



ASSESSMENT OF PHYSICOCHEMICAL AND MICROBIOLOGICAL INDICATORS OF SURFACE WATER QUALITY IN INDIA

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ABSTRACT

Surface-water quality is influenced by physicochemical conditions and microbiological contamination, both of which are important for environmental monitoring and public-health protection. This study assessed physicochemical and microbiological indicators across lakes, ponds, and tanks in India using secondary water-quality records from 683 monitoring stations. Physicochemical parameters included temperature, dissolved oxygen, pH, conductivity, biochemical oxygen demand, and nitrate, while microbiological indicators included faecal coliform and total coliform. Descriptive statistics, Kruskal–Wallis tests, chi-square analysis, and Spearman correlation were used to evaluate variation and relationships among indicators. Lakes represented the largest proportion of monitoring locations. Significant differences among water-body types were observed for dissolved oxygen, pH, conductivity, biochemical oxygen demand, nitrate, faecal coliform, and total coliform, while temperature did not differ significantly. Tanks generally showed higher median levels of several pollution-related indicators, whereas ponds had comparatively better water-quality classification patterns. Microbiological indicators showed substantial variation across monitoring locations. Biochemical oxygen demand demonstrated the strongest positive relationships with both faecal and total coliform, while dissolved oxygen showed a negative association with total coliform. Water-quality classification was significantly associated with water-body type. Overall, the findings indicate that physicochemical and microbiological indicators should be assessed together to provide a more complete understanding of surface-water quality and to support targeted monitoring and pollution-control strategies across India.

Key words: Surface water quality; Physicochemical indicators; Microbiological indicators; Coliform; India

1. INTRODUCTION

Surface-water bodies are key elements of freshwater systems and play a vital role in the provision of water for domestic purposes, agriculture, fisheries, ecosystem functions, recreation and livelihoods. Extensive pressures are being faced by the lakes, ponds, tanks, rivers and reservoirs in India due to population growth, urbanization of areas, untreated or partially treated effluents, agricultural runoff and other anthropogenic activities. These pressures can affect the water chemistry, the ecological quality and can amplify the risks of microbial contamination. The national monitoring datasets thus offer valuable information for surface-water resource conditions in varying geographic areas. The dataset from the Central Pollution Control Board–National Water Monitoring Programme provides an extensive snapshot of lakes, ponds, and tanks in India, including data on both water quality and microbiological parameters for water-quality assessment (Grace, 2026).

Physicochemical parameters have been extensively used in the characterization of the environmental conditions of surface waters. Temperature affects biological activity and oxygen, and dissolved oxygen is indicative of the water's ability to sustain aquatic life. The data for pH is useful for determining acidity and alkalinity, conductivity is useful for determining the presence of dissolved ionic substances, biochemical oxygen demand is useful for determining the amount of biodegradable organic matter, and nitrate is useful for determining nutrient enrichment from agricultural and domestic sources. Such indicators have been proved to be useful in detecting spatial variation, pollution patterns, and overall changes in the water quality in studies carried out in Indian water bodies (Mishra et al., 2023). Hydrochemical and bacteriological evaluation of ponds has also indicated that the physicochemical parameters cannot adequately capture the contamination situation, especially in cases of microbial pollution (Bhatnagar & Thakral, 2023). Integrated assessment of the Gomti River has shown that both the bacteriological and the physicochemical parameters should be considered when assessing the surface-water quality (Kumar et al., 2022).

Further regional studies have also shown that the surface water quality is highly variable depending on the local environmental and anthropogenic factors. The results of the geochemical assessment of surface waters in Tawang highlighted variation in water-quality characteristics, which can impact the suitability of water for various purposes (Gaur et al., 2022). There is also a significant concern for microbiological contamination as human and animal wastes have multiple

opportunities for entering surface waters. In Punjab, studies have been carried out that revealed the correlation between microbial contamination and physicochemical conditions of surface-water systems, emphasizing the need for integrated monitoring approaches (Zehra et al., 2020). Further, the high level of coliforms in the water sources reported in Sikkim highlights the potential public-health implications of contamination with faecal microorganisms and the need to consider the microbiological indicators along with classical physicochemical parameters (Singh et al., 2019).

Although a large number of water-quality studies have been conducted, there are still significant gaps in the evaluation of surface-water quality in India. Water-quality assessment is often heavily reliant on physicochemical parameters and composite indices, which do not necessarily reflect microbiological degradation (Nayar, 2020) as was mentioned in earlier reviews. Bacteriological quality assessments have been conducted in Chennai in groundwater and surface water, but have been geographically localized and offer no general comparisons between various types of surface-water bodies (Shahina et al., 2020). Likewise, studies on Mettur Reservoir have shown that spatial and temporal variations in surface water quality are significant, and that the quality of surface water may not apply to other reservoirs (Saha et al., 2021). Ganges studies have been done using a combination of physicochemical, heavy metal, and microbiological indicators, but in a limited geographic area of the river (Kumar et al., 2020). The studies of hydrogeochemistry in Uttar Pradesh also provided useful information for the region but mostly for local surface-water conditions (Tiwari et al., 2017). Thus, comparative evidence incorporating both physical and chemical and microbiological indicators is limited for many lakes, ponds and tanks.

A more comprehensive evaluation is therefore needed to add a water-quality pattern to a variety of surface-water environments. Past Indian studies have shown the usefulness of spatial and temporal analysis to differentiate the differences in physico-chemical conditions and pollution pattern (Saha et al., 2022). The overall water-quality status of the water bodies can be assessed by comparing the physicochemical parameters, and this can be helpful to get information of variation in overall water-quality status of water bodies (Jain et al., 2022). Additionally, water quality changes exhibited due to changes in human activities indicate that water quality can respond significantly to anthropogenic pressure variations, further emphasizing the need for systematic monitoring (Selvam et al., 2020). International evidence also suggests that the two parameters, physicochemical and bacteriological, should be used together, as it would offer a

more complete picture of the state of surface water (Haque et al., 2019). With this as the rationale, a national secondary data is used in the present study to evaluate the physicochemical and microbiological indicators in lakes, ponds and tanks in India.

Research Objectives

To assess the physicochemical and microbiological characteristics of lakes, ponds, and tanks across India using national surface-water monitoring data.

To compare major water-quality indicators and water-quality classes across different surface-water body types.

To examine the relationships between physicochemical parameters and microbiological indicators of surface-water quality.

2. METHODOLOGY

2.1 Study Design

The study took the secondary data-based observational analysis and analytical design to ascertain the surface-water quality in the country. The cross-sectional method was used to assess the water quality of points monitored by the Nation for the various indicators assessed here: physicochemical and microbiological.

2.2 Data Source

The water-quality data were retrieved from the CPCB-NWMP (2024) processed data from National Water Monitoring Programme with the help of Mendeley Data (Grace, 2026). These records contain monitoring data for surface-water bodies in various states and union territories in India and are arranged in a standardized format with physicochemical, microbiological, and water-quality classification variables.

2.3 Study Sample

A total of 683 surface-water monitoring stations were included in the analysis, which are spread over various regions of India. Monitored water bodies included lakes, ponds, and tanks, with the geographic scope providing a broad representation, and the various types of water bodies allowing comparative assessment of water-quality conditions among different inland surface-water environments.

2.4 Study Variables

Identification and classification variables used in the study were Station ID, State, water-body

type, and water-quality class. Physicochemical indicators included temperature, dissolved oxygen, pH, conductivity, biochemical oxygen demand and nitrate concentration, while microbiological indicators included faecal coliform and total coliform concentration.

2.5 Data Preparation

Records available were analyzed after retaining the variables relevant to the objectives of the study. The information was checked for completeness, duplicate observations, consistency of types of variables, and formatting problems. Continuous measurements were aggregated into the two domains of physicochemical measurements and microbiological measurements and categorical variables were standardized for comparative assessment.

2.6 Statistical Analysis

The data from categorical variables were presented in the form of frequencies and percentages, and the data from continuous variables were presented in the form of mean and standard deviation or median and interquartile range depending on their distribution. Appropriate parametric or non-parametric tests were used to compare water-quality indicators for lakes, ponds and tanks. Pearson or Spearman correlation was used to evaluate relationships among the various physicochemical and microbiological indicators, and chi-square test was used to evaluate the association between water-body type and water-quality class. Statistical significance was set at a p-value of < 0.05 .

3. RESULTS

3.1 Distribution of Surface-Water Monitoring Stations

Three types of surface-water bodies were analyzed: lakes, ponds and tanks. There was a highly skewed distribution of representation across the study sample. The relative contribution of each water-body type to the monitoring network is shown in Figure 1.

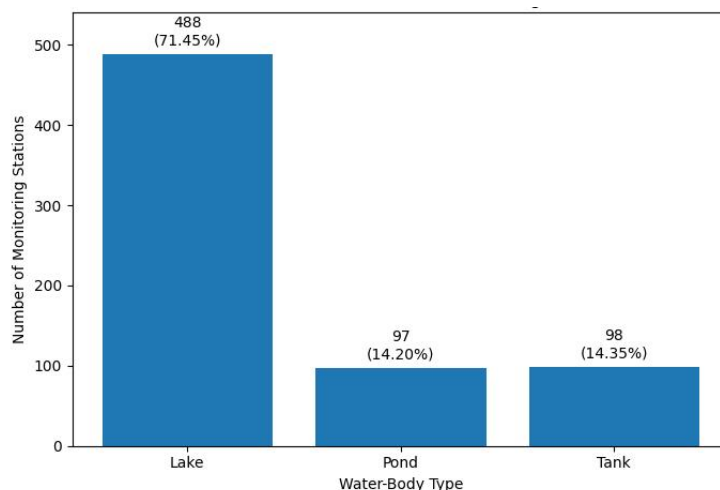


Figure 1. Distribution of monitoring stations by water-body type

As can be seen in the figure, the majority of the monitoring network consisted of lakes, while ponds and tanks were underrepresented and at a similar level. This distribution should be taken into account in interpreting the following comparisons, as subsequent comparisons are more strongly influenced by the distribution of observations made on the lake of the water-body category than is seen on the other two categories.

3.2 Physicochemical Characteristics of Surface Water

The results of the physicochemical indicators exhibited a marked spatial differences among the monitored surface waters. Table 1 shows that the temperature and pH stayed fairly constant in contrast to the other parameters. There was moderate variability in dissolved oxygen and a more variable range for conductivity, biochemical oxygen demand and nitrate. A large difference between mean and median conductivity, BOD, and nitrate values indicates that some monitoring stations also had much higher conductivity, BOD, and nitrate concentrations than the majority of stations.

Table 1. Descriptive statistics of physicochemical water-quality indicators

Parameter	Mean	SD	Median	IQR	Minimum	Maximum
Temperature	25.39	3.46	26.00	3.50	9.00	32.00
Dissolved oxygen	5.12	2.19	5.55	3.25	0.30	11.05
pH	7.54	0.47	7.50	0.50	4.60	10.15
Conductivity	1884.47	10658.46	789.00	924.50	18.50	262250.00
BOD	9.20	12.40	4.40	7.80	1.00	83.15
Nitrate	6.56	22.00	2.49	5.16	0.30	454.28

3.3 Microbiological Characteristics

There were also significant differences in the microbiological indicators from one monitoring station to another. Generally, total coliforms were higher than faecal coliforms as seen in Table 2. The maximum values for both indicators were quite high relative to the median values, indicating that the microbiological contamination was high at some locations compared to others. This trend shows that there are significant differences in microbiological water quality among the surface-water bodies evaluated.

Table 2. Descriptive statistics of microbiological water-quality indicators

Parameter	Mean	SD	Median	IQR	Minimum	Maximum
Faecal coliform	2,470,124.51	63,137,702.97	401.50	1,714.50	2.00	1,650,000,105.00
Total coliform	5,247,698.47	133,924,593.13	1,110.00	6,225.00	2.00	3,500,001,750.00

3.4 Comparison of Water-Quality Indicators by Water-Body Type

There were variations in water-quality parameters between lakes, ponds, and tanks. Significant differences were found for dissolved oxygen, pH, conductivity, BOD, nitrate, faecal coliform and total coliform as shown in Table 3. There was no significant difference in temperature between the three types of water body. Ponds tended to have lower values for a number of pollution variables, with tanks having higher median conductivity, BOD, nitrate and coliform. Intermediate patterns were typically observed in lakes.

Table 3. Comparison of physicochemical and microbiological indicators by water-body type

Parameter	Lake, Median (Q1–Q3)	Pond, Median (Q1–Q3)	Tank, Median (Q1–Q3)	H	p-value
Temperature	26.00 (24.00–27.50)	26.50 (25.00–27.50)	26.50 (24.50–27.88)	4.124	0.127
Dissolved oxygen	5.47 (3.29–6.66)	6.20 (4.40–7.05)	5.53 (3.66–6.30)	7.821	0.020
pH	7.50 (7.30–7.80)	7.40 (7.25–7.60)	7.55 (7.35–7.80)	9.087	0.011
Conductivity	823.50 (347.25–1278.50)	437.00 (151.50–867.50)	943.25 (555.75–1547.50)	36.276	<0.001

BOD	4.40 (2.25–10.15)	2.90 (2.10–5.00)	7.25 (3.50–16.00)	30.179	<0.001
Nitrate	2.34 (0.81–5.80)	1.48 (0.90–6.15)	4.04 (2.48–8.20)	33.380	<0.001
Faecal coliform	460.00 (37.75–2212.50)	78.50 (25.00–515.00)	520.00 (25.62–4739.62)	16.052	<0.001
Total coliform	1211.00 (410.00–7138.75)	730.00 (215.00–1115.00)	3625.00 (346.25–18512.50)	21.071	<0.001

3.5 Water-Quality Classification Across Water-Body Types

The water-quality classification was different for the three water-body types. Ponds had the highest percentage and tanks had the lowest percentage in the excellent, good and very poor categories, respectively, as shown in Table 4. Lakes had a more uniform distribution among the four water-quality classes. The chi-square test revealed a significant relationship between water-body type and water-quality classification, suggesting that the distribution of water-quality classes varied by water-body type (lakes, ponds, and tanks).

Table 4. Distribution of water-quality classes by water-body type

Water-body type	Excellent	Good	Poor	Very Poor
Lake	110 (22.5%)	146 (29.9%)	107 (21.9%)	125 (25.6%)
Pond	30 (30.9%)	38 (39.2%)	13 (13.4%)	16 (16.5%)
Tank	16 (16.3%)	29 (29.6%)	22 (22.4%)	31 (31.6%)

Chi-square = 14.476; df = 6; p = 0.025.

There were differences in water-quality classification between the lakes, ponds, and tanks. In Figure 2, the percentage of each water-quality class (excellent, good, poor, and very poor) is shown for each of the three surface-water body types.

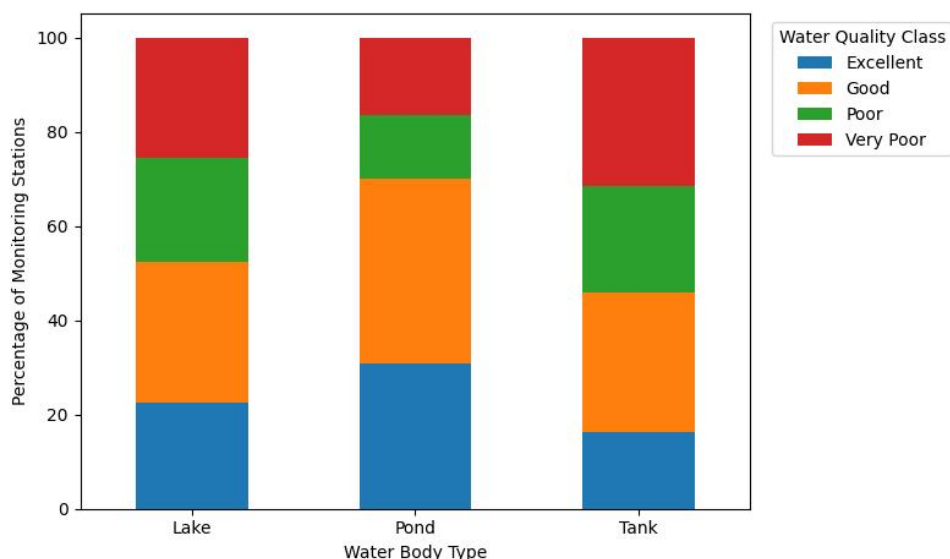


Figure 2. Distribution of water-quality classes across lakes, ponds, and tanks

As illustrated, ponds had a higher percentage of monitoring stations in the excellent and good categories, while tanks had a relatively higher percentage in the very poor category. The distribution of lakes was more even among all four classes. Chi-square analysis also showed a significant relationship between water-body type and water-quality classification.

3.6 Relationships Between Physicochemical and Microbiological Indicators

The association between the various water-quality parameters (physicochemical and microbiological) was assessed by Spearman correlation analysis. These associations for all measured parameters are summarized in Figure 3.

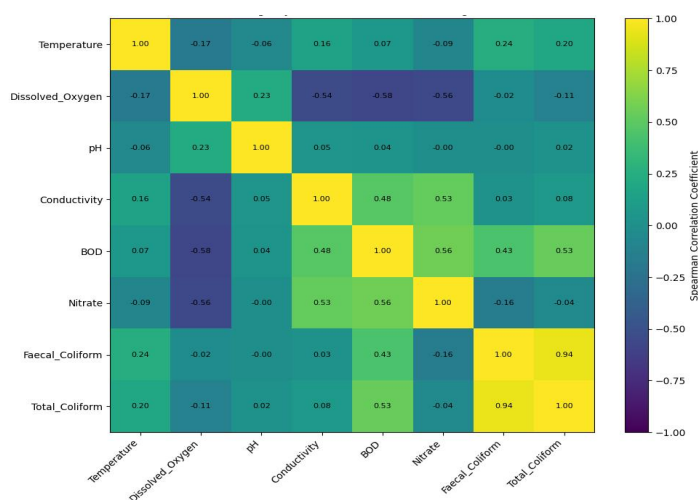


Figure 3. Spearman correlation matrix of physicochemical and microbiological water-quality indicators

The highest microbiological correlation was between faecal coliform and total coliform, showing that both microbiological indicators correlated positively. There were also significant positive relationships between BOD and both the coliform measures, especially the total coliform measure. However, dissolved oxygen was negatively correlated with a number of pollution parameters such as BOD, nitrate and total coliform. There was only weak relationship between the microbial indicators and the temperature and little association between the pH and most variables. The overall picture indicates that BOD is the most consistently associated physicochemical parameter, with microbiological contamination.

4. DISCUSSION

The present study shows that water quality is variable, both in terms of physical and chemical properties as well as microbiological properties among the lakes, ponds and tanks of India. The range for the microbiological indicators, nitrate, and biochemical oxygen demand (BOD) were fairly large, while the range for temperature and pH were comparatively small. Results show significant differences between means and medians for some parameters, suggesting that some monitoring sites had much poorer conditions than others. There were also significant differences between water-body types. The median conductivity, biochemical oxygen demand, nitrate, faecal coliform and total coliform values were generally higher in tanks, while ponds exhibited comparatively lower values for some pollution parameters. The patterns indicate that water-body variables could have an impact on the accumulation, dilution, or persistence of chemical and microbial contaminants.

These differences were confirmed by the water-quality classification. The percentage of monitoring points in the excellent and good categories was higher for ponds than for tanks, while the percentage of monitoring points in the very poor category was higher for tanks than for ponds. Lakes exhibited a wider range in all four quality categories. The high correlation between water-body type and water-quality class suggests that water quality was consistent across different water types (lakes, ponds and tanks). These variations can be related to differences in water exchange, land use, pollutant input, accumulation of organic matter, hydrological conditions and human activities. The microbiological results were notable in that faecal and total coliforms showed significant spatial differences, with the microbial quality of surface water being more strongly affected in some waters than others. Correlation analysis was used to provide further information on relationships between chemical conditions and microbial contamination. The strongest positive correlation was with BOD and the faecal and total coliform counts. This

correlation indicated that areas with higher organic loading also were likely to have higher microbiological loading. A very strong correlation between faecal and total coliform also suggests that the two microbial indicators responded in a similar way at all monitoring sites. The relationships of microbial indicators with temperature were weaker than positive, while dissolved oxygen was negatively related to total coliform. There was little correlation between the pH and the microbial contamination. The results suggest that none of the physico-chemical parameters is able to depict microbiological quality in a satisfactory manner, but biochemical oxygen demand seems to be specially interesting when combined with coliform indexes.

The current data largely agree with previous water-quality surveys that applied a similar combined physicochemical approach to delineate differences among water sources and zones of lesser water quality. The current observation that multiple indicators are needed to comprehensively characterize water condition corroborates the finding of Olasoji et al (2019) who showed the value of integrated water-quality assessment, both for surface and groundwater water sources. In a similar vein, Debassi et al. (2025) explored how various water sources compare with their respective physicochemical and microbiological data, highlighting the need to consider both physical and biological aspects when assessing water contamination. Taoufik et al. (2017) also performed multivariate analyses on surface water, which focused on the interrelationship between the various water quality parameters, as opposed to analysing the data individually.

The large microbial diversity found in the current analysis is similar to that found in river-water studies where microbiological and physicochemical data were taken. The simultaneous microbiological and physicochemical assessment was found to be useful in an industrially influenced river environment, as reported by Leong et al. (2018). The relationships between the water-quality parameters observed in this study are also in line with that of Kothari et al., (2021) who studied correlation between different water quality parameters in Uttarakhand. Rural water sources have also demonstrated that bacteriological quality must be evaluated along with the physicochemical conditions in order to determine overall water safety (Sila, 2019). In Indian context, seasonal changes of the Yamuna River have revealed significant variation in the physico-chemical water parameters, indicating that spatial and environmental variations need to be accounted when inferring water quality patterns (Bhat et al., 2018).

From the practical point of view, the results suggest integrated monitoring of the physicochemical and microbiological indicators, and not only on the basis of one single

parameter or water-quality domain. Water bodies that are identified with high organic loading and high levels of coliforms may need more attention in monitoring. Variation between lakes, ponds and tanks also indicates that monitoring and management strategies should consider the type of water body and not interpret the data in the same way for any surface water.

A number of restrictions must be taken into account. The study relied on secondary records and thus variables and monitoring structure were limited to those available. However, not all types of Indian surface water were analyzed, such as rivers and streams, except lakes, ponds and tanks. Further, microbiological indicators were available for only two, thus restricting the evaluation of specific pathogenic organisms. The limitations of the cross-sectional analysis also makes interpretation of temporal and seasonal changes difficult.

Further studies are needed to include more water-bodies, more geographic locations, more seasons and more microbiological indicators. The differences between monitoring locations might be explained by integrating land use, wastewater discharge, rainfall, population density and catchment characteristics. Longitudinal and spatial analyses could also be used to pinpoint areas of persistent contamination and to better prioritize surface-water monitoring and management interventions.

5. CONCLUSION

This study evaluated the physical and chemical parameters and microbiological parameters for the surface water condition of lakes, ponds and tanks in India. Results indicated a significant difference in water-quality among the three types of water bodies. Conductivity, biochemical oxygen demand, nitrate, faecal coliform, and total coliform varied significantly from monitoring site to monitoring site; other factors (temperature and pH) remained fairly constant. Levels of several pollution-related indicators were generally better in ponds, and the water-quality classification patterns were comparatively good. Lakes showed intermediate status and more widespread conditions on the areas assessed. The level of microbiological contamination was highly variable in the different locations and usually the total coliform concentrations were higher than the faecal coliform concentrations. The positive correlation with both microbiologic indicators was best with biochemical oxygen demand, whereas faecal and total coliform exhibited good positive correlation, suggesting consistent microbiologic contamination patterns. Dissolved oxygen was negatively correlated to total coliform while pH was poorly correlated with microbial contamination. In general, the results suggest that both the physical and chemical

and microbiological data be considered jointly to gain a more thorough understanding of the surface-water quality. There are also differences between lakes, ponds and tanks which shows the importance of water-body specific assessment. The study underscores the importance of a comprehensive monitoring approach to help identify sensitive surface waters and guide more targeted water quality management and pollution control efforts in India.

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