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An application of water quality index (WQI) and PASTA software programme to evaluate the water quality in selected waterbodies of Mysore, Karnataka, India

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Abstract
Lingambudhi and Mandakahalli waterbodies are major lakes in Mysore. A few decades ago, Lingambudhi lake has lost its quality, because of development of housing colonies and overgrazing. Mandakahalli lake provides water for irrigation to the surrounding agricultural areas and it is used for fishing purposes. Recently the agricultural runoff and sewage inputs into the lake has led to degradation. Water quality index (WQI) was calculated by taking ten physico-chemical parameters and dynamic analysis of Phytoplankton diversity in these two lakes of Mysore has been discussed. Nine diversity indices have been derived using the PASTA software programme. A total of 29 algal species have been identified. An attempt has been made to correlate, the interaction of phytoplankton and the variation of water quality parameters in the selected lakes of Mysore. The values are above the upper limits in terms of WQI, which indicated that the water was not safe for human use. Both the water bodies were low in dissolved oxygen and least abundance of plankton indicate negative inferences. The WQI and diversity of Phytoplankton is widely used to evaluate and solve the problems of failures of management strategies for improving water quality of the polluted waterbodies.

Keywords: Water quality, lakes, algal diversity indices, physico-chemical parameter, WQI

Introduction
The Mysore district is situated in the southern part of Deccan Peninsula in Karnataka in India. It lies between $11^0 30'$ and $12^0 50'$ north latitude and $75^0 45'$ and $77^0 45'$ east longitude. Two lakes (Mandakahalli and Lingambudhi) which are the major water bodies in city of Mysore. These lakes are polluted due to the mixing of sewage and agriculture effluents. These lakes are the sources of water supply and provide aesthetic value to the city. The study attributes of lakes physico-chemical parameters provides a thorugh insight into the trophic stage of these lakes. Observation of inputs, out-let point, geographical locations and surrounding areas helps us provide better and cleaner technologies for restoration. Diversity of phytoplankton measures is more useful in lake ecosystem, which harbor a large variety of algal species in general and species diversity within genera. Therefore application of species richness indices is very essential and it is necessary to apply models that describe the distribution of species abundance. Ecologists have designed a large range of indices and models for measuring diversity. Diversity consists of two components firstly the variety and secondly the relative abundance of species. Investigations on ecological diversity are often restricted to species richness which is a direct count of the number of species present (Pianka 1983) [19]. The present study is based on the data collected over a period of one year on the WQI and distribution of algal biodiversity in two lakes of Mysore. The study of Phytoplanktons in these lakes can account for the extent of eutrophication occurring in these lakes. Phytoplankton are important primary producer and the basis of the food chain in open water, some species on the other hand can be harmful to human and other vertebrate by releasing toxic substance like hepatotoxins and neurotoxins etc.

Materials and Methods

Water samples were collected from Mandakahalli and Lingambudhi lakes during May 2021-April 2022 from different spots (the middle, outlets and insets) water samples were collected in one litre plastic bottles, were analyzed in the laboratory for important physico-chemical parameter according to the methods described by APHA (2002) [1] Tiwari and Manzoor Ali (1988) [12] Trivedy and Goel (1986) [29], separate water samples were collected for Phytoplankton, sedimentation of water was made in 4% formaldehyde, phytoplankton were counted 1 ml sample under compound research microscope (40 x magnification) and identified according to Fristch (1975) [6] Philopose (1967) [18], Prescott (1982) [22] Hosmani and Bharathi (1980) [8]. Water quality index WQI calculation and Plankton count was done by Suxena (1987) [24]. The Phytoplankton was expressed as organism per ml for the purpose of calculating diversity indices. The data were subjected to a software programme PAST (Hammer et al. 2001) [7] which generates nine diversity indices. The formula designed for various index are described below dominance index = 1-J is evenness of relative diversity (H/Hmax) where absolute evenness = 1.00.

Water Quality Index (WQI)

Water Quality Index (WQI) indicates the quality of water in terms of index number, which represents the overall quality of water for intended use. It is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water ICMR (1975) [10] and Mahadev *et al.* (2010) [14].

WQI Calculation

For the calculation of WQI, ten physico-chemical parameters of water like pH, dissolved oxygen, total dissolved solids, total suspended solids, calcium, magnesium, total hardness, chloride, chemical oxygen demand and nitrate were taken into consideration. The calculation of WQI was done following the arithmetic index method of Chatterjee and Raziuddin (2008) [4] as follows.

Calculation of Sub Index (or) Quality Rating (q_n)

Let there be 'n' water quality parameters and quality rating or sub index (q_n) corresponding to n^{th} parameter is number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. The q_n is calculated using the following expression.

$$q_n = 100\ [(V_n-V_{io})/(S_n-V_{io})]$$

where

q_n = quality rating for the n^{th} water quality parameter

V_n = estimated value of the n^{th} parameter at a given sampling station

S_n = standard permissible value of n^{th} parameter

V_{io}= Ideal value of n^{th} parameter in clean water

All the ideal values (V_{io}) are taken as zero for the drinking water except for pH = 7.0 and for dissolved oxygen = 14.5 (mg/l)

Calculation of Quality Rating for pH

For pH ideal value is 7.0 (neutral water) and permissible value is 8.5 (polluted water). Therefore, quality rating for pH is calculated from the following relation.

$$q_{pH} = 100\ [(V_{pH}-7.0)/(8.5-7.0)]$$

where V_{pH} = Observed value of pH

Calculation of Quality Rating for Dissolved Oxygen

The ideal value (V_{Do}) for dissolved oxygen is 14.6 mg/l and the standard permissible value for drinking water is 6 mg/l. Therefore, quality rating is calculated by following relation.

$$q_{Do\ =\ 100}\ 100\ [(V_{Do}-14.6)/(6-14.6)]$$

Where

V_{Do} = Measured value of dissolved oxygen

Calculation of Unite Weightage (W_n)

The unit weights (W_n) for various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$$W_n = K/S_n$$

Where

W_n-Unit weight of n^{th} parameters

S_n = Standard value for n^{th} parameters

K = Constant for proportionality

Calculation of WQI

WQI is calculated from the following equation

$$WQI = \frac{\sum_{n=1}^{n} q_n W_n}{\sum_{n=1}^{n} W_n}$$

Where

WQI = Water Quality Index

q_n = Quality rating for the n^{th} parameter

W_n =-Unite weight for n^{th} parameter

Index softwares allows for data management and easy interpretation by non-technical personnel and the general public

The shannon Weiner Index (H) assumes all species are represented samples randomized = ∑ pi in pi ; Pi-proportion of the ith species and in natural logarithm. The Simpsons diversity index (1949) is calculated as Ds= ∑ (ni (ni-1/N (n-1) where Ds-Bias corrected from simpson index, ni is number of individuals of species 1, N=total number of species in community. Pielou's evenness index (1975) measures equitability and compare the observed Shannon weiner index against the distribution of individuals between the observed species that would maximize diversity. The index is expressed as J=H/log (s). The maximum value this would take is log (s) where S is the total number of species in the habitat. Menhinick's index Dmm (Whittaker 1977) [30] is expressed as Dmm = S/N where N is the number of individuals in the sample and S the species number. Margalef's (1968) [15] is expressed as D=(S-1)/In N. It is calculated as the species number (s) minus 1 divided by the loganthom of the total number of individual (N).

The shannon's equitability index (EH) = H/max-H/ In S (Lloyd and Ghelard 1964) [11]. The fisher and index is expressed as ax, ax 2/2, a x 3/3….. a x n/n.

The berger parker dominance index expressed d = Nmax/N. N max. A reciprocal of the index 1/d is often used so that and intercase in the value of the index accompanes an increase in diversity and reduction in dominance.

Results and Discussion

The mean values of various physico-chemical parameters during different seasons for the period between May 2021 and April 2022 are presented in Table 1. Water quality standard (ICMR 1975) [10] and units weights are shown in Table-2. Quality rating and calculated log values are listed in Table 3 where as sub index values and WQI are given in Table 4. The pH of water was above 7.50 in all the season in both lakes. Higher values of pH in all seasons can be attributed to high growth rate of algal population, which utilized CO_2 through photosynthetic activity same observation was made by Perkin (1976) [17]. In the present observation pH values were within ICMR standards (7.0-8.5). The Dissolved Oxygen (DO) is an important test to study the quality of water. The maximum amount of DO (6.90 mg/l) was observed during rainy season in Lingambudhi lake while minimum (3.70 mg/l) was noted during winter in Mandakahalli lake.

The lower values could be attributed to addition of sewage and agricultural effluent containing oxidizable organic matter and consequent upon the biodegradation and decay of vegetation at higher temperature (Anvar Batcha 2001) [2]. High total dissolved solids (TDS) content (980 mg/l) was recorded in during winter in Mandakahalli lakes, lower values recorded in 720 mg/l in Lingambudhi lake, whereas, the permissible limits is 500 mg/l as per ICMR standards. High TDS values due to mixing of sewage and agriculture effluents was observed in both the lakes. Similar observation was made by Hosmani and Bharathi (1980) [8] where calcium, magnesium and total hardness were below the permissible limit due to mixing of sewage and agriculture effluents. However, no significant changes in calcium, magnesium and hardness were noted during all the seasons. Also, it was noted that, Chloride and nitrate concentration were below the permissible limit of ICMR standards. Chemical Oxygen Demand (COD) values were found maximum in both lakes during all the seasons. The high values of COD (25.0 mg) was noted during winter in Mandakahalli mainly due to input of organic pollutants. The water quality index for all the seasons are represented in Table 4. The index values may be due to massive discharge of domestic waste agricultural run-off and greater human interference Chattergee and Raziuddin (2008) [4]. The status of Mandakahalli and Lingambudhi lake water quality values is above the upper limit in terms of WQI. The WQI provides information on the quality of water for different uses such as drinking irrigation recreation and aquatic life etc. As per the results of WQI for both lakes indicated that is poor for human consumption. The water quality is always in endangered condition and that it regularly deviates from normal level. The results obtained in our study are similar to a study carried out by Shankar P. Hosmani (2010) [9].

Diversity indices generated by PAST SOFTWARE programme

The results of the distribution of photoplankton in two lakes are presented in table 5 and the calculated diversity indices are presented in table 6. The dominance index in the present study indicates that Mandakahalli lake (0.06) and Lingabudhi lake (0.1) have the least dominance has a very diverse phytoplankton ecosystem. This is due to presence of high pH ambient temperature, DO and abundance of swage from the surrounding residential areas. Shannon and weiner index (1949) it is also determine the pollution status of a water body. Normal values range from 0 to 4. This index is combination of species present and the evenness of the species, examining the diversity in the range of polluted and un polluted ecosystem Wilham and Dorris (1968) [31]. Both lakes indicates that maximum pollution in shannaon's index and least diversity in simpson's index. Pielons index indicate least diversity index mainly due to the low value of DO and high value of pH. Both the menhinrek's and margalef's were measure richness of species in an ecosystem. Therefore richness of species can be seen in both the lakes.

The Shannon equitability index is measures of the evenness with which individual are divided among the taxa present. The explanation for this index is that for a given richness (total number of species in a community. S) Simpson's diversity index increases as diversity increases and for a given equtability simpson's index increases as richness of species increase. The present study indicates that individuals of community in both lakes are not evenly distributed with values ranging from 0.96 to 0.98.

Fisher's alpha index it represented the first attempt to describe mathematically the relationship between the number of species and the number of individuals of those species extensively in entomological studies. According to the index is very low in Lingambudhi lake (12.7) and highest in Mandakahalli lake (50.9). This indicates that abundance of species in Mandakahalli lake.

Berger-parker dominance index (1970). This index is most strongly influenced by evenness of the indices (Shannon & Weiner (1949) its reciprocal values is an index of diversity. In the present study indicates that individuals of community in both lakes are not completely evenly distributed. The values are high in Lingambudhi lake (0.15) and is least in Mandakahalli lake.

Various diversity measures have potential applications in aquatic ecosystems mainly in conservation, it is often understood that species rich communities are better than species poor communities, secondly, in environment monitoring it is assumed that the above adverse effects of pollution will be reflected in the reduction of diversity change in the composition of species abundance. Both these factors involve diversity as an index of good eco system. Rosenberg (1976) [23] and Patrick (1973) [16] are of the opinion that enriched at polluted ecosystem display a reduction in diversity. Shannon and Weiner index is widely adopted in pollution monitoring. Platt *et al.* (1984) [21] used the Simpsons index in bio-monitoring. Sterner (1989) [26] discussed the role of phytoplankton species and assemblage as bio indicators. Simple species richness and dominance measures are invariably informative. There is considerable evidence that conservation strategies may be improved if information on species abundance pattern is taken in to account.

Table 1: Seasonal variation of physico-chemical parameter in two lakes of Mysore

Parameter	Mandakahalli Lake			Lingabudhi Lake		
	Summer	Rainy	Winter	Summer	Rainy	Winter
pH	8.05	7.56	8.01	8.47	7.78	7.63
Dissolved Oxygen	4.89	5.13	3.70	5.02	6.90	6.30
Total dissolved solid	915	945	980	832	790	720
Total suspended solid	145.0	192.50	142.50	121.5	180.0	170.0
Calcium	64.73	61.30	73.95	60.58	36.25	32.01
Magnesium	32.03	33.37	26.68	23.39	13.25	18.28
Total hardness	293.0	290.0	294.0	245.00	150.0	174.0
Chloride	71.44	66.03	118.57	115.38	117.16	119.59
Chemical Oxygen demand	19.25	14.75	25.00	12.00	11.00	11.75
Nitrate	43.00	44.00	40.00	24.00	28.00	30.00

All parameter are expressed as mg/L except pH

Table 2: Water quality standards (ICMR) and unit weightage

Parameter	Standard (Sn)	Unit weight (Wn)
pH	7.00 to 8.5	0.2344
Dissolved Oxygen	6.00	0.0346
Total dissolved solid	500.00	0.0004
Total suspended solid	500.00	0.0004
Calcium	75.00	0.0027
Magnesium	50.0	0.0041
Total hardness	500	0.0004
Chloride	250	0.0008
Chemical Oxygen demand	4	0.0052
Nitrate	45	0.0011

Table 3: Water quality rating (q_n) calculated Log (q_n) value of two lakes of Mysore

Parameter	Mandakahalli Lake			Lingabudhi Lake		
	Summer	Rainy	Winter	Summer	Rainy	Winter
pH	52.00	42.0	98.00	70.00	70.00	37.00
Log (q_n)	1.7160	16.232	1.9912	1.8451	1.8451	1.5682
Dissolved Oxygen	101.16	96.13	111.39	126.74	112.90	110.11
Log (q_n)	2.005	1.9845	2.046	2.1029	2.0526	2.0418
Total dissolved solid	116.0	104.00	127.00	135.00	123.00	127.00
Log (q_n)	2.064	2.0170	2.103	2.1303	2.0899	2.1038
Total suspended solid	36.00	34.00	42.50	28.50	29.00	38.50
Log (q_n)	1.5563	1.5314	1.628	1.4548	1.4623	1.5854
Calcium	48.33	42.68	80.77	98.60	86.30	81.73
Log (q_n)	1.6845	1.6302	1.9072	1.9938	1.9360	1.9123
Magnesium	26.65	36.56	46.78	53.36	64.06	66.74
Log (q_n)	1.4256	1.5630	1.6671	1.7272	1.8065	1.8243
Total hardness	30.00	34.00	49.00	58.80	58.60	58.00
Log (q_n)	1.4772	1.5314	1.690	1.7693	1.7692	1.7634
Chloride	28.57	26.52	47.40	46.14	23.40	47.80
Log (q_n)	1.4559	1.4235	1.675	1.6640	1.3692	1.6794
Chemical Oxygen Demand	275.00	293.00	300.00	625.00	481.0	368.00
Log (q_n)	2.439	2.4668	2.4771	2.795	2.6821	2.5658
Nitrate	1.022	1.355	0.933	1.42	1.55	1.88
Log (q_n)	0.0094	0.1319	0.0299	0.1522	0.19033	0.2741

Table 4: Calculated Sub Index (q_n, W_n) values of different parameters and water quality index of (WQI) of two lakes of Mysore

Parameter	Mandakahalli Lake			Lingabudhi Lake		
	Summer	Rainy	Winter	Summer	Rainy	Winter
pH	0.0432	0.036	0.0432	0.046	0.040	0.038
Dissolved Oxygen	0.0710	0.070	0.0727	0.070	0.0693	0.0068
Total dissolved solid	0.00083	0.000842	0.00085	0.00084	0.00825	0.0080
Total suspended solid	0.00058	0.000634	0.00058	0.0005	0.00062	0.00612
Calcium	0.0052	0.00516	0.00538	0.0051	0.0045	0.00440
Magnesium	0.0074	0.0074	0.0070	0.0068	0.0058	0.0064
Total hardness	0.0007.7	0.0070	0.00070	0.00067	0.000590	0.000612
Chloride	0.00109	0.00134	0.00133	0.00134	0.001164	0.001138
Chemical Oxygen Demand	0.1394	0.133	0.145	0.1281	0.126	0.12822
Nitrate	0.00209	0.0030	0.0016	0.00032	0.00010	0.00145
Total hardness	0.27149	0.2581	0.27834	0.25988	0.24889	0.2497
Antilog	187.0	181.1	189.3	181.9	174.0	177.7
WQI	187.0	181.1	189.3	181.9	174.0	177.7

Table 5: Distribution of Algae in two lakes in Mysore

Sl. No.		Mandakahalli Lake	Sl. No.		Lingabudhi Lake
	Total species, Total individual	21 26		**Total species, Total individual**	12 20
I.	**Chlorococcales**		**I.**	**Chlorococcales**	
1	Pediastrum tetras	01	1	Pediastrum duplex v. reticulatum	01
2	Scenedesmus quadric cauda v. maximum	01	**II.**	**Desmidaceae**	
II.	**Desmidaceae**		2.	Euastrum anstaum v. Simplea	02
1	Euastrum anstaum v. Simplex	01	**III.**	**Bacillariophyceae**	
III.	**Bacillariophyceae**		3.	Syndera ulna	02
1.	Syndera ulna	01	4.	Fragillaria construens v. venter	01
2.	Gyrosigma accuminatum	01	5.	Gomphonema angustrum	01
3.	Gomphonema balatoneis	01	6.	Cyclotella latenata	02
4.	Cymbella cymbelliformis v nerei	01	7.	Epthemia zebra v. parcalus	02
5.	Mastoglolia recta v. kolhapurensis	01	8.	Pinnularia stomatophoroidn v. ornate	03
6.	Cyclotella latenata	02	9.	Navicula smiles	03
7.	Epithemia zebra v. parcalus	03	10.	Cyclotella striata	01
8.	Pinnularia stomatophoroides v. ornate	02	**IV.**	**Euglenophyceae**	
9.	Navicula smiles	02	11.	Euglena spirogyra	01
10.	Nitzschia obtusata v. scalpaliform	01	**V.**	**Cyanophyceae**	
11.	Cocconies permagna	01	12.	Calothrix marchica	01
12.	Cocconies placentula	01			
IV.	**Euglenophyceae**				
13.	Lepocinclis acute	01			
14.	Anisomea obliques	01			
15.	Trachelomonas hispida v. coronata	01			
16.	Lepocindis ovum	01			
17.	Phacus orbicularis v. caudatus	01			
	Cynophyceae				
18.	Arthrospire platensis f granulata	01			

Table 6: Diversity indices of planktonic algae in two lakes of Mysore

Sl. No.		Mandakahalli Lake	Lingabudhi Lake
1.	Dominance Index	0.06	0.1
2.	Shannon Index	2.97	2.39
3.	Simpson's index	0.94	0.9
4.	Pielou's index	0.93	0.91
5.	Menhinick's index	4.11	2.68
6.	Margalef's index	6.14	3.67
7.	Equitibility index	0.98	0.96
8.	Fisher's alpha index	50.9	12.7
9.	Berger-parker index	0.11	0.15
	Total Taxa	21	12
	Total individuals	26	20

Conclusion
From the present observation, it can be concluded that the both lakes are polluted. The lakes display low diversity, in terms of physico-chemical and plankton activity. As per the results of WQI, both lakes indicated that the water quality for all purpose is poor indicating that the water quality is always in endangered condition and that it regularly deviates from normal level. The water bodies have low dissolved oxygen show a least abundance of plankton an occasional occurrences of bloom calculating the diversity indices during this period may indicate a negative inference. The WQI and planktonic diversity index is widely used tool to solve problems of data management and to evaluate success and failures of management strategies for improving water quality. This can be easily interpreted by the political decision makers, non technical water management and the general public in this two such indices have been used to determine the water quality of the considered lakes.

Conflict of interest
The authors declare no competing interests

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