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Study of Phosphorus Related Assimilative Capacity of Futala Lake of Nagpur City

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Abstract:

A mathematical model was used to assess the phosphorus (P) related assimilative capacity of Futala Lake of Nagpur City, Maharashtra. The model was used to assess the variations in the system's P assimilative capacities during critical seasons as well as various patterns of anthropogenic activities. The total P mass input approximated 0.96 mt/y at Futala lake. Higher total P concentration was recorded during the summer season with 0.160 mg/L at Futala Lake. The results indicate a very strong negative impact of anthropogenic activities on the P related assimilative capacity of the Futala lake of Nagpur. Furthermore, the study also revealed a strong positive correlation of sediment heterotrophic bacterial density with organic matter content.

Key words:
Phosphorus, assimilative capacity, phosphatases, heterotrophic bacteria.

Introduction:

Today, the problem of freshwater availability has become omnipresent, and the problem is not only pertaining to the quantity of freshwater but also the quality of freshwater. Largely, the quality of freshwater is related to the assimilative capacity, which is the ability of an area to maintain a "healthy" environment and "accommodate" wastes (GESAMP, 1986). Rapid urbanization and industrialization is responsible for generation of considerable amounts of waste that includes effluents containing nutrients, pesticides, organic and inorganic compounds as pollutants. These effluents can have detrimental impacts on the local environment, depending on the amounts released, the time-scale over which the release takes place, and the assimilation capacity and flushing ability of the local recipient water body (Axler*et al.,* 1996; Kelly *et al.,* 1996). The environmental impact of dissolved constituents (nutrients, chemicals and pesticides) depends on the rate at which those products are diluted before being assimilated by the pelagic ecosystem (Black, 2001). However, in restricted exchange environments such as lakes and reservoirs, there is a risk of high levels of nutrients accumulating in one area, causing hyper nutrification and potentially creating undesirable effects (Midlen and Redding, 1998 and Mac Garvin, 2000). The biogeochemical processes play an important part in deciding the fate of organic matter in an aquatic ecosystem and the organic matter utilization rate by aerobic or anaerobic microorganisms decide the overall health of system, as the nutrient release rates are directly responsible for the overall productivity of the system (Ghosh et al, 2005). Nutrients are essential for survival of all organisms, but sizeable increase of nutrient levels pose a threat to the ecosystem health by facilitating the overgrowth of algae (algal blooms). Phosphorus (P) is a globally important pollutant of freshwater lakes and reservoirs. Most laundry detergents in India are phosphate based. In India, per capita consumption of detergents in 2004 was 4.0 kg per annum, which is projected to rise. The figures are of concern because high quality detergents have as much as 35 per cent sodium tripolyphosphate (STPP) in them and the main problem is that of phosphate-based detergents promoting eutrophication of aquatic environments. Based upon the relationship between P concentration and algal bloom frequency, observed in lakes, the desired phosphorus level in lake water is recommended as 0.02 mg/L. In India, it is not uncommon to see ponds, lakes and part of rivers choking with algae or other aquatic plants. In the Indian context, this is a grim situation since these water bodies are the primary sources of water for a large section of the population.

India has addressed the eutrophication problem only at the level of sewage treatment plants (STPs). The ever-increasing demand of phosphate-laden detergents in rural areas will increase eutrophication of the local water bodies that serve as the primary water resource. The quantitative information on both the external pollutant inputs (allochthonous) and the processes affecting pollutant dynamics within the ecosystem (autochthonous) are necessary for setting an appropriate guideline for total maximum load, which can be accommodated by the system. Setting a maximum load input for P generally requires identification of a water body concentration standard above which the uses of the resource are considered to be impaired. Empirical relationships or models then help to quantify the external loading rate, necessary to achieve the standard. In view of the above, a mathematical model of mass balance, proposed by Havens and Schelske (2001) is used in this study (with few modifications) for determination of P assimilative capacity of the select aquatic ecosystems of Nagpur City of Maharashtra.

The model proposed by Havens and Schelske (2001) is as follows

$$M_{in} + M_{atmos} = P_{lake} \times Q_{out} + P_{lake} \times A \times K_{net} \quad \text{................} \quad (1)$$

In this equation,

M_{in} is the P mass input (metric tons year^{-1})

M_{atmos} is the input from the atmosphere (precipitation)

P_{lake} is the lake water P concentration (mg m^{-3})

Q_{out} is the outflow volume (km^3 year^{-1})

A is lake area (km^2)

K_{net} is the net P assimilation/sedimentation rate (m year^{-1})

Based on the lake or reservoir P budget, a decrease or increase in K_{net} trend, seasonally or annually, an assessment of P assimilative capacity can be carried out. In an aquatic body, the decrease in K_{net} value suggests that the water body (lake or reservoir) has lost some of its capacity to assimilate P (Havens, 1997).

Material and methods:

Study Area:

This study was carried out in the Nagpur City of Maharashtra. The study was carried out at Futalalake (**N**21^0, 8.95' **E**79^0, 5.08') from the Nagpur city. The results reported on are from samples taken over a one - year period (i.e. 2012 - 2013) where the sampling was carried out in each month.

Determination of physico-chemical characteristics and estimation of phosphate.

Physico – chemical parameters such as sediment temperature (Unomot Instruments, Holland) and pH (Multi parameter kit, Merck, Germany) were analyzed on site, while organic matter content (VS) of ten percent sediment slurry was determined by muffling known quantity of heat dried (110 ^{0}C for 1 hr) sample at 550 ^{0}C following Standard Methods (APHA, AWWA – WPCF, 2005). Sediment samples were collected using boat and an Eckman dredge. Total phosphate was estimated following standard methods (APHA, AWWA – WPCF, 2005) and the results were expressed as PO_4, mg/l.

Total P input and physical parameters.

Regular surveys were carried out to determine the total P input to the select systems. All possible sources of P such as detergents, soaps, surface run off etc. were considered to determine the total P mass input. The surface area of the aqua reservoirs was calculated by using a Global Positioning System (GARMIN, Taiwan).

Estimation of heterotrophic bacterial density.

The numbers of viable aerobic heterotrophic bacteria were estimated through the Pour Plate method. Three or five replicates of series of 10-fold sediment dilutions, in appropriate selective liquid media (see below), were prepared. Cultures (aerobes) were incubated at 37 ^{0}C, in the dark, for 3 weeks. The presences of bacteria was scored positive on the basis of colony formation, and confirmed by microscopic observation. Plate count agar medium containing yeast extract (2 $g{\cdot}l^{-1}$), bacto peptone (1 $g{\cdot}l^{-1}$) and glucose (2 $g{\cdot}l^{-1}$) was used for the growth of aerobic heterotrophic bacteria (APHA, AWWA – WPCF, 2005). The pH was adjusted to 7 prior to autoclaving, in all media.

Statistical analysis.

Pearson correlation was performed to test relationships between all investigated variables in the study period. Deference's among sites and sampling periods were investigated by means of one- way analysis of variance

(ANOVA). Differences within sites were estimated through comparing the means (‘*t*’ test).

Results and discussion:

Annual study of select abiotic and biotic parameters

The sediment temperature values at Futala lakes were fairly similar throughout the study period, while the pH and VS content exhibited significant ($P < 0.05$) variation. Average values of select environmental parameters are presented in Table 1. Heterotrophic bacterial density was more in the sediments by one to two orders of magnitude than the water column (Table 2). Average cell counts of sediment microflora of Futala approximated 1.2×10^7 cells per g wet wt. sediment respectively. In general the heterotrophic bacterial counts from sediment of Futala were more enumerable during the summer period.

Estimation of K*net*and phosphatases activities:

The regular surveys and data collection regarding various anthropogenic activities (such as washing of clothes, bathing etc.) showed the nutrient load in terms of phosphate at Futala Lake was 0.098 and 0.012 mg/L of total and ortho phosphate respectively. The data generated for the selected model are presented in Table 3.

The K*net* value of Futala lake varied from 2.66 to 4.08 m/yr. The K*net* value showed a strong positive linear correlation with total phosphate ($r^2 = 0.876$, $P < 0.001$). The variation of K*net* value indicates increase or decrease of lake’s P assimilative capacity (Havens, 2001) and our results, obtained from Futala Lake indicate the progressive loss of P assimilative capacity. This phenomenon may be attributed to the imbalances between the total P mass input (through various anthropogenic activities) and the release of organic P via phosphatases activity.

Table. 1- Sediment temperature, pH and VS values obtained from Futala lake of Nagpur City during 2013-14

Parameter	Futala lake
Sediment temp. (^{0}C)	26.5 ± 2.6 (24.3 – 29.0)
pH (pH units)	7.1 –7.4
Organic matter (mg/l)	2730 ± 490 (1600 - 3400)

The results are average of four observations, ± standard deviation. Values in parentheses represent the range of the parameters

Table. 2- Heterotrophic bacterial density obtained from water and sediment samples obtained from Futala lake of Nagpur City.

		Futala lake
Post Monsoon	**Water**	2.00E+05
	Sediment	4.80E+07
Winter	**Water**	4.30E+04
	Sediment	4.30E+05
Summer	**Water**	2.60E+03
	Sediment	2.60E+05
Monsoon	**Water**	1.30E+05
	Sediment	1.30E+05

Table. 3- Average ***Knet*** value obtained during 2013 – 2014 at Futala Lake of Nagpur City

Sr. No.	Variable	Futala Lake
1.	M_{in}	0.96 metric tons/yr
2.	M_{atmos}	Nil
3.	P_{lake}	0.126 ± 0.030 (mg/L)
4.	Q_{out}	Nil
5.	A	1.2 km^2
6.	K_{net}	**3.1 (m/yr)(based on Eqn. 1)** (total variation 3.8 to 2.7 n/yr during the study period)

Figure. 1- Futala Lake in Nagpur City

Conclusion:

Eutrophication or Nutrient pollution is a process by which water bodies gradually age and become more productive but affecting the water quality. Any natural process like this might take thousands of years to progress but human activities accelerate this process tremendously, which is evident in this study also. From the data collected in this investigation, it can be concluded that the Futala Lake is experiencing progressive loss of P assimilative capacity, which will subsequently result in the higher P conc. In the surface water thereby further promoting the algal growth. Besides, the abundant availability of P in the system (Futala Lake) will also provide opportunity to the heterotrophic bacteria to grow rapidly in the subsurface of the sediment resulting anaerobic degradation of the organic matter. Hence, it is warranted that careful strategy should be delineated to address the P assimilative capacity of the lakes in general that of Futala in particular.

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