A Study on Physico-Chemical Parameters and Water Quality Index (WQI) of Varuna Lake, Mysore, Karnataka, India

Article · February 2022

2 authors:

Abhilash H R
Yuvaraja's college,University of Mysore, Mysore,India
4 PUBLICATIONS **1** CITATION

Malliah Mahadevaswamy
11 PUBLICATIONS **22** CITATIONS

Indian Journal of Natural Sciences *www.tnsroindia.org.in ©IJONS*

Vol.12 / Issue 70 / February / 2022 *International Bimonthly (Print)* *ISSN: 0976 – 0997*

RESEARCH ARTICLE

A Study on Physico-Chemical Parameters and Water Quality Index (WQI) of Varuna Lake, Mysore, Karnataka, India

H. R. Abhilash[1] and M. Mahadevaswamy[2]*

[1]Research Scholar, Department of Zoology, Yuvaraja's College (Autonomous), University of Mysore, Mysore -570005, Karnataka, India.
[2]Professor of Zoology, Department of Zoology, Yuvaraja's College (Autonomous), University of Mysore, Mysore - 570005, Karnataka, India.

Received: 09 Nov 2021 Revised: 15 Dec 2021 Accepted: 11 Jan 2022

***Address for Correspondence**
M. Mahadevaswamy
Professor of Zoology,
Department of Zoology,
Yuvaraja's College (Autonomous), University of Mysore,
Mysore - 570005, Karnataka, India.
Email: maadhuycm@gmail.com

ABSTRACT

Water is the most vital and necessary item for all life forms. The quality of freshwater resources is greatly impacted by anthropogenic activities especially those in the urban vicinities, which are frequently utilized as dumping stations for urban sewage. The Varuna Lake is located on the outskirts of Mysore city and is undergoing rapid transformation as several residential projects are springing up in the vicinity. This study aims to determine the physico-chemical quality of Varuna Lake water. The study period was divided into three seasons: post-monsoon (October-January), pre-monsoon (February-May) and monsoon (June-September) seasons. Surface water samples from three locations were collected and various water quality parameters were analyzed following standard methods. The mean values of all parameters were compared with drinking water quality standard given by BIS and ICMR. The data was statistically treated using one way ANOVA to find out seasonal variation in different water quality parameters. Pearson correlation analysis was performed to analyze relationship between water quality variables. There was a significant seasonal variation in some of the physico-chemical parameters as revealed by high values of pH, conductivity, turbidity, chemical oxygen demand and biological oxygen demand during pre-monsoon season. From the correlation analysis conductivity was found to have a positive relationship with water temperature and total dissolved solids. Most of the water quality parameters had a substantial negative correlation with pH. The overall WQI index was 80.27, which indicates poor water quality. The lake water was found to be more polluted than previous studies on the same lake.

Keywords: Varuna Lake, seasonal variation, water quality, water quality index (WQI).

INTRODUCTION

Fresh water ecosystems are more vulnerable to degradation than their terrestrial or marine counterparts [1]. Since the beginning of civilization, man has used aquatic resources for various purposes such as agriculture, hydropower, industries, fisheries, municipal supplies, recreational use and have put severe strain on water bodies by dumping untreated sewage, industrial, and technical wastes, in the hopes that a massive column of water, through dilution and the action of numerous detoxifying agents, would render the toxic substances harmless [2, 3]. India, like many other countries throughout the world, is facing severe crises of water shortages and pollution issues on a vast scale as a result of fast growing cities, flourishing industry, and an increase in its population [4]. Studies have shown that increase in anthropogenic activities in and around water bodies harms aquatic ecosystems and exacerbates environmental issues [5-7]. Therefore, regular monitoring of physicochemical properties of a water body is critical for both long and short term studies [8]. There are several methods to analyze water quality data that vary depending on informational goals, the type of samples, and the size of the sampling area [9]. Physico-chemical analysis is the most significant aspect when assessing the quality of water for its best utilization like drinking, irrigation, fisheries, and industrial purpose and helpful in understanding the complex processes, interaction between the climatic and biological processes in the water [10]. Furthermore, the data obtained from physiochemical properties can be used to calculate the water quality index (WQI). The WQI can condense a large amount of data to a single number, allowing it to express data in a more logical and simplified form, and also reveal annual cycles, spatial and temporal variation, and trends in water quality at low concentrations [11].

Several studies have been undertaken in Mysore city to assess water quality of freshwater lakes using water quality index. Mahesha and Balasubramanian [12] studied the impact of urbanization and industrialization on the water quality of Dalvoy Lake and found out that the WQI was 47.72 during pre-monsoon and 42.75 in post-monsoon and suggested that the lake water was suitable for agriculture purpose. However, when the same lake was studied six years later by Upadhyay and Chandrakala [13], it was found out that the lake was heavily impacted by untreated urban sewage which resulted in higher water quality index value of 158, these results shows the continuing deterioration of urban water bodies. In another study the WQI of Kukkarahalli Lake was studied by Mamatha [14]and reported that lake water quality was very poor with a WQI of 81.09. Similarly the WQI and abundance of zooplanktons in three contrasting lakes (Varuna, Madappa and Giribetta) of Mysore district was undertaken by Deepthi and Yamakanamardi [15]and they reported that Varuna Lake was moderately polluted (WQI-69), while Madappa and Giribetta lakes were severely polluted with a WQI of 83 and 93 respectively. In the current investigation an attempt is made to evaluate the water quality of Varuna Lake. The main aim of this study was to describe the seasonal variation of physico-chemical parameters and to investigate causes and factors which are responsible for such variation. Furthermore, to compute water quality index (WQI) in order to determine the overall quality of the lake from a pollution standpoint.

MATERIALS AND METHODS

Study area

Varuna Lake is located 13.3km from Mysore district, Karnataka state, India (76°74'58.72" E latitude, 12°27'50.31" N, longitude and 719 meters above the mean sea level). The lake is adjacent to Mysore - Trichy road and it is surrounded by Varuna, Chikkalli and Varakodu village (Fig. 1). The lake is commercially used for water sports by Outback adventures. The surrounding areas of the lake have lately been developed into residential areas, making it a desirable real estate destination. The lake is connected to the Varuna canal, which delivers Cauvery water and serves as a primary source of water, and it is supplemented by rain and runoff from the surrounding watershed.

Water sample collection and physico-chemical analysis

Sampling was done monthly for 1 year (October 2017 – September 2018) from three sampling sites. Surface water samples were collected (between 8.00 am and 10.00 am) by dipping 1 L labeled polythene plastic bottles. Parameters like water temperature and pH were measured on site, using a mercury thermometer and Hanna HI98107 pH meter, respectively. Further analysis of various physico-chemical parameters such as dissolved oxygen, electrical conductivity, total dissolved solids, salinity, turbidity, free carbon dioxide, total alkalinity, total hardness, nitrate, phosphate, sulphate, chloride, biological oxygen demand (BOD) and chemical oxygen demand (COD) were carried out in the laboratory as per standard methods [16, 17]. The mean values of the measured parameters for each season were compared with BIS and ICMR standards and pollution status was determined using water quality index (WQI) method. Data on physico-chemical variables were subjected to one way ANOVA ($p < 0.05$), and where significant difference existed, means were separated using Tukey's test. Pearson correlation analysis was also performed to establish whether there existed a relationship among the measured physicochemical water quality variables. This was calculated after $\log_{10}$ transformation of all variables after scaling so that all values were >1. All the statistical analysis was performed using SPSS (version 16) software.

Water quality index computation

The water quality index was calculated using twelve parameters based on their importance in water quality analysis. These parameters are pH, conductivity, total dissolved solids, dissolved oxygen, calcium, hardness, total alkalinity, BOD, nitrate, sulphate, chloride and turbidity. The values used for each parameter were the mean value of each season investigated during the study period. The standards for drinking water used in this study are recommended by BIS and ICMR [18, 19].The relative weights calculated for each parameter is shown in the Table 1. The calculation of WQI was performed by following the 'weighted arithmetic index method' as described by Brown et al. [20], using the equation:

$WQI = \sum Q_n W_n / \sum W_n$

Where Qn is the quality rating of n^{th} water quality parameter, Wn is the unit weight of n^{th} water quality parameter.

The quality rating Qn is calculated using the equation:

$Q_n = 100[(V_n - V_i) / (S_n - V_i)]$

Where Vn is the actual value of the parameter obtained, Vi represents the ideal value of that parameter. [Vi = 0, except for pH (Vi = 7) and DO (Vi = 14.6 mg/l)],

Sn is the standard permissible value for the n^{th} water quality parameter.

Unit weight (Wn) is calculated using the formula:

$W_n = K/S_n$

Where K is the constant of proportionality and it is calculated using the equation:

$K = [1/\sum 1/V_s = 1, 2, \ldots n]$

The water quality status (WQS) according to WQI is shown in Table 2.

RESULTS AND DISCUSSION

Physico-chemical parameters: The mean values of surface water quality parameters of the Varuna Lake are grouped into three seasons, post-monsoon (October to January), pre-monsoon (February to May) and monsoon (June to September). The seasonal variation of different physico-chemical variables from October 2017 to September 2018 are shown in the Table 3. There was a statistically significant difference between seasons in water temperature ($F(2, 9) = 7.96$, $p = .010$), COD ($F(2, 9) = 8.88$, $p = .007$)and BOD ($F(2, 9) = 7.25$, $p = .013$). As with rest of the parameters there was no significant difference between the seasons ($p > 0.05$).

Water temperature: The water temperature values of Varuna Lake varied according to the seasonal rhythm, seasonally the highest average value of water temperature was observed during pre-monsoon season. As reveled by the Tukey's post hoc test there was significant difference in temperature b/w pre-monsoon and post-monsoon seasons ($p = .007$), while there was no statistically significant difference between the post-monsoon vs monsoon ($p = .188$) or between pre-monsoon vs monsoon ($p = .151$).Water temperature is crucial because it strongly influence many physical and chemical characteristics of water including the solubility of oxygen and other gases, rates of chemical reaction, toxicity and microbial activity[22]. The highest temperature was recorded during pre-monsoon (30.73 °C) which could be due to high solar radiation, clear atmosphere and low water level [23] and the lowest was recorded during post-monsoon season (26.92°C) which can be attributed to low ambient temperature.

pH: The pH defines the concentration of protonions (H^+) found in the water. The optimal pH for drinking water is described in the range of 6.5 to 8.5 by BIS standards. The water was alkaline in nature throughout the year. According to Gupta et al.,[24] when pH exceeds 8.5, the taste of water becomes more salty, causing eye discomfort and skin disorders. The average mean value of pH during the investigation was 8.18 during post-monsoon, 8.98 during pre-monsoon and 8.24 during monsoon. There was no significant difference in pH throughout the study period, which was in accord to the previous study in the same lake [15].

Electrical conductivity: Electrical conductivity (EC) is the ability of water to conduct electric current and is also a measure of total number of dissolved salts or ions [7]. The electrical conductivity in Varuna Lake was 250.67 µS during post-monsoon, 273.67µS during pre-monsoon season and 260.17 µS during monsoon season. Seasonal variations in conductivity especially in lakes where inflow of water is marginal the fluctuation primarily depends on temperature and evaporation[25]. The highest value of 273.67 µS during pre-monsoon corresponds with the highest water temperature recorded during the same season.

Total dissolved solids: The total dissolved solid (TDS) in water is a measurement of the combined contents of all inorganic and organic components present in water as molecules, ions, or micro-granular suspended forms[26].The observed average total dissolved solids value was 139.5 mg /L during post-monsoon, 142.67 mg/L during pre-monsoon and 132 mg/L during monsoon season. The mean value of TDS was found below the prescribed limit (500 mg/L) of BIS, and there was no significant seasonal variation during the study period. Pearson correlation matrix revealed a strong connection between conductivity and TDS as revealed by correlation test ($p < 0.01$). The highest conductivity (273.67 S/cm) and TDS (142.67 mg/L) values were found in the pre-monsoon period, which corresponds to a decrease in water levels, which is associated with an increase in dissolved solids concentration [25].

Turbidity: Turbidity is a function of light dispersing and absorbing properties of water caused by the occurrence of suspended matters like clay, silt, colloidal organic particles and plankton [27]. Suspended particles absorb heat which causes water temperature to increase and it holds less oxygen than cold-water [28].In the present study, high turbidity was recorded during pre-monsoon season (8.12 NTU) which was slightly higher than the acceptable limit (5 NTU).

Dissolved oxygen: Dissolved oxygen is a critical measure in water quality assessment since it indicates whether or not a water body is polluted. The concentration of DO depends upon the water temperature, water agitation, types and number of aquatic plants, light penetration and amount of dissolved or suspended solids [7]. The mean values of DO recorded during the entire study period were well above the prescribed limit (5 mg/L) of BIS standards. The highest mean value of 5.4 mg/L was recorded during the monsoon season, while the lowest average (5.2 mg/L) was obtained during the post-monsoon and pre-monsoon seasons, which was slightly different from the monsoon season. Concentrations of less than 5 mg/L may disrupt the functioning and survival of biological communities, whereas concentrations of less than 2 mg/L may result in fish mortality [29].

Free carbon dioxide: Carbon dioxide in water is produced by the breakdown of organic materials and the respiratory activity of aquatic plants and animals [27]. In the present investigation the mean concentration of free carbon dioxide during the post-monsoon and monsoon seasons in the lake was less than 4 mg/L, and it was completely absent during the pre-monsoon season.

Calcium: Calcium is the most abundant divalent ion in fresh water and is necessary for shell formation, bone formation, and plant lime precipitation [30].Calcium is found in all natural waters; however it is augmented by the discharge of various sewage and waste water [31].The observed mean value of calcium was 22.20mg/L during post-monsoon, 16.49mg/L during pre-monsoon and 17.63mg/L during monsoon. The values recorded in all seasons were within the permissible limit (75mg/L) of BIS standards.

Hardness: Hardness of the water is a feature resulting from the presence of alkaline earth metals in natural waters, particularly calcium and magnesium [32]. The dissolution of soil minerals and rocks causes this feature, but it can also be induced by direct contamination by trash from a variety of anthropogenic sources [33]. Kannan [34] divided water into three categories based on hardness values: 0 – 60 mg/L soft, 61 – 120 mg/L moderately hard, 121–160 mg/L is hard, while greater than 180 mg/L as very hard. The highest concentration of hardness in the water sample was recorded during post-monsoon 101.83mg/L, which was well within the permissible limit (300mg/L) of the BIS standards. The results were parallel to the values reported previously for this lake [15].

Alkalinity: Alkalinity is a measure of the capacity of water to neutralize a strong acid [35]. Surface water alkalinity is predominantly determined by carbonate and hydroxide concentration, but also includes contributions from borates, phosphates, silicates, and other bases [36]. The highest alkalinity was recorded during pre-monsoon 107.5 mg/L and the lowest during monsoon (93.17mg/L) season. The low alkalinity value in surface waters during the monsoon was most likely due to rainwater dilution [29].

Chemical oxygen demand (COD): Chemical oxygen demand is a metric that accounts for both biologically oxidizable and chemically inert organic materials[30].In the present investigation the highest amount was recorded during pre-monsoon season (42.93mg/L) which may be due to decrease in water level, increase in salinity, temperature and microbial utilization of oxygen during the time of decomposition [37]. The concentration of COD decreased during monsoon season probably because of inflow of rainwater, decreased temperature and salinity. Increased COD levels suggest a higher concentration of organic and inorganic pollutants that requires more oxygen to oxidize in thermal conditions [38]. The statistical data from ANOVA revealed a significant difference ($p < 0.05$) among various seasons. Further, the Tukey post hoc test showed there was significant difference in COD between post-monsoon and pre-monsoon seasons ($p = .011$) and pre-monsoon vs monsoon ($p = .015$). There was no statistically significant difference between the post-monsoon vs monsoon ($p = .89$).

Biological oxygen demand: BOD 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 [39]. It indicates the amount of perishable organic matter present in water. As a result, a low BOD indicates good water quality, whereas a high BOD suggests contaminated water [40].The BOD of Varuna Lake was found within the permissible limit (5mg/L) of ICMR during the study period.

Nitrate: Nitrate is a vital nutrient that influences the productivity of aquatic ecosystems and speeds up the growth of algae and macrophytes [7]. Nitrates enter freshwater through the discharge of sewage and industrial wastes and run off from agricultural fields[41]. Nitrate value recorded in the study was 1.40mg/l during post-monsoon, 0.59mg/L during pre-monsoon and 1.68mg/L during monsoon season. The values recorded from all the seasons showed low concentration of nitrate, which was well within the permissible levels as per the standards.

Phosphate: Phosphate is an essential micronutrient for living organisms that is found in trace amounts in natural water bodies and is a major limiting factor that regulates primary productivity. Phosphate in natural waters is the result of the degradation of organic phosphorus contained in wastewaters by bacteria. Runoff from agricultural fields loaded with phosphate fertilizers can also introduce them in large quantities into the water bodies [42]. The concentration of phosphate measured in Varuna Lake was less than 0.1mg/L throughout the study period.

Sulphate: Sulphate is a common anion present in low concentration in natural waters. Sulphate sources in water bodies include rainfall run-off, fertilizers, sewage effluents, and dissolution of sulphide minerals present in granite [43]. The mean concentration of sulphate in the present investigation was found in the range of 4.9mg/L to 10.92mg/L, which was way below the acceptable range of BIS standards.

Chloride: Chloride occurs in all surface natural waters, but in very low concentration in freshwater bodies. The presence of a high chloride concentration is thought to be a sign of pollution caused by a large amount of organic waste from animal origin [31]. Chloride value obtained in the study was 21.47mg/L during post-monsoon, 30.40mg/L in pre-monsoon and 26.37mg/L in monsoon season. The chloride concentration in the Varuna Lake was found within the acceptable limit of 250mg/L.

Correlation among physico-chemical variables

Correlation matrix among the various physico-chemical parameters of Varuna Lake from October 2017 to September 2018 is represented in Table 4. The correlation analysis revealed that temperature was positively correlated (r =0.790, $p<0.01$) with electrical conductivity. Studies have shown that electrical conductivity depends on the amount and composition of ions and temperature [44, 45]. Similarly there was a strong positive correlation between TDS and EC (r =0.718, $p<0.01$), calcium and hardness (r =0.761, $p<0.01$), COD vs BOD (r =0.961, $p<0.01$). The results showed that TDS was positive correlated with hardness (r =0.614, $p<0.05$) and total alkalinity (r =0.660, $p<0.05$). Calcium and magnesium, which occur naturally in water bodies, are among the most highly available alkali metals in the environment responsible for the hardness in water [46]. The pH showed a negative correlation with calcium (r= -0.661, $p<0.05$) and nitrate (r= -0.753, $p<0.01$). Dadgar [47] discovered a clear inverse linear correlation between nitrate and water pH, where he showed that increasing nitrate levels in water causes pH values to decline.

Water quality index (WQI)

The summary of WQI values for all seasons are given in the Table 5. The calculated WQI implies that the lake water quality was "Poor" during post-monsoon and monsoon and "Unsuitable" during pre-monsoon season. The high WQI score during the Pre-monsoon season can be attributed to a higher pollution load during summer than during the rainy and winter seasons, which is also attributed by high conductivity, pH, and chloride concentrations [48]. Several workers have reported high water quality index during pre-monsoon seasons [15, 49, 29].The overall WQI of Varuna Lake fell within the 'very poor' category of WQI classification and is not suitable for daily needs. These values were found to higher than what was previously reported (WQI- 69) by other workers in the same lake [15]. This indicates that the lake's water quality is steadily degrading over time. The major source of pollution was from agriculture runoff and domestic sewage inputs. Overall it can be concluded that the water quality of the lake Varuna is poor and needs to be treated before human usage; however it is suitable for agriculture and fisheries with proper treatment. The findings of this study may aid decision-makers in the sustainable management and protection of the lake.

ACKNOWLEDGEMENT

The authors are thankful to the Principal of Yuvaraja's College, Mysore for providing laboratory facilities. In addition the researchers want to appreciate the help of Dr.Goutham.S and Mr.Lokesh.D for their assistance during the field work.

CONFLICT OF INTEREST

The author(s) declares no conflict of interest.

REFERENCES

1. Dudgeon, D, Arthington, AH, Gessner, MO, Kawabata, ZI, Knowler, DJ, Lévêque, C, et.al. Freshwater biodiversity: importance, threats, status and conservation challenges.*Biol. Rev. Camb. Philos. Soc*, 2006; 81(2): 163–182.
2. Jindal R, Sharma C. Studies on water quality of Sutlej River around Ludhiana with reference to physicochemical parameters. *Environ. Monit. Assess*, 2011; 174(4): 417–425.

3. Ramachandra MM. Water Quality Monitoring of Magadi Hill Range Lakes and Reservoirs of India. *Hydrology*, 2018; 6 (1): 18.
4. Rakhecha PR. Water environment pollution with its impact on human diseases in India. *Int. J. Hydrol*, 2020; 4(4)152–158.
5. Upadhyay P, Mishra, Gupta AK. Studies on the physico-chemical status of two ponds at Varanasi and Bhadohi under biotic stress. *Plant Arch*, 2010; 10 (2): 691–693.
6. Verma P, Purohit A, Patel N.Pollution Status of Chandlodia Lake Located In Ahmedabad- Gujarat. *Int J Eng Res Appl*, 2012; 2 (4): 1600–1606.
7. Bhat S, Mahesh M, Ramachandra TV. Assessment of Seasonal Variation in Water Quality and Water Quality Index (WQI) of Hebbal Lake, Bangalore, India. *J. Ecol. Environ*, 2019; 37: 309–317.
8. Wood A. Constructed wetlands in water pollution control: Fundamentals to their understanding. *Water Sci. Technol.*, 1995; 32 (3):21–29.
9. Alobaidy AHMJ, Abid HS, Maulood BK. Application of Water Quality Index for Assessment of Dokan Lake Ecosystem, Kurdistan Region, Iraq. *J. Water Resour. Prot*, 2010; 2 (9): 792–798.
10. Salve BS, Hiware CJ. Studies on water quality of Wanparkalpa reservoir, Nagapur, Near Parli Vaijinath, Dist Beed, Marathwada region.*J. Aquat. Biol*, 2006; 21 (2):113–117.
11. Tyagi S, Sharma B, Singh P, Dobhal R.Water Quality Assessment in Terms of Water Quality Index.*Am. J. Water Resour*, 2013; 1(3): 34–38.
12. Mahesha, Balasubramanian A. Analysis of Water Quality Index (WQI) in Dalvoy Lake, Mysore City, India.*Nat. Environ. Pollut. Technol*, 2010; 9(4): 663–670.
13. Upadhyay A, Chandrakala M.Water quality assessment of Dalvoy Lake water, Mysore, Karnatake, India.*Int. J. Sci. Environ. Technol*, 2016; 5(5): 3254–3261.
14. Mamatha M.Water Quality Assessment of Kukkarahalli Lake Water Mysore, Karnataka, India.*Int. Res. J. Eng. Technol*, 2017; 4(3): 2303–2307.
15. Deepthi S, Yamakanamardi SM.Abundance of Cladoceran zooplankton in Varuna, Madapa and Giribettethelakes of Mysore, Karnataka state, India. *Int. J. Sci. Environ. Technol*, 2014; 3(3):885–900.
16. Eaton AD, Standard methods for the examination of water and wastewater, Washington, D.C; 2005.
17. Trivedy RK, Goel PK, "Chemical and biological methods for water pollution studies.," *Environ. Publ. India*; 1986.
18. BIS, Specifications for Drinking Water-Indian Standard: IS 10500. New Delhi, India; 2012.
19. ICMR, Manual of standards of quality for drinking water supplies. New Delhi, India; 1975.
20. Brown RM, McCleiland NJ, Deininger RA, O'Connor MF.A Water Quality Index—Crossing the Psychological Barrier. *Proceedings of the International Conference on Water Pollution Research*. Jerusalem, 1972; 787–797.
21. Chaterjee C, Raziuddin M. Determination of water quality index (WQI) of a degraded river in Asanol Industrial area, Raniganj, Burdan, West Bengal.*Nat. Environ. Pollut. Technol*.2002;1.
22. Dallas H, Day J. The Effect of Water Quality Variables on Aquatic Ecosystems: A Review. *Water Res. Comm. Pretoria South Afr,* 2004.
23. Latha NS, Rai NA. Ecological studies of Banjara lake with reference to water pollution. *J. Environ. Biol.*, 1998; 19: 179–186.
24. Gupta N, Pandey P, Hussain J. Effect of physicochemical and biological parameters on the quality of river water of Narmada, Madhya Pradesh, India. *Water Sci*, 2017; 31(1): 11–23.
25. Pal M, Samal N, Roy P, Biswas Roy M. Electrical Conductivity of Lake Water as Environmental Monitoring –A Case study of Rudra sagar Lake.*J. Environ. Sci. Food Technol,2015*.
26. Sharma S, Chhipa RC.Seasonal variations of ground water quality and its agglomerates by water quality index.*Glob. J. Environ. Sci. Manag*, 2016; 2(1): 79–86.
27. Hussain BA, Chandra BR, Amalesh D.A Study of the Limnology and Ichthyology of Dhir Beel at Dhubri, Assam, India. *Int. Res. J. Biol. Sci*, 2015; 4(8): 40–48.
28. Kalaiarasi M, Paul P, Lathasumathi C, Stella C.Seasonal variations in the physico-chemical characteristics of the two coastal waters of Palk-strait in Tamil Nadu, India.*Glob. J. Environ. Res*,2012; 6(2):66–74.

29. Thakor FJ, Bhoi DK, Dabhi HR, Pandya SN, Nikitaraj BC.Water Quality Index (W.Q.I.) of Pariyej Lake Dist. Kheda - Gujarat.*Curr. World Environ*, 2011;6: 225–231.
30. Saluja DS. Physico-Chemical Analysis of Potable Water Quality of Machna River at District Betul (M.P.). *Int. J. Sci. Res*, 2018; 9(4):1294-1296.
31. Singh A, Jayakumar S. Water Quality Assessment of Kanwar Lake, Begusarai, Bihar, India.*Imp. J. Interdiscip. Res*, 2016;2(4):793-803.
32. Oliveira-Filho EC, Caixeta NR, Simplício NCS, Sousa SR, Aragão TP, Muniz DHF. Implications of water hardness in ecotoxicological assessments for water quality regulatory purposes: a case study with the aquatic snail Biomphalaria glabrata (Say, 1818). *Braz. J. Biol*, 2014;74:175–180.
33. Wurts W.Understanding Water Hardness.*World Aquac*, 1993; 24:18.
34. Kannan K, Fundamentals of Environmental Pollution. New Delhi:S. Chand and Company ltd., 1991.
35. Wetzel RG, *Limnology*, 2nd ed. Philadelphia. U.S.A: Saunders College Publishing, 1983.
36. Qureshimatva MR, Maurya RR, Gamit SB, Patel RD, Solanki HA. Determination of Physico-Chemical Parameters and Water Quality Index (Wqi) of Chandlodia Lake, Ahmedabad, Gujarat, India.*J. Environ. Anal. Toxicol*, 2015; 5(4):288.
37. Dhinamala K, Pushpalatha M, Samuel T, Raveen R.Spatial and temporal variations in the water quality parameters of Pulicat Lake, Tamil Nadu, India.*Int. J. Fish. Aquat. Stud*, 2015; 3(2): 255-259.
38. Koushik S, Saksena DN, Physico-chemical limnology of certain fresh water bodies of Central India, in fresh water eco-system of India. New Delhi, India: Daya Publ. House, 1999.p.1-58.
39. Kaur S, Kaur J.Assessment of Seasonal variations in oxygen demanding parameters (DO, BOD, COD) along Sirhind Canal passing through Moga, Punjab, India.*Int. J. Innov. Sci. Eng. Technol*, 2015; 2(5): 697-700
40. Unadkat K, Parikh P.Water Quality Index of Harni Pond, District Vadodara, Gujarat. *Res. Rev*, 2018; 1:6–15.
41. Solanki AH, "Status of soils and water reservoirs near industrial areas of Baroda: pollution and soil - water chemistry," Lap Lambert Acad. Publ. Germany; 2012.
42. Lazizi A, Laifa A. Assessment of the Surface Water Quality: A Case of Wadi El-Kébir West Watershed, Skikda, North-East Algeria.*Nat. Environ. Pollut. Technol*, 2020; 19(5): 1977–1985.
43. Khatri N, Tyagi S.Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Front. Life Sci*, 2015; 8(1): 23–39.
44. Smith SH. Temperature Correction in Conductivity Measurements1. *Limnol. Oceanogr*, 1962; 7(3):330–334.
45. Hayashi M. Temperature-Electrical Conductivity Relation of Water for Environmental Monitoring and Geophysical Data Inversion. *Environ. Monit. Assess*, 2004; 96 (3):119–128.
46. Potasznik A, Szymczyk S.Magnesium and calcium concentrations inthe surface water and bottom deposits of a river-lake system.*J. Elem*, 2015; 20(3):677–692.
47. Dadgar P, Payandeh PE. Investigation of Nitrate Concentration and Its Correlation with Water pH in Drinking Water Distribution Network of the City of Tabriz.*Int. J Sci. Std,* 2017;5(4):726-731.
48. Yogendra K, Puttaiah ET. Determination of water quality index and suitability of an urban waterbody in Shimoga Town, Karnataka. *Proceedings of Taal2007: The 12th World Lake Conference*, 2008; 342–346.
49. Kulkarni VS, Tapase BS. Physico-chemical parameters and water quality index of Gandhisagar Lake of Umrer in Nagpur District.*J. Biosci*, 2011; 2(3):366–369.

Table 1: Relative weight (W_n) of parameters used for WQI calculation.

Parameters	Standard (Sn)	Recommended agency	Wn=K/Sn
pH	8.5	ICMR/BIS	0.15163
Cond.(µS)	300	BIS	0.00430
TDS	500	ICMR/BIS	0.00258
DO	5	ICMR/BIS	0.25778
Calcium	75	ICMR/BIS	0.01719
Hardness	300	ICMR/BIS	0.00430

TA	200	BIS	0.00644
BOD	5	ICMR	0.25778
Nitrate	45	BIS	0.02864
Sulphate	200	BIS	0.00644
Chloride	250	ICMR/BIS	0.00516
Turbidity	5	BIS	0.25778
		$\sum W_n =$	1.00000

BIS: Bureau of Indian Standard and ICMR: Indian Council of Medical Research

Table 2: Water quality index grading [20, 21]

WQI	Water quality status	Possible usage
0-25	Excellent	Drinking, irrigation and industrial
26-50	Good	Drinking, irrigation and industrial
51-75	Poor	Irrigation and industrial
76-100	Very poor	Irrigation
Above 100	Unsuitable for drinking and fish culture	Proper treatment required before use

Table 3: Seasonal fluctuation in physicochemical parameters at Varuna Lake from October 2017 to September 2018

Parameters	Post-monsoon (Mean ± SD)	Pre-monsoon (Mean ± SD)	Monsoon (Mean ± SD)	F-Value[1]	p-value
Water temp. (°C)	26.92 ± 0.07	30.73 ± 0.16	28.76 ± 0.88	7.9676	0.0102*
pH	8.18 ± 0.04	8.98 ± 0.26	8.24 ± 0.25	3.9227	0.0596
E.C. (µS cm $^{-1}$)	250.67 ± 7.00	273.67 ± 8.42	260.17 ± 31.57	1.1954	0.3464
T.D.S (mg L^{-1})	139.5 ± 4.92	142.67 ± 4.04	132 ± 15.74	2.1301	0.1748
Turbidity (NTU)	3.83 ± 0.73	8.12 ± 1.63	3.51 ± 0.56	1.9486	0.1981
DO (mg L^{-1})	5.27 ± 0.14	5.28 ± 0.1	5.4 ± 0.22	0.0921	0.9129
FCO2 (mg L^{-1})	3.98 ± 2.17	0	3.85 ± 2.91	1.8593	0.2109
Calcium (mg L^{-1})	22.20 ± 0.86	16.49 ± 0.59	17.63 ± 2.10	2.4069	0.1454
Hardness (mg L^{-1})	101.83 ± 2.08	91.50 ± 3.12	93.17 ± 13.14	1.6741	0.2409
TA (mg L^{-1})	101.92 ± 3.74	107.50 ± 1.09	93.17 ± 8.89	2.0348	0.1866
COD (mg L^{-1})	20.34 ± 1.14	42.93 ± 2.66	21.47 ± 2.82	8.8825	0.0074*
BOD (mg L^{-1})	1.57 ± 0.13	3.81 ± 0.27	1.85 ± 0.24	7.2554	0.0133*
Nitrate (mg L^{-1})	1.40 ± 0.26	0.59 ± 0.14	1.68 ± 0.19	0.8587	0.4557
Phosphate (mg L^{-1})	< 0.1	< 0.1	< 0.1	-	-
Sulphate (mg L^{-1})	9.1 ± 0.76	10.92 ± 0.75	4.9 ± 0.32	1.6602	0.2434
Chloride (mg L^{-1})	21.47 ± 2.17	30.40 ± 0.54	26.37 ± 0.46	2.5784	0.1302

[1]*value obtained from one way - ANOVA test; * = Significant (p<0.05).*

Note: E.C – Electrical conductivity; T.D.S – Total Dissolved Solids; DO – Dissolved Oxygen; FCO2 – Free Carbon-di-Oxide; TA – Total Alkalinity; COD – Chemical Oxygen Demand; BOD – Biological Oxygen Demand;

Table 4: Correlation coefficient between water quality parameters in Varuna Lake

	WT	pH	EC	TDS	DO	Ca	Hard.	TA	COD	BOD	NO^-_3	SO^{2-}_4	Cl^-	Tur.
WT	1.00													
pH	0.28	1.00												
EC	.790**	-0.14	1.00											
TDS	0.37	-0.04	.718**	1.00										
DO	-0.05	0.28	-0.17	-0.37	1.00									
Ca	-0.33	-.661*	0.22	0.50	-0.25	1.00								
Hard.	-0.10	-0.51	0.41	.614*	0.03	.761**	1.00							
TA	0.35	-0.05	0.43	.660*	-0.24	0.27	0.37	1.00						
COD	0.56	0.53	0.27	0.15	0.03	-0.47	-0.41	0.25	1.00					
BOD	0.51	0.50	0.21	0.02	0.10	-0.48	-0.47	0.25	.961**	1.00				
NO^-_3	-0.15	-.753**	0.22	0.14	0.00	0.41	.680*	0.18	-0.52	-0.50	1.00			
SO^{2-}_4	0.11	-0.02	0.16	0.46	-0.24	0.42	0.18	0.50	0.29	0.18	-0.29	1.00		
Cl^-	0.25	0.17	0.14	0.03	-0.13	-0.16	-0.35	0.30	0.41	0.56	-0.28	0.08	1.00	
Tur.	0.20	0.48	0.05	0.21	-0.16	-0.55	-0.24	0.13	0.24	0.15	-0.08	-0.36	-0.01	1.00

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

Note: WT – Water temperature; E.C – Electrical conductivity; T.D.S – Total Dissolved Solids; DO – Dissolved Oxygen; Ca - calcium; Hard. – Hardness; TA – Total Alkalinity; COD – Chemical Oxygen Demand; BOD – Biological Oxygen Demand; NO^-_3– Nitrate; SO^{2-}_4– Sulphate; Cl^-- Chloride; Tur. - Turbidity

Table 5: Summary of water quality index of Varuna Lake.

Seasons	WQI	WQS
Post-monsoon	66.35	Poor
Pre-monsoon	107.92	Unsuitable
Monsoon	66.55	Poor
Overall WQI	80.27	Very Poor

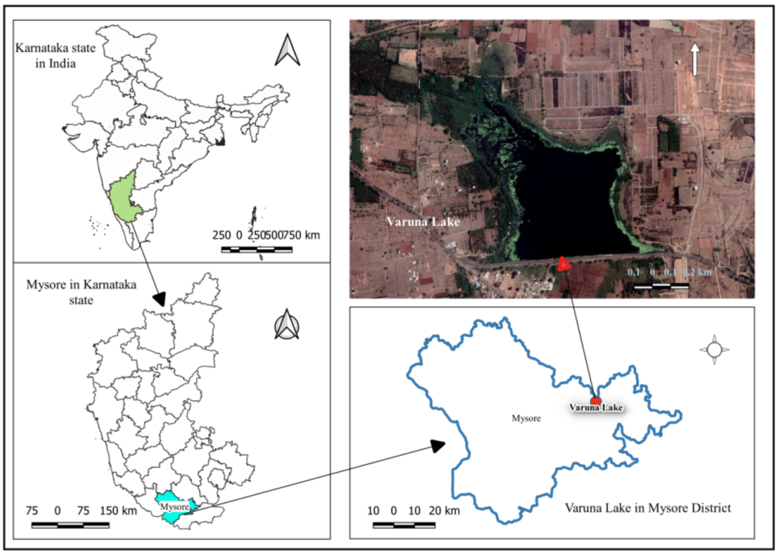

Fig. 1: Map of Mysore district showing the location of Varuna Lake