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Evaluation of trophic status of certain lakes in Nagpur city

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ABSTRACT

Considering the importance of lakes in the urban environment of Nagpur city, the present study aims at the assessment of trophic status of lakes in Nagpur city. The limnological study to assess the water quality was directed towards environmental survey of the environs of the lake, sources of pollution, and water analysis for physicochemical and biological parameters including phytoplankton and zooplankton, chlorophyll concentration and oxygen balance measurement into the water. The present work aims at utilizing Biomonitoring method based on indicators of water quality namely phytoplankton & Zooplankton for the purpose of assessing trophic status of 5 urban lakes in Nagpur city. The trophic status of the lakes was correlated with the biological and physicochemical characteristics.

KEYWORDS

Trophic status;
Lakes;
Eutrophication;
Limnology.

INTRODUCTION

The trophic state analysis plays vital role in determination of health of the lakes. Temperature, oxygen concentration, chlorophyll concentration, phytoplankton, zooplankton, etc. are the indicators of trophic state analysis of the lakes. The turbidity or water clarity is function of the presence of suspended solids, dissolved organic material, or phytoplankton abundance[2]. Eutrophication of the reservoirs is related to changes in the water temperature. Decrease in water temperature levels decreases the primary production as a result the phytoplankton is outside their optimal temperature range for activity. Decrease in the amount of phytoplankton increases clarity and the level of dissolved oxygen in the lake water[1]. Bachmann[2] reported decrease in oxygen content with increase in the temperature of water reservoirs.

Phosphorus and nitrogen are essential nutrients present in the lakes. Nitrogen enters the lake through industrial runoff, precipitation, fixation of atmospheric nitrogen, animal waste and sewage. Bachmann[2] identified sediment surface runoff and sewage as major sources of phosphorus to the surface water bodies. According to Bronmark and Hansson[3], eutrophication of water bodies is related to increased levels of phosphorus. This mineral of phosphorus triggers an increase in the primary production of the lake and a decrease in water clarity. An increase in the primary productivity of the lake increases shading by phytoplankton which leads to a decrease in the overall productivity of the lake.

Being a byproduct of photosynthesis, the increased primary production leads in higher level of oxygen within the lake environment. In progress of time the bacteria present in the water reservoir decompose the dead

phytoplankton and decaying matter in the water bodies. In this process the bacteria utilize oxygen present in the water body. This leads in the depletion of dissolved oxygen in the water bodies. Bachmann[2] reported decrease in dissolved oxygen levels with increase in the phytoplankton of water bodies.

Chlorophyll levels are strongly associated with the concentration of phosphorus[2]. Phytoplankton uses the pigment chlorophyll *a* in photosynthesis. In temperate lakes, phosphorus (measured as soluble reactive phosphorus) is the limiting agent for primary production. According to Kalff and Knoechel (1978), phosphorus loading and retention is proportional to the amount of biomass. Kalff and Knoechel (1978) have observed Chlorophyll *a*, an estimate of biomass, and increases with increase in phosphorus concentration of water bodies. The ultimate increase in zooplankton was also observed as a function of availability of food and nutrients in the water reservoirs. Leibold (1989) observed limited zooplankton in the water reservoirs as a shortage of food source and density- dependent inhibition.

Deterioration of lake water is also responsible for public health problems in surrounding area. Therefore, regular monitoring of lake water quality & lake ecosystem is necessary for taking appropriate environmental measures to protect & conserve lake water quality suitable for urban ecosystem.

Nagpur in Maharashtra State is one of the green cities in India and is endowed with many lakes. These lakes are in different stages of eutrophication due to long period of negligence. However, some efforts are being carried out by civic authorities to maintain the quality of these lakes.

Gorewada Lake is exclusively used for drinking water supply to a part of the Nagpur city .Phutala Lake is a beautiful lake in the background of hills on its two sides. One side of the hill is now being used to develop botanical garden for Nagpur city. This lake is also used for fishery purpose. Ambazari lake located in the heart of Nagpur city is the worst polluted due to disposal of wastewater. However recently the lake has been desludged partially to remove the polluted sediments and beautified to improve its aesthetic value. However, these efforts are inadequate. Police line (Takli) Lake is for aesthetic purpose, however, the slum area around the lake is responsible for pollution of lake water.

The present study was undertaken in view of importance of lakes in the urban environment. The limnological study to assess the water quality was directed towards environmental survey of lake, sources of pollution, and water analysis for physicochemical and biological parameters including phytoplankton and zooplankton, chlorophyll concentration and oxygen balance measurement of water. Biological monitoring with plankton is economical as compared to physicochemical methods and biological monitoring with other groups of aquatic organisms. The main purpose of biological analysis is to protect & preserve the biological integrity of natural ecosystem, which include preventive measures.

The observations of this study will be useful for local civic bodies to understand the status of lakes in Nagpur city from pollution point of view as well as the sources of pollution to the lake. An effort has also been made to suggest the remedial measures for restoration of lake water quality. The data collection will help to plan proper effective remediation programme for restoration of lake water quality and for preventive regular maintenance of the lake for its sustainability.

Lakes could be generally classified on the basis of nutrient levels & microbial activity.

Oligotrophic - Low nutrients, minimum microbial activity.

Mesotrophic - Moderate nutrients, moderate microbial activity.

Eutrophic - High nutrient, high microbiological activity.

Overall, lakes all over the country are exhibiting varying degrees of environmental degradation caused by encroachments, eutrophication (from domestic and industrial effluents) and siltation. The high population density ensures that many water bodies are under severe and direct pressure from anthropogenic activities in their catchments.

MATERIALS AND METHODS

A total of five sites were selected for detail experimental studies. Viz. Ambazari Lake, Gandhi Sagar Lake, Gorewada Lake, police Line Lake, Phutala Lake. The Lake water samples were collected in the months of

May and June and were analyzed. Observations were made at the period of 15 days. Onsite temperature and pH of the water was measured whereas dissolved oxygen was fixed and analyzed in the laboratory. pH, Alkalinity, total hardness, chlorides, dissolved oxygen, chemical oxygen demand, phosphate, sulphate, and total dissolved solids were estimated as per the standard methods prescribed by APHA[6].

Oxygen balance measurement

Depending on the water temperature organic pollution and light condition a dynamic equilibrium results, which manifests itself in a day and night variation in the dissolved oxygen content of the surface water. By simple measurement of the oxygen content of the water during a day and night period, an oxygen curve is obtained which can be evaluated by means of the Brujewitsh formula

$$Po_2 = O_{2\ max} + K \times O_{2\ night} \times \frac{N}{24 - n}$$

Where, Po_2 = Oxygen production, $O_{2\ max}$ = The difference between the maximum & minimum oxygen content during 24 hrs period, $O_{2\ night}$ = The decrease in oxygen content during the night, N = The length of the night in hr., n = The length of the day in hr., K = Coefficient, which is equal to the ratio of the time between sunrise & afternoon maximum, to the length of the day in hr. generally, the value of the coefficient is 0.85.

Shannon wiener index (SWI)

Community analysis in ecology often report some measure of diversity. Two types of diversity are commonly recognized. Former is richness or number of taxa present and later is evenness, a measure of how equally individuals are allocated among the taxa. Shannon Wiener Index of diversity measures both richness and evenness and is the best estimate of diversity. Diversity changes due to impact of some environmental factor or due to pollution.

$$\text{Shannon Wiener Diversity Index (d)} = -\sum_{i=1}^{x} n/N \cdot \log_2 n/N$$

Where, n = number of individuals of "i" species, N = total number of individuals of all species (x), x = total number of species in the sample

When,

d = <1: It indicates Eutrophic water or nutrient deficient water

d = 1 – 3 : It indicates Mesotrophic or nutrient rich or mediumly polluted water

d = >3 : it indicates Eutrophic water

Palmer's pollution index

Bioindicator species indicating organic pollution are helpful in limnological studies to classify water bodies according to trophic status i.e. Oligotrophic, Mesotrophic or Eutrophic. Looking for the presence and absence of these species in the water samples is the simplest approach in this direction. Palmer (1969) considered the tolerance capacity of these species to organic pollution and expressed them numerically. The summation of these values in a sample gives the value of Palmer's Pollution Index. The ranges of index values indicative of organic pollution are:

<15 : organic pollution is absent

15-20 : presence of organic pollution

>20 : presence of high level of organic pollution.

RESULTS AND DISCUSSION

Environmental & Limnological survey of 5 Lakes in Nagpur was carried out in environmentally critical summer season months i.e. May & June. Initially environmental observations were made on the morphology of the lakes, human activity around it, sources of pollution, & death of the Lakes etc. Limnological observations were made at the period of 15 days in May & June 2008.

Environmental survey

All the Lakes were visited & observations were made. It was observed that Gorewada Lake is well protected by Local Civil authorities as this Lake is in use for public water supply. The sources of pollution are the run off water from the catchments area.

Ambazari Lake is a Large Lake with supply of water for urban plantation only. This Lake is used for recreational purpose with a public garden on its bank. The sources of pollution to the Lake are run off water from surrounding residential area & by the growth, death & decay of macrophytes in it.

Gandhi Sagar Lake has one Nalla as only source of water. Therefore, this lake has been recorded to be highly polluted a few years back. However, the Lake restoration measures have shown the improvement of Lake Water quality to some extent. Disposal of solid waste & immersion of idols of God Ganpati & Goddess Durga are also the sources of pollution to the Lake.

The Phutala Lake receives pollution through run off from surrounding residential area. Lot of macrophytes also grow every year in the Lake & contribute the pollution after their death & decay.

The police line Takli Lake is a shallow Lake with rain water as the only source of water for the Lake. Therefore, in Summer Season the water body shrinks to a small size & water become green due to concentration of pollution.

The above discussion shows that Gorewada Lake, Ambazari Lake & Phutala Lake is large, mediumally deep, permanent water bodies which play an important role in the ecology & in the beautification of Landscape. Gandhi Sagar Lake & Police Line Takli Lake are shallow water bodies & need a permanent source of good quality water as well as control of anthropogenic sources of pollution.

It is observed that the pH above standards for drinking water were found in police line lake especially in the beginning of May. This may be due to either algal blooms in the bottom or pH of the water under stipulated standards. The Dissolved oxygen was observed to be in the range from 8.63 ppm to 11.36 ppm indicating the super saturation of water due to algal blooms in the Lake.

The available Phosphate concentration was observed in the range of 0.28 ppm to 0.85 ppm indicating sufficient amount of phosphate in the Lakes which must have been responsible for algal bloom condition in the Lake. Phosphate concentration was highest in the Police Line Lake followed by Ambazari Lake, Phutala Lake, Gandhi Sagar Lake & Gorewada Lake. This observation indicates that detergent from the domestic waste water is the possible source of ample phosphate in the lakes. The quantity of sulphate is very less as compare to drinking water sample. Chlorophyll – a concentration represents standing biomass in the lake water which in term indicates productivity status depending on eutrophication levels. The chlorophyll–a content in the lake varied from 1.62 mg /lit to 89.35 mg / lit. Highest Chlorophyll-a values were observed in case of Police Line Lake, Ambazari Lake & Gandhi Sagar Lake while very low chlorophyll-a content was observed in Phutala Lake & Gorewada Lake.

Suess (1982) classified Lake in different trophic levels on the basis of net productivity of the Lake measured in terms of mg dry weight of phytoplankton standing crop per lit. Water sample as given below

	Trophic status	Algal productivity (dry weight)
1)	Oligotrophic	< 50 mg / L
2)	Mesotrophic	50- 100 mg/L
3)	Eutrophic	> 100 mg/L

Based on these values, the chlorophyll content in Police Line Lake, Gandhi Sagar Lake & Ambazari Lake are above 50 mg/L & below 100 mg/L indicating that these are mesotrophic lakes while the chlorophyll-a content in Phutala Lake & Gorewada Lake are below 20 mg/L indicating that they are oligotrophic lakes during the study.

The heavy metal content in lake water is very low & may act as trace element to support the growth of planktons in the lake.

Above discussion shows that most of the lakes have good water quality as compared to drinking water standard. However the nutrient enrichment especially phosphate is observed to trigger the growth of plankton in the lake water. Therefore, the water of Police Line, Ambazari & Gandhi Sagar Lakes is not aesthetically acceptable. The Gorewada Lake has comparatively better water quality.

Biological status of lake water

Observations were made on phytoplankton and zooplankton indictors of water quality. A list of trophic state Indices used in this investigation is given in Table. The results are discussed below.

Phytoplankton species diversity

Average values of Palmer's pollution index (PPI) are 16 for each of Gorewada Lake & Police Line Lake, indicating marginal level of pollution. Gandhi Sagar Lake had PPI value of 19 indicating presence of organic pollution & Ambazari Lake & Phutala Lake has PPI values of 21 & 22 respectively indicating higher levels of Eutrophication. Accordingly Gorewada & Police Line Lake are least polluted, Gandhi Sagar Lake mediumly polluted & Ambazari & Phutala Lake highly polluted.

Phytoplankton groups can be considered as indicator of water quality in the broad sense. Bacillariophyceae is indicator of clean Lake Water. Chlorophyceae (especially Chlorococcales) indicate highest level of organic pollution, while presence of

cynophyceae indicates medium level of organic pollution. Euglenphyceae is also a good indicator of organic pollution however; it is always present in small amount. The relative concentration of these groups varies depending on level of Eutrophication

It has been observed that the count of pollution indicator species is highest in Gandhi Sagar Lake followed in decreasing order by Ambazari Lake, Police Line Lake, Phutala Lake & Gorewada Lake. Similarly the ratio of indicator to non indicator species is higher in Gandhi Sagar & Ambazari Lake & gradually decreases in Police Line, Phutala & Gorewada Lake.

Zooplankton species diversity

Zooplankton Groups can be considered as indicator of water quality in the broad sense. Cladocera is indicator of clean Lake Water, Ostracoda is also indicator of clean lake water, Rotifers is indicator of organic pollution & Copepoda is indicator of mediately polluted lake water. The relative Concentration of these groups varies depending on level of eutrophication.

In Gorewada Lake, total count of all these groups is lowest as well as they occur in more or all equal proportion along with small population of Insecta. This indicate lowest level of eutrophication along with presence of all nutrients at optimum level with slight organic pollution .Thus, Gorewada Lake occupies lowest level of Eutrophication in Nagpur city.

Gorewada Lake has 6, Gandhi Sagar Lake has 9, Ambazari Lake has 11, Police Line Lake has 11, and Phutala Lake has 12 Zooplankton species. Total number of species in a sample is the indicator of water quality. In the present case, we can say that Gorewada & Phutala Lake with lower taxa & level of eutrophication

TABLE 1 : Physicochemical characteristic of the lakes in Nagpur during May June 2008

Sr. No	Parameters	ABZ	GSG	GRW	PHU	PLT	ISDW
1.	Temperature,ºC	31.3±0.23	32.65±0.55	30.3±1.64	31.5±2.67	31.83±2.85	-
2.	pH	8.0±0.52	7.95±0.02	8.56±0.19	8.47±0.43	8.46±0.47	6.5-8.5
3.	Conductivity,ms/cm	0.697±0.05	1.06±0.02	0.41±0.006	0.752±0.07	0.92±0.04	-
4.	Alkalinity	8.2±0.1	27.0±0.05	10.0±0.28	10.96±0.65	18.46±1.36	200
5.	Dissolved oxygen	11.36±1.08	8.7±0.2	9.5±2.4	8.63±2.38	9.76±2.32	-
6.	Phosphate	0.61±0.04	0.4±0.4	0.29±0.01	0.46±0.06	0.81±0.025	-
7.	Sulphate	27.14±1.16	45.2±0.02	28.4±1.28	31.76±0.4	44.8±0.77	200
8.	Nitrate	0.65±0.005	1.42±1.20	0.25±0.008	0.55±0.008	0.48±0.009	45
9.	Biological Oxygen demand	18.3±2.05	14.3±0.03	4.7±0.47	7.0±1.63	9.0±0.81	-
10.	Total suspended solids	5.3±0.34	5.7±0.2	0.39±0.02	4.13±0.24	5.9±0.16	-
11.	Chlorophyll	67.36±16.47	62.69±5.0	2.10±0.34	15.39±3.44	70.62±0.25	-
12.	Oxygen balance measurement	10.59±0.91	8.42±0.36	-	10.27±0.34	-	-

All parameter expressed in mg/l except pH, temperature, conductivity. ISDW = Indian standard for drinking water (IS:10500-1991) The values are ±SD of four determinations.

TABLE 2 : Distribution of heavy metals in the lakes water of Nagpur city in May-June 2008

Heavy metals	ABZ	GSG	GRW	PHU	PLT	ISDW
Mn	0.021±0.03	0.012±0	0.011±0	0.018±0	0.037±0.03	0.05
Cu	0.011±0.01	0.002±0	0.021±0	0.020±0.003	-	0.05
Pb	0.057±0.02	0.047±0.007	0.028±0.008	0.029±0.003	0.055±0.001	0.3
Fe	0.345±0.02	0.204±0.086	0.033±0.013	0.033±0.009	0.184±0.008	-
Ni	0.126±0.09	0.067±0.05	0.035±0.018	0.094±0.005	-	5.0
Zn	0.103±0.06	0.019±0.003	0.029±0.037	0.034±0.03	-	0.01
Cd	0.003±0.003	0.006±0.001	0.002±0.0005	0.005±0.002	0.021±0.002	0.01
Cr	-	0.026±0	Nil	Nil	-	-
Co	0.007±0.007	0.022±0	0.005±0.001	0.016±0.01	-	-

TABLE 3 : Occurrence of phytoplankton in the lakes of Nagpur city during May-June 2008

Sr. No.	Algal Group / Algal Species	Ambazari Lake	Gandhi Sagar Lake	Police Line Lake	Phutala Lake	Gorewada Lake
	Cyanophyceae					
1.	*Oscillatoria* sp.	√	√	√	√	√
2.	*Anacysis* sp.	-	√	√	√	√
3.	*Chroococcus* sp.	--	√	√	√	√
4.	*Anabaena* sp.	√	-	-	-	-
5.	*Microcystis* sp.	√	-	-	-	-
	Chlorophyceae					
6.	*Chlorella* sp.	√	√	-	√	√
7.	*Ankistrotdesmus* sp.	√	√	-	√	√
8.	*Chloroccoccum* sp.	√	√	√	√	√
9.	*Chlamydomomas* sp.	-	-	-	-	-
10.	*Tetraedron* sp.	√	-	√	-	√
11.	*Selenastrum* sp.	√	-	√	√	-
12.	*Scenedesmus* sp.	√	√	-	√	√
13.	*Trochischia* sp.	-	-	-	√	√
	Bacillariophyceae					
14.	*Navicula* sp.	√	√	√	√	√
15.	*Nitzia* sp.	√	-	√	-	√
16.	*Cocconeis* sp.	-	-	-	√	√
17.	*Stephanodiscus* sp.	√	-	-	√	√
18.	*Fragillaria* sp.	-	-	√	√	√
19.	*Synedra* sp.	√	-	-	√	-
	Euglenophyceae					
20.	*Euglena* sp.	√	√	√	√	√
	Total	14	8	9	15	15

TABLE 4 : Occurrence of zooplankton in the lakes of Nagpur city during May-June 2008

Sr. No.	Zooplankton Group / Species	Ambazari Lake	Gandhi Sagar Lake	Police Line Lake	Phutala Lake	Gorewada Lake
	Rotifera					
1.	*Brachionus forficula*	√	√	√	√	√
2.	*Lecane* sp.	√	√	√	√	√
3.	*Keratella* sp.	√	√	√	√	-
4.	*Monostylabulla* sp.	-	-	√	-	-
5.	*Brachionus calyciflour*	-	-	√	√	-
6.	*Lepadell* sp.	-	-	√	-	-
7.	*B. quadridentata*	√	-	√	√	-
	Cladocera					
8.	*Moina* sp.	√	√	√	√	-
9.	*Daphnia* sp.	√	√	-	√	√
10.	*Allonella* sp.	√	√	-	√	-
	Copepoda					
11.	*Cyclop* sp.	√	√	√	√	√
12.	*Diaptomus* sp.	√	√	√	√	-
13.	*Nauplius* sp.	√	√	-	√	√
	Ostracoda					
14.	*Cypris* Sp.	√	-	-	√	√
	Insecta					
15.	Dragonfly nymph	-	-	√	-	-
	Total	11	9	11	12	6

TABLE 5 : Zooplankton population and Shannon Weiner index of the lakes in Nagpur city during May-June 2008

Sr. No	Lakes	Species	Sub Total Count	Grand Total	Shannon Weiner Index
1	Police line	Rotifera	517	2212	2.45
		Cladocera	650		
		Copepoda	1011		
		Insecta	34		
2	Phutala	Rotifera	770	1955	2.37
		Cladocera	251		
		Copepoda	900		
		Ostracoda	34		
3	Ambazari	Rotifera	600	2601	2.35
		Cladocera	583		
		Copepoda	1384		
		Ostracoda	34		
4	Gorewada	Rotifera	68	938	1.10
		Cladocera	51		
		Copepoda	785		
		Ostracoda	34		
5	Gandhi sagar	Rotifera	134	684	2.15
		Cladocera	150		
		Copepoda	400		

TABLE 6 : Phytoplankton Population, Shannon Weiner index and Palmer Pollution index of lakes in Nagpur city during May-June 2008

Sr. No	Lakes	Species	Sub Total Count	Grand Total	Shannon Weiner Index	Palmer Pollution Index
1	Gorewada	Cynophyceae	115	451	2.57	16
		Chlorophyceae	199			
		Bacillariophyceae	114			
		Euglenophyceae	23			
2	Phutala	Cynophyceae	244	874	2.50	22
		Chlorophyceae	425			
		Bacillariophyceae	183			
		Euglenophyceae	22			
3	Ambazari	Cynophyceae	716	2235	3.42	21
		Chlorophyceae	902			
		Bacillariophyceae	524			
		Euglenophyceae	93			
4	Police line	Cynophyceae	397	1305	1.71	16
		Chlorophyceae	182			
		Bacillariophyceae	545			
		Euglenophyceae	181			
5	Gandhi sagar	Cynophyceae	1531	12511	2.53	19
		Chlorophyceae	10338			
		Bacillariophyceae	38			
		Euglenophyceae	604			

is gradually increasing in Ambazari, Police Line Takli & Phutala Lake.

From the data the eutrophication levels of the lakes under study are

Gandhi Sagar > Ambazari > Police Line > Phutala > Gorewada Lake.

Suggestion for lake restoration & maintenance

ii. Regular Survey & quarantine of catchment area to control pollution & weeds.

iii. Afforestation of catchment area to check soil erosion.

iiii. Yearly cleaning operations to remove the macrophytes from the lake & their proper reuse & recycle through composting or Biogas plant.

CONCLUSION

The present work aims at utilizing Biomonitoring method based on indicators of water quality namely phytoplankton & zooplankton for the purpose of assessing trophic status of 5 urban lakes in Nagpur city. Similarly physicochemical observations were also undertaken to coreleate with the biological observations. It has been found that various community parameters of phytoplankton & Zooplankton are best indicators of lake water quality & its tropic status. The trophic indices based on plankton population are useful indicator of lake water quality. Being the important water reservoirs of the city restoration & rehabilitation as well as regular maintenance of these lakes is necessary for sustainable use in future for a long period.

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