

## Physiochemical assessment of five Indian river systems: A study of hardness and pH

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### Abstract

Rivers are the lifelines of India, sustaining its people, agriculture, and ecosystems while holding deep cultural and spiritual significance. Their water quality directly influences public health, biodiversity, and the socio-economic fabric of the regions they flow through. Regular scientific assessment of river water quality is essential to detect emerging ecological threats and guide effective conservation policies. This study presents a comparative assessment of water quality across five major Indian river locations: the Ganges at Haridwar, the Yamuna at Mathura, the Gomti at Lucknow, the Sarayu at Ayodhya, and the Triveni Sangam at Prayagraj. Two key physicochemical parameters, pH and water hardness, were evaluated to determine the health of these river systems. Water samples were collected between January and April using standardized protocols to minimize contamination. Laboratory analyses were conducted using a digital pH meter and complexometric titration with EDTA. The pH levels across all five samples were found to be within the WHO-recommended range, indicating a generally stable acidic-alkaline balance. However, hardness measurements revealed moderate to high mineral content, indicating the presence of significant dissolved calcium and magnesium ions in certain locations. This study highlights the need for localized water quality monitoring and contributes baseline data for future comparative research in river ecology and public health policy.

**Keywords:** Water Quality; pH; Water Hardness; River Pollution; EDTA Titration; Physicochemical Analysis

### 1. Introduction

Rivers have long served as the arteries of human civilization, supporting life, agriculture, and industry across generations. From the fertile banks of the Ganges to the spiritual confluence at Prayagraj, India's river systems continue to sustain not just ecosystems but also deeply rooted cultural and economic practices. However, increasing urbanization, industrial discharge, agricultural runoff, and religious practices have placed immense stress on the quality of these freshwater bodies [1].

Monitoring river water quality is crucial for maintaining ecological health and ensuring public safety. The pH level of water reflects its acidity or alkalinity, influencing biological activity and the solubility of metals. Extremely acidic or alkaline waters can disrupt aquatic life, reduce biodiversity, and interfere with natural biochemical cycles. Hardness, primarily caused by dissolved calcium and magnesium ions, impacts both environmental systems and human use, which contributes to scaling in pipelines, affecting aquatic flora and fauna, and altering water chemistry.

### 2. Literature Review

Water quality assessment today relies on physical, chemical, and biological parameters—many of which are recommended by the World Health Organization (WHO). Among the most crucial indicators of river health are pH and hardness, as they directly affect both aquatic ecosystems and human usage [2-5].

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## 2.1. pH of Water

The pH of water reflects its hydrogen ion concentration and is measured on a logarithmic scale ranging from 0 to 14. Neutral water has a pH of 7, while values below 7 are acidic and above 7 are alkaline. Deviations in pH can lead to ecological disruptions. Low pH levels may cause:

- Increased metal leaching from river sediments
- Reduced microbial activity
- Higher fish mortality

Conversely, high pH levels can:

- Disrupt gill function in aquatic life
- Increase ammonia toxicity, which is harmful to both fish and plant species

These fluctuations not only damage aquatic biodiversity but also influence the water's suitability for domestic, agricultural, and industrial use [6].

## 2.2. Water Hardness

Water hardness primarily arises from the presence of dissolved calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ) ions. It is classified into:

- Temporary hardness, caused by bicarbonates, is removable through boiling or treatment with sodium carbonate
- Permanent hardness, caused by sulphates and chlorides, is removable only through more advanced methods like the permutit process

The **total hardness** is the sum of both types and is generally expressed in milligrams per litre (mg/L) of calcium carbonate ( $\text{CaCO}_3$ ). According to the standard classification:

- 0–60 mg/L is considered soft
- 61–120 mg/L is moderately hard
- 121–180 mg/L is hard
- Above 180 mg/L is very hard

Hard water has multiple implications. While not typically harmful to health, it can:

- Alter riverbed chemistry
- Lead to scaling in pipes and irrigation systems
- Affect the solubility of other pollutants
- Influence aquatic plant and animal physiology

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## 3. Methodology

### 3.1. Sample Collection

Water samples were collected from five locations across northern India: The Ganges at Haridwar, the Yamuna at Mathura, the Gomti at Lucknow, the Sarayu at Ayodhya, and the Triveni Sangam at Prayagraj.

Samples were drawn using airtight plastic containers, approximately 2 feet from the riverbank to avoid contamination from surface debris and shoreline silt. The collection was conducted between January and April, with efforts made to ensure uniform conditions across all sites. After sedimentation, visible silt deposits were carefully decanted to maintain clarity during testing.

### 3.2. Sample Storage

Samples were stored for 2 to 3 days in a cool, shaded environment, avoiding exposure to direct sunlight. This helped preserve chemical stability before analysis.

### 3.3. Instruments and Reagents Used

Digital pH Meter: Calibrated before each use with standard buffer tablets of pH 4, 7, and 9. The electrode was kept immersed in potassium chloride (KCl) solution between readings to maintain sensitivity and precision.

Complexometric Titration: Hardness was measured via EDTA titration. The reagents used included: Eriochrome Black T indicator, Ammonia buffer to maintain pH ~10, Standard EDTA solution prepared and standardized before titration

### 3.4. Hardness Analysis

The hardness of each water sample was determined using a complexometric titration method. A 0.1 M solution of disodium ethylenediaminetetraacetic acid (EDTA) served as the titrant. The buffer was prepared by dissolving 5 g of ammonium chloride in 25 mL of concentrated ammonia, then diluting it to 50 mL with distilled water. Eriochrome Black T was used as the indicator. In the presence of calcium and magnesium ions, the solution turned wine red, which shifted to green-blue at the end point, indicating complete complexation.

Results were calculated in mg/L of CaCO<sub>3</sub>, which is equivalent to parts per million (ppm). Observations were compiled into tables and bar graphs for easier interpretation and comparative visualization.

### 3.5. Theoretical Notes

The digital pH meter operates on the principle of the electrochemical potential difference between the measuring glass electrode and a reference electrode. For hardness titration, the EDTA forms stable chelates with Ca<sup>2+</sup> and Mg<sup>2+</sup> ions, allowing quantification of total hardness.

### 3.6. Precautions

#### 3.6.1. For pH measurement

- The glass electrode should remain moist when not in use.
- Gently blot the electrode with tissue; do not rub.
- Avoid trapped air bubbles in the electrode bulb.

#### 3.6.2. For hardness titration

- The ammonia buffer must be freshly prepared and tightly sealed.
- Avoid overheating or direct sunlight exposure during titration.
- Always clean and rinse the apparatus between samples to prevent cross-contamination.

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## 4. Results

**Table 1** pH Observations

River Location	pH Value
Yamuna at Mathura	8.10
Ganga at Haridwar	7.80
Saryu at Ayodhya	7.50
Triveni Sangam at Prayagraj	8.20
Gomti at Lucknow	8.15

All measured pH values fall within the acceptable range of 6.5 to 8.5 set by WHO for surface waters. This indicates that the sampled rivers are slightly alkaline, a typical trait of many Indian rivers due to mineral dissolution from rocks and soil. The values suggest a balanced aquatic environment without major acidic or basic pollutants.

**Table 2** Hardness Observations

River Location	Hardness (ppm / mg/L)
Yamuna at Mathura	185.2
Ganga at Haridwar	173.1
Saryu at Ayodhya	111.1
Triveni Sangam at Prayagraj	197.4
Gomti at Lucknow	148.1

Water hardness values ranged from 111.1 ppm to 197.4 ppm, indicating moderate to high levels of calcium and magnesium ions. Based on common water hardness classification, the Saryu River (111.1 ppm) is moderately hard, while the Yamuna, Ganga, Gomti, and Triveni Sangam all approach or exceed 180 ppm, categorizing them as hard to very hard waters.

## 5. Discussion

The physicochemical assessment of these five river systems reveals a relatively stable pH but a concerning trend of increasing hardness, particularly in rivers with higher urban or industrial proximity. These findings must be contextualized within the broader environmental challenges facing Indian rivers.

### 5.1. Environmental Impact of River Pollution

River pollution in India stems from multiple anthropogenic activities [8-9]:

- Industrial discharge, particularly from tanneries, chemical plants, and pharmaceutical industries [10-11].
- Untreated sewage and agricultural runoff, rich in nitrates and phosphates
- Cultural practices, including immersion of idols and mass bathing events
- Open defecation (though not very prominent) and solid waste dumping

These pollutants degrade water quality and contribute to:

- Mass fish deaths
- Declining populations of species like the Gangetic dolphin
- Microplastic contamination
- Algal blooms and toxic foam, as witnessed in the Yamuna during Chhath Puja

### 5.2. Human-River Interaction

Rivers serve as the backbone of livelihoods, particularly for:

- Fishing communities
- Agricultural irrigation networks
- Cultural and spiritual traditions

However, pollution has disrupted this relationship. Elevated coliform levels and heavy metal contamination pose serious health threats, including water-borne diseases and chronic exposure to toxins, particularly in vulnerable areas like Kanpur's leather industry zone.

### 5.3. Policy Efforts and Gaps

Programs such as the Yamuna Action Plan and Namami Gange Mission have made progress, especially in infrastructure development and awareness campaigns. However, persistent challenges include:

- Weak enforcement
- Public apathy
- Lack of real-time monitoring and open data

Despite these gaps, community-led cleanups and local activism offer hope. Globally successful models such as the restoration of the River Thames in the UK and Sabarmati Riverfront in India show that political will and public engagement can reverse decades of degradation.

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## 6. Conclusion

This study provided a physicochemical assessment of five Indian river systems, focusing on two critical water quality indicators: pH and hardness. All five locations showed pH values within the WHO-acceptable range, indicating a stable acid–base balance in these freshwater systems. However, hardness values revealed moderate to high levels of dissolved minerals, with several sites approaching or exceeding the threshold for very hard water.

These findings hold practical relevance for ecological health, public water use, and policy development. The measured parameters indicate a need for regular monitoring, particularly in the context of rapid urbanization and increasing pollution pressures. The results underscore that even culturally sacred rivers are not immune to environmental stressors.

Moving forward, a combination of technological intervention, policy enforcement, and community participation will be essential to sustain India's river systems. This report hopes to serve as both a scientific contribution and a call to action.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

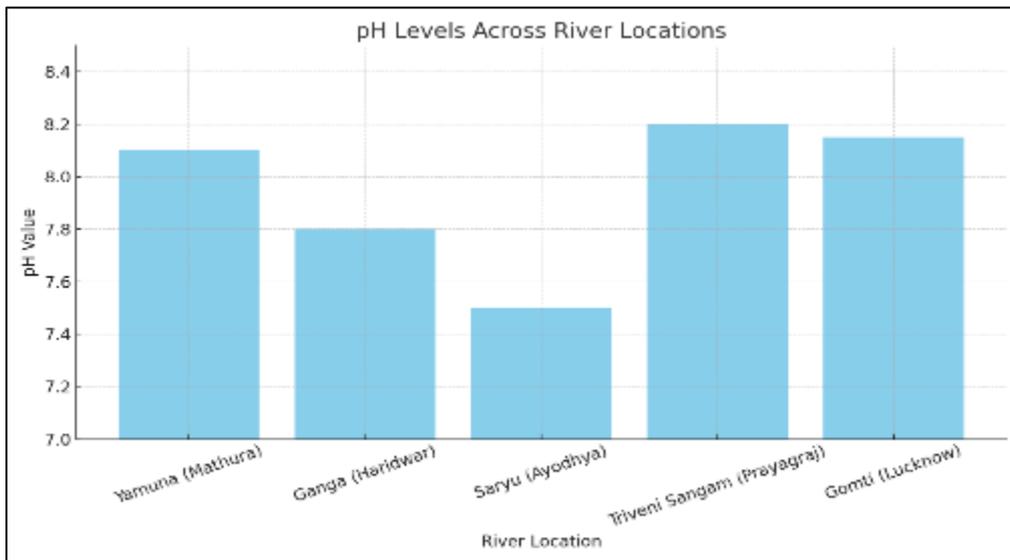
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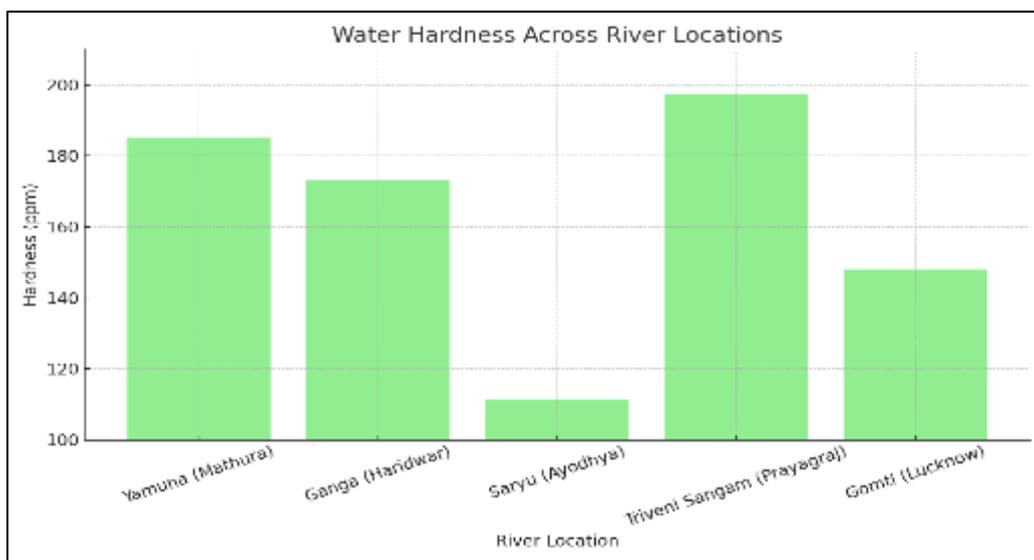
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### Annexure: Graphs



**Graph 1** pH Values Across Five River Locations



**Graph 2** Hardness Across Five River Locations