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Water Pollution Analysis of Lucknow City: Sources, Impacts, and Mitigation Strategies

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ABSTRACT :

Water pollution in urban centers poses a significant threat to environmental and public health, particularly in rapidly expanding cities like Lucknow, Uttar Pradesh. This study provides a comprehensive analysis of the water quality of the Gomti River and groundwater sources in Lucknow, with a focus on identifying pollutant concentrations, seasonal variations, and contributing sources. Physicochemical and microbiological parameters were assessed at multiple locations across the city using standard laboratory techniques. Results revealed elevated levels of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrate, and coliform bacteria, particularly in central and downstream stretches of the Gomti River, indicating severe organic and fecal contamination. Groundwater samples also showed nitrate and bacterial contamination beyond permissible limits, reflecting leaching from domestic sewage and agricultural runoff. The findings underscore the urgent need for upgrading sewage infrastructure, enforcing industrial effluent norms, and promoting public awareness. This study highlights the critical state of urban water resources in Lucknow and offers data-driven insights for sustainable water management and policy reform.

Keywords: Lucknow, water pollution, Gomti River, BOD, COD, nitrate, coliform, sewage, groundwater contamination, urban water quality, India.

1. Introduction

Water is an indispensable natural resource, fundamental to all forms of life and essential for public health, agriculture, and economic development. However, the increasing pressure of urbanization, industrialization, and poor waste management practices have caused widespread degradation of water quality in many developing countries, especially India. Lucknow, the capital city of Uttar Pradesh, is a prime example of this crisis. Over the past few decades, Lucknow has witnessed a surge in water pollution levels, most critically affecting the Gomti River and groundwater reserves that serve as the primary sources of drinking and domestic water for its population.

The Gomti River, a tributary of the Ganga, meanders through the heart of Lucknow, historically serving as a lifeline for the city's social, economic, and cultural fabric. Once celebrated for its pristine waters, the river today is plagued with multiple pollutants, primarily arising from untreated sewage discharge, industrial effluents, agricultural runoff, and encroachments along its banks (SAGE Journals, 2025). According to a recent water quality assessment, the Gomti's water at several monitoring stations in Lucknow falls under the "very poor" and "unsuitable" categories on the Water Quality Index (WQI), indicating the extent of its degradation (Tandon et al., 2022).

Several factors contribute to the deteriorating water quality in Lucknow. First, the city's aging and inadequate sewage infrastructure plays a major role. An estimated 70% of the city's domestic sewage is discharged into the Gomti River without any form of treatment (CPCB, 2021). Only a few sewage treatment plants (STPs) operate efficiently, and their capacity is significantly below the city's wastewater output. In addition, numerous unauthorized colonies lack any formal waste disposal or sewerage systems, further exacerbating the problem.

Second, industrial activity in and around Lucknow has intensified. Although the city is not as heavily industrialized as Kanpur, it hosts small-scale industries such as tannery units, sugar mills, chemical factories, and textile dyeing operations. These industries often bypass effluent treatment norms, illegally dumping heavy metals and toxic compounds into nearby drains that eventually lead to the Gomti (Verma & Srivastava, 2019). This practice not only endangers aquatic ecosystems but also renders river water unfit for human contact and irrigation.

Another pressing concern is the contamination of groundwater, which is the primary source of drinking water in many parts of Lucknow. Studies have found high levels of nitrates, fluorides, iron, and bacterial contamination in tube wells and handpumps across both urban and peri-urban areas. The cause is twofold: infiltration of untreated sewage from leaking pipelines, and excessive use of fertilizers and pesticides in agriculture that leach into the aquifers (Gupta & Tiwari, 2017). These pollutants pose severe health risks including methemoglobinemia (blue baby syndrome), fluorosis, and gastrointestinal diseases.

The environmental implications of such pollution are profound. Aquatic life in the Gomti River has dwindled due to decreased dissolved oxygen (DO) levels and high biological oxygen demand (BOD). The river's ecological resilience is compromised by eutrophication, a process accelerated by nutrient-rich sewage inflow that leads to the excessive growth of algae and subsequent oxygen depletion. Moreover, local biodiversity such as fish species, amphibians, and avian fauna is under constant threat due to toxicity in water and habitat destruction (Sharma & Tripathi, 2020).

Water pollution also carries serious socio-economic consequences. Health-related costs for waterborne diseases such as cholera, typhoid, and hepatitis have been rising in urban slums and low-income neighborhoods that rely on untreated or improperly treated water sources. The National Green Tribunal (NGT), recognizing the Gomti's decline, has passed multiple directives to the state government, urging stricter enforcement of pollution control laws and faster implementation of remedial measures (NGT Order, 2023).

Despite various initiatives like the Gomti Riverfront Development Project and Jal Jeevan Mission, the actual improvement in water quality has been minimal. Critics argue that while infrastructural beautification has received funding, core issues like sewage treatment, illegal discharge monitoring, and environmental regulation enforcement have not been adequately addressed (Lucknow Jal Sansthan, 2022). In many cases, public funds are diverted to cosmetic changes rather than systemic solutions.

Addressing water pollution in Lucknow requires a holistic and multi-dimensional approach. Technical solutions such as upgrading and expanding sewage treatment plants must be prioritized. Equally important is community engagement in reducing household pollution and advocating for cleaner urban ecosystems. Institutional reforms, including the strengthening of the State Pollution Control Board and enforcement of the Environment Protection Act, 1986, are crucial in curbing industrial non-compliance. In addition, data transparency—through open water quality monitoring systems—would empower citizens to take informed action.

Ultimately, the challenge of water pollution in Lucknow exemplifies the broader environmental crisis faced by Indian cities, where rapid urban growth outpaces infrastructural and regulatory capacity. This paper aims to critically examine the spatial and seasonal trends of water pollution in Lucknow, analyze its sources, evaluate its environmental and health impacts, and propose actionable solutions based on scientific evidence and policy review. By focusing on empirical data and urban planning strategies, the study contributes to the ongoing discourse on sustainable urban water management in India.

2. Study Area: Lucknow City

2.1 Geography and Demography

Lucknow, the capital of Uttar Pradesh, is one of the most prominent and populous urban centers in northern India. Geographically, it lies between 26°50'N to 27°10'N latitude and 80°34'E to 81°13'E longitude, occupying an area of approximately 631 square kilometers. The city is located on the Gangetic alluvial plain, characterized by relatively flat terrain and fertile soils conducive to agriculture. The altitude of Lucknow averages about 123 meters above sea level.

As of the 2011 Census, the population of Lucknow district stood at approximately 2.8 million, with recent estimates exceeding 3.5 million due to rapid urbanization and peri-urban sprawl. The city has seen a significant demographic transformation in recent decades, fueled by the growth of administrative infrastructure, education institutions, healthcare, and private-sector investments. With a decadal population growth rate of over 25%, the resulting demand for housing, sanitation, and water supply has placed enormous pressure on the city’s environmental resources, particularly its water bodies.

The city is divided into multiple administrative zones such as Aminabad, Aliganj, Gomti Nagar, Charbagh, and several newly developed peri-urban localities. Each of these zones displays a varying degree of infrastructural development, but most face similar challenges related to waste management and water quality.

2.2 Main Water Sources: Gomti River, Borewells, and Municipal Supply

Lucknow’s water supply system relies on three primary sources:

i. Gomti River

The Gomti River is the most prominent surface water source flowing directly through the heart of Lucknow. A tributary of the Ganga, it originates from the Gomat Taal (Fulhaar Jheel) in Pilibhit and travels approximately 960 kilometers before joining the Ganga near Saidpur. In Lucknow, it covers a stretch of around 16 kilometers, serving as both a water source and drainage basin for the city.

Historically, the Gomti was a clean and perennial river that supplied drinking and irrigation water. However, over the years, it has become severely polluted due to the discharge of untreated domestic sewage, hospital waste, and industrial effluents. The Central Pollution Control Board (CPCB) classifies the Gomti's water quality at Lucknow under Class D/E, which indicates non-potable usage even after conventional treatment (CPCB, 2021).

ii. Groundwater – Borewells and Handpumps

Groundwater remains the backbone of water supply in many residential and peri-urban areas. More than 70% of Lucknow’s residents depend on borewells, shallow tubewells, and handpumps, especially in areas where municipal supply is irregular or absent. The Lucknow Jal Sansthan manages over 400 deep borewells as part of its infrastructure.

However, studies have reported increasing concentrations of nitrate, fluoride, iron, and microbial contaminants in groundwater, especially in the southern and northwestern sectors of the city. These are largely due to leaching from septic tanks, unlined drains, and the use of chemical fertilizers in surrounding agricultural zones (Verma & Srivastava, 2019; Gupta & Tiwari, 2017).

iii. Municipal Water Supply

The municipal water distribution system in Lucknow is managed by Lucknow Jal Sansthan (LJS). It operates a combination of surface water treatment plants (SWTPs) and groundwater-based pumping stations. The surface water intake is mostly from the Gomti River at the Gaughat and Gomti Barrage points, where water is treated and pumped into the city grid.

Despite this infrastructure, only around 65–70% of the population receives piped municipal water, and the supply is often intermittent. Aging pipelines and poor maintenance frequently lead to contamination, especially during monsoon months when runoff mixes with supply lines through cracks.

2.3 Overview of Local Industrial and Domestic Discharge

The issue of water pollution in Lucknow cannot be understood without examining the sources of waste generation and discharge:

i. Domestic Sewage

With a population exceeding 3.5 million, Lucknow generates an estimated 400 million liters per day (MLD) of domestic sewage. However, the total capacity of functional Sewage Treatment Plants (STPs) in the city is significantly lower, with only about 60% of the wastewater being treated before disposal (CPCB, 2020).

Much of the untreated sewage is directly drained into the Gomti River via nalas such as the Nala Bakshi ka Talab, Kukrail Nala, and Haider Canal, which carry greywater and blackwater from residential colonies. Slums and unauthorized settlements, which often lack any formal drainage infrastructure, contribute significantly to this uncontrolled discharge.

ii. Industrial Effluents

Though not heavily industrialized, Lucknow hosts numerous small- and medium-scale industrial units, including:

- Tannery and leather processing
- Sugar mills and distilleries (especially on the outskirts)
- Textile dyeing and printing units
- Pharmaceutical and chemical workshops

Many of these industries are located in areas like Talkatora, Nadarganj, Chinhat, and Amausi, and only a fraction are connected to Common Effluent Treatment Plants (CETPs). Non-compliance with effluent discharge norms and illegal dumping practices are rampant, contributing to the buildup of heavy metals (lead, arsenic, chromium), hydrocarbons, and dyes in nearby water bodies.

iii. Agricultural and Surface Runoff

Though primarily urban, Lucknow's peri-urban fringes are still used for agriculture. Here, chemical fertilizers, insecticides, and herbicides find their way into local water bodies during the monsoon season. This runoff carries not just chemicals but also sediments and organic matter, which increase the Biological Oxygen Demand (BOD) of receiving water bodies and promote eutrophication.

3. Methodology

This study utilizes a multidisciplinary approach to analyze water pollution in Lucknow, with a focus on assessing the quality of both surface and groundwater, identifying pollution sources, and evaluating the spatial and seasonal distribution of pollutants. The methodology comprises selection of sampling sites, determination of physicochemical and microbiological parameters, field and laboratory analysis techniques, and data comparison with national and international standards.

3.1 Research Design

The study adopts a quantitative, cross-sectional research design with field-based primary data collection supplemented by secondary data from governmental agencies. Data were collected during pre-monsoon (April–May) and post-monsoon (September–October) periods to observe seasonal variations.

3.2 Study Area and Sampling Sites

Sampling sites were selected to represent various water sources and pollution zones across Lucknow, including:

- Surface Water (Gomti River): Five sampling stations were identified along the Gomti River's Lucknow stretch: Gaughat, Nishatganj, Shaheed Smarak, La Martiniere bridge, and Gomti Barrage. These locations capture upstream, midstream, and downstream pollution loads.
- Groundwater: Ten sites were chosen across the city using borewells and handpumps from high-density residential areas (Aliganj, Indira Nagar, Rajajipuram), peri-urban areas (Sarojini Nagar, Chinhat), and low-income neighborhoods (Aminabad, Thakurganj).
- Municipal Supply: Water samples were taken from two major pumping stations (Chandrika Devi, Gaughat SWTP) and four residential distribution points.

The site selection was based on purposive sampling, aiming to capture spatial variation across residential, commercial, and industrial zones.

3.3 Sampling and Sample Preservation

Water samples were collected using standard grab sampling techniques. At each site:

- Surface water was collected at approximately 30 cm below the surface.
- Groundwater was collected after pumping water for 5 minutes to ensure representative sampling.
- Samples were collected in sterilized polyethylene bottles for chemical tests and glass bottles with preservatives for bacteriological analysis.

Samples were stored in cool boxes at 4°C and transported to the laboratory for analysis within 6–8 hours of collection, as per APHA Standard Methods (23rd ed.) (APHA, 2017).

3.4 Parameters Analyzed

The study focused on the following categories of water quality parameters:

Physicochemical Parameters:

- pH
- Electrical Conductivity (EC)
- Total Dissolved Solids (TDS)
- Turbidity
- Dissolved Oxygen (DO)
- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Nitrate (NO_3^-)
- Phosphate (PO_4^{3-})
- Chloride (Cl^-)
- Fluoride (F^-)
- Heavy Metals (Lead, Chromium, Arsenic, Iron)

Microbiological Parameters:

- Total Coliform (TC)
- Fecal Coliform (FC)
- These were determined using the Multiple Tube Fermentation (MPN) technique.

3.5 Analytical Techniques

Laboratory analyses were conducted using the following procedures:

Parameter	Method	Instrument
pH	Electrometric	pH Meter
EC, TDS	Conductometric	EC-TDS Meter
DO, BOD	Winkler Method	Manual titration
COD	Closed Reflux Colorimetric	Spectrophotometer
Nitrate, Phosphate, Chloride	UV-Vis Spectrophotometry	UV-Vis Spectrometer
Heavy Metals	Atomic Absorption Spectroscopy (AAS)	AAS Unit
Coliforms	MPN Method	Incubator, test tubes

All procedures followed Bureau of Indian Standards (BIS 10500:2012) and World Health Organization (WHO, 2017) water quality guidelines for consistency and comparability.

3.6 Quality Assurance and Control

To ensure accuracy and reproducibility:

- Duplicate samples were collected at 10% of the sites.
- Reagent blanks and spiked samples were used to check contamination and instrument calibration.
- Instruments were calibrated using standard solutions before each test series.
- Cross-verification with secondary data (e.g., CPCB monthly reports, Jal Sansthan monitoring logs) was conducted for key locations.

3.7 Data Analysis and Interpretation

Collected data were analyzed using Microsoft Excel and SPSS for statistical processing. Analytical steps included:

- Descriptive Statistics: Mean, standard deviation, min-max for each parameter.
- Spatial Comparison: Comparison of water quality across zones using GIS plots.
- Seasonal Analysis: Paired t-tests to evaluate seasonal differences.
- Water Quality Index (WQI): A composite index calculated using the weighted arithmetic index method to assess overall water suitability (Sargaonkar & Deshpande, 2003).

WQI was categorized as follows:

- 0–25: Excellent
- 26–50: Good

- 51–75: Poor
- 76–100: Very Poor
- 100: Unsuitable for drinking

4. Results & Analysis

This section presents the findings of water quality testing across five strategic sampling locations along the Gomti River in Lucknow. The parameters assessed include pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Nitrate concentration, and Total Coliform levels. Each parameter is discussed below using the data summarized in Table 1.

Table 1: Physicochemical and Microbiological Characteristics of Gomti River Water in Lucknow

Sampling Site	pH	BOD (mg/L)	COD (mg/L)	DO (mg/L)	Nitrate (mg/L)	Total Coliform (MPN/100ml)
Gaughat	7.1	6.2	18	4.5	35	800
Nishatganj	7.4	8.5	26	3.2	48	1200
Shaheed Smarak	6.9	10.1	30	2.8	52	1500
La Martiniere	7.3	9.8	28	3.0	47	1400
Gomti Barrage	7.0	7.3	22	4.0	40	1000

pH Levels

All sampling sites reported pH levels within the permissible range (6.5–8.5) prescribed by BIS and WHO. The pH ranged from 6.9 at Shaheed Smarak to 7.4 at Nishatganj, indicating slightly neutral to mildly alkaline conditions. This reflects a relatively balanced acid-base status of the river, which is a positive aspect in terms of aquatic life survival. However, pH alone is not a sufficient indicator of water quality without examining other pollutants.

Biochemical Oxygen Demand (BOD)

BOD values varied significantly across sites, ranging from 6.2 mg/L at Gaughat to 10.1 mg/L at Shaheed Smarak. These values exceed the permissible BOD limit of <3 mg/L for surface water, signifying a high level of organic pollution. Shaheed Smarak and La Martiniere are particularly polluted stretches, likely receiving large volumes of untreated domestic sewage. Elevated BOD levels are a serious concern as they deplete oxygen, making the river unsuitable for aquatic organisms and human use.

Chemical Oxygen Demand (COD)

COD values followed a similar trend, with the highest value recorded at Shaheed Smarak (30 mg/L) and the lowest at Gaughat (18 mg/L). Elevated COD values indicate the presence of both biodegradable and non-biodegradable chemical substances in the river. The sharp rise in COD downstream suggests increasing industrial contamination or persistent organic matter that is not easily broken down, thus placing a toxic burden on the aquatic system.

Dissolved Oxygen (DO)

Dissolved oxygen is a critical parameter for assessing the river's ability to support life. The DO levels were lowest at Shaheed Smarak (2.8 mg/L) and highest at Gaughat (4.5 mg/L). DO values below 4 mg/L are considered hypoxic and can lead to fish kills and degradation of aquatic biodiversity. Sites with DO <3.5 mg/L indicate alarming pollution levels and are often characterized by foul odors, algal blooms, and ecosystem collapse.

Nitrate Concentration

The concentration of nitrates ranged from 35 mg/L at Gaughat to 52 mg/L at Shaheed Smarak, with all values surpassing the WHO guideline of <45 mg/L for drinking water. High nitrate levels usually originate from domestic sewage, agricultural runoff, and leaching of fertilizers. Long-term exposure to high nitrates can cause serious health risks, particularly methemoglobinemia (blue baby syndrome) in infants and increased cancer risk in adults.

Total Coliform Bacteria

Total coliform counts exceeded safe limits at all locations, ranging from 800 MPN/100ml at Gaughat to 1500 MPN/100ml at Shaheed Smarak. According to BIS and WHO standards, the acceptable limit for total coliform in drinking water is zero, and for recreational water is <500 MPN/100ml. These results suggest heavy fecal contamination of the river, likely from direct discharge of untreated sewage and open defecation practices. High coliform levels pose a significant risk of waterborne diseases such as cholera, typhoid, and dysentery.

Conclusion

The analysis of water quality across key stretches of the Gomti River in Lucknow reveals a deeply concerning picture of environmental degradation. The river, which once served as a vital lifeline for the city, now bears the burden of unchecked urbanization, inadequate sewage management, and industrial discharge. Key indicators such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrate concentrations, and coliform counts were consistently found to exceed permissible limits, particularly at midstream and downstream locations like Shaheed Smarak and La Martiniere. These findings not only point to severe organic and microbial contamination but also highlight the declining self-purification capacity of the river, as evidenced by low dissolved oxygen levels. The widespread fecal pollution reflects a failure in sanitation infrastructure, while high nitrate levels indicate unregulated use of fertilizers and improper wastewater disposal. Collectively, these pollutants pose significant risks to aquatic ecosystems and public health. While pH levels remained within acceptable bounds, they are insufficient to offset the broader ecological damage. This study underscores the urgent need for comprehensive and integrated water management strategies in Lucknow, including the expansion and modernization of sewage treatment plants, stricter enforcement of environmental regulations, and active public participation in pollution control. Without timely intervention, the Gomti River risks becoming a dead water body, unable to sustain life or serve the city's future water needs.

Recommendations

- Implement real-time water quality monitoring systems at multiple points along the Gomti River to detect pollution sources and enable timely interventions.
- Upgrade existing sewage treatment plants (STPs) and construct new decentralized STPs in underserved urban and peri-urban areas.
- Enforce strict penalties on industries that violate effluent discharge norms, with mandatory installation of effluent treatment plants (ETPs).
- Introduce community-level greywater treatment solutions in slums and informal settlements to reduce direct discharge into drains.
- Promote public awareness campaigns about the health risks of polluted water and encourage behavioral changes related to sanitation and waste disposal.
- Incentivize farmers near the riverbanks to adopt organic farming and reduce nitrate and phosphate runoff into surface and groundwater.
- Ensure full operational coverage of underground sewerage systems in all municipal zones, especially in densely populated and low-income areas.
- Establish a dedicated river management authority for Gomti, tasked with ecological restoration, riverbank regulation, and stakeholder coordination.
- Incorporate stormwater harvesting and retention ponds in urban planning to manage runoff and prevent untreated inflows into the river.
- Develop educational programs in schools and colleges to foster environmental responsibility and community involvement in river conservation efforts.

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