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Impact of urbanization and study of water quality index on Gidadakonenahalli Lake, Bangalore urban district, Karnataka, India

Gayathri Shekar[1] Latha Narayan[1] Ramachandra Mohan Muniyellappa[1*]

[1] Lake Management and Water Quality Research Unit, Department of Zoology, Jnana Bharathi Campus, Bangalore University, Bangalore, 560056, India.

* Author for correspondence: mohanramachandr@gmail.com
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Abstract
The water pollution of Gidadakonenahalli Lake in Bangalore city, Karnataka, India was studied. In order to determine the water quality of the lake the present paper attempted to evaluate the physico-chemical, biological and bacteriological parameters and it was analyzed for a period of one year from January to December 2010. The surface water samples was subjected to comprehensive physico-chemical analysis involving parameters such as water temperature, pH, total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), chloride, total alkalinity, total hardness, phosphate, nitrate and sulphate. Biological parameters included quantitative analysis of planktons using 'Sedwickrafter counting cell'. Fecal coliforms were enumerated by membrane filtration technique. Correlations coefficients were calculated and they identified the type of correlation existing among the physico-chemical and biological parameters of the sample water. Water quality index (WQI) was calculated using weighted arithmetic index approach. A significant seasonal variation in the water quality of Gidadakonenahalli Lake was observed during the present study. Water quality index value was 849.01. The result shows that the quality of water in the lake is severely polluted.
Key words: Physico-chemical parameters; Pollution; Water quality index; Gidadakonenahalli Lake.

Introduction

Water is the most important compound which shapes the land and regulates the climate, then; it profoundly influences life. The quality of water is usually described according to its physical, chemical and biological characteristics. Rapid industrialization and indiscriminate use of chemical fertilizers and pesticides in agriculture are causing heavy and varied pollution in aquatic environment leading to deterioration of water quality and depletion of aquatic biota.

Lake monitoring has become an essential part of lake management due to increased human populations and the associated increase in pollution threats. Lake monitoring may provide early warning signs of ecosystem degradation resulting from contaminant inputs, nutrient addition, sediment runoff, and overuse of the resource. By monitoring the physical, chemical, and biological status of a lake, changes of many aspects of the ecosystem can be detected quickly, and hopefully, harmful impacts can be eliminated before their consequence become unmanageable.

A lake does indeed have its own processes with a complete array of plants, animals, and microorganisms. However, the lake ecosystem is greatly influenced by factors outside its immediate basin. Weather, climate, atmospheric inputs, hydrology, and land use practices can all exert a strong influence on lakes. Lakes have a limited existence that is influenced by morphology, nutrient and sediment input, and geographical and geological setting. During its existence the lake is an ecosystem of complex physical, chemical, and biological interactions. The biological community of a lake system can be abundant and diverse; and it is through this community that nutrients and chemicals are cycled through the system.

A few reports dealing with the physico-chemical parameters of lakes from Bangalore are available. However from time to time there has been a change in the water quality due to various kinds of pollution. Kishe (2004), Manjare et al. (2010), Christensen et al. (2011), Sarah et al. (2006) presented a study on Manasbal Lake. Shinde et al. (2011) studied the physico-chemical parameters and the correlation coefficient of Harsool-Savangi dam, Aurangabad. Khan et al. (2012) analyzed the physicochemical parameters of Triveni Lake and studied its seasonal variation. Similar studies can be found in Cude (2001) and Lumb et al. (2011). Therefore from the point of view of monitoring water quality to obtain update information on biodiversity with associated changes in the physico-chemical parameters in the habitat, analysis of water was carried out. The aim of the present investigation was to determine the water chemistry of Gidadakonenahalli Lake using certain physico-chemical parameters that are considered to play a major role in the distribution, periodicity and abundance of phytoplankton and zooplankton.

Materials and methods

Study area

Gidadakonenahalli (Mallathalli) Lake is located adjacent to the Bangalore University Campus near Kengeri on Bangalore-Mysore road. It is located at about 11 km from the heart of the city. It is surrounded by the new B.D.A. layout, namely Visvesvaraya layout (8^{th} Block) that is located towards west and block 9 in the eastern side of the lake, which is an urban area with densely populated houses. The water spread area of lake is 20.68 ha and watershed area is 6.18 km^2. The total area of the lake including boundary line and bunds is about 29.274 ha. The shore line length of the lake is 2,700 m and length of the bund is 436 m. It is situated between 12°57'46.5''N Latitude and 77°29'41.6''E Longitude, and has elevation of 840.64 m. The study area is shown in Fig.1 and Fig. 2 which shows the satellite image of Gidadakonenahalli Lake.

Sources of lake contamination

The Lake contamination has taken place in the study area due the following ways:

1. The sewage water from residential colonies and apartments were discharged directly into the lake through three inlet channels.

2. Because of flow of about 5 MLD sewage through the inlet channels, the lake sediment bed was loaded with sewage solids containing oxidisable organic matter, total nitrogen and phosphorous.

Collection and analysis of water samples

The surface water samples from Gidadakonenahalli Lake were collected early in the morning (8:00 am to 9:00 am). Samples were collected at monthly interval in plastic cans of two liters capacity at a depth of 10 cm. Water temperature and pH of water samples were measured in the field immediately using a mercury glass thermometer and pH meter respectively. Collected water samples were brought immediately to the laboratory for the estimation of various other physicochemical parameters as: total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), chloride, total alkalinity, total hardness, phosphate, nitrate and sulphate. Collection of plankton sample was made by sieving 50 liters of habitat water from approximately 10-12 cm below the surface level passed through a 25 µm mesh net and finally concentrated to 25 ml. The population of plankton accumulated in the container were then transferred to other bottle and immediately preserved in 4% formalin, labeled and then transferred to laboratory for further experimentation. Each sample was stirred smoothly just before microscope examination. One ml from the agitated sample was transferred to a Sedge-wick Rafter counting cell with a wide mouth graduated pipette. The abundance of plankton was estimated by counting their presence per focus of the microscopic field. For bacteriological examination sample was collected in 125 ml presterilized (at 121°C) borosil bottles and analysis was carried out using standard method. Fecal coliforms were determined by membrane filtration technique using M–FC agar base. All the measurements and estimations were made following APHA (2005).

Statistical analysis

The relationship between various physico-chemical parameters of water samples were analyzed statistically conducting Pearson correlation using statistical software (SPSS 2008). Statistical analysis of correlation coefficient was made on the basis of substantial availability of findings for the reality and significance of the result. The water quality index (WQI) was calculated using weighted arithmetic index (WAI) approach (refer equation 1, 2 and 3). The objective of water quality index was originally proposed by Horton (1965). It has been used by many researchers (Brown et al. 1970; Mitchell 2000; Sanchez et al. 2007). A commonly-used water quality index (WQI) was developed by the National Sanitation Foundation (NSF) in 1970 (Brown et al. 1970). Parameters as dissolved oxygen, fecal coliforms, pH, biological oxygen demand, phosphate, nitrate and total dissolved solids were recognized as preliminary indication of quality as is used in calculating quality index.

$$Q_i = \left(\frac{M_i - I_i}{S_i - I_i} \right) \times 100 \qquad (1)$$

Where: Q_i = quality rating corresponding to the i^{th} parameter is a number reflecting the relative value of the parameter, M_i = estimated values of the parameters in the laboratory, I_i = Ideal values of the i^{th} parameter (ideal values are taken as zero except for pH = 7 and DO = 14) and S_i = standard values of the i^{th} parameter.

$$W_i = \frac{k}{S_i} \qquad (2)$$

Where: W_i = unit weight; k = 1; S_i = recommended standards of the corresponding parameter.

$$WQI = \frac{\sum W_i Q_i}{\sum W_i} \qquad (3)$$

Where: WQI= the overall water quality index.

Results and discussion

The present study was conducted in Gidadakonenahalli Lake (Fig. 1) for monitoring the level of water pollution and its impact in various physico-chemical, biological and bacteriological parameters. Quality of an aquatic ecosystem is dependent on the physical and chemical qualities of water and also on biological diversity of the system. Cairns and Dickson (1971) states that the analysis of biological materials along with chemical characteristics of water determines a valid method of water quality assessment. Hence, the physico-chemical characteristics and plankton composition during different months from January to December 2010 observed in the present study have been discussed below.

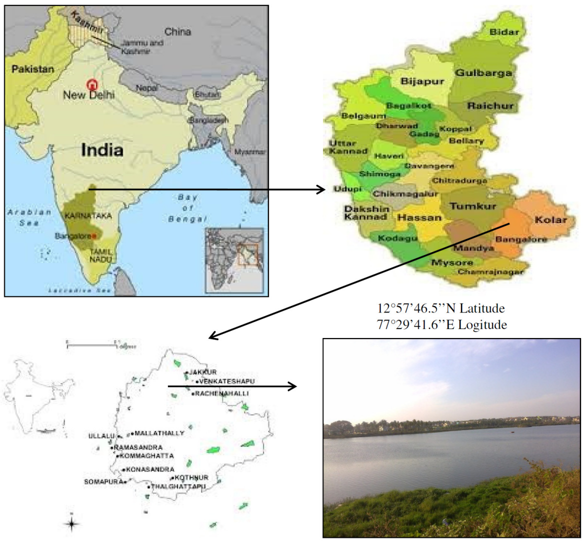

Figure 1. Location of Gidadakonenahalli Lake, Bangalore, India.

Figure 2. Satellite image of Gidadakonenahalli Lake, Bangalore, India.

The Table 1 depicts the monthly variation in physico-chemical, biological and bacteriological parameters of Gidadakonenahalli Lake. The analysis indicates that during the study period the water temperature varied from 32.3–25.8°C. The temperature is one of the most important factor in aquatic environment since it regulates physico-chemical as well as biological activities (Kumar et al. 1996). The rise in temperature can be resulted in high rate of evaporation and may cause decline in water level during summer months. McCombie (1953) stated that temperature may affect the seasonal cycle of phytoplankton. Jana (1973) and Chari (1980) observed that temperature is a critical factor for the seasonal periodicity of phytoplankton. The present study revealed that phytoplankton has a negative correlation with temperature (Table 2).

Table 1. Monthly variation in physico-chemical, biological and bacteriological parameters of Gidadakonenahalli Lake during January to December in 2010.

Sl.N°	Parameters	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Water temperature	°C	26.2	27.1	30.1	31.2	32.3	29.1	28.3	29.2	27.1	26.8	26.4	25.8
2	pH	-	7.9	8.1	8.8	9.7	9.8	9.1	9.4	8.9	8.4	7.8	7.4	8.1
3	TDS	mg L^{-1}	600	500	1,200	1,300	1,500	1,100	1,000	1,100	900	800	800	700
4	EC	µmhos cm^{-1}	937.50	781.25	1,875.00	2,031.25	2,343.75	1,718.75	1,562.50	1,718.75	1,406.25	1,250.00	1,250.00	1,093.75
5	DO	mg L^{-1}	9.10	8.45	5.85	5.20	4.55	5.85	6.50	7.15	7.15	7.80	8.45	8.45
6	BOD	mg L^{-1}	5.82	6.90	7.50	9.60	10.10	9.80	9.90	8.70	8.40	8.90	6.80	6.30
7	COD	mg L^{-1}	16.9	26.4	19.6	20.8	36.8	26.2	19.9	19.8	18.5	12.6	15.9	18.1
8	Chloride	mg L^{-1}	212.12	236.40	225.00	261.50	256.80	196.20	186.10	174.30	172.80	169.80	188.10	189.40
9	Alkalinity	mg L^{-1}	396	369	438	429	439	446	362	286	299	194	186	163
10	Hardness	mg L^{-1}	439	432	484	543	539	536	528	497	491	493	486	448
11	Phosphate	mg L^{-1}	4.8	6.8	8.1	6.4	6.2	5.9	6.3	6.1	6.4	5.8	4.9	5.0
12	Nitrate	mg L^{-1}	3.8	4.9	4.6	5.8	6.2	6.4	6.6	6.8	7.2	7.4	3.8	3.9
13	Sulphate	mg L^{-1}	22.1	21.8	19.6	16.5	14.9	15.9	20.6	21.8	22.2	24.1	20.8	19.3
14	Phytoplankton	Units mL^{-1}	2,532	1,976	1,847	1,703	1,212	1,558	1,404	1,160	1,118	1,156	1,102	2,125
15	Zooplankton	Units mL^{-1}	28	22	31	26	33	29	40	29	30	31	28	26
16	Total coliforms	cfu 100 mL^{-1}	150	179	210	300	328	419	337	289	224	212	189	178

TDS = total dissolved solids, EC = electrical conductivity, DO = dissolved oxygen, BOD = biological oxygen demand, COD = chemical oxygen demand.

Table 2. Correlation matrix among the physico-chemical, biological and bacteriological parameters of Gidadakonenahalli Lake during January to December 2010.

Parameter	WT	pH	TDS	EC	DO	BOD	COD	Chl	Alk	Har	Pho	Nit	Sul	Phy	Zoo
WT	1	0.886**	0.932**	0.932**	-0.941**	0.710**	0.672*	0.646*	0.702*	0.744**	0.556	0.338	-0.730**	-0.256	0.262
pH		1	0.842**	0.842**	-0.904**	0.790**	0.639*	0.507	0.696*	0.774**	0.463	0.441	-0.723**	-0.164	0.414
TDS			1	1.000**	-0.951**	0.758**	0.520	0.408	0.515	0.855**	0.426	0.405	-0.716**	-0.429	0.432
EC				1	-0.951**	0.758**	0.520	0.408	0.515	0.855**	0.426	0.405	-0.716**	-0.429	0.432
DO					1	-0.825**	-0.610*	-0.494	-0.643*	-0.861**	-0.557	-0.465	0.758**	0.357	-0.406
BOD						1	0.435	0.123	0.395	0.925**	0.332	0.809**	-0.480	-0.615*	0.556
COD							1	0.642*	0.620*	0.363	0.280	0.119	-0.729**	-0.058	0.034
Chl								1	0.680*	0.178	0.344	-0.277	-0.638*	0.350	-0.255
Alk									1	0.389	0.537	0.096	-0.571	0.256	0.135
Har										1	0.218	0.601*	-0.623*	-0.590*	0.545
Pho											1	0.294	-0.128	-0.106	0.147
Nit												1	0.041	-0.677*	0.451
Sul													1	-0.016	-0.050
Phy														1	-0.415
Zoo															1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

WT = water temperature, TDS = total dissolved solids, EC = electrical conductivity, DO = dissolved oxygen, BOD = biological oxygen demand, COD = chemical oxygen demand, Chl = Chloride, Alk = Alkalinity, Har = Hardness, Pho = Phosphate, Nit = Nitrate, Sul = Sulphate, Phy = Phytoplankton, Zoo = Zooplankton.

The pH remained alkaline throughout the study period, maximum pH was recorded in May (9.8) and minimum in the month of November (7.4). The pH showed negative correlation with phytoplankton (Table 2). However, earlier research by Jana (1973) and Chari (1980) observed that high pH value was related to heavy bloom of phytoplanktons. In the present study total dissolved solid (TDS) and electrical conductivity (EC) values ranged from 500 to 1500 mg L^{-1} and 781.25 to 2343.75 µmhos cm^{-1} which were minimum in February and maximum in May. Water with high solid content has inferior palatability and may induce unfavorable physiological reaction in the transient consumer (Jameel 1998). Conductivity is a good and rapid method to measure the total dissolved solids and is directly related to total solids (Mishra and Saksena 1993). The dissolved oxygen (DO) concentration ranged from 4.55 to 9.1 mg L^{-1}, and was minimum in May and maximum in October. The observed low DO values may be due to decomposition of organic matter and decay of vegetation as suggested by Jameel (1998).

The biological oxygen demand (BOD) concentration is used as the index of organic pollution that can be decomposed by bacteria under aerobic conditions (Sladeček et al. 1982). Similarly the chemical oxygen demand (COD) level is also very important to evaluate the water quality with respect to presence of organic and inorganic pollutants. In the present study the level of BOD and COD ranged from 5.82 to 10.1 mg L^{-1} and 12.6 to 36.8 mg L^{-1}, respectively. The chloride concentration ranged from 169.8 mg L^{-1} in October to 261.5 mg L^{-1} in April. The Alkalinity concentration ranged from 194 mg L^{-1} in October to 446 mg L^{-1} in June. Das and Chand (2003) recorded low alkalinity, which might be due to dilution effect of rainfall. Kataria et al. (1996) have measured maximum value of alkalinity due to confluence of industrial and domestic waste. The present results shared well agreement with the findings of above authors.

The hardness concentration ranged from 432 mg L^{-1} in February to 543 mg L^{-1} in April. The total hardness is the total soluble magnesium and calcium salts present in the water expressed as its $CaCO_3$ equivalent. The phosphate concentration ranged from 4.8 mg L^{-1} in January to 8.1 mg L^{-1} in March. Heron (1961) has indicated that the phosphate increase may be due to decayed phytoplanktons and concentration of zooplankton excreta. Addition of phosphorus in different forms causes explosive growth of algae which lead to eutrophication of the lake. The nitrate concentration ranged from 3.8 mg L^{-1} in November and January to 7.4 mg L^{-1} in October. The sulphate concentration ranged from 14.9 mg L^{-1} in May to 24.1 mg L^{-1} in October.

From the arrived correlation coefficients values (Table 2) it can be stated that electrical conductivity (EC) is most strongly correlated to total dissolved solids (TDS) and is significant at 0.01 level. The rest of the parameters are not highly correlated with each other. The result revealed that most of the physico-chemical parameters show negative correlation with phytoplankton except for DO, chloride and alkalinity, while zooplanktons showed positive correlation with all the physico-chemical parameters except for phytoplanktons, sulphate, chloride and DO.

According to the results shown in Table 3, the calculated values of water quality index from weighted arithmetic index (WAI) method of Gidadakonenahalli Lake was found to be 849.01 which is above 100 and the water quality rating of the lake is unfit and it is concluded to be severely polluted. The Table 4, provides details of water quality rating corresponding to the range of WAI values.

Table 3. Determination of water quality index of Gidadakonenahalli Lake, Bangalore, India.

Sl.N°	Parameters	Unit	Estimated value (Mi)	Q-value (Q_i)	Weight factor (W_i)	W_iQ_i	WQI[(1)]
1	DO	mg L^{-1}	7.04	174.00	0.17	29.58	849.01
2	Fecal coliforms	cfu 100 mL^{-1}	251.25	125.62	0.16	20.09	
3	pH	-	8.61	107.33	0.11	11.80	
4	BOD	mg L^{-1}	8.22	137.00	0.11	15.07	
5	Phosphate	mg L^{-1}	6.05	6,050.00	0.10	605.00	
6	Nitrate	mg L^{-1}	5.61	12.40	0.10	1.24	
7	TDS	mg L^{-1}	958.33	191.66	0.07	13.41	
					$\sum W_i = 0.82$	$\sum W_iQ_i = 696.19$	

Water quality rating of the lake is unfit and is severely polluted.

DO = dissolved oxygen, BOD = biological oxygen demand, TDS = total dissolved solids, WAI = weighted arithmetic index.

(1) $WQI = \frac{\sum W_iQ_i}{\sum W_i}$

Table 4. Water quality classification based on WQI value.

WQI - value range	Water quality
0 < 25	Excellent
25 < 50	Good
51 < 75	Bad
75 < 100	Very bad
> 100	Unfit

Microbial status

The coliform bacterium is the primary bacterial indicator for fecal pollution in water. According to the results of the present study shown in Table 1, microbial parameter was found to fall in a far higher range than laid for fresh water by CPCB (Trivedy et al. 1987). The data of the fecal coliform load indicated the maximum of 419 cfu 100 mL^{-1} in the month of June. In the present study it is observed higher bacterial population with the commencement of monsoon and relatively lower bacterial density during winter. This is in conformity to the observations of Singh (1985), Patralek (1992), Parihar et al. (2003) and Mohan et al. (2007). Higher bacterial population during monsoon months was obviously due to transport of organic matter from various sources through surface runoff from the catchment area. This is in accordance with Singh (1985), while Sharma and Mall (1988) and Patralek (1992) opined that temperature also governs the bacterial population.

Conclusion

The protection and management of surface water, one of the most valuable natural resources is emerging as a major public concerns in India. Human population growth has significantly altered the environment of many natural water bodies. As a result, the composition of the biota of these water bodies is affected. Lakes are ecologically deteriorated due to unabated discharge of pollutants and heavy fishing pressures. During the study period seasonal, the variation of the physico-chemical and biological parameters was analyzed and the following conclusion can be drawn from the acquired data.

Water quality index is a good indicator of pollution in aquatic ecosystem. In the present study, water quality index was found to be 849.01. The WQI value greater than 100 indicates that the water is unfit and characterizes heavily deterioration condition. The deteriorating quality of water in the lake might be due to the discharge of sewage water from residential colonies and apartments surrounding the lake. From the results of the present study it may be concluded that the abundance of plankton is not alike throughout the study period but few species of planktons were dominating which indicates the eutrophic condition of the lake. Hence highest priority should be given to water quality monitoring and indigenous technologies should be adopted to make water fit for domestic and drinking purpose after treatment.

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