



Physicochemical Characterization of Urban Lake Waters in Bengaluru Using Hardness and Total Dissolved Solids Indicators

Mowlya M, Nandini N, Chandana S, Rakesh V, Dr.Ethiraj J
Department of Forensic Science, Garden City University, Bengaluru.

Abstract

This study aims to evaluate water hardness, total dissolved solids (TDS), and pH levels in selected urban lakes of Bengaluru and its outskirts to assess their overall water quality status. Water samples were collected from nineteen lakes and analysed using standard laboratory techniques, including EDTA titration for total hardness, gravimetric/electrometric methods for TDS, and pH measurement using a calibrated pH meter. The results revealed considerable spatial variation among lakes, with total hardness ranging from 426-2946ppm as CaCO₃ and TDS values varying between 182-678 mg/L, with the highest concentrations observed in lakes located near dense urban and industrial zones. Several lakes exceeded recommended freshwater quality limits, indicating potential ecological stress and reduced suitability for sensitive aquatic organisms. These findings highlight the influence of urbanization and anthropogenic activities on lake water chemistry and emphasize the need for regular monitoring and targeted management strategies to protect and restore urban freshwater ecosystems.

Paper Status

Received : Aug 2025
Accepted : Dec 2025
Published : Dec 2025

Key Words

Physicochemical analysis
Total dissolved solids
Urban lakes
Water hardness
Water quality assessment

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Citation: Mowlya M, Nandini N, Chandana S, Rakesh V, Dr.Ethiraj J (2025). Physicochemical Characterization of Urban Lake Waters in Bengaluru Using Hardness and Total Dissolved Solids Indicators, International Research Journal of Science and Technology, 3(1), 458-462. ISSN: 2707-3955.

1.Introduction

Bengaluru has experienced rapid urban expansion over recent decades, placing considerable pressure on its freshwater resources, particularly urban lakes. Historically, the city supported an interconnected network of over 200 man-made lakes designed for water storage, groundwater recharge, agriculture, and climate regulation. However, accelerated urbanization has resulted in the encroachment, pollution, and degradation of many of these water bodies, leaving the remaining lakes under significant environmental stress. Despite their deteriorating condition, urban lakes continue to play a vital ecological and socio-economic role by supporting biodiversity, regulating microclimates, and sustaining local water needs [1,2].

Among the physicochemical parameters used to assess freshwater quality, water hardness and total dissolved solids (TDS) are important indicators of ionic composition and overall mineralization. TDS represents the total concentration of dissolved inorganic and organic substances in water, while hardness primarily reflects the presence of calcium and magnesium ions. Although hardness contributes to TDS, the two parameters may vary independently depending on geological conditions, land use patterns, and anthropogenic inputs. Evaluating these parameters together provides insight into the dominant sources of dissolved ions and the chemical character of lake water.

Elevated levels of hardness and TDS can adversely affect aquatic ecosystems by altering ionic balance, imposing osmoregulatory stress on organisms, and reducing species diversity. High mineral content may also influence nutrient availability, algal composition,

* Corresponding Author: Rakesh V
Department of Forensic Science, Garden City University,
Bengaluru. Email: rakeshvenkat305@gmail.com

and reproductive success in sensitive aquatic species. In urban environments, domestic wastewater discharge, detergent use, agricultural runoff, and industrial activities further modify lake water chemistry, often leading to increased alkalinity and overall degradation of water quality.

Although several studies have reported water quality issues in individual lakes of Bengaluru, comparative data on hardness, TDS, and associated pH variations across multiple urban lakes remain limited. A systematic assessment of these parameters is necessary to understand spatial variability and to evaluate the ecological condition of lakes influenced by differing degrees of urban pressure.

The objective of this study is to comparatively assess water hardness, total dissolved solids, and pH in nineteen lakes around Bengaluru and its outskirts, and to evaluate their suitability with respect to aquatic life and domestic water relevance [3,4].

2. Methodology

2.1 Sample Collection

Water samples were collected from selected lakes located in urban and peri-urban areas of Bengaluru, representing varying degrees of anthropogenic influence such as domestic runoff and urban activity. Sampling was carried out during the September month under stable weather conditions to minimize short-term environmental variability.

Surface water samples were collected using pre-cleaned polyethylene bottles. Prior to final collection, each bottle was rinsed three times with the respective lake water sample. The collected samples were transported to the laboratory in insulated containers and analysed immediately to prevent alterations in physicochemical properties.

2.2 Measurement of pH

The pH of the water samples was measured using a calibrated digital pH meter (MK VI). Calibration of the instrument was performed before analysis using standard buffer solutions of pH 4.0, 7.0, and 9.2. The integrated glass electrode was rinsed with distilled water and gently blotted dry between successive buffer solutions and sample measurements.

The electrode was immersed directly into each lake water sample, and readings were recorded after stabilization. Measurements were carried out in triplicate, and the mean value was reported. The electrode was rinsed and stored appropriately between measurements according to the manufacturer's guidelines.

2.3 Determination of Total Hardness (EDTA Titrimetric Method)

Total hardness was determined using the EDTA complexometric titration method, following standard analytical procedures [7].

0.01 M EDTA solution, ammonia–ammonium chloride buffer (pH 10), and Eriochrome Black T (EBT) indicator. A 25 mL aliquot of the water sample was transferred into a clean conical flask, followed by the addition of 2 mL of buffer solution. Three drops of EBT indicator were added, producing a wine-red color. The sample was titrated against standardized 0.01 M EDTA solution until the color changed from wine-red to clear blue, indicating the endpoint. All titrations were performed in triplicate to ensure accuracy.

Total hardness was calculated and expressed as milligrams per litre (mg/L) of calcium carbonate (CaCO₃) using the formula:

$$\text{Total Hardness (mg/L as CaCO}_3\text{)} = \frac{V_{\text{EDTA}} \times M_{\text{EDTA}} \times 1000}{V_{\text{sample}}}$$

where V_{EDTA} is the volume of EDTA used (mL), M_{EDTA} is the molarity of EDTA, and V_{sample} is the volume of the sample (mL).

2.4 Determination of Total Dissolved Solids (TDS)

Total dissolved solids were measured using a calibrated digital TDS meter. Calibration was carried out using a standard TDS solution in accordance with the manufacturer's instructions. The probe was immersed directly into each water sample, and readings were recorded after stabilization. Measurements were conducted in triplicate, and mean values were used for analysis. The probe was rinsed with distilled water between successive measurements to avoid cross-contamination.

The study demonstrated that the advance organizer teaching strategy significantly improved both academic achievement and retention in senior secondary school chemistry compared to the conventional lecture method. The approach provided students with a conceptual framework that facilitated the integration of new information with prior knowledge, resulting in deeper understanding and better long-term recall. Additionally, gender differences were observed in both achievement and retention within the experimental group, with male students outperforming their female counterparts. The findings affirm the value of learner-centered strategies such as advance organizers in enhancing meaningful learning and addressing persistent

challenges in chemistry education in Nigerian secondary schools.

3. Results and Discussion

Water quality parameters including pH, total hardness, and total dissolved solids (TDS) were analysed for nineteen lakes located in and around the Bengaluru metropolitan region. The results reveal substantial spatial variability, reflecting differences in surrounding land use, anthropogenic pressure, and hydrological conditions.

3.1 Variation in Water Hardness

Based on total hardness expressed as mg/L CaCO₃, the lake waters were classified into very soft, soft, hard, and very hard categories (Tables 1–4). Total hardness values ranged from 70 mg/L in Ulsoor Lake to 530 mg/L in Hoskote Lake, indicating considerable heterogeneity across the study area.

Very soft to soft water categories (Tables 1 and 2) were observed in lakes such as Ulsoor, Lalbagh, Yedyuru, Gudnahalli, and Hesaragatta, with total hardness values generally below 150 mg/L. These lakes are either maintained urban water bodies or are located in comparatively less disturbed zones, suggesting lower mineral enrichment or dilution through rainwater inflow.

Hard and very hard water categories (Tables 3 and 4) were predominantly associated with lakes located in peri-urban or rapidly urbanizing regions, including Bashettihalli, Upparahalli, and Madanayakanahalli. Madanayakanahalli Lake recorded the highest calcium concentration (2946 ppm CaCO₃) along with a high total hardness of 440 mg/L, indicating significant mineral loading. Such elevated hardness levels may arise from prolonged water retention, evaporation, geological contributions, and continuous inflow of untreated runoff [8,9].

3.2 Total Dissolved Solids (TDS) Distribution

TDS values across the nineteen lakes ranged from 93 mg/L (Gudnahalli) to 857 mg/L (Upparahalli). Lakes categorized as very hard water generally exhibited higher TDS values, suggesting that dissolved solids in these systems originate not only from calcium and magnesium but also from other dissolved constituents such as bicarbonates, chlorides, and organic residues.

Gudnahalli and Hoskote lakes showed comparatively low TDS values despite moderate

hardness levels, indicating that calcium and magnesium ions may dominate the dissolved fraction in these waters. In contrast, Upparahalli and Madanayakanahalli lakes recorded high TDS values (>600 mg/L), reflecting increased contributions from dissolved and suspended materials, possibly linked to urban runoff, domestic wastewater, and detergent residues. Similar associations between urbanization and elevated TDS have been reported in earlier studies on Indian urban lakes (Tyagi et al., 2013; Choudhary et al., 2021).

3.3 Relationship Between Hardness and TDS

The combined assessment of hardness and TDS provides insight into the chemical character of the lake waters. In several lakes, high TDS values were accompanied by high hardness, indicating that calcium and magnesium ions make a substantial contribution to overall dissolved solids. However, in some cases, elevated TDS values were not directly proportional to hardness, suggesting the presence of other dissolved ions. This decoupling highlights the importance of analyzing both parameters together rather than independently when assessing water quality.

3.4 pH Characteristics

The pH values of all lake water samples ranged from 6.8 to 8.5, falling within the generally acceptable range for freshwater aquatic systems. Slightly alkaline conditions were observed in lakes such as Koduru and Upparahalli, which may be attributed to detergent input, carbonate dissolution, or domestic wastewater inflow. Despite the variations in hardness and TDS, the pH values suggest that acidification is not a major concern in the studied lakes at the time of sampling.

3.5 Environmental Implications

Although pH conditions across all lakes were favorable for aquatic life, elevated hardness and TDS levels in several lakes may impose long-term ecological stress by altering ionic balance and influencing species composition. Lakes with consistently high dissolved solids are likely to favor more tolerant aquatic organisms, potentially reducing biodiversity. The observed spatial patterns underscore the influence of urbanization on lake water chemistry and emphasize the need for continuous monitoring to prevent further degradation.

Table 1. Physicochemical characteristics of lakes classified as very soft water

Lake	Total Hardness (mg/L as CaCO ₃)	TDS (mg/L)	pH	Calcium level in ppm
Ulsoor	70	182	7.5	426
Lal bagh	100	229	7.8	520
Yedyuru	74	121	7.7	573
Gudnahalli	78	93	7.9	600
T. Dasarahalli	182	244	7.3	706

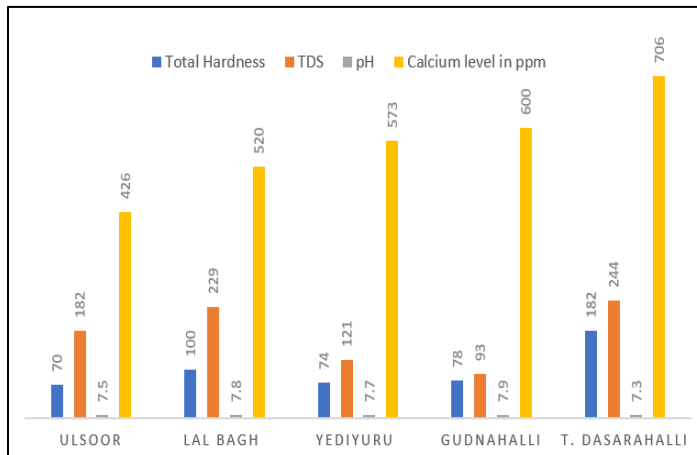


Fig 1: Graphical Representation of Physicochemical characteristics of lakes classified as very soft water

Table 2. Physicochemical characteristics of lakes classified as soft water

Lake	Total Hardness (mg/L as CaCO ₃)	TDS (mg/L)	pH	Calcium level in ppm
Hesaragatta	120	179	7.5	826
Doddakadathur	116	160	8	853
Banavara	160	231	7.2	920
Gandhinagar	150	174	7.1	946
Koduru	100	214	8.2	986

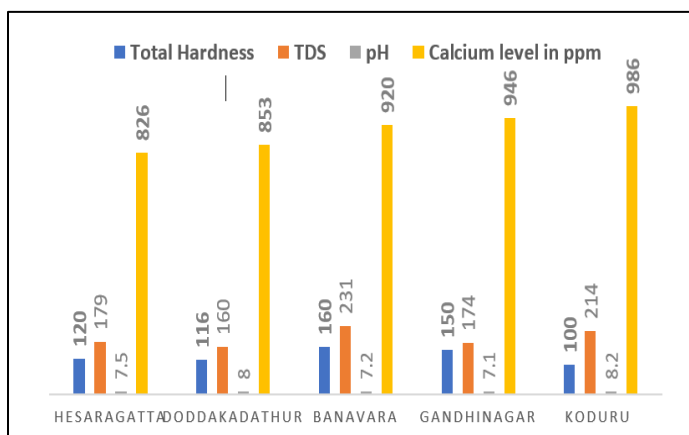


Fig 2: Graphical Representation of Physicochemical characteristics of lakes classified as soft water

Table 3. Physicochemical characteristics of lakes classified as hard water

Lake	Total Hardness (mg/L as CaCO ₃)	TDS (mg/L)	pH	Calcium level in ppm
Anchepalya	120	194	6.8	1000
Bheemakuppe	170	416	7.8	1240
Kommaghata	200	296	7.7	1293
Cubbon park	182	284	7.5	1306
Hormavu	230	401	7.5	1306
Bashettihalli	244	426	7.6	1440

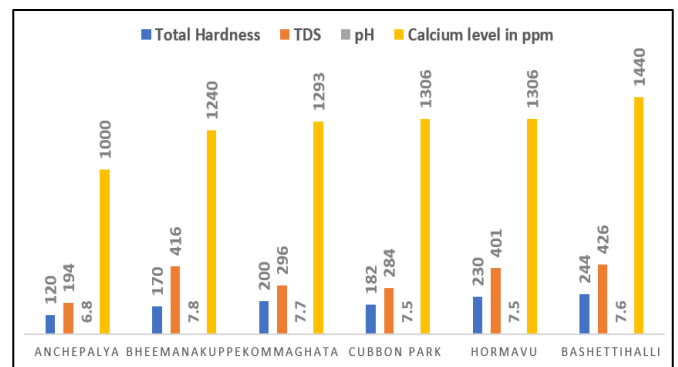


Fig 3: Graphical Representation of Physicochemical characteristics of lakes classified as Hard water

Table 4: Very Hard water

Lake	Total Hardness (mg/L as CaCO ₃)	TDS (mg/L)	pH	Calcium level in ppm
Upparanahalli	350	857	8.5	2453
Hoskote	530	103	7.2	2893
Madanayakanahalli	440	678	7.2	2946

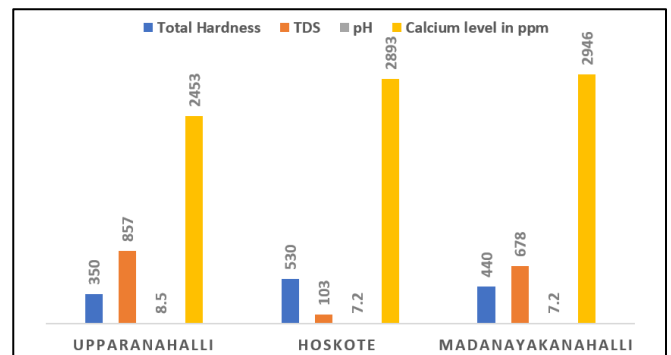


Fig 4: Graphical Representation of Physicochemical characteristics of lakes classified as very hard water

Conclusion

This study demonstrates pronounced spatial variability in water hardness, total dissolved solids (TDS), and pH among nineteen lakes in and around Bengaluru, reflecting differences in urbanization intensity and anthropogenic

influence. While pH values across all lakes remained within the acceptable range for freshwater systems, hardness and TDS levels varied widely, with several lakes classified as hard to very hard. Lakes located in densely urbanized or rapidly developing peri-urban areas exhibited elevated mineral and dissolved solid concentrations, whereas comparatively lower values were observed in less disturbed lakes, indicating better water quality conditions [5.6].

The observed variability underscores the sensitivity of urban lake systems to land-use changes, wastewater inflow, and surface runoff. Elevated hardness and TDS levels, although not immediately altering pH, may contribute to long-term ecological stress by modifying ionic balance and influencing aquatic community structure. From a management perspective, these parameters serve as practical indicators for identifying lakes at risk of chemical degradation and for prioritizing restoration and mitigation efforts. Regular monitoring of hardness and TDS can therefore play a critical role in urban water resource management and lake conservation planning in rapidly expanding cities like Bengaluru.

Future research should focus on seasonal variation in physicochemical parameters to capture monsoon and post-monsoon influences, as well as the analysis of heavy metals and biological indicators such as plankton diversity and macrophyte distribution. Integrating chemical and biological assessments will provide a more comprehensive understanding of urban lake health and support evidence-based strategies for sustainable freshwater ecosystem management.

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