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Spatio-Temporal Dynamics of Water Quality in Bheemanakuppe Lake Amidst Anthropogenic Alterations, Bangalore District, Karnataka

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ABSTRACT

Freshwater lakes are indispensable economic, ecological, and cultural lifelines. Urgent action against degradation and biodiversity loss is critical to ensure sustainable water resources, protect human health, and safeguard national economies. In this study, water quality parameters such water quality parameters such as Temperature (27 ± 0.5), pH (7.4 ± 0.1), Total Dissolved Solids (TDS) (360 ± 10), Electrical Conductivity (EC) (460 ± 10), Total Hardness (TH) (122.33 ± 2.52), Dissolved Oxygen (DO) (7.5 ± 0.3), Biological Oxygen Demand (BOD) (1.17 ± 0.15), Chemical Oxygen Demand (COD) (27.67 ± 2.52), Chloride (32.33 ± 2.52), Calcium (82.33 ± 2.52), Magnesium (31.67 ± 1.53), Sodium (27.67 ± 2.52), and Potassium (22 ± 2) were analyzed at Bheemanakuppe Lake in 2024-25. The data were analyzed using Pearsons's correlation matrix and Water Quality Index (WQI) to evaluate the overall health and suitability of lake water. Highly positive correlations were observed between Chloride (Cl) and Sodium (Na) (0.92), as well as between COD and Chloride (0.92). A strong positive correlation was also found between BOD and pH (0.85). In contrast, strong negative correlations were observed between Total Alkalinity (TA) and Sodium, Chloride, and COD (ranging from −0.85 to −0.89). Additionally, Potassium (K) showed moderate negative correlations with BOD and Sodium (approximately −0.75). The Water Quality Index (WQI) was used to condense these parameters into a single, interpretable value, which remained within the "Good" category, with an average of 45.1 during the 2024–2025 period. The study emphasizes the importance of continuous monitoring and the implementation of strategic measures for the preservation and sustainable management of Bheemanakuppe Lake. It also provides valuable insights for local communities, enabling them to make informed decisions to protect and safeguard this vital water resource.

Keywords: Physiochemical parameters, Pearson correlation, Water quality index, Bheemanakuppe Lake, Sustainable management.

INTRODUCTION

Water is an essential and widely distributed resource on Earth. It fulfills the various necessities of human civilization, improves climate and landscape quality, supports flora and fauna (Sharma et al., 2008), and is continuously recycled through the hydrological cycle. Despite their importance, urban lakes are often small, shallow, and significantly impacted by surrounding land use. Stormwater runoff is a major source of pollutants, carrying sediments, nutrients, heavy metals, and microbial contaminants, which severely degrade water quality (UNEP, 2006; Singh et al., 2020).

According to the Central Pollution Control Board (CPCB, 1995), water quality refers to the physical, chemical, and biological characteristics of water that determine its suitability for various uses. In India, water pollution is addressed through several legal frameworks, including: (1) the Water (Prevention and Control of Pollution) Act, 1974, which focuses on the prevention and control of water pollution; (2) the Environment (Protection) Act, 1986, which broadly covers environmental and water quality issues; (3) public nuisance provisions under the

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Indian Penal Code allowing action against polluters; and (4) public interest litigations under Articles 32 and 226 of the Indian Constitution, enabling citizens to seek legal remedies (Pathak, 2013).

Urban lakes, although limited in size and depth, are vital components of city ecosystems. While large lakes are generally natural, smaller lakes are often semi-natural systems developed or modified by humans for water retention and management (Maurya, 2015). These lakes act as ecological indicators of a city's environmental health, helping regulate the microclimate and supporting biodiversity, which in turn benefits surrounding communities (Benjamin et al., 1996; Ramachandra et al., 2018).

Lakes have significant environmental and socio-economic importance. They support groundwater recharge and discharge, provide water for drinking and irrigation, sustain livelihoods such as fishing and agriculture, and offer recreational opportunities including boating, walking, and environmental education. Additionally, lakes play a crucial role in flood control, streamflow regulation, and emergency water supply for firefighting. They also contribute to nutrient cycling and climate change adaptation, making them essential natural assets for sustainable development (MEA, 2005; Ramsar Convention Secretariat, 2016).

MATERIALS AND METHODS

Study site:

Bheemanakuppe lake Fig: 1 is located at Latitude; 12° 54′ 52″ N; Longitude; 77° 26′ 0″ E is a freshwater water lake in Bengaluru south urban district, Karnataka close to Bheemanakuppe hamlet under Ramohalli Gram Panchayat Mysore road and Nice Ring Road provide access to this semi-urban neighbourhood which is encircled by residential schemes like Ramohalli, Kumbalagodu and Kengeri Hobli, despite its small size the lake contributes to the local community and natural habitat by offering recreational and aesthetic benefits.

Experimental design: During the study period from October 2024 to September 2025, surface water samples were collected monthly and analyzed for various physico-chemical parameters. Samples were collected in clean polyethylene containers during the morning hours between 7:30 a.m. and 9:30 a.m. Water temperature was measured on-site using a centigrade thermometer. The pH was recorded in the field using a calibrated pH meter. For the analysis of Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD), water samples were collected in 300 mL BOD bottles, and DO was fixed immediately at the sampling site. All other parameters were analyzed according to standard methods prescribed by APHA (2005). The obtained results were compared with World Health Organization (WHO) standards. Pearson correlation analysis was performed, and selected key parameters were used to calculate the Water Quality Index (WQI) of the lake (Tables 1 and 2).

RESULT AND DISCUSSION

Water temperature is a critical factor that directly or indirectly affects several other water quality parameters, such as pH, dissolved oxygen (DO), and alkalinity (Maansi et al., 2022). These interactions collectively influence the overall quality of the water. At Bheemanakuppe Lake, the average surface water temperature ranged from a low of 24.2 °C during the monsoon season to a high of 26.06 °C in the summer. Despite slight seasonal and spatial variations, the temperature remained relatively stable throughout the year. Importantly, the recorded temperatures fell within the acceptable limits established WHO, suggesting that the water conditions are conducive to proper chemical and biological processes.

Electrical conductivity (EC) is a crucial parameter used to evaluate salinity, ionic strength, major solute concentrations, and total dissolved solids (TDS) in natural waters (McCleskey et al., 2012). In this study, EC values ranged from 301 µS/cm in the post-monsoon season to 358 µS/cm during winter. Although minor fluctuations were observed across different sites and seasons, these variations were not considered significant. Importantly, all measured values remained below the permissible limits set by WHO standards for drinking water. Elevated EC levels in natural waters are typically attributed to the weathering of certain sedimentary rocks and to human activities, including discharges from industrial, agricultural, and domestic sewage sources (WHO, 2017).

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Total dissolved solids (TDS) mainly consist of inorganic salts such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates, along with small amounts of organic matter. This composition suggests the presence of inorganic pollution within the water system (Bhutiani et al., 2018). TDS and electrical conductivity (EC) are closely related parameters (Alobaidy et al., 2010); however, no clear seasonal patterns were observed between them. The average TDS values ranged from 129.25 mg/L during the monsoon to 238.0 mg/L in the summer, remaining well below the WHO standard of 500mg/L, indicating that the water is suitable for drinking. Notably, there were no significant variations in TDS values across different sites or seasons.

Water hardness is primarily caused by the presence of cations such as calcium and magnesium (Sawyer, McCarty, & Parkin, 2003). The total hardness (TH) values showed variability, ranging from 128 mg/L to 140 mg/L in the summer while other seasons exhibited relatively consistent levels. Importantly, all observed TH values were well within the permissible range recommended by WHO standards.

pH, which measures the acidity or alkalinity of a solution based on hydrogen ion concentration, is a critical parameter for evaluating water quality across various uses (Wetzel, 2001). It influences numerous chemical and biological processes within aquatic environments. In this study, the average pH values ranged from 7.60 to 8.2, indicating that the water was neutral to mildly alkaline, and comfortably within the recommended limits of 6.5 to 8.4 WHO guidelines. Similar pH levels were observed across all sampling sites and seasons, though slightly elevated values (around 8.0) were recorded during the monsoon.

Dissolved oxygen (DO) is a critical parameter in aquatic ecosystems, essential for the survival of diverse aquatic organisms. It is widely recognized as an indicator of waterbody health and quality (Smith et al., 2010; Johnson and Lee, 2012). DO levels in water bodies fluctuate daily and seasonally (Garcia and Martinez, 2015), influenced by factors such as temperature, salinity, turbidity, atmospheric pressure, and photosynthetic activity (Brown, 2008). In the study area, average DO concentrations ranged from 6.2mg/L in summer to 7.2 mg/L in postmonsson, with no significant differences detected across sampling sites or seasons. However, these values frequently approached or fell below the WHO guideline of 5.0 mg/L for safe drinking water, indicating suboptimal water quality. This shortfall may be due to reduced photosynthetic oxygen production (Patel et al., 2019) and could also be linked to nutrient enrichment or disruptions in the natural oxygen regulation processes.

Biochemical Oxygen Demand (BOD) quantifies the amount of oxygen consumed by aerobic microorganisms during the breakdown of organic material (Davis and Thompson, 2012; Nguyen et al., 2021). Elevated BOD levels, often resulting from industrial, domestic, or agricultural effluents, can significantly reduce dissolved oxygen in aquatic environments, threatening the survival of aquatic organisms (Martinez et al., 2008). Therefore, BOD is a key indicator for assessing organic pollution in water bodies (Singh and Kumar, 2015). During the study, mean BOD values ranged from 1.2 mg/L during summer to 3.2 mg/L in the post-monsoon season. BOD values were within the WHO guidelines, indicating good water quality and showing an enhanced water quality management.

Chemical Oxygen Demand (COD) is a measure of the oxygen required to chemically oxidize organic matter in water, typically using agents such as potassium dichromate (Davis and Thompson, 2012; Nguyen et al., 2021). As an indirect indicator of total organic pollution, COD is widely applied to monitor municipal wastewater impacts on aquatic systems (Davis and Thompson, 2012; Patel et al., 2019). Elevated COD concentrations can render water bodies unsuitable for fisheries and agricultural use (Martinez et al., 2008). In this study, mean COD values ranged from 19.0 mg/L during the post-monsoon season to a peak of 70.0 mg/L in summer. Seasonal fluctuations were notable, with summer showing the highest COD levels (51.67–70.0 mg/L), followed by winter (38.0–54.67 mg/L), while other seasons exhibited relatively stable values. These COD values exceeded WHO recommended limits, suggesting significant organic contamination likely driven by increased oxygen demand in chemical oxidation processes.

In water chemistry, ions are classified as cations (positively charged ions) and anions (negatively charged ions). The balance between these ions governs key water quality characteristics such as salinity, hardness, alkalinity, and overall hydrochemical behavior.

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Gibbs (1970) and subsequent researchers have identified three primary processes—or controlling factors—that influence both the total and relative concentrations of major ions in surface waters:

1. **Evaporation–Crystallization (or Precipitation) Process**: This involves an increasing ratio of evaporation to precipitation (such as rainfall), which can lead to differential loss of ions through mechanisms like mineral precipitation or degassing.

2. **Rock Dominance**: The composition of the underlying geological strata significantly influences ion content, as different minerals release different ions during weathering.

3. **Atmospheric Precipitation Dominance**: The chemical composition of rainfall or other forms of atmospheric input also plays a role, depending on the nature of aerosols, dust, and airborne particles (Kilham 1990).

These processes are interrelated rather than independent and together determine the natural levels of specific conductivity and the concentrations of various ions in freshwater systems. Ion concentrations in precipitation are typically low and vary based on the atmospheric sources of dust and aerosols (Gorham, 1961). As precipitation interacts with soils and rocks, ion concentrations generally increase due to chemical weathering—unless the geology is particularly resistant. Additionally, evaporation may further concentrate ions, although some may be removed from solution through mineral formation or gas release.

In the present study, the major ionic composition of the water body was represented by chloride (32.33 ± 2.52 mg/L) among anions, and calcium (82.33 ± 2.52 mg/L), magnesium (31.67 ± 1.53 mg/L), sodium (27.67 ± 2.52 mg/L), and potassium (22 ± 2 mg/L) among cations. These ions collectively indicate the chemical nature of the water and reflect both natural geochemical processes and possible anthropogenic influences affecting the lake system.

Pearson Correlation

Highly positive correlations were observed between Chloride (Cl) and Sodium (Na) (r = 0.92), indicating a strong influence of salinity, likely due to the presence of common salt (NaCl). A similarly strong positive correlation between Chemical Oxygen Demand (COD) and Chloride (r = 0.92) suggests that fluctuations in organic matter are closely associated with dissolved salts, possibly influenced by surface runoff. Additionally, a high positive correlation between Biological Oxygen Demand (BOD) and pH (r = 0.85) indicates that increasing organic pollution is associated with a shift towards more alkaline conditions in the water.

In contrast, strong negative correlations were observed between Total Alkalinity (TA) and Sodium, Chloride, and COD (ranging from −0.85 to −0.89), suggesting that higher alkalinity levels are associated with reduced concentrations of these pollutants. Furthermore, Potassium (K) showed moderate negative correlations with BOD and Sodium (approximately −0.75), indicating that higher organic pollution and sodium levels are associated with a decrease in potassium concentration.

The Water Quality Index (WQI): WQI was utilized to integrate multiple physicochemical parameters into a single, easily interpretable value, providing an overall assessment of water quality in Bheemanakuppe Lake. WQI values remained within the 'Good' range: 45.1 throughout the year 2024-2025. A comprehensive summary of the water quality data for the year 2024-2025 is presented in Table 2. Overall, these findings highlight clear water quality within Bheemanakuppe Lake, emphasizing the need for cautious use to prevent further decrease of water quality.

CONCLUSION

Water quality plays a fundamental role in supporting healthy communities, sustainable ecosystems, and long-term development goals. Globally, water pollution continues to pose significant environmental and public health challenges; however, certain water bodies still exhibit resilience and maintain good quality, offering a model for sustainable management. In the present study, Bheemanakuppe lake was assessed using a comprehensive set of

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physico-chemical parameters. The findings indicate that the lake water remains within acceptable standards for most tested parameters, suggesting it is currently unpolluted and does not pose any immediate risk to public health or ecological balance. This relatively good water quality can be attributed to lower pollution inputs, natural self-purification processes, or effective informal waste management practices in the surrounding area.To maintain and enhance this favorable condition, it is important to adopt proactive and preventive strategies. Public awareness campaigns should be promoted to educate residents about the importance of proper waste disposal, minimising the use of harmful chemicals, and maintaining hygiene in the lake's vicinity. Community-led clean-up drives, ecological monitoring, and collaboration with local authorities can further help safeguard the lake from future threats. Protecting unpolluted water bodies like Bheemanakuppe Lake not only ensures safe water availability for local populations but also contributes to regional environmental sustainability and biodiversity conservation.

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Table 1: Showing the Mean and Standard deviation of the Water Quality Parameters of Bheemanakuppe Lake:

Water Parameters	Mean	Standard Deviation
Water Temperature	27	0.5
pH	7.4	0.1
Total Dissolved Solids	360	10
Total Hardness	122.33	2.52
Electrical Conductivity	460	10
Dissolved Oxygen	7.5	0.3
Biological Oxygen Demand	1.17	0.15
Chemical Oxygen Demand	27.67	2.52
Chloride	32.33	2.52
Calcium	82.33	2.52
Magnesium	31.67	1.53
Sodium	27.67	2.52
Potassium	22	2

Table 2: Showing the calculation of Water Quality Index of Bheemanakuppe Lake:

Water Parameters	**Mean (Vi)**	**WHO Std (Si)**	**Ideal (Vi)**	**Qi (Quality rating)**	**Wi (Weight)**	**Qi × Wi**
pH	7.4	8.5	7	20.00	0.200	4.00
TDS (mg/L)	360	500	0	72.00	0.100	7.20
Total Hardness (mg/L)	122.33	500	0	24.47	0.050	1.22
Chloride (mg/L)	32.33	250	0	12.93	0.100	1.29
Calcium (mg/L)	82.33	75	0	109.77	0.100	10.98

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Magnesium (mg/L)	31.67	30	0	63.34	0.100	6.33
Sodium (mg/L)	27.67	200	0	13.84	0.100	1.38
BOD (mg/L)	1.17	3	0	39.00	0.250	9.75
					ΣWi=1.0	**ΣQiWi=**42.15
Total WQI=42.15/1.00=42.15						

Table 3: Showing the Water Quality Classification based on the Water Quality Index

WQI Range	**Quality of Water**
0–25	Excellent
26–50	Good
51–75	Poor
76–100	Very Poor
>100	Unsuitable

Table 4: Calculation of Water Quality Index:

Component	Symbol / Formula	Description
Quality Rating	Qi = ((Vi − Videal) / (Si − Videal)) × 100	Vi = observed mean value; Si = WHO standard value; Videal = ideal value (0 for most parameters, 7 for pH)
Unit Weight	Wi = 1 / Si	Si = WHO recommended standard value for each parameter
WQI Formula	WQI = Σ(Qi × Wi) / ΣWi	Overall Water Quality Index calculated using weighted aggregation
Ideal Value	Videal	0 for most parameters; 7 for pH
Total Unit Weight	ΣWi = 1.00	Sum of all unit weights used in calculation
Σ(Qi × Wi)	—	42.15
Final WQI	—	42.15
Water Quality Interpretation	—	Good (WQI: 0–50)

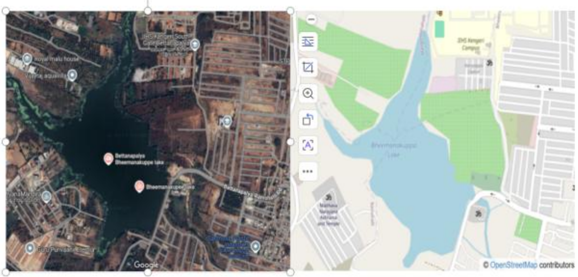

Fig: 1 Bheemanakuppe lake located at Latitude; 12° 54′ 52″ N;

Longitude; 77° 26′ 0″ E