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Assessment of Seasonal Variation in Water Quality and Water Quality Index (WQI) of Hebbal Lake, Bangalore, India

Sudarshan P., Mahesh M. K., Ramachandra T. V.

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Abstract Wetlands are transition zones on earth that plays a major role in nutrient dynamics and governs the primary productivity. Bangalore and its urban conglomerates comprise of many man-made wetlands that were built for various hydrological purposes to serve the needs and water demand of the city. Bangalore wetlands have been experiencing anthropogenic stress especially due to the sustained inflow of sewage altering the chemical integrity of wetlands. The present study was carried out to evaluate seasonal variation in the physico-chemical parameters of water quality and to compute water quality index of Hebbal Lake, Bangalore. Water samples were collected from 4 sites and were analyzed for pH, Electrical conductivity, TDS, Dissolved oxygen, Nitrate, BOD, Total hardness, Ca, Mg, chlorides and alkalinity according to standard methods. Seasonal variations in water quality parameters were recorded, compared with standards and pollution status was studied using water quality index, Results showed that BOD, alkalinity (sample S1),TDS and EC were higher than prescribed limits by BIS standard. High levels of nutrients and organic load was seen in the inlet region compared to middle and outlets. Overall water quality index showed the lake falls under very poor category. The results revealed anthropogenic activity and entry of untreated sewage into the lake through inlet.

Keywords Bangalore, Hebbal Lake, Physico-chemical parameters, Water quality index.

Sudarshan P*., Mahesh M. K.
Department of Botany, Yuvaraja's College, Mysore 570005, India

Ramachandra T.V.
Energy and Wetlands Research Group, Center for Ecological Sciences Indian Institute of Science, Bangalore 560012, India
e-mail: bhat.sudarshanp@gmail.com
*Corresponding author

Introduction

Lakes and ponds cover only a very small portion of earth's surface. Freshwater lakes are the wealth of a nation, being a source of water for both irrigation and drinking. The surface water is an integral part of natural environment and its quality is very sensitive and critical issue in many countries. Also, with an increased understanding of the importance of drinking water quality to public health and raw water quality to aquatic life, there is a great need to assess surface water quality (Ouyang 2003). It gets affected through various factors mainly by anthropogenic activities. Freshwater ecosystems are getting deteriorated because of the developmental activities and highest degradation are caused by humans and their related activities in their immediate catchment areas and drainage basins (Rast 2009, Mishra and Garg 2011, Amin et al. 2014).

Increases in impermeable surfaces, as well as vehicular traffic related to the flow of people and material in the growing regional economy can increase pollution loads and runoff to urban and periruban water bodies (Lebel 2009). Water quality deterioration in lakes has recently been a matter of great concern due to its negative impacts on social economic and health aspects and has been recognized as a serious problem at local regional and global levels. Due to population growth and industrial development, numerous water bodies have become heavily polluted over past several years. The major problem with the lake is implemented by rainy water or other feeding sources that once contaminated, it is defaulted restore its quality (Dubey 2016).

Water quality is the characteristics of water which influence its beneficial use as well as the sustainability of ecosystem. The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem and the suitability for human use (Lianthuamluaia et al. 2013). The quality of surface water is governed by the natural and anthropogenic processes including rainfall, erosion, hydrological features, industrial and agricultural activities (Bhat and Pandit 2014). The quality of water in lakes, reservoirs, rivers are determined by physico-chemical and biological parameters. Water quality index provides overall water quality at a certain location and time based on multiple water quality parameters. Water quality monitoring is one of the key tools, to identify and keep a check on the pollution status and ensure about the efficiency of management plans (Singh and Jayakumar 2016). Hence monitoring of these aquatic resources is crucial for sustainable management.

Bangalore and its urban conglomerates comprise of many man-made wetlands that were built for various hydrological purposes to serve the needs and water demand of the city. Bangalore wetlands have been experiencing anthropogenic stress especially due to the sustained inflow of sewage altering the chemical integrity of wetlands. The present study was carried out to evaluate seasonal variation in the physico-chemical parameters of water quality and to compute water quality index (WQI) of Hebbal Lake, Bangalore.

Materials and Methods

Study area

Hebbal Lake is situated in Bangalore urban district ($13^0 02'47.57''$ N latitude and $77^0 35'13.66''$ E longitude) of Karnataka state India (Fig. 1). The lake is situated at 839 amsl. It is surrounded by 3 villages and located along Bangalore Bellary Road in the Northern part. The area of the lake is 192.48 acres. The lake is mainly used for fishing and washing purposes.

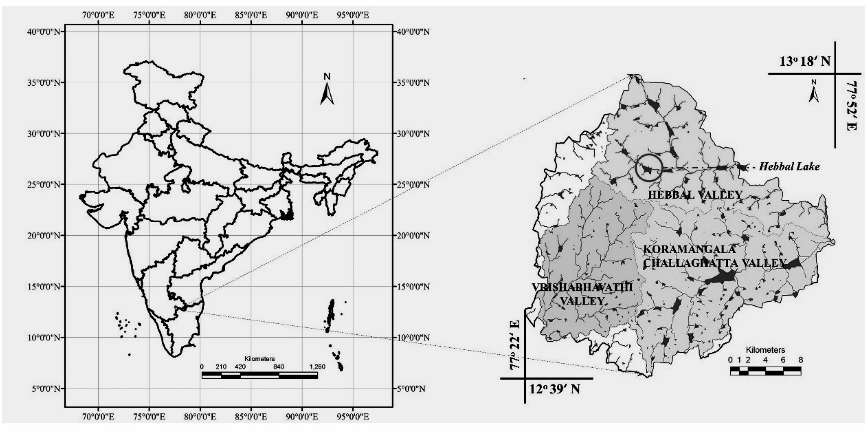

Fig. 1. Study area.

Fig. 2. Sampling locations.

Water sample collection and physico-chemical analysis

Sampling was conducted monthly from June 2016 to July 2017. Surface water samples were collected from 4 sites (Fig. 2; inlet, middle and outlet) using acid washed, dried polythene 1 liter bottles. Parameters like dissolved oxygen (DO), Total dissolved solids (TDS), pH, Electrical conductivity (EC) were measured on site using probe. Samples were taken into lab and preserved at 4^0C. Further analysis of various physico-chemical parameters(Nitrate, BOD, Total hardness, Ca, Mg, chlorides and alkalinity) were carried out in laboratory as per standard methods (Singh and Jayakumar 2016, APHA 2005, Trivedi and Goel 1986). Seasonal variations in water quality parameters were recorded compared with standards and pollution status was studied.

Water quality index

Water quality index provides a simpler model for expressing the water quality and it has played important role in water resource management (Lumb et al. 2011, Mohebbi et al. 2013, Sutadian et al. 2016). It defines the whole status of water body by a single number and informs the public about its state (Simoes et al. 2008). This index gives aggregate data on various water quality parameters at different time and places and converts the whole information into a single value giving information about that particular space at a particular time (Alobaidy et al. 2010). In this study Weighted Arithmetic Mean WQI (Horton 1965) is used to calculate WQI. Eleven parameters are chosen for the calculation. They were pH, EC, TDS, DO, BOD, nitrate, total hardness, Ca, Mg, chlorides, alkalinity. The season wise mean values were considered. The standard for drinking water was recommended by BIS (Indian standard specification for drinking water 2012). The weighted arithmetic mean approach calculates the WQI using 3 steps.

In the first step unit weight (W_i) for various parameters were calculated by using the following formula (Tiwari and Mishra 1985)

$$W=K\in (1/S); \text{ Where, } K= 1/\sum (1/S_1 +1/S_2+ S_3+ ...... +1/S_n)$$

In the second step, the quality rating scale (Q_i) for each parameter was calculated using the equation :

$$Q_i = \{(Q_{act} -Q_{ideal})/ (S_{std}-Q_{ideal})\}*100$$

For all the parameters except DO and pH, the value

Table 1. Water quality index scale.

WQI	Rating
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
Above 100	Unsuitable

of Q_{ideal} are zero, as it is the value of that parameter in pure water. For pH, value of Q_{ideal} is 7.0 and for Do, it has a value of 14.0. After calculating the weight of the parameter and quality rating scale, WQI has been calculated using the formula:

$$WAWQI = \sum_{i=0}^{i=n} WQ/\sum W_i$$

W_i = Unit weight of each water quality parameter, K = Proportionality constant, Q_i = Quality rating scale for each parameter, Q_{act}= Estimated concentration of i^{th} parameter in the analyzed water, Q_{ideal} = Value of the parameter in pure water, $S_{standard}$ = Standard value of i^{th} parameter, n = No of water quality parameters. The final water quality index obtained can be summarized in a table to obtain the overall water quality status of water body as in Table 1. Table 2 lists BIS standards and unit weights.

Results and Discussion

pH

It maintains the acidic or basic property and is a vital characteristic of any aquatic ecosystem by controlling all biochemical activities and physio-chemical attributes (Jalal and Kumar 2012). The value of pH below 6.5 causes discontinuation in the making of vitamins in human body. When pH becomes more than 8.5, the taste of water becomes more salty and causes eye irritation and skin disorder (Gupta et al. 2017). The mean values were 7.7-8.2 during summer 7.3-7.9 (monsoon) and 7.1-8.3 during post monsoon (Fig. 3a). S1 showed least (summer) and S4 had higher (post monsoon) pH values than other sites during the study period. Similar trend was reported by Deepa et al. (2016), Ajayan and Kumar (2016), Luharia et al. (2016).

Table 2. BIS standards and unit weights (W_n) of studied water quality parameters.

Parameters	BIS standard	Unit weight (W_n)
pH	6.5-8.5	0.1947
Total dissolved solid (TDS)	500	0.00331
Electrical conductivity (EC)	300	0.005517
Dissolved oxygen (DO)	5	0.3310
Total hardness	300	0.0055
Ca	75	0.02207
Mg	30	0.0552
Alkalinity	200	0.0083
Chlorides	250	0.00662
BOD	10	0.3310
Nitrate	45	0.0368
		$\sum W_n$=1.000

Table 3. Summary of water quality index of Hebbal Lake.

	Water quality index			
Sampling sites	Monsoon	Post monsoon	Summer	Overall water quality index
S1	127.2	136.09	119.56	127.6
S2	81.7	106.27	112.6	100.2
S3	74.38	91.56	86.84	84.3
S4	85.39	75.54	59.8	73.6
	92.2	102.4	94.7	96.4

Total dissolved solids (TDS)

TDS is determined for measuring the amount of solid materials (inorganic and organic) dissolved in water. Any alteration in the balance of ionic concentrations by natural or anthropogenic activities causes detrimental effects (Tiwari 2015). The increase in TDS increases the apparent color of the water, water temperature and decreases the rate of photosynthesis (Chauhan and Sagar 2013). The mean values of TDS ranged from 595 to 612 mg/l during summer, 472 to 511 mg/l during monsoon and 603 to 705 mg/l during post monsoon season (Fig. 3b). During study period S1 had highest TDS in post monsoon and S3 the least in monsoon season respectively.

Electrical conductivity (EC)

Electrical conductivity is an ability of aqueous solution to carry electric current. The depends on presence of ions their total concentration, mobility, valence, relative concentrations and temperature of measurement. Electrical conductivity is directly correlated

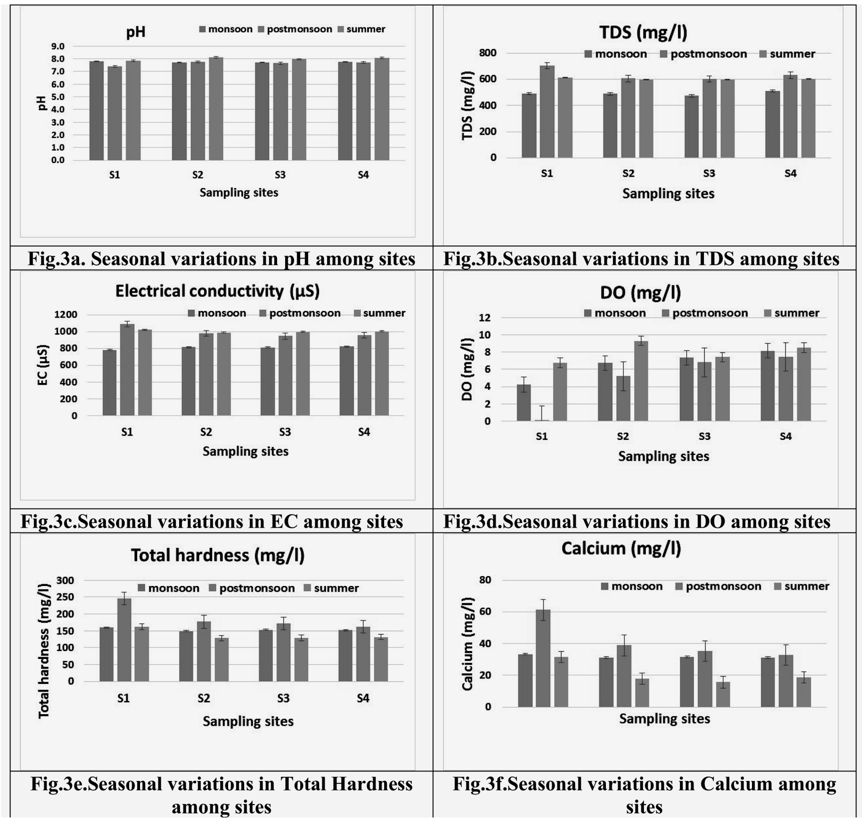

Fig.3a. Seasonal variations in pH among sites | Fig.3b.Seasonal variations in TDS among sites | Fig.3c.Seasonal variations in EC among sites | Fig.3d.Seasonal variations in DO among sites | Fig.3e.Seasonal variations in Total Hardness among sites | Fig.3f.Seasonal variations in Calcium among sites

Fig. 3a. Seasonal variations in pH among sites. **Fig. 3b.** Seasonal variations in TDS among sites. **Fig. 3c.** Seasonal variation in EC among sites. **Fig. 3d.** Seasonal variations in DO among sites. **Fig. 3e.** Seasonal variations in total hardness among sites. **Fig 3f.** Seasonal variations in calcium among sites.

with the total dissolved solids. Figure 3c summarizes the variations in electrical conductivity over the study area. The values of EC in summer season varied from 840 to 1208 µS. The values ranged fron 725-890 µS and 833-1201µS during monsoon and post monsoon respectively. S1 had the highest and S2 had the least. It was increasing from monsoon to summer with summer season having highest value.

Dissolved oxygen (DO)

Dissolved oxygen is an important on site parameter that gives an indication of pollution in water body. The combined activity of dissolution of oxygen and photosynthetic activity maintains the level of DO in water bodies. It depends upon the water temperature, water agitation, types and number of aquatic plants, light penetration and amount of dissolved or suspended solids. DO levels between 5-8 mg/l are satisfactory for the survival and growth of aquatic organisms. In the present study the values range between 0 to 12 mg/l (Fig. 3d). In summer the DO varied from 2.5 (S1) to 12 (S2) mg/l. It varied from 0 (S1) to 7.9 mg/l (S4) in monsoon and 2.5 (S1) to 9.6 mg/l (S4) in post monsoon.

Total hardness

Hardness is the capacity of water to react with detergent. It is mainly because of calcium and magnesium salts. The permanent hardness is due to chloride and sulfate whereas the temporary hardness which can be removed by boiling is due to carbonates and bicarbonates. Total hardness is used to describe the

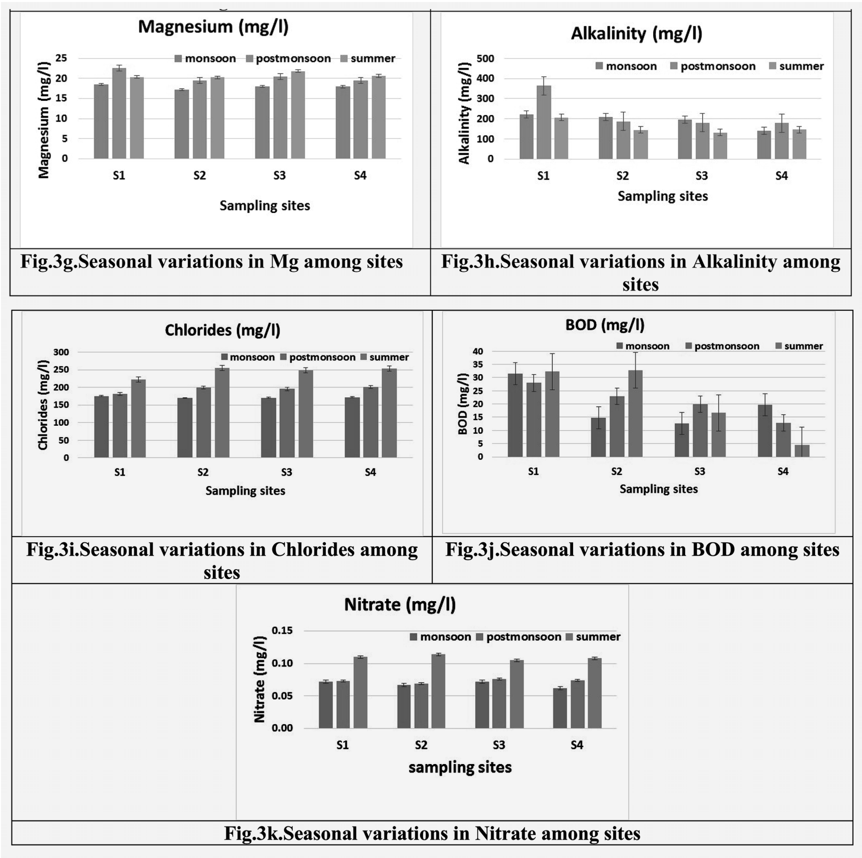

Fig. 3g. Seasonal variations in Mg among sites. **FIg. 3h.** Seasonal variations in alkalinity among sites. **Fig. 3i.** Seasonal variations in chlorides among sites. **Fig. 3j**. Seasonal variations in BOD among sites. **Fig. 3k.** Seasonal variations in nitrate among sites.

effects of dissolved minerals (mostly calcium and magnesium) determining suitability of water for domestic, industrial and drinking purpose attributed to presence of strontium, ferrous iron, bicarbonates, sulfates, chloride and nitrate of calcium and magnesium (Deepa et al. 2016). High values of hardness are probably due to regular addition of large quantities of detergents used by nearby residential localities which drains into water bodies. The hard water can cause indigestion problem and possibilities of forming calcium oxalate crystals in urinary tracts. Average total hardness values varied as follows: 116 (S3)-196 mg/l (S1) during summer; 138 (S4)-164 mg/l (S1) during monsoon and 164 (S3)-296 mg/l (S1) during post monsoon (Fig. 3e). It was within prescribed limits by BIS at all sites during the study period. S1 had the highest concentration (post monsoon) and S4 the least (summer).

Calcium (Ca)

Calcium is an element which exists in divalent form in water. It is the main component of different aquatic shells and bones of vertebrates. Usually Ca is found in all natural waters, but the discharge of sewage and wastewater enhances its concentration. Seasonal variation of calcium is shown in Fig. 3f. The range of Ca in the study varied from 14.4-39.6 mg/l during summer, 29.2-38.4 mg/l during monsoon and 30.5-73.7 mg/l during post monsoon with S1 having the highest value (post monsoon) and S3 the least (summer). It was within permissible limits during study period.

Magnesium (Mg)

It is also one of the important element of usually it is found along with calcium but in very low concentration and contributes to hardness of water along calcium. It is main component of chlorophyll. Magnesium values were as follows-17-24 mg/l during summer; 15.85-17.55 mg/l during monsoon; 18-27.29 mg/l during post monsoon. Highest Fig. 3g) Mg was observed at SI during post monsoon and least at S4 during summer.

Alkalinity

In natural waters alkalinity is due to dissolution of CO_2 in water (Patil et al. 2018). High alkalinity indicate the presence of strongly alkaline industrial waste water and sewage. The degradation of plants, living organisms and organic waste also be the reason for increase in carbonate and bicarbonate levels thereby increasing alkalinity. The observed alkalinity values ranged between 108-250 mg/l summer; 170-450 mg/l monsoon and 300-460 mg/l post monsoon (Fig. 3h). It was above the standard limits given by BIS in all seasons at S1. Highest alkalinity was observed in S1 during post monsoon and lowest was at S4 during summer season.

Chlorides

The high chloride concentration in water is an index of pollution. It is mainly present in sewage, effluents farm drainage and remains unaltered during purification of sewage (Patil et al. 2018). Excess chloride would reduce the Do content of water, which turns harmful to aquatic organisms (Deepa et al.2016). Figure 3i gives the seasonal variation of chlorides during the study period. Chloride values ranged between 188-295 mg/l; 158-186 mg/l and 178-218 mg/l during summer, monsoon and post monsoon seasons respectively. It was above desirable limit during summer at S2 and S4. Highest chloride concentration was observed at S2 (summer) and lowest was at S1 (monsoon).

Biochemical oxygen demand (BOD)

It is important part of assessing the organic pollution of aquatic ecosystem. It is the measure of quantity of oxygen required by bacteria and other microorganisms under aerobic condition in order to biochemically degrade and transform organic matter present in the water bodies. The consequences of high BOD include aquatic organisms becoming stressed, suffocating and eventually death (Dhinamala et al. 2015). Figure. 3j illustrates the variation in BOD at sampling sites. The lowest seasonal average BOD was 4.5 mg/l at S4 while the highest value was 56.9 mg/l at S1 during monsoon season respectively. It was obove reference values set by BIS in all sites during study period except S4 during summer.

Nitrate (NO_3)

Nitrate is an important nutrient which plays key role in deciding the productivity of aquatic ecosystem and accelerates growth of algae and macrophytes. Nitrate occurs in water from various natural sources and due to human activities like food production, agriculture and manure, disposal of domestic and industrial sewage (Lodh et al. 2014).Excess amounts of nitrates in drinking water can create serious health problems in humans. It can change normal hemoglobin to methaemoglobin which reduces the ability of the blood to transport oxygen to cells. In severe cases it can lead to respiratory and heart problems and death (Deepa et al. 2016). The average values of nitrate were 0.1-0.12 mg/l during summer; 0.02-0.11 during monsoon and 0.05-0.1 mg/l during post monsoon respectively (Fig. 3k). The highest value was 0.12 mg/l at S2 and lowest average value was 0.02 mg/l at S4.

Water quality index (WQI)

First step in calculation of WQI using weighted arithmetic index given unit weight for each parameter. The unit weight of each parameter and standard values for each parameter as per BIS is given in Table 2. The summary of WQI values of the water samples from all the 4 sampling sites for all seasons are given in Table 3. The results showed that water samples from S1 fall under unsuitable water category (WQI>100) during all seaons, S2 had very poor (75<WQI<100) water quality during monsoon and unsuitable during post monsoon and summer seasons. Water samples from S3 was under very poor category during post monsoon and summer but it was poor (50<WQI<75) during monsoon. At S4 water quality was poor during summer and very poor during monsoon and post monsoon seasons. Highest value of WQI was seen at S1 during post monsoon and lowest was at S4 during summer. Overall lake water falls under very poor category.

Conclusion

Seasonal variation in various physico-chemical parameters of Hebbal Lake was studied and water quality index was computed. The season wise variations in the WQI values were examined based on seasonal water quality analysis data of 4 sampling sites. TDS, EC, BOD were above permissible limits as per BIS in all 4 sites. Alkalinity was higher than permissible limits at S1. In inlet (S1) high amount of organic and other ionic contents were observed than other sampling sites. Overall water quality index showed that S1 and S2 was under unsuitable category, S3 very poor and S4 under poor category during study period. Based on this study it can be concluded that effective measures are urgently required to prevent entry of contaminated water and improve the overall water quality of the lake.

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