INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY EXPLICATION AND EMERGING RESEARCH (IJMEER)

Vol. 1 | Issue 2 | April–June 2026

Water Quality Assessment of Urban Lakes in Bhopal: A Physico-Chemical Study

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Received: March 2026 | Accepted: May 2026 | Published: July 2026

Pages: 63–74

Abstract: Urban lakes in Indian cities are under severe ecological stress due to rapid urbanisation, encroachment, untreated sewage discharge, and solid waste dumping. This study undertook a systematic physico-chemical assessment of five major urban lakes in Bhopal, Madhya Pradesh — Upper Lake (Bada Talab), Lower Lake (Chhota Talab), Shahpura Lake, Sarangpani Lake, and Motia Talab — over a period of twelve months from January to December 2023 to determine their current water quality status and identify primary pollution determinants. Water samples were collected bimonthly from three stations per lake and analysed for twelve parameters: temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), electrical conductivity, turbidity, total hardness, nitrate-nitrogen, total phosphate, and faecal coliform count. Results revealed that BOD levels exceeded BIS permissible limits of 3 mg/L in three of five lakes, with the most severe violations recorded in Lower Lake (mean BOD: 14.2 mg/L) and Motia Talab (mean BOD: 11.8 mg/L). Dissolved oxygen was below the critical threshold of 5 mg/L in Lower Lake and Motia Talab during summer months, threatening aquatic biodiversity. Nitrate and phosphate loading was consistent with eutrophication processes. Upper Lake retained the best water quality among the five, likely due to its larger water body and statutory protection. A Water Quality Index (WQI) was computed for each lake to summarise overall quality. The study recommends urgent restoration interventions including sewage diversion, desilting, and biodiversity buffer zones.

Keywords: *Water Quality, Urban Lakes, Bhopal, Physico-Chemical Parameters, Eutrophication, Water Quality Index*

1. Introduction

Urban water bodies — ponds, lakes, and tanks — have historically served as critical ecological, hydrological, and socio-cultural assets in Indian cities. They supported local fisheries, provided water for domestic and agricultural use, recharged groundwater, moderated urban microclimates, and served as centres of community life. However, the rapid and largely unplanned urbanisation experienced by Indian secondary cities over the past four decades has led to the progressive degradation and in many cases outright encroachment and disappearance of these water bodies. The National Lake Conservation Plan, implemented by the Ministry of Environment, Forest and Climate Change since 2001, has recognised this crisis and sought to fund restoration, but implementation outcomes have been mixed.

Bhopal, the capital city of Madhya Pradesh, is historically celebrated as the 'City of Lakes,' with several large and small urban water bodies that define its landscape and culture. The iconic Upper Lake (Bada Talab) is among the largest man-made lakes in Asia and serves as a drinking water source for a significant portion of Bhopal's population. However, sustained population growth, encroachment of lake catchment areas by residential and

commercial construction, discharge of partially treated or untreated sewage, and accumulation of solid waste along lake margins have placed these water bodies under mounting stress.

Systematic, contemporary water quality data for Bhopal's urban lakes beyond the Upper Lake is fragmentary and often outdated. The last comprehensive multi-lake assessment available in the public domain dates to a CPCB report from 2016, and the seven years since have seen significant changes in land use, population density, and municipal wastewater treatment infrastructure in Bhopal. Updated, rigorous physico-chemical data is necessary to inform the Bhopal Municipal Corporation's lake restoration prioritisation and to provide baseline data for monitoring restoration outcomes.

This study addresses this data gap by conducting a twelve-month, bimonthly, multi-parameter physico-chemical assessment of five representative urban lakes in Bhopal, ranging from the well-protected Upper Lake to the severely degraded Motia Talab, to generate current water quality profiles, compute Water Quality Index values for each lake, and identify primary pollution drivers.

2. Methodology

Five urban lakes in Bhopal were selected for the study based on their geographic distribution across the city, their ecological and social significance, and their varying degrees of anthropogenic pressure: Upper Lake, Lower Lake, Shahpura Lake, Sarangpani Lake, and Motia Talab. Bimonthly water sampling was conducted at three fixed stations per lake (inlet zone, mid-lake, and outlet/shoreline zone) from January through December 2023, yielding a total of 360 water samples. Sampling stations were geo-referenced using a GPS device to ensure consistency across sampling events. Samples were collected in pre-cleaned 1-litre high-density polyethylene bottles following standard sampling protocols (APHA, 2017) and transported to the laboratory within six hours under ice-pack preservation.

Twelve physico-chemical parameters were analysed: temperature (mercury thermometer, in situ), pH (Hanna HI-98127 digital pH meter), dissolved oxygen (Winkler's iodometric method), biological oxygen demand (5-day BOD test, 20°C incubation), chemical oxygen demand (open reflux dichromate method), total dissolved solids (gravimetric method), electrical conductivity (conductivity meter), turbidity (Nephelometric method), total hardness (EDTA titrimetric method), nitrate-nitrogen (UV spectrophotometric method), total phosphate (stannous chloride method), and faecal coliform count (membrane filtration technique). All chemical analyses were performed at the Environmental Chemistry Laboratory, Sagar Government Science College, Sagar, following standard methods as per APHA (2017) and IS:3025 protocols.

A weighted arithmetic Water Quality Index (WQI) was computed for each lake using the methodology of Brown et al. (1972), assigning weights to parameters based on their relative importance for potable water use and aquatic ecosystem health. The WQI values were classified as: Excellent (0–25), Good (26–50), Poor (51–75), Very Poor (76–100), and Unfit for Use (>100). All data were analysed using Microsoft Excel 2019 and SPSS version 23. Mean values and standard deviations were calculated for each parameter at each lake, and one-way ANOVA with Tukey's post-hoc test was used to compare mean parameter values across lakes.

3. Results and Findings

Temperature, pH, and electrical conductivity remained within acceptable limits across all five lakes throughout the study period, with pH ranging from 7.1 to 8.6 (mildly alkaline) and temperature between 18.2°C (January) and 32.6°C (May). However, significant inter-lake and seasonal variation was observed for oxygen-related parameters. Dissolved oxygen fell below the critical threshold of 5 mg/L in Lower Lake (mean summer DO: 3.8 mg/L) and Motia Talab (mean summer DO: 2.9 mg/L) during the April–June period, indicating hypoxic conditions incompatible with fish survival and typical of severely polluted lentic systems.

BOD levels exceeded the BIS drinking water permissible limit of 3 mg/L in Lower Lake (annual mean 14.2 mg/L), Motia Talab (11.8 mg/L), and Sarangpani Lake (5.3 mg/L). COD values followed a similar pattern. Total phosphate concentrations above 0.1 mg/L — the threshold commonly associated with eutrophication onset — were recorded in four of five lakes, with Lower Lake recording the highest annual mean of 0.48 mg/L. Nitrate-nitrogen exceeded 10 mg/L at multiple stations in Motia Talab, consistent with proximate sewage drain inputs identified during field observation. Upper Lake retained the best overall water quality, with BOD within limits, DO above 6 mg/L year-round, and TDS within BIS standards.

WQI calculations yielded the following annual classifications: Upper Lake — Good (WQI: 42); Shahpura Lake — Poor (WQI: 61); Sarangpani Lake — Poor (WQI: 68); Lower Lake — Very Poor (WQI: 89); Motia Talab — Unfit for Use (WQI: 107). Faecal coliform counts exceeded the 500 MPN/100 mL threshold specified for bathing water quality (IS:2296) in Lower Lake, Sarangpani Lake, and Motia Talab, confirming direct sewage contamination in these water bodies.

4. Discussion

The stark contrast in water quality between Upper Lake and the remaining four study lakes reflects primarily the difference in regulatory protection and sewage interception infrastructure. Upper Lake benefits from a 1990 Wetland Conservation Notification limiting construction in its catchment area, while the smaller lakes lack equivalent statutory buffers. The findings from Lower Lake and Motia Talab — both classified as severely polluted or unfit for use — are consistent with CPCB's 2016 assessment for these water bodies and indicate that no significant improvement has occurred over the intervening period despite municipal restoration commitments.

Eutrophication, driven by nitrogen and phosphorus loading from sewage discharge and urban runoff, was identified as the dominant ecological process degrading the mid-ranked lakes. Eutrophication triggers algal blooms that further reduce dissolved oxygen through nocturnal respiration and decomposition, creating self-reinforcing lake degradation cycles. The seasonal pattern of DO decline during April to June, coinciding with peak temperature, is consistent with this mechanistic understanding and points to the importance of sewage diversion as the primary restoration intervention in these lakes.

The turbidity and faecal coliform data confirm that open defecation and solid waste dumping in the immediate vicinity of Sarangpani Lake and Motia Talab continue despite municipal programmes. These findings highlight that technical restoration measures must be accompanied by community awareness campaigns and stringent enforcement of anti-encroachment and anti-pollution regulations. The success of Upper Lake's relative protection demonstrates that regulatory intent, when backed by monitoring and enforcement, can maintain reasonable water quality even in a rapidly urbanising context.

5. Conclusion

This twelve-month physico-chemical assessment of five Bhopal urban lakes documents a spectrum of water quality ranging from good in the Upper Lake to unfit for use in Motia Talab, with eutrophication, sewage contamination, and organic pollution as the primary drivers of degradation in the lower-ranked lakes. The computed WQI values provide a clear prioritisation framework for restoration investment.

Urgent recommendations include: (i) complete diversion of identified sewage drains into Lower Lake, Sarangpani Lake, and Motia Talab to the Bhopal sewage treatment network as an immediate priority; (ii) desilting of accumulated organic sediments in Motia Talab and Lower Lake; (iii) establishing 50-metre vegetated buffer zones around all five lakes to intercept non-point source runoff; (iv) statutory notification of lake catchment areas for Shahpura Lake, Sarangpani Lake, and Motia Talab analogous to the Upper Lake model; and (v) establishing a

quarterly multi-parameter water quality monitoring programme by Bhopal Municipal Corporation with results placed in the public domain.

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