l^{-1}$) was observed, however nitrite is absent. Nitrate increased further in June (1·39 ± 0·46 $mg l^{-1}$) and July (3·84 ± 0·19 $mg l^{-1}$). In June a sudden rise in nitrite to 331·4 ± 214 $\mu g l^{-1}$ was observed, and increased further in July (515 ± 132 $\mu g l^{-1}$, the highest concentration of the season).

No clear pattern was observed in diel variations of SRP (figure 3). The minimum and maximum values of SRP were $171 \pm 53\ \mu g\,l^{-1}$ in January, $956 \pm 44\ \mu g\,l^{-1}$ in April respectively. In the month of August maximum variations between the 3 sites were observed (mean values of A, B and C were 936 ± 181, 799 ± 98 and $870 \pm 179\ \mu g\,l^{-1}$ respectively).

Site-specific and diel variations were not uniform with regard to silica. The minimum and maximum monthly mean values were $5{\cdot}71 \pm 0{\cdot}9\ mg\,l^{-1}$ in July and $19{\cdot}9 \pm 1{\cdot}33\ mg\,l^{-1}$ in October respectively. Figure 3 represents the values at 12 h in 3 sites. The minimum and maximum values of chlorophyll *a* were in September ($8{\cdot}6\ mg\,m^{-3}$) and in May ($32\ mg\,m^{-3}$) respectively.

4. Discussion

Nitrate available in aquatic systems may either be assimilated by algae and aquatic macrophytes, or transferred to underlying sediments where it undergoes denitrification. Sediments with high concentrations of available carbon remove nitrate faster than sediments with low available carbon (Reddy and Reddy 1987). Nitrification is a rapid irreversible sink for ammonia leading to the formation of nitrite and nitrate (Lipschultz *et al* 1986). This process takes place mainly in the upper centimeters of oxic sediments. It also takes place in the overlying water column at lower rates. Geldermalsen (1985) observed that nitrate showed maximum values in summer and ammonia is produced throughout the year in small amounts and nitrite is produced only in winter and spring.

It has been reported that ammonia is preferred over nitrate by phytoplankton (Horrigon and McCarthy 1982; Miyazaki and Ichimura 1986; Mitamura and Saijo 1986; Reddy *et al* 1987). The observed decrease of ammonia in June and July (figure 2) can be attributed to utilization by phytoplankton. Ammonia was observed in high concentrations at 6 h than 12, 18 and 24 h is because of its uptake variation over diel cycles with slower rates in nights (Furnas *et al* 1986). Toxicity of unionized ammonia to warm-water fishes occurred at $0{\cdot}67\ mg\,l^{-1}$ (72 h, LC-50) for large mouth bass *Micropterus salmoides* (Tomasso and Carmichael 1986). Unionized ammonia never reached such a concentration in Banjara lake during this study. Nitrate showed an increasing trend until March ($3{\cdot}76 \pm 1{\cdot}4\ mg\,l^{-1}$) (table 1), was attributed to a high rate of nitrification. Higher amounts of nitrite in March, and decreased oxygen in March ($3{\cdot}2\ mg\,l^{-1}$) and April ($3{\cdot}68\ mg\,l^{-1}$) (the mean value of other months is $10{\cdot}64\ mgl^{-1}$), support this view. On the other hand denitrification is known to play an important role in fluctuations of nitrate in water (Billen *et al* 1985). A decreased level of nitrate in the summer was explained by Geldermalsen (1985) as follows.

(i) Ammonia is less available because it is consumed more easily by phytoplankton than it is converted by nitrifying bacteria to nitrate.

(ii) The oxygen supply to the upper layer of sediments is for the greater part consumed by enhanced mineralization causing oxygen to penetrate the sediment for only a few millimeters.

(iii) Denitrification in the sediments is enhanced by higher temperature, so that nitrate is converted to nitrogen.

(iv) Nitrate is consumed by the phytoplankton.

High amounts of nitrate in July in this study can probably be explained by the load of sewage due to appreciable rainfall in June (8·2 cm) and July (16·4 cm).

Factors that affect bacteria involved in two step conversion of ammonia to nitrate could cause accumulation of nitrite. Sewage effluents also contain high amounts of nitrite (Lewis and Morris 1986). Nitrite level in June ($331{\cdot}4 \pm 214\ \mu g\,l^{-1}$) and July ($515 \pm 132\ \mu g\,l^{-1}$) was mainly due to rainfall caused sewage load and could be toxic to fish (Lewis and Morris 1986). However, no toxicity was observed in terms of fish kill. This may be explained because of the presence of high amounts of chloride and calcium carbonate, which tend to reduce nitrite toxicity (Lewis and Morris 1986).

Ammonia and SRP increased simultaneously due to the bacterial break down of organic matter (Barica 1975). Diel and seasonal variations of nitrogen and phosphorus nutrients were shown in figures 2 and 3. Water temperature may effect the phosphorus cycle in aquatic systems apart from changes in oxygen concentration. Kelderman (1980) noticed that phosphorus was released from sediments from April–September, and adsorbed from October–March. The observed high amounts of SRP in August ($868{\cdot}5 \pm 167\ \mu g\,l^{-1}$) and April ($956 \pm 44\ \mu g\,l^{-1}$) might be mainly due to sewage and domestic waste loading mainly through rainfall (21·8 cm in August, 6·1 cm in March and 0·8 cm in April) and partly due to release from sediments. November, December and January (lowest $171 \pm 107\ \mu g\,l^{-1}$) may represent the seasons of phosphorus adsorption (table 1 and figure 3).

The floating macrophyte *Eichhornia crassipes* and the submerged *Elodea densa* are known to remove SRP from waters and are also responsible for changes in phosphorus (Reddy *et al* 1982, 1987; Reddy 1983). However, the role of *Eichhornia* in the dynamics of SRP could not be ascertained in this study due to its periodic removal from the lake.

Silica occurs in natural waters either in solution or as silicate polymers derived from catchment soils or of biogenic origin (from dead diatoms). The soluble reactive silicon is probably the only form of silicon available for diatoms and other phytoplankton (Reynolds 1984). Saad and Abbas (1985) noticed an increase in silicate concentration after rainfall and arrival of flood waters and lower silicate levels in highly saline waters. It is evident that blooming of diatoms decreases soluble silicate (Zafar 1967; Seenayya 1971; Saad and Abbas 1985). Biogenic enhancement of silica in summer was observed due to remineralization of sedimented frustules (Lukatelich and McComb 1986). In this study the highest concentration of silica ($19{\cdot}9 \pm 1{\cdot}33\ mg\,l^{-1}$) was observed in October; this decreased to $7{\cdot}13 \pm mg\,l^{-1}$ in December (figure 3). The decrease is attributed to diatom blooming in November and December (diatoms in these months were about 50% of the total phytoplankton and they are less than 15% throughout the study period). Seasonal variations may also be due to sediment action, surface runoff and remineralization of sedimented diatoms. Sediment acts as a buffer and releases silica as and when its concentration decreases in the overlying waters (Geldermalsen 1985).

Cyanophyceae were maximum in May and June with more than 50% of the total algae, chlorophyceae in April with 45% of total algae. Chlorophyll *a* was at a maximum in May ($32\ mg\,m^{-3}$) mainly due to cyanophyceae and partly due to chlorophyceae. The observed chlorophyll values (Chl *a* $8{\cdot}6$–$32\ mg\,m^{-3}$) are fairly high when compared to the values of 1980 (average total chlorophyll 0·26 mg l^{-1}; Johnson 1983) and are comparable to other tropical south Indian eutrophic lakes (Hegde 1985). The highest concentration of chlorophyll *a* was observed at N/P ratio of 5·3 is also nearer to a crude rule of 7 : 1 N/P ratio supports maximum blooms.

Nitrate is very high when compared to the values of 1980. The maximum nitrate during present study is $3{\cdot}84 \pm 0{\cdot}19$ mg l^{-1} (mean annual concentration $1{\cdot}48 \pm 1{\cdot}07$ mg l^{-1}) and very high when compared to 0·99 mg l^{-1} (average 0·64 mg l^{-1}) of 1980 (Johnson 1983). Apart from nitrate, ammonia and nitrite were also present in significantly high amounts (annual means $172{\cdot}9 \pm 101$ μg l^{-1}, $187{\cdot}7 \pm 159$ μg l^{-1} respectively). Maximum amount of phosphate during present study is 956 ± 44 μg l^{-1}. But in 1980 the maximum value (3·4 mg l^{-1}) is higher than present study. However, average is 450 μg l^{-1} less than current value (annual mean value is $478{\cdot}2 \pm 227{\cdot}5$ μg l^{-1}). Thus, significant increase of nutrients in lake are of considerable interest.

5. Conclusion

This is the first report regarding seasonal and diel variations of nutrients in Banjara lake. Eventhough clear pattern of diel variations were not observed for nitrate; phosphorus and silica; ammonia showed a clear diel variation having higher concentrations at 6 h due to its less uptake during nights. In this lake major source for nutrient loading is sewage, domestic wastes which often enhanced by rainfall. This lake being an interception tank between Osman sagar (Oligotrophic) and Hussain sagar (Hyper eutrophic) a long term study of nutrient dynamics including heavy metals and changes in phytoplankton would be quite useful in taking necessary steps to maintain it pollution free and in identifying biomonitors of aquatic pollution.

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