# Comprehensive Assessment of Potable Water Quality in Lucknow City: Physicochemical Parameters and Microbial Indicators

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***Abstract*—Ensuring the availability of safe drinking water is vital for public health and sustainable urban development. This study assessed the physicochemical and bacteriological quality of drinking water from five strategically selected locations in Lucknow city, Uttar Pradesh, India, representing residential, commercial, peri-urban, and transport hub areas. Monthly sampling was conducted between January and May 2025, and the water quality was evaluated against the Indian Standard IS: 10500-2012 drinking water specifications. Parameters such as temperature, pH, turbidity, total dissolved solids (TDS), conductivity, total hardness, calcium, magnesium, sulphate, chloride, phosphate, nitrate, fluoride, and alkalinity were analyzed using standard protocols. Additionally, biological parameters including biochemical oxygen demand (BOD), chemical oxygen demand (COD), total coliform, and E. coli were assessed. The results revealed that while most physicochemical parameters remained within permissible limits, occasional exceedances of turbidity, TDS, and nitrate were observed, particularly at commercial and peri-urban locations. Bacteriological analysis indicated intermittent detection of total coliforms and E. coli in some areas, especially during warmer months, suggesting potential contamination sources linked to aging infrastructure and poor water storage practices. The findings underscore the necessity for continuous monitoring, timely water treatment interventions, and public awareness programs to maintain water safety. This study offers essential baseline data to support municipal water management and public health protection initiatives in urban environments.**

***Index Terms*—Water Quality, Physicochemical Parameters, Bacteriological Assessment, Temporal Variation, Drinking Water, Lucknow**

## 1. INTRODUCTION

Water is one of the most vital natural resources on Earth, indispensable for sustaining life and supporting ecological balance. It plays a central role not only in maintaining biological systems but also in enabling economic, social, and cultural development. With increasing population pressures, industrialization, urbanization, and unsustainable agricultural practices, the availability and quality of safe drinking water have become a serious environmental and public health concern globally. Water bodies, particularly in urban centers, are increasingly under threat from diverse anthropogenic activities that discharge untreated or partially treated domestic, agricultural, and industrial effluents into natural water systems, leading to significant water quality deterioration.

In India, the problem is particularly acute due to rapid urban expansion, inadequate sewage treatment infrastructure, and lax enforcement of environmental regulations. Urban centers like Lucknow, the capital city of Uttar Pradesh, have witnessed considerable demographic growth accompanied by increased demand for freshwater resources. The primary sources of potable water in Lucknow comprise surface water from the Gomti River and subsurface groundwater extracted through borewells, public taps, and piped municipal supply systems. Both sources face contamination risks owing to untreated sewage, leachate from unregulated solid waste disposal, agricultural runoff, and industrial discharges. Consequently, ensuring the availability of clean and

safe drinking water in such rapidly urbanizing regions has emerged as a pressing challenge.

Several studies conducted in different parts of India and abroad have documented the degradation of water quality and the health risks posed by consuming contaminated water. Parameters such as temperature, pH, turbidity, total dissolved solids (TDS), electrical conductivity, total hardness, and the presence of fluoride, chloride, nitrate, phosphate, and sulphates are commonly assessed to determine the physico-chemical quality of drinking water. Simultaneously, bacteriological indicators like Total Coliforms and Escherichia coli (E. coli) are vital to ascertain the biological safety of water supplies, as these microorganisms indicate possible fecal contamination and associated pathogenic risks. Regular monitoring of these parameters is, therefore, critical to safeguarding public health, especially in densely populated urban and peri-urban settings.

In this context, the present study was undertaken to evaluate the drinking water quality across selected locations within Lucknow city. The study covers a combination of residential, commercial, transport hub, and rural-urban fringe areas, representing varied socio-economic and land-use characteristics. Five strategically chosen sampling sites—Indira Nagar (S1), Aminabad (S2), Charbagh Railway Area (S3), Gomti Nagar (S4), and Mohanlalganj (S5)—were included to comprehensively understand the spatial distribution of water quality within the city. The selection of these sites was guided by their strategic relevance, dependence on diverse water sources (piped supply, borewells, hand pumps, public taps, and storage tanks), and their representation of contrasting urban typologies.

The study aimed to assess the physico-chemical and bacteriological characteristics of drinking water over a monitoring period extending from January to May 2025. Seventeen water quality parameters were analyzed in total, including basic indicators like temperature, pH, and turbidity; salinity-related variables such as electrical conductivity, TDS, and chloride; hardness contributors like total hardness, calcium, and magnesium; nutrient and pollutant indicators such as nitrate, phosphate, and sulphates; as well as alkalinity and fluoride concentrations. Biological water quality was evaluated through measurements of biochemical oxygen demand (BOD), chemical oxygen demand (COD), and enumeration of Total Coliforms and E. coli using standard procedures as per the Bureau of Indian Standards (IS: 10500:2012) and World Health Organization (WHO) guidelines.

An integral part of this research was the temporal analysis of water quality parameters to capture monthly variations in response to changing environmental conditions, human activities, and water source utilization patterns. This aspect is especially relevant in northern India, where climatic variability and seasonal fluctuations influence hydrological processes, pollutant loading, and water quality. By grouping the water quality parameters into five logical categories—basic water quality indicators, salinity & mineral content, hardness contributors, nutrient & pollutant indicators, and alkalinity & fluoride—the study facilitated a systematic and comprehensive interpretation of spatial and temporal trends.

The outcomes of this investigation are expected to provide crucial insights into the prevailing status of drinking water quality in Lucknow city. It offers empirical evidence on the degree of compliance of water sources with national drinking water standards and highlights potential risks posed to public health through contaminated water consumption. The findings can serve as a valuable reference for urban water managers, environmental regulators, municipal corporations, and public health authorities in framing evidence-based policies, improving water supply systems, prioritizing water quality monitoring, and implementing remedial interventions to mitigate waterborne health hazards. Furthermore, this study contributes to the growing body of literature on urban water quality management in rapidly developing Indian cities, emphasizing the necessity of integrating systematic water quality surveillance with sustainable urban planning and public health strategies.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The present study was conducted in Lucknow, the capital city of Uttar Pradesh, India. Geographically situated between 26.8467° N latitude and 80.9462° E longitude, Lucknow serves as a significant cultural, administrative, and commercial hub of northern India (Fig.1). The city has witnessed rapid population growth, urban sprawl, and infrastructure expansion in

recent decades. It relies primarily on surface water from the Gomti River and groundwater sources accessed through piped municipal supply, borewells, hand pumps, and public taps to meet its potable water demands.

For this study, five strategically selected sampling sites representing diverse land-use characteristics, water sources, and demographic profiles within the city were chosen as shown in Table 1.

Table 1: Selected Water Sampling Sites in Lucknow City

| S. No. | Sampling Site | Symbol | Type of Area | Water Source |
|---|---|---|---|---|
| 1 | Indira Nagar | S1 | Residential | Piped supply & borewell |
| 2 | Aminabad | S2 | Commercial/Old city | Piped supply & handpump |
| 3 | Charbagh Railway Area | S3 | Public/Transport Hub | Public taps & storage tanks |
| 4 | Gomti Nagar | S4 | Modern Residential | Municipal piped supply |
| 5 | Mohanlalganj | S5 | Rural-urban Fringe | Borewell |

These sites were selected to capture a representative range of socio-economic and water supply conditions within Lucknow city.

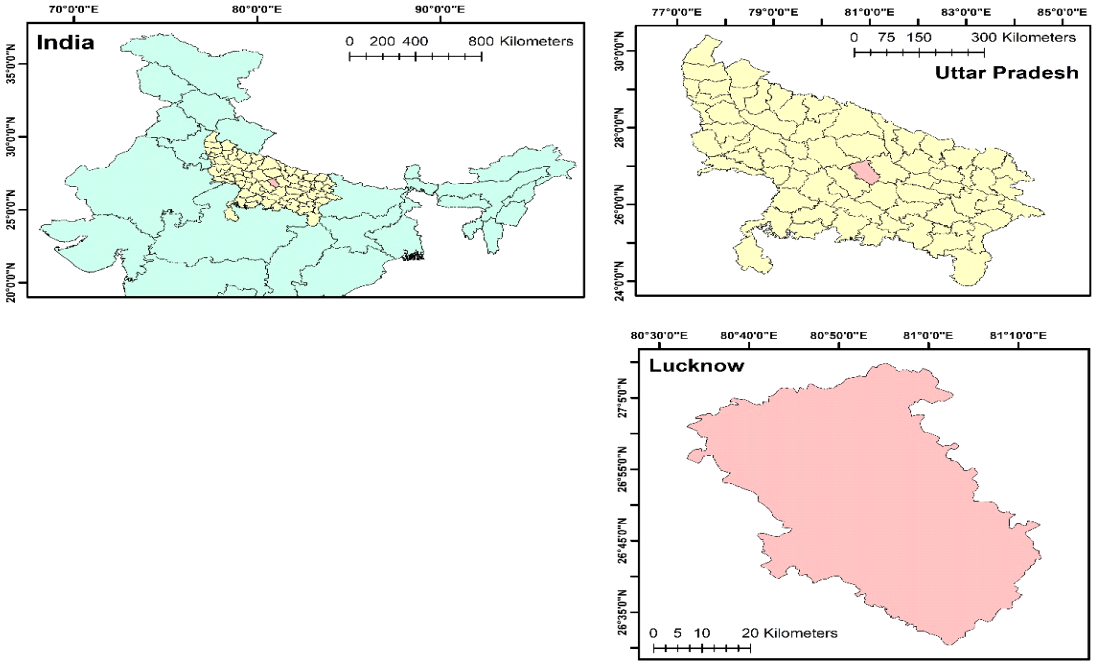


Fig. 1. Study area map

2.2 Sampling Period and Frequency

The study was conducted over a continuous five-month period, from January to May 2023, to capture potential temporal variations in water quality due to seasonal fluctuations and changing environmental conditions. Water sampling was carried out once a month at each site, typically between 8:00 a.m. and 10:00 a.m., maintaining consistency in sampling time to minimize diurnal variations.

2.3 Sample Collection and Preservation

A total of 25 water samples (5 sites × 5 months) were collected in pre-sterilized glass bottles for physico-chemical analysis and in pre-sterilized screw-capped tubes for bacteriological analysis. Water from piped supply and borewells was collected after allowing it to run for a few minutes to flush out stagnant water. Samples from storage tanks and public taps were taken directly. All samples were labeled appropriately, stored in insulated iceboxes, and transported to the laboratory within four hours of collection for immediate analysis.

2.4 Physico-Chemical Analysis

Seventeen physico-chemical parameters were analyzed using standard methods prescribed by the Bureau of Indian Standards (IS: 10500:2012) and APHA (2017) protocols. The parameters included:

- Basic Indicators: Temperature, pH, and Turbidity.
- Salinity and Mineral Content: Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Chloride.
- Hardness Contributors: Total Hardness (TH), Calcium ($Ca^{2+}$), and Magnesium ($Mg^{2+}$).
- Nutrient and Pollutant Indicators: Sulphate ($SO_4^{2-}$), Phosphate ($PO_4^{3-}$), and Nitrate-N ($NO_3^-$-N).
- Alkalinity and Fluoride ($F^-$).

Measurements for parameters like temperature and pH were performed on-site using portable meters, while other parameters were analyzed in the laboratory using titrimetric, colorimetric, gravimetric, and spectrophotometric methods.

2.5 Bacteriological Analysis

Microbiological assessment involved determining the presence of:

- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Total Coliforms (MPN/100 mL)
- E. coli (MPN/100 mL)

Bacteriological parameters were estimated using the multiple tube fermentation technique (MTFT) and standard nutrient broth culturing procedures. Confirmation of E. coli was carried out using EC broth medium with incubation at 44.5°C for 24 hours.

2.6 Data Analysis

The recorded water quality data were compiled, and statistical analyses were conducted to determine monthly averages, standard deviations, and ranges for each parameter at each location. Comparative analysis was performed against the permissible limits specified by IS: 10500:2012. Sspatial (site-wise) variations were graphically represented using bar charts and line plots to facilitate interpretation of patterns and trends.

## 3. RESULTS AND DISCUSSION

This study involved the comprehensive assessment of drinking water quality from five strategically selected locations in Lucknow city, incorporating both physicochemical and bacteriological parameters. The evaluation was conducted across five consecutive months, from January to May 2025, allowing for temporal as well as spatial analysis. The findings were critically compared against the permissible limits prescribed by the Bureau of Indian Standards (IS: 10500-2012) to assess potability and public health implications (Fig. 2).

3.1 Physicochemical Parameters

The physicochemical parameters of the sampled water sources varied across different locations and months, reflecting the influence of natural, anthropogenic, and infrastructural factors on water quality within Lucknow city (Table 2).

Temperature: Water temperature ranged between 20.2°C to 24.3°C across the five sites. The highest average temperature was recorded at Site S3 (Charbagh Railway Area), a densely trafficked commercial and public zone, with values peaking at 24.3°C in May. Seasonal variation was evident, with a gradual increase from January to May at all sites, in line with ambient climatic changes. Although water temperature itself does not pose a direct health risk, it can influence other physicochemical and microbial parameters, particularly by promoting microbial activity in warmer months.

pH: The pH values of all water samples remained within the desirable range (6.5–8.5) as per IS 10500:2012. Values ranged from 7.35 to 7.85, with the lowest observed at S3 and the highest at S2 (Aminabad). Minor fluctuations across months indicated relative chemical stability. However, slightly higher pH values at certain sites can be attributed to variations in alkalinity and dissolved carbonates.

**Turbidity:** Turbidity, an important indicator of suspended particulates and microbial risk, ranged from 0.9 to 5.2 NTU. While turbidity levels at Sites S2 and S5 remained well within acceptable limits, sites like S3 and S1 occasionally exceeded the desirable 1 NTU, notably peaking at 5.2 NTU in April at S3. Elevated turbidity in public taps and storage tanks (S3) suggests possible contamination from pipeline breaches or storage tank sedimentation, warranting urgent intervention.

Table 2: Average Concentration of Physicochemical Parameters (Jan-May 2025)

| S. No. | Parameters and Unit | IS: 10500 Drinking Water Standards | Permissible Limit in the Absence of Alternate Source | S1 | S2 | S3 | S4 | S5 |
|---|---|---|---|---|---|---|---|---|
| 1 | Temp. (°C) | 20 | - | 22.5 ± 1.1 | 22.2 ± 1.3 | 22.8 ± 1.3 | 21.9 ± 1.2 | 21.8 ± 1.3 |
| 2 | pH | 6.5 – 8.5 | <6.5 & >9.2 | 7.61 ± 0.05 | 7.78 ± 0.06 | 7.4 ± 0.04 | 7.68 ± 0.06 | 7.49 ± 0.05 |
| 3 | Turbidity (NTU) | 1 | 5 | 3.6 ± 0.43 | 1.2 ± 0.22 | 4.7 ± 0.52 | 1.8 ± 0.32 | 2 ± 0.35 |
| 4 | Conductivity (µmhos/cm) | 500 | 3000 | 928 ± 13.51 | 762 ± 15.25 | 1195 ± 25.5 | 880 ± 17.68 | 668 ± 13.51 |
| 5 | TDS (mg/L) | 500 | 2000 | 612 ± 5.59 | 510 ± 11.18 | 830 ± 15.81 | 585 ± 11.18 | 488 ± 12.04 |
| 6 | Chloride (mg/L) | 250 | 1000 | 282 ± 4.82 | 230 ± 3.81 | 340 ± 7.91 | 258 ± 5.59 | 210 ± 4.47 |
| 7 | Total Hardness (mg/L) | 200 | 600 | 139 ± 3.13 | 123 ± 2.99 | 160 ± 6.27 | 133 ± 4.6 | 113 ± 2.22 |
| 8 | Calcium (mg/L) | 75 | 200 | 99 ± 2.97 | 85 ± 2.24 | 112 ± 3.83 | 92 ± 3.03 | 76 ± 2.41 |
| 9 | Magnesium (mg/L) | 30 | 100 | 41 ± 1.92 | 38 ± 0.96 | 49 ± 2.7 | 41 ± 1.58 | 36 ± 1.04 |
| 10 | Sulphate (mg/L) | 200 | 400 | 55 ± 2.39 | 48 ± 1.58 | 61 ± 2.39 | 50 ± 1.58 | 42 ± 1.04 |
| 11 | Phosphate (mg/L) | 0.01 | 0.03 | 0.016 ± 0.001 | 0.012 ± 0.001 | 0.019 ± 0.001 | 0.013 ± 0.001 | 0.01 ± 0.001 |
| 12 | Nitrate as $NO_3$-N (mg/L) | 45 | No relaxation | 18.4 ± 0.96 | 12.2 ± 0.57 | 25 ± 1.58 | 15 ± 0.79 | 10 ± 0.79 |
| 13 | Alkalinity (mg/L) | 200 | 600 | 312 ± 4.95 | 274 ± 6.67 | 348 ± 10.01 | 296 ± 6.1 | 260 ± 6.88 |
| 14 | Fluoride (mg/L) | 1.0 | 1.5 | 0.85 ± 0.02 | 0.75 ± 0.02 | 0.65 ± 0.02 | 0.7 ± 0.02 | 0.5 ± 0.02 |

Electrical Conductivity (EC): Conductivity values varied significantly, ranging from 650 to 1225 µmhos/cm. The highest readings were consistently noted at S3, reflecting higher ionic concentrations likely sourced from leachates, mineral deposits, and urban runoff. Sites with borewell sources (S1 and S5) recorded relatively lower conductivity values, suggesting minimal salt content.

Total Dissolved Solids (TDS): TDS concentrations closely mirrored conductivity patterns, with values ranging from 475 mg/L to 850 mg/L. Except for S3, where levels approached the permissible limit of 1000 mg/L, all sites remained within acceptable limits. Elevated TDS levels, especially in commercial and public-use areas, indicate cumulative dissolved mineral presence and potential contamination from aging pipelines or groundwater intrusion.

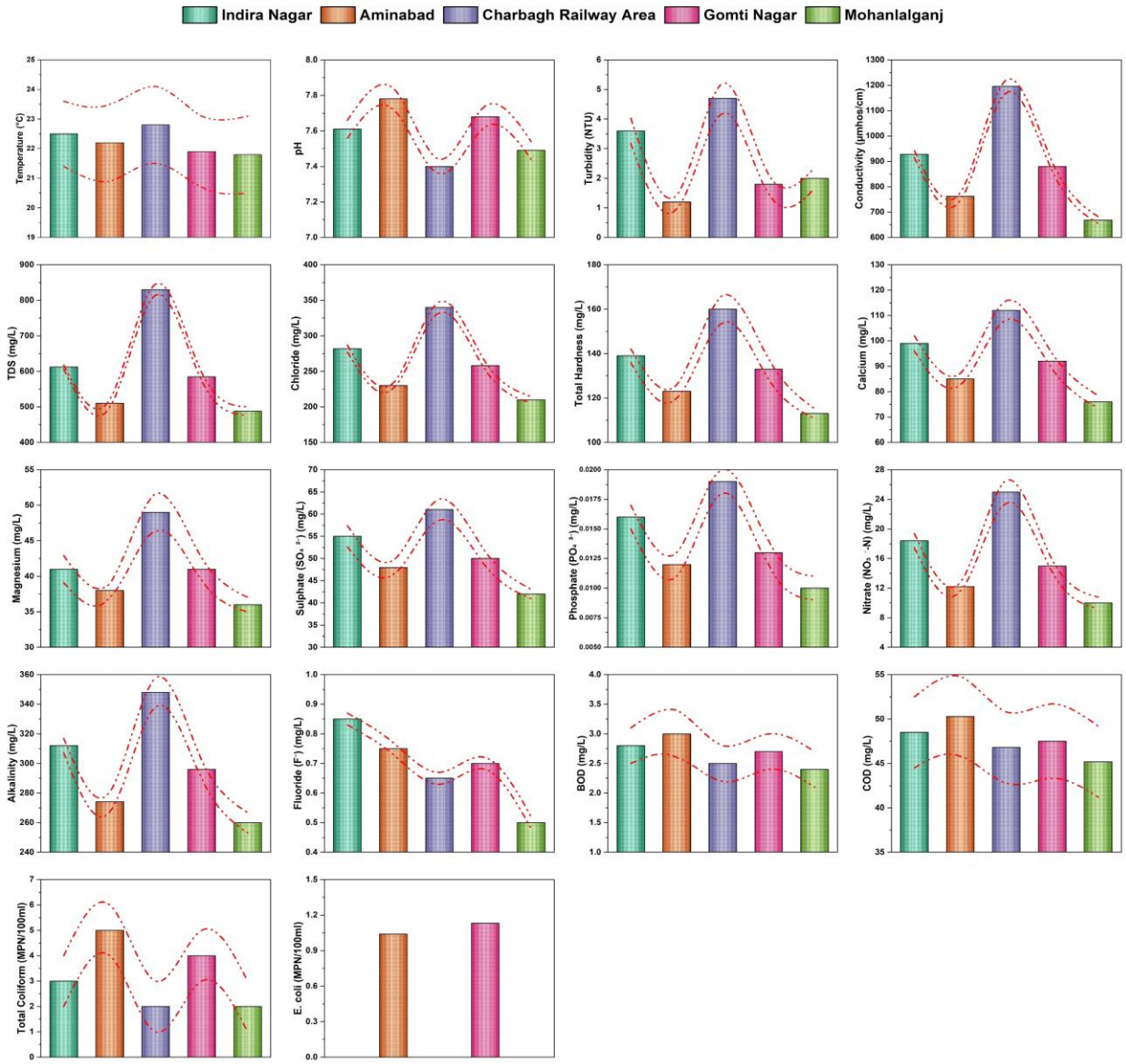


Fig. 2 Average concentration of physicochemical and biological water quality parameters across five selected sites in Lucknow City.

Chloride Content: Chloride concentrations varied from 204 to 350 mg/L, exceeding the desirable 250 mg/L limit at certain locations and months, particularly at S3 and S1. Higher chloride values typically result from sewage effluent infiltration or industrial discharge. However, even the highest levels observed were within the permissible limit in the absence of alternate sources.

Total Hardness: Measured as mg/L $CaCO_3$, total hardness ranged between 110 and 169 mg/L, within the acceptable range (200 mg/L). Groundwater-fed areas like S3 showed higher values compared to municipally supplied zones, aligning with typical groundwater mineral profiles rich in calcium and magnesium ions.

Calcium and Magnesium: Calcium content varied between 73 mg/L and 117 mg/L, remaining within the 75–200 mg/L limit, while magnesium ranged from 35 mg/L to 52 mg/L, safely below the maximum allowable 100 mg/L. Spatial trends revealed higher concentrations in central urban zones with aged borewell infrastructure.

Sulphate, Phosphate, and Nitrate: Sulphate levels ranged from 41 to 64 mg/L, well within the 200 mg/L

limit. Phosphate values were generally low (0.009–0.02 mg/L), suggesting limited detergent or fertilizer runoff influence. Nitrate levels, however, displayed notable seasonal and spatial variability, ranging from 9 to 27 mg/L. The highest concentrations were observed at S3, attributed to possible leaching from nearby effluent disposal and agricultural activity in peri-urban stretches. Importantly, all values remained below the critical threshold of 45 mg/L.

Alkalinity and Fluoride: Alkalinity ranged from 251 to 360 mg/L, exceeding the desirable 200 mg/L level across all sites but staying within the permissible 600 mg/L. This high alkalinity is characteristic of the regional groundwater profile and contributes to the slightly alkaline pH readings. Fluoride concentrations ranged from 0.48 to 0.88 mg/L, well within the acceptable 1.0–1.5 mg/L range, with slightly higher values at S1 and S2.

3.2 Bacteriological Parameters

The microbiological quality of drinking water was assessed through the quantification of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Coliform, and E. coli counts (Table 3).

BOD and COD: BOD values ranged between 2.2 to 3.3 mg/L, indicating low to moderate organic pollution. COD values ranged from 42.5 to 53 mg/L, reflecting biodegradable and chemical organic matter load. Higher values were consistently recorded at S2 (Aminabad), a densely populated old-city area, suggesting possible sewage ingress and compromised storage hygiene.

Total Coliforms and *E. coli*: Coliform counts ranged from 1 to 6 MPN/100 mL. Although within permissible limits, occasional spikes at S2 and S4 during March–April indicated microbial contamination risks, potentially from aging pipelines and increased ambient temperatures. *E. coli*, a direct fecal contamination indicator, was generally absent but sporadically detected at S2 and S4, with counts not exceeding 1.16 MPN/100 mL. These results underline the critical need for continuous chlorination and infrastructure surveillance.

| S. No. | Parameters and Unit | IS: 10500 Drinking Water Standards | Permissible Limit in the Absence of Alternate Source | S1 | S2 | S3 | S4 | S5 |
|---|---|---|---|---|---|---|---|---|
| 1 | BOD (mg/L) | <5 | — | 2.8 ± 0.3 | 3.0 ± 0.4 | 2.5 ± 0.3 | 2.7 ± 0.3 | 2.4 ± 0.3 |
| 2 | COD (mg/L) | <250 | — | 48.5 ± 4.0 | 50.3 ± 4.5 | 46.8 ± 4.0 | 47.5 ± 4.2 | 45.2 ± 4.0 |
| 3 | Total Coliform (MPN/100ml) | Nil | — | 3 ± 1 | 5 ± 1 | 2 ± 1 | 4 ± 1 | 2 ± 1 |
| 4 | *E. coli* (MPN/100ml) | Nil | — | 0 | 1.04 | 0 | 1.13 | 0 |

## 4. CONCLUSION

This study presents a systematic evaluation of drinking water quality from five representative locations within Lucknow city, encompassing both piped municipal supplies and borewell sources. The assessment covered a comprehensive range of physicochemical and bacteriological parameters, monitored over a five-month period from January to May 2025, and compared against the standards set by the Bureau of Indian Standards (IS: 10500-2012).

The results confirmed that while most water quality parameters generally conformed to the desirable and permissible limits, several sites exhibited periodic deviations, particularly in parameters such as turbidity, total dissolved solids (TDS), chloride, nitrate, and microbial indicators. Notably, locations like Charbagh Railway Area (S3) and Aminabad (S2) demonstrated elevated turbidity and microbial contamination, attributable to factors such as high population density, older water supply infrastructure, frequent leakage incidents, and proximity to untreated waste discharge points.

Physicochemical parameters such as pH, conductivity, sulphate, phosphate, fluoride, calcium, and magnesium largely remained within permissible

limits across all sampling points. However, alkalinity levels exceeded the desirable threshold at all sites, reflective of the regional groundwater chemistry and high carbonate content in the aquifer systems. Temporal analysis revealed that water quality parameters, particularly turbidity, BOD, COD, and coliform counts, demonstrated notable seasonal variations, with higher values recorded during the warmer months of April and May. This is likely due to increased microbial activity, evaporation-driven concentration of dissolved solids, and possible surface runoff contamination in peri-urban areas.

Bacteriological analysis highlighted occasional detection of total coliforms and E. coli in certain samples, particularly from S2 and S4, indicating intermittent fecal contamination. Though within acceptable limits, their presence underscores the need for continuous chlorination and regular sanitary inspections of water supply lines and public distribution systems.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

- Routine Monitoring: Regular physicochemical and microbiological monitoring of all municipal and borewell water sources, with particular emphasis during pre-monsoon months.
- Infrastructure Upgrades: Replacement and maintenance of old, leaking pipelines in older parts of the city such as Aminabad and Charbagh to prevent contamination.
- Water Disinfection: Reinforcement of chlorination practices at public taps, storage tanks, and borewell outlets to minimize microbial risks.
- Public Awareness Campaigns: Educating residents about proper water storage, handling practices, and the importance of using covered containers.
- Policy Interventions: Municipal authorities should prioritize investments in water treatment facilities and continuous quality surveillance systems for high-risk areas.

This study serves as a valuable baseline for future long-term water quality monitoring programs and for strengthening public health interventions in Lucknow city.

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