

STUDY OF WATER QUALITY AND DYNAMIC ANALYSIS OF PHYTOPLANKTONS IN FOUR FRESHWATER LAKES OF MYSORE, INDIA

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Abstract: Lakes in urban regions are ecological security zones and true indicators of sustainable urban development. They provide opportunities for recreation, study of local aquatic life and ornamental purposes. As a result of increasing land use conflicts and effluent disposal, water bodies and their catchments in the urban regions have been the real casualties. The lakes considered have their specific importance. Lingambudhi Lake was one of the major lakes in Mysore a few decades ago. However, because of development of housing colonies and overgrazing, this lake has lost its quality. Hinkal Lake has been a sewage disposal site for the surrounding Hinkal area. Due to lack of natural water, the Government has decided to convert it into commercial areas. Mandakalli Lake provides water for irrigation to the surrounding agricultural areas and is used for fishing purposes. But due to agricultural runoff and sewage inputs, this lake has undergone degradation over the years. Kukkarahalli Lake is a major lake and is used for ornamental and recreational purposes. However, the disposal of treated domestic wastewater has caused severe pollution in the lake. In order for the policy makers and general public to understand the extent of pollution in these lakes, water quality indices have been formulated. In this study, water quality indices which have been used are Canadian Council of Ministers of Environment (CCME) and National Sanitation Foundation (NSF). CCME provides information on quality for all designated purposes of a lake, while NSF provides the quality level, if the lake is being used, or is to be used for drinking purposes. One of the remarkable aspects of the lake environment is the large number of phytoplankton species that are present at any given time. Phytoplankton diversity in four lakes of Mysore has been discussed. Nine diversity indices have been derived using the PASTA software program. An attempt has been made to correlate the presence and interactions of phytoplanktons and the variation of water quality parameters in the considered lakes.

Keywords: Lakes, phytoplankton, NSF WQI, CCME WQI, PASTA, water quality parameters.

I. INTRODUCTION

Mysore district lies in the Southern Maiden (Southern Plateau) and it is in the southern most part of Karnataka State. The lakes being considered in this study are Lingambudi, Hinkal, Kukkarahalli and Mandakalli lakes, taking into account their age, extensiveness and diversity of use. These lakes, since are the sources of water supply and provide aesthetic value to the city, need to be kept cleaned. The study of attributes of lakes such as pH, temperature, DO, turbidity, etc, provides a thorough insight into the trophic stages of these lakes. Observations of the inputs, outlet points, geographical locations and surrounding areas helps us to make primary field analysis and helps us to provide better and cleaner technologies for restoration. The study of phytoplanktons in these lakes can account for the extent of eutrophication occurring in these lakes. Phytoplanktons in a reservoir are important biological indicators of the water quality. While phytoplanktons are important primary producers and the basis of the food chain in open water, some species on the other hand can be harmful to human and other vertebrates by releasing toxic substances (hepatotoxins or neurotoxins etc.) into the water. Proliferation of harmful organisms, particularly species should be monitored. Phytoplankton studies and monitoring are useful for control of the physico-chemical and biological conditions of the water in any irrigation project. The application of water quality index softwares allows for data management and easy interpretation by non-technical personnel and the general public. Also, the study of phytoplanktons, along with their inter-relationships and their interactions helps provide useful information for the further removal of fertilizing nutrients.

II. METHODS AND METHODOLOGY

A. Description of Study Sites

Lingambudi Lake is a perennial freshwater lake situated in the basin of River Cauvery. The lake was serving as a source of drinking water, irrigation, and fish produce. It spread over 217 acres.

Kukkarahalli Lake also called Kukkarahalli Kere is located in the heart of the Mysore city. It provides lung-space to the city. The lake drains a catchment area of more than 414 square kilometers.

Mandakalli Lake is located in the southern part of Mysore city. It has an overall catchment area of 150 acres and serves as a source for irrigation and fishing purposes.

Hinkal Lake has nearly 40 acres of storage area. The main water source is rain water. However, domestic sewage from the surrounding areas has become a common source of water for the lake.

B. Collection of Samples

A sample is a part or piece taken from a larger entity and presented as being representative of the whole. The sampling methods are chosen keeping in mind the following-

- Parameters to be sampled.
- Identification of proper equipment and procedures for safe, accurate and effective Sampling.
- Identification of representative sampling sites.
- To collect adequate volumes for the required analyses.
- To preserve samples to maintain integrity.
- Sample transport procedures.
- Procedures to ensure that holding times are not exceeded.

There are two main types of sampling which are considered to obtain the lake samples are-

- Grab sampling: A grab sample, also known as a catch sample, consists of a single sample taken at a specific time. A grab sample takes a snapshot of the characteristics of the water at a specific point and time.
- Composite sampling: A composite sample, also known as an integrated sample, is a sample which consists of a mixture of several individual grab samples collected at regular and specified time periods, each sample taken in proportion to the amount of flow at that time.

The phytoplankton samples were obtained by the following procedure:

- Use Whole Water Composite Sampler bottle to collect phytoplankton.
- Open the cap on the top end of the sampler bottle and field rinse by submerging it three times in the lake and draining.
- Slowly lower the sampler bottle into the lake as vertically as possible.
- Cap the upper end firmly and slowly raise the sampler.
- Lift the sampler, keeping it as vertical as possible.
- Since composite sampling is done, repeat the procedure in all the other sampling points and fill the sampler bottle with water till the bottle neck.
- Preserve the phytoplankton sample with 4% formalin solution per 100 ml sample.
- Label the phytoplankton sample and keep it stored in a dark place.

C. Parametric Analyses

The parameters considered in this study are:

- Change in water temperature
- pH
- Turbidity
- Dissolved oxygen
- Chemical oxygen demand
- Total dissolved solids
- Total coliforms
- Total nitrates and Total phosphates

Changes in water temperature were determined by measuring the difference in temperatures of the samples at site and laboratory conditions, in °C. pH was measured using a calibrated pH meter, in pH units. Turbidity was measured using a calibrated turbidity meter, in NTU. Phosphates and total nitrates were measured by colorimetric methods using

spectrophotometer in 470 and 410nm respectively. DO and BOD were measured through titrametric method. COD was measured through closed reflux method and TDS was measured by determining the difference in weights of crucible before and after they were kept in the hot air oven, set at a temperature of 103°C, in mg/l. Total coliforms were measured using MPN technique.

D. Identification of Phytoplankton

The phytoplanktons were identified following the underlying procedure:

The sampled water for analysis of the phytoplankton is preserved with 4% formalin solution per 100 ml sample, labeled and stored in a dark place until the sample starts sedimenting at the bottom (minimum 24 hours duration for the sample to form sedimentation).

The water from top layers is discarded so that the phytoplanktons that have been collected at the bottom in the sediments can be analyzed.

A drop from the sedimented water is taken on a glass slide and a drop of Lugol’s iodine solution is added to it and mixed.

A few such slides from the sedimented water is taken and 4-5 slides are made for each lake.

The slides are then covered with a Cover-Slip to avoid the external disturbances using a needle.

These slides are then viewed under a microscope using Lackey’s drop method.

Photos from the observations are then collected and based on these photographs the phytoplankton species are identified and numbered for each lake.

E. Water quality indices

The water quality indices determined in this study were the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) and National Sanitation Foundation (NSF WQI). Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) provides a convenient mean of summarizing complex water quality data that can be easily understood by the public, water distributors, planners, managers and policy makers. The CCME WQI incorporates three elements:

- Scope – the number of water quality parameters (variables) not meeting water quality objectives (F1).
- Frequency – the number of times the objectives are not met (F2).
- Amplitude - the extent to which the objectives are not met (F3). [2]

The CCME WQI is hence:

$$CCME\ WQI = 100 - \left(\frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732} \right) [2]$$

The index produces a number between 0 (worst) to 100 (best) to reflect the water quality. The following table shows the characterization of the water quality index:

TABLE I
CHARACTERIZATIONS OF WATER QUALITY INDEX [4]

Rating	CCME-WQI	Characterization of water sample
Excellent	95.0-100	Water quality intact, conditions close to natural levels
Good	80.0-94.9	Water quality is protected with only a minor degree of threat or impairment, conditions rarely depart from natural, desirable levels
Fair	65.0-79.9	Water quality usually intact, but occasionally endangered, conditions often deviate from natural levels
Marginal	45.0-64.9	Water quality frequently endangered, conditions very often deviate from natural levels
Poor	0-44.9	Water quality almost always endangered, conditions regularly deviate from normal levels

The National Sanitation Foundation Water Quality Index is calculated using only selected physic-chemical parameters, which are:

- Change in water temperature
- Ph
- Turbidity
- Dissolved oxygen
- Chemical oxygen demand

- Total dissolved solids
- Total coliforms
- Total nitrates and Total phosphates [5]

The WQI integrates raw analytical data and generates a single number that expresses subjectively, the quality of water. Based on the number obtained, the following table is referred to give the corresponding water quality rating:

TABLE II
 WATER QUALITY INDEX RATING OF LAKES [5]

WQI	Rating
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very poor

Based on the phytoplanktons identified, a diversity profile and nestedness pattern was developed using the PASTA software. PAST ver.1.34 (2005), provide detailed information of the PAST software and instructions on how to use it. It outlines the various functions, indices and related programs PAST offers to calculate. The salient features of the software are:

- PAST is free.
- PAST is tailor-made for paleontology. This means that it includes functions which are not found in off-the-shelf programs (for example cladistics, ordination, morphometry and biostratigraphy), and that it does not include functions which are of little use to paleontologists and that only make the user interface more confusing.
- PAST is easy to use and therefore well suited for introductory courses in quantitative paleontology.
- PAST comes with a number of example data sets, case studies and exercises, making it a complete educational package. [17]

III. RESULT AND DISCUSSION

A. Water quality indices

Water Quality Index (WQI) is a widely used tool to solve problems of data management and to evaluate success and failures of management strategies for improving water quality. The index is a numeric expression used to transform large quantities of water characterization data into a single number which represents the water quality level. The number is placed on a relative scale to justify the water quality in categories ranging from bad to excellent. This can be easily interpreted by the political decision makers, non-technical water managers and the general public [5]. In this study, two such indices have been used to determine the water quality of the considered lakes.

1. National Sanitation Foundation Water Quality Index (NSF-WQI): this index is used to classify water bodies according to suitability for drinking water supply [5]. The results are as follows:

1. Name of the Lake: Lingambudhi Lake						
No	Parameters	Units	Site 1	Site 2	Site 3	Composite
1	pH	pH Units	7.65	7.6	7.66	7.84
2	Turbidity	NTU	05	11	6.3	16
3	TDS	mg/L	0.97	0.97	0.89	0.79
4	DO	mg/L	2.7(25%)	1.2(15%)	2.1(27%)	2.5(32%)
5	COD	mg/L	58.8	36.8	14.75	36.89
6	Total Nitrates	mg/l	0.95	2.05	1.42	2.66
7	Total Phosphates	mg/L	11.25	33.13	31.25	19.38
8	Coli forms	CFU	3	3	3	2
9	BOD	mg/L	25.6	15.33	5.9	14.76
10	Water quality Index		42.02	48.55	53.66	46.82
11	Water Quality Rating		Bad	Bad	Medium	Bad

2. Name of the Lake: Mandakalli Lake						
No	Parameters	Units	Site 1	Site 2	Site 3	Composite
1	pH	pH Units	8.7	8.76	8.41	8.69
2	Turbidity	NTU	08	8.6	6.9	8.4
3	TDS	mg/L	1.46	0.95	1.16	1.30
4	DO	mg/L	05(63%)	1.1(14%)	2.4(32%)	2(25%)
5	COD	mg/L	89.6	76.8	70.4	19.2
6	Total Nitrates	mg/l	4.62	5.83	3.24	4.9
7	Total Phosphates	mg/L	51.25	53.13	50.63	55
8	Coliforms	CFU	3	2	3	2
9	BOD	mg/L	35.56	30.72	28.16	7.68
10	Water quality Index		50.49	36.43	43.10	47.20
11	Water Quality Rating		Medium	Bad	Bad	Bad

3. Name of the Lake: Hinkal Lake						
No	Parameters	Units	Site 1	Site 2	Site 3	Composite
1	pH	pH Units	7.7	7.7	7.75	7.89
2	Turbidity	NTU	6.2	6.4	5.6	6.5
3	TDS	mg/L	2.34	17.5	1.30	0.42
4	DO	mg/L	2.29(28%)	3.2(41%)	2.4(30%)	3(38%)
5	COD	mg/L	179.2	140.8	185.6	140.8
6	Total Nitrates	mg/l	4.66	4.62	4.52	5.48
7	Total Phosphates	mg/L	130	130	121.9	99.38
8	Coliforms	CFU	3	2	3	2
9	BOD	mg/L	77.91	56.32	74.24	35.87
10	Water quality Index		36.48	46.58	44.47	45.09
11	Water Quality Rating		Bad	Bad	Bad	Bad

4. Name of the Lake: Kukkarahalli Lake						
No	Parameters	Units	Site 1	Site 2	Site 3	Composite
1	pH	pH Units	9.41	9.5	9.47	9.42
2	Turbidity	NTU	22	20	19	23
3	TDS	mg/L	1.26	1.74	2.07	2.26
4	DO	mg/L	2.2(28%)	3.2(41%)	2.9(37%)	2(25%)
5	COD	mg/L	160	153.6	153.6	172.8
6	Total Nitrates	mg/l	2.66	2.71	2.81	4.19
7	Total Phosphates	mg/L	43.75	38.13	38.13	53.13
8	Coliforms	CFU	3	3	3	2
9	BOD	mg/L	64	66.78	60.79	72
10	Water quality Index		36.78	38.29	37.59	34.82
11	Water Quality Rating		Bad	Bad	Bad	Bad

The results of NSF WQI indicate that all four lakes considered in this study have bad water quality. The index ranges from 42.22 - 53.66 for Lingambudhi Lake, 36.43 - 50.49 for Mandakalli Lake, 36.48 - 46.58 for Hinkal Lake and 34.82 – 38.29 for Kukkarahalli lake. We can infer that, if the water from these lakes is to be supplied for domestic and industrial purposes, then the treatment must include primary, secondary and advanced treatment options to provide good quality water and to reduce risks to human and aquatic health.

2. Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI): the Canadian Council of Ministers of the Environment (CCME) was designed to evaluate surface water quality for the purpose of protecting aquatic life aided with specific guidelines. The water quality index was calculated by entering the obtained parametric values CCME-WQI software 1.0. The software allows the input of various parameters, which then provides information on the quality of water for different uses such as drinking, irrigation, recreation, aquatic life, etc. We have considered drinking and livestock usage as criteria of usage of the considered lakes [4]. The results obtained are as follows:

1. CCME WQI for Lingambudi Lake:

Data Summary	Overall	Drinking	Livestock
CWQI	13	13	18
Categorization	Poor	Poor	Poor
F1 (Scope)	100	100	100
F2 (Frequency)	56	56	22
F3 (Amplitude)	99	99	99

2. CCME WQI for Mandakalli Lake:

Data Summary	Overall	Drinking	Livestock
CWQI	9	9	15
Categorization	Poor	Poor	Poor
F1 (Scope)	100	100	100
F2 (Frequency)	72	72	44
F3 (Amplitude)	99	99	99

3. CCME WQI for Hinkal Lake

Data Summary	Overall	Drinking	Livestock
CWQI	10	10	15
Categorization	Poor	Poor	Poor
F1 (Scope)	100	100	100
F2 (Frequency)	67	67	44
F3 (Amplitude)	99	99	99

4. CCME WQI for Kukkarahalli Lake:

Data Summary	Overall	Drinking	Livestock
CWQI	7	7	13
Categorization	Poor	Poor	Poor
F1 (Scope)	100	100	100
F2 (Frequency)	78	78	56
F3 (Amplitude)	99	99	99

The Canadian Water Quality Index for all four analyzed lakes indicated that the water quality for all purposes is poor, indicating that the water quality is almost always in endangered condition and that it regularly deviates from normal level. The overall Canadian Water Quality Index (CWQI) for Lingambudhi Lake is 13, for Mandakalli Lake is 9, for Hinkal Lake is 10 and Kukkarahalli Lake is 7. The results obtained in our study are similar to a study carried out by Hosmani, et.al; in 2011 and Mahesh, et.al; in 2012 where they concluded that the CWQI for all lakes in Mysore are poor.

B. Correlation with plank tonic diversity

The following table shows the phytoplankton identifies in the four lakes:

TABLE III
PHYTOPLANKTONS IDENTIFIED IN ALL FOUR LAKES

S.no:	Species	Lingambudhi	Mandakalli	Hinkal	Kukkarahalli
1	Synedra ulna	78	189	6	6
2	Gomphonema gracela	203	241	5	4
3	Navicula rhomboidus	91	227	0	0
4	Eunotia monodon	46	115	5	7
5	Microcystis crassa	18	24	12	507
6	Microcystis aeruginosa	23	0	52	348
7	Scenedesmus bijugatus	21	10	105	44
8	Chlorococcus bijugatus	235	17	89	56
9	Oscillatoria subbrevis	127	25	54	45
10	Lepocinclis ovum	5	0	10	0

TABLE IV
DIVERSITY INDICES GENERATED BY PAST SOFTWARE

Lakes	Lingambudhi	Mandakalli	Hinkal	Kukkarahalli
Taxa	10	8	9	8
Individuals	847	848	338	1017
Dominance index	0.18	0.22	0.21	0.37
Simpson's index	0.81	0.77	0.78	0.62
Shannon's index	1.9	1.65	1.71	1.23
Evenness index	0.66	0.65	0.61	0.42
Menhinick index	0.34	0.27	0.48	0.25
Margalef index	1.33	1.03	1.37	1.01
Equitability index	0.82	0.79	0.78	0.59
Fisher α index	1.59	1.22	1.69	1.18
Berger Parker index	0.27	0.28	0.31	0.49

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 environmental monitoring, it is assumed that the adverse effects of pollution will be reflected in the reduction of diversity. Shannon's index is often used for monitoring of pollutants and Simpson's index is used in bio-monitoring [20].

According to the results obtained from the software, it can be inferred that though Kukkarahalli Lake has a large amount of phytoplanktons, the diversity and evenness is very low. The dominating phytoplankton species are *Microcystis crassa* and *Microcystis aeruginosa*. The reason for the dominating characteristic of the *Microcystis* family is the toxic nature. The present conditions, such as low DO values and high COD values influence the growth of these two phytoplanktons.

Lingambudhi Lake, though with the lowest value for dominance, has a very diverse phytoplankton ecosystem. The dominating species are *Chlorococcus bijugatus* and *Gomphonema gracela*. *Gomphonema gracela* is characteristic to lakes with moderate to heavy pollution; hence it can easily survive in most of the lakes in Mysore. Other identified species are also present in sufficient amounts. This is due to the presence of favorable conditions for the growth of these planktons such as near neutral pH, ambient temperature, absence of industrial discharge and abundance of sewage from the surrounding residential areas. Thus, the lake indicates maximum pollution in Shannon's index and highest biodiversity in Simpson's index.

Presence of excess phosphates in the Hinkal Lake provides sufficient nutrients for the growth of phytoplanktons; hence it has the highest species richness. This lake consists of *Scenedesmus bijugatus* as a dominating species followed by *Chlorococcus bijugatus*. *Chlorococcus bijugatus* is present in Lingambudhi Lake too, indicating similar DO conditions.

The interactions between phytoplanktons can be further understood from the Bary-Curtis similarity index, which graphically represents the identified phytoplanktons, their behavior with other planktons and the resulting similarities between the lakes [21].

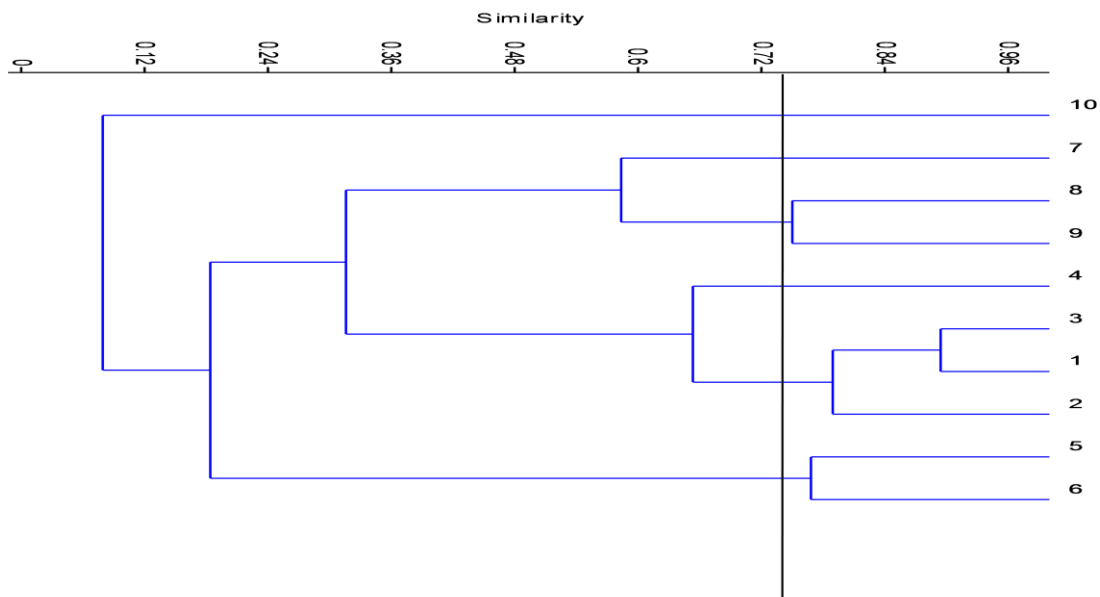


Fig. 1 Bary-Curtis similarity index

The numbers 1-10 indicate the phytoplanktons that have been previously identified and mentioned in table 3.2.1. The line drawn at 0.75 similarity index is set as a reference mark. Species 8 and 9 appear to be the closest to the reference line, indicating maximum similarity. Species 5 and 6 follow next in terms of similarity. This indicates that the lakes in which these organisms occur have similar physico-chemical characteristics. Species 8, i.e. *Chlorococcus bijugatus* and species 9, i.e. *Oscillatoria subbrevis* are found in abundance in Lingambudhi Lake, therefore, it can be said that the conditions present in Lingambudhi Lake are favorable for the growth of these two phytoplanktons in combination. Species 5 and 6, i.e. *Microcystis crassa* and *Microcystis aeruginosa* are dominant in Kukkarahalli Lake, thereby inferring that the characteristics present in this lake allows the growth of these two species.

Species 1 and 3, i.e. *Synedra ulna* and *Navicula rhomboidus* in combination with species 2 (*Gomphonema gracela*) occur in Mandakalli Lake in abundance, hence, it can be said that the nutrient conditions and oxygen levels are optimal for the growth of these three species. However, the presence of species 4 (*Eunotia monodon*) can cause decrease in the

amount of species 1,2 and 3. This is because *E.monodon* requires more nutrients and oxygen to survive, thereby cutting into the supply present for the species originally present in the lakes.

Due to the toxic nature of *M. crassa* and *M. aeruginosa*, their presence with any other phytoplankton will lead to the decrease of the other prevailing phytoplanktons. Species 10, i.e *Lepocinclis ovum* has a high intake phosphate for survival and reproduction, hence, it's presence in any cluster will decrease the amount of phytoplanktons originally present in the lakes.

III. CONCLUSION

From the experiments conducted in our study, we can conclude that the lakes are highly polluted. The lakes display high diversity, in terms of biochemical and plankton activity.

The total richness of chemicals, which may be the result of waste inputs and extracellular products liberated by the death and decay of algal blooms common in water bodies, accelerates the occurrence of blooms. These in turn respond to the biochemical concentration of waters.

The water bodies have low dissolved oxygen, relatively high phosphates and nitrogen and show a quantitative abundance of plankton with variable quantities and occasional occurrence of blooms.

This study of water quality and phytoplankton analysis provides a scientific base for long-term ecological research on biological resources and for policy development for ecological environmental protection. These studies give us a brief report on how to manage our environmental issues and what best can be done to protect them. The constant monitoring of species diversity and abundance, along with their nestedness patterns provide a cost-effective method of determining the possible problematic parameters in a lake.

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