

Assessment of Groundwater Quality using Physico-Chemical Parameters: A Comprehensive Review

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Abstract— In many parts of the world, especially in developing nations, groundwater is an essential source of agricultural and drinking water. However, the quality of groundwater has drastically declined due to fast industrialization, urbanization, and agricultural activity. Some of the main reasons of its contamination are residential and commercial waste, landfills, inadequate drainage systems, seepage via sewage lines, agricultural practices including heavy fertilizer and pesticide usage, irregular rainfall, and poor management. In order to determine whether water is suitable for home, agricultural, and industrial applications, this review study examines groundwater quality using important physicochemical characteristics. In connection with the water quality standards set by the Bureau of Indian Standards, significant parameters like pH, total dissolved solids (TDS), hardness, alkalinity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrates, chlorides, sulphates, and heavy metals are examined.

Key Words: Groundwater, Dissolved solids, pH, Heavy metals, Pesticides.

1. INTRODUCTION

One of the most significant natural resources, groundwater is the world's main supplier of industrial, agricultural, and drinking water [1]. A sizable section of the populace in many developing nations, like India, relies on groundwater for everyday household requirements since it is easily accessible and reasonably priced [2]. Because groundwater naturally filters through soil and geological formations, it is typically thought to be cleaner than surface water [3]. However, its sustainability and quality have been severely impacted by growing human activity. Groundwater quality has declined as a result of rapid urbanization, industrial expansion, intensified agriculture, and inappropriate waste disposal methods. Natural geochemical processes, sewage infiltration, industrial effluents, and agricultural runoff are some of the ways that contaminants including nitrates, heavy metals, dissolved salts, and organic pollutants get into groundwater systems [4]. Agriculture, environmental stability, and human health are all seriously threatened by poor groundwater quality. Contaminated groundwater is frequently associated with methemoglobinemia (blue baby syndrome), fluorosis, waterborne illnesses, and other medical conditions [5], [6].

To ascertain if groundwater is suitable for industrial, agricultural, and drinking uses, its quality must be assessed. Because they offer quantifiable markers of chemical composition and pollution levels, physicochemical parameters are essential for assessing the quality of water [7]. pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness, alkalinity, dissolved oxygen (DO), chemical and biochemical oxygen demand (BOD and COD), chlorides, sulphates, nitrates, and the presence of heavy metals are important metrics that are often utilized. To assess water appropriateness, these criteria are contrasted with the standard norms established by the Bureau of Indian Standards [8].

It is essential to comprehend physicochemical properties in order to identify pollution patterns, evaluate potability, make sure irrigation is appropriate, and create long-term groundwater management plans [9]. Particularly in areas undergoing fast industrialization, intensive agriculture, and urbanization, ongoing observation and evaluation are crucial. Thus, assessing groundwater using physicochemical characteristics offers a scientific foundation for safeguarding water resources and guaranteeing the supply of clean water for current and future populations [4], [10].

2. SIGNIFICANCE OF PHYSICOCHEMICAL PARAMETERS IN GROUNDWATER QUALITY

Groundwater's chemical makeup, mineral content, and the existence of dissolved materials from both natural geochemical processes and human activity are all reflected in its physicochemical properties, which are essential markers of groundwater quality [4]. In addition to supporting the identification of pollution or degradation in quality, their assessment aids in determining whether groundwater is suitable for drinking and household usage [10]. The Bureau of Indian Standard IS: 10500-2012 specify the permitted limits of the physicochemical parameters of groundwater, which define its quality and appropriateness for human use [11].

2.1 Physical Parameters

These describe the observable and measurable physical characteristics of groundwater.

1. Temperature

- Influences chemical reactions, solubility of gases, and microbial activity.
- Affects dissolved oxygen and taste.

2. Color

- Indicates presence of dissolved organic matter, iron, or manganese.

3. Odour & Taste

- May indicate contamination by organic matter, hydrogen sulfide, or industrial pollutants.

4. Turbidity

- Caused by suspended particles (clay, silt, microorganisms).
- Measured in NTU.

5. Total Dissolved Solids (TDS)

- Sum of dissolved inorganic and organic substances.
- Indicator of salinity and mineralization.

6. Electrical Conductivity (EC)

- Measures ionic content of water.
- Directly related to TDS.

7. Total Suspended Solids (TSS)

- Particles not dissolved in water.

2.2 Chemical Parameters

These determine water chemistry and suitability for drinking and irrigation.

A. General Chemical Parameters

pH

- Indicates acidity/alkalinity.
- Influences solubility of metals and minerals.

Total Hardness (TH)

- Caused by calcium and magnesium.
- Expressed as CaCO_3 .

Alkalinity

- Capacity of water to neutralize acids.
- Due to bicarbonates, carbonates, hydroxides.

Dissolved Oxygen (DO)

- Indicates biological activity and organic pollution.

Biological Oxygen Demand (BOD)

- Oxygen required by microorganisms to decompose organic matter.

Chemical Oxygen Demand (COD)

- Measures total oxygen required to oxidize organic and inorganic substances.

B. Major Cations

- Calcium (Ca²⁺)
- Magnesium (Mg²⁺)
- Sodium (Na⁺)
- Potassium (K⁺)

C. Major Anions

- Chloride (Cl⁻)
- Sulfate (SO₄²⁻)
- Bicarbonate (HCO₃⁻)
- Nitrate (NO₃⁻)
- Fluoride (F⁻)
- Phosphate (PO₄³⁻)

3. TRACE AND HEAVY METALS

Important for toxicity assessment:

- Iron (Fe), Manganese (Mn), Lead (Pb), Cadmium (Cd)
- Chromium (Cr), Arsenic (As), Nickel (Ni), Zinc (Zn)
- Copper (Cu), Mercury (Hg)

4. DERIVED WATER QUALITY INDICES

Water Quality Index (WQI)

- Aggregates multiple parameters into a single value.

Sodium Adsorption Ratio (SAR)

- Important for irrigation suitability.
- Residual Sodium Carbonate (RSC)
- Permeability Index (PI)
- Kelly's Ratio (KR)
- Magnesium Hazard (MH)

5. HYDROCHEMICAL FACIES & GRAPHICAL METHODS

- Piper diagram
- Gibbs diagram
- Wilcox diagram
- Schoeller diagram

Table 1: Physical Parameters – IS 10500-2012

Parameter	Units	Test Method	WHO Acceptable Limit
pH	—	Digital electrode pH meter	6.5 – 8.5
Turbidity	NTU	Nephelometer	≤ 5 NTU
Electrical Conductivity	μS/cm	Digital conductivity meter	1500 μS/cm
Temperature	°C	Analytical thermometer	5°C – 20°C

Table 2: Chemical Parameters – IS 10500-2012

Parameters	Units	Acceptable Limit	Permissible Limit
Calcium	mg/L	75	200
Chloride	mg/L	250	1000
Magnesium	mg/L	30	100
Nitrate	mg/L	45	—
Total Alkalinity	mg/L	200	600
Sulphate	mg/L	200	400

6. METHODOLOGY

The present study was carried out to assess the groundwater quality in Rooma, Kanpur, through systematic sampling and analysis of various physico-chemical parameters. A well-structured methodology was adopted to ensure the accuracy, reliability, and representativeness of the results. The study area was first surveyed to understand the geographical setting, land use pattern, and possible sources of contamination such as residential discharge, agricultural runoff, and improper waste disposal. Based on these observations, suitable sampling locations were selected to cover different zones of the study area, ensuring a comprehensive evaluation of groundwater quality.

6.1 Sample Collection

Groundwater samples were collected from various sources including hand pumps, bore wells, and tube wells, which are commonly used for drinking and domestic purposes. Standard procedures were followed during sampling to avoid contamination and to maintain the integrity of the samples. Clean and sterilized polyethylene or glass bottles were used for sample collection, and proper precautions were taken such as rinsing the containers with distilled water and sample water prior to collection. Water was allowed to flow for a few minutes before sampling to obtain fresh and representative samples. Each sample was carefully labeled with necessary details such as location, date, time, and source, and field observations like color, odor, and temperature were recorded at the time of collection.

6.2 Sample Preservation and Transportation

After collection, the samples were preserved under controlled conditions to prevent any physical, chemical, or biological changes. The samples were stored at low temperatures (around 4°C) using iceboxes and were transported promptly to the laboratory for analysis. In certain cases, appropriate preservatives were added depending on the parameter to be analyzed, following standard guidelines. Parameters such as pH and temperature were measured at the site to avoid variations during transportation. All procedures were conducted in accordance with standard methods to ensure consistency and reliability of results.

6.3 Laboratory Analysis

The collected samples were then analyzed in the laboratory for various physico-chemical parameters including pH, Total Dissolved Solids (TDS), turbidity, alkalinity, hardness, chloride, nitrate, calcium, and magnesium. The obtained results were compared with standard permissible limits to evaluate the suitability of groundwater for drinking and domestic purposes. The data were systematically recorded, interpreted, and presented in tabular and graphical forms for better understanding. Thus, the adopted methodology provided a comprehensive framework for assessing groundwater quality and identifying potential issues affecting water safety in the study area.

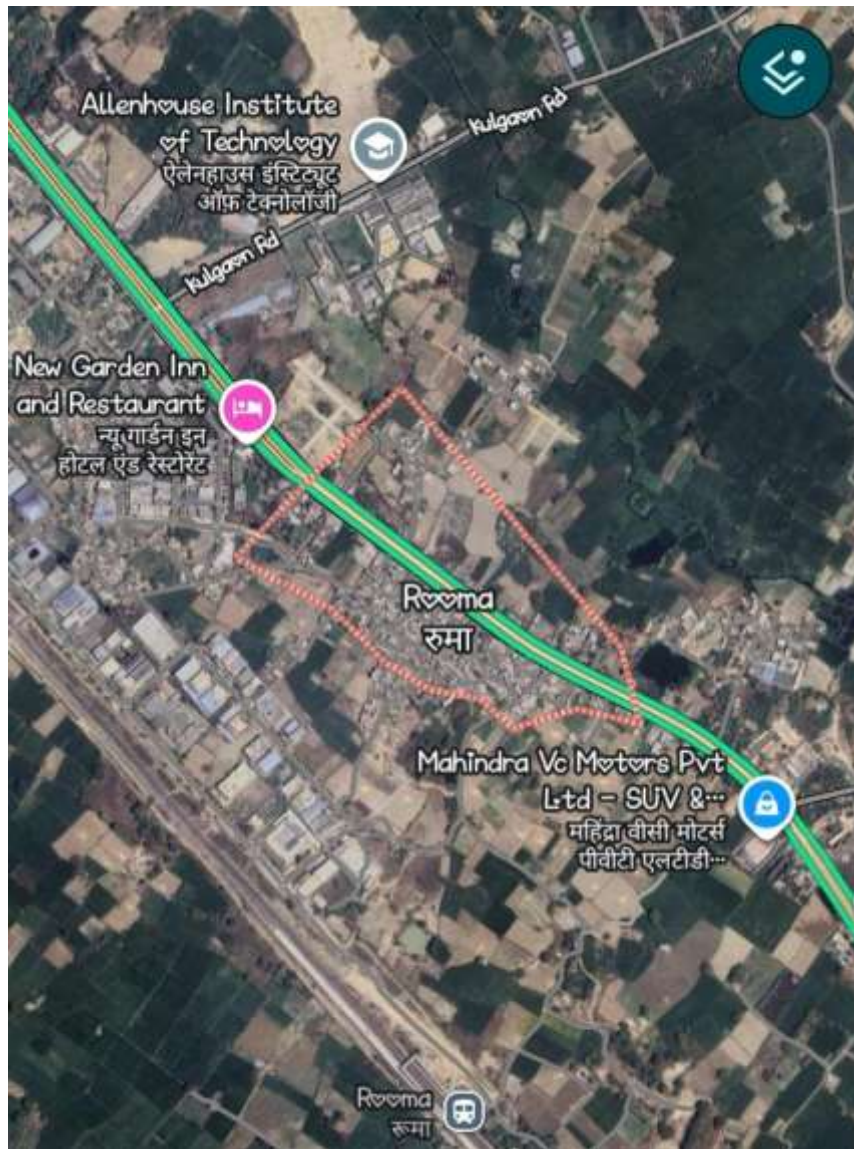


Fig. 1: Satellite View of the Study Site – Roama, Kanpur

7. RESULTS AND DISCUSSION

The physicochemical analysis of water samples (Sample 1 to Sample 5) was carried out for parameters such as pH, TDS, temperature, hardness, chloride, fluoride, nitrate, magnesium, alkalinity, and turbidity. The results indicate that the pH of all samples is slightly alkaline, while TDS values fall within a moderate and acceptable range. Hardness and alkalinity levels are observed to be moderate to high, reflecting the presence of dissolved minerals in the water. Chloride and magnesium concentrations are relatively higher in some samples but remain within permissible limits. Fluoride and nitrate levels are found to be within safe limits, making the water suitable for consumption. Additionally, turbidity values are low across all samples, indicating good clarity of water.

Table 3: Physicochemical Parameters of Groundwater Samples – Rooma, Kanpur

PARAMETER	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	UNIT	MEAN (AVG.)
pH	7.2	7.4	7.3	8.4	8.9	–	7.84
TDC	220	265	250	170	180	mg/L	217.0
TEMP	20	23	25	23	22	°C	22.6
TOTAL HARDNESS	120	145	140	106	118	mg/L as CaCO ₃	125.8
CHLORIDE	60	80	100	80	160	mg/L	96.0
FLUORIDE	0.5	0.2	0.6	0.5	0.3	mg/L	0.42
NITRATE	5.0	5.0	0.5	2.5	0.5	mg/L	2.7
MAGNESIUM	130	125	117	126	117	mg/L	123.0
ALKALINITY	250	350	525	350	250	mg/L as CaCO ₃	345.0
TURBIDITY	0.6	0.7	0.8	0.5	0.9	NTU	0.70

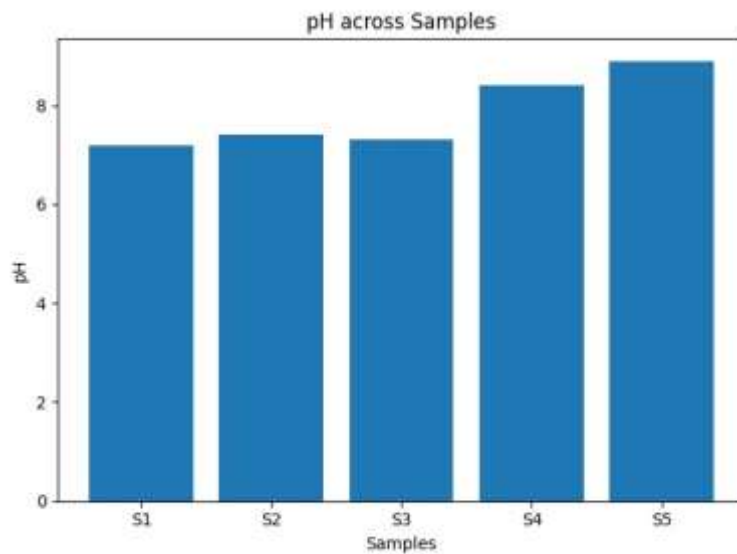


Fig. 2: pH across Samples

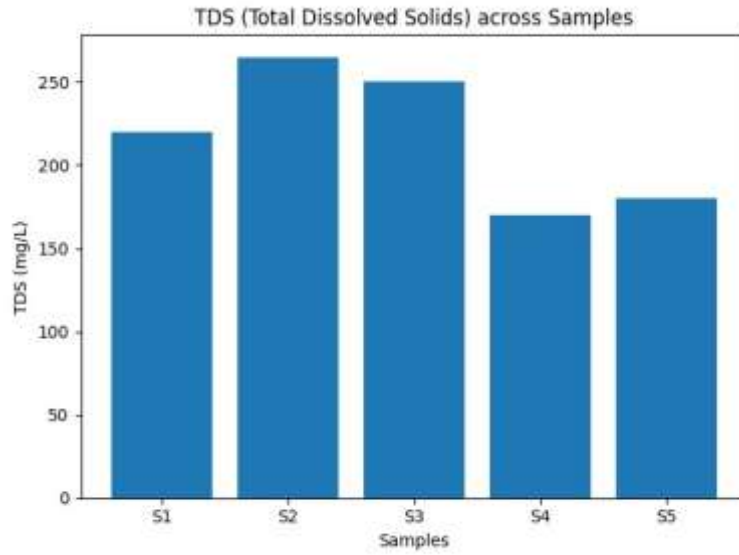


Fig. 3: TDS (Total Dissolved Solids) across Samples

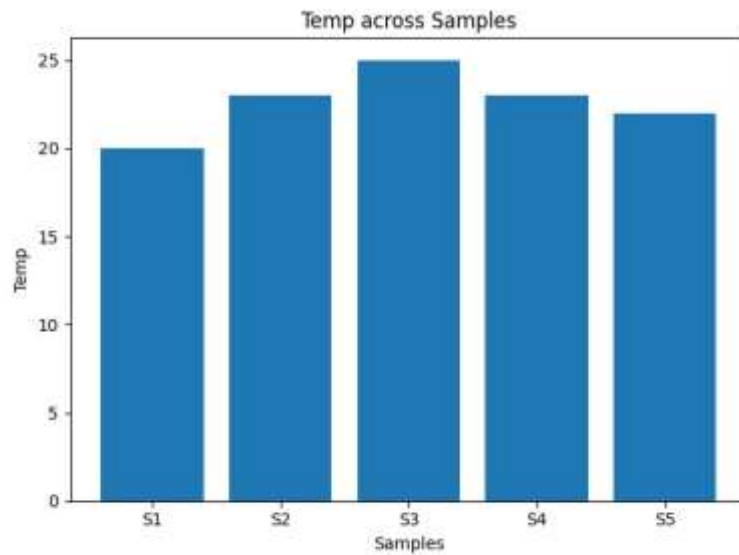


Fig. 4: Temperature across Samples

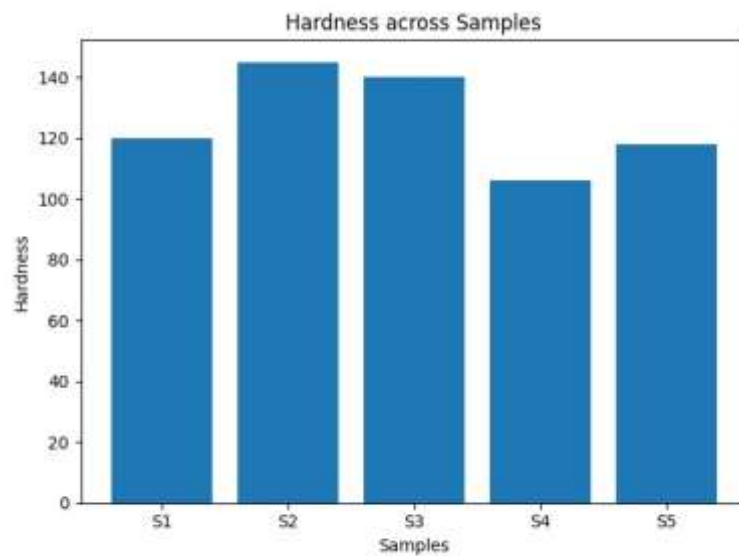


Fig. 5: Total Hardness across Samples

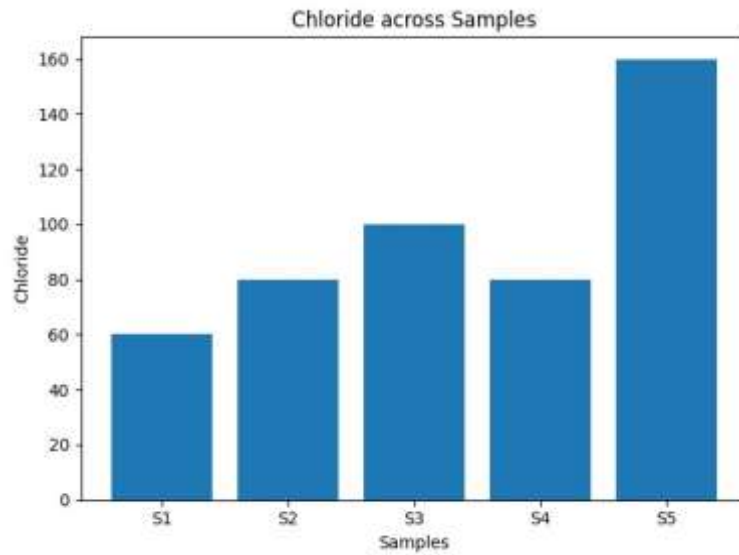


Fig. 6: Chloride across Samples

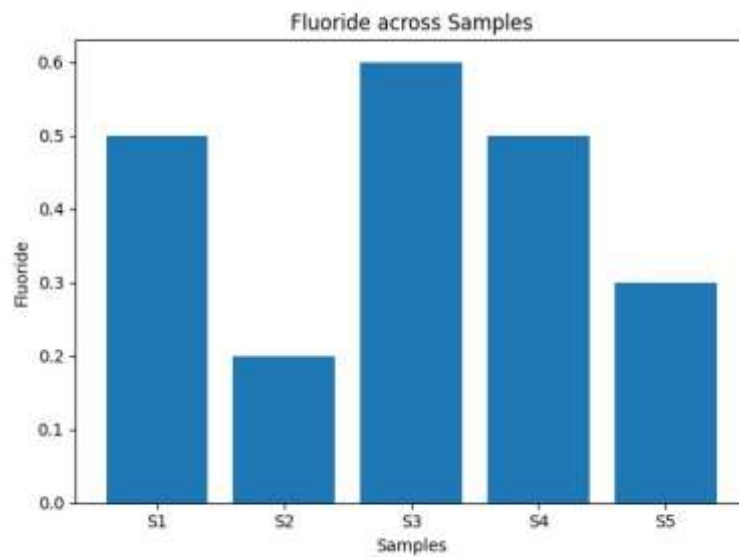


Fig. 7: Fluoride across Samples

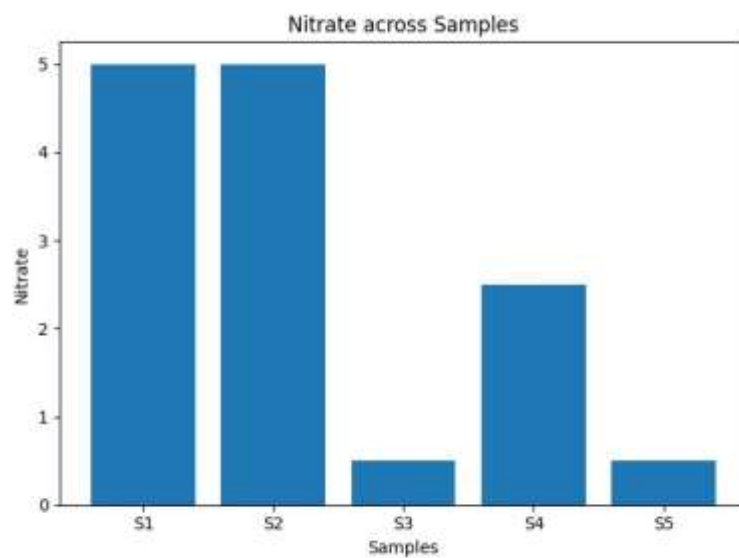


Fig. 8: Nitrate across Samples

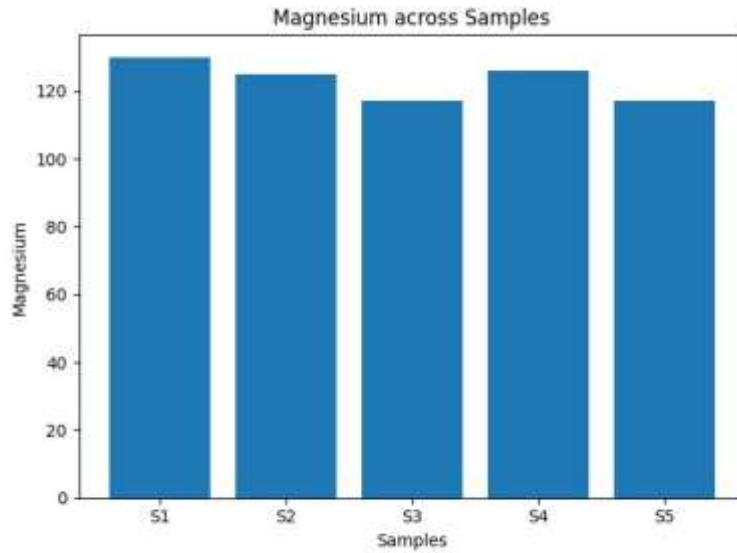


Fig. 9: Magnesium across Samples

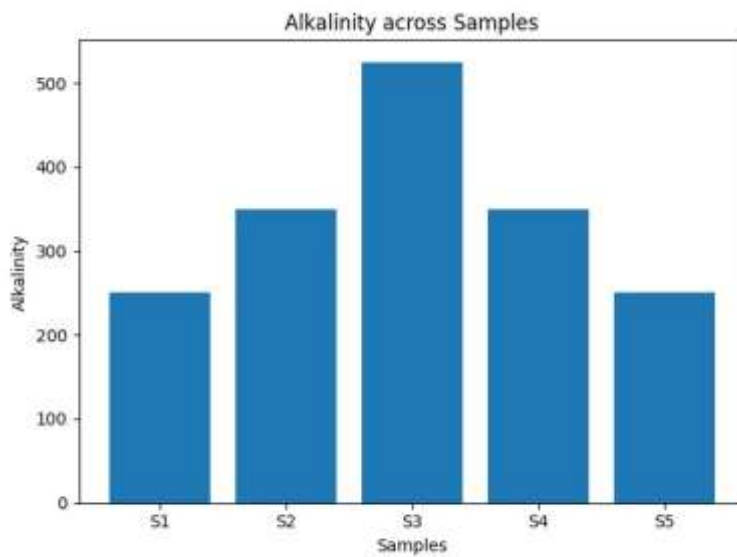


Fig. 10: Alkalinity across Samples

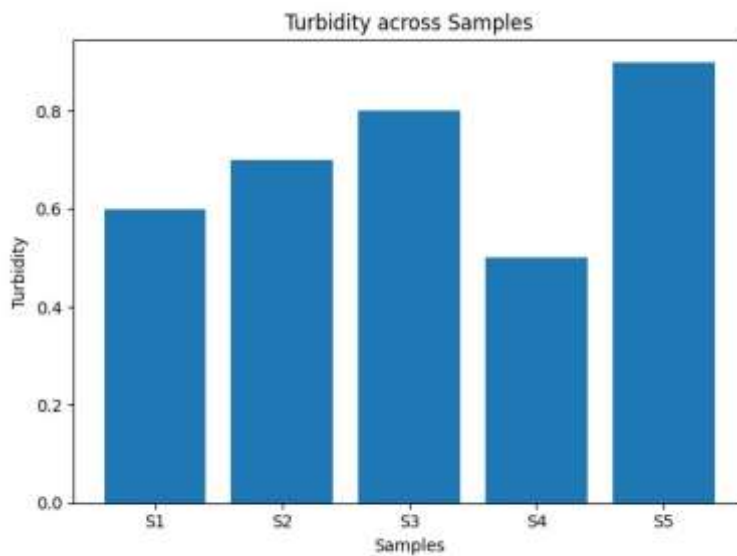


Fig. 11: Turbidity across Samples

8. CONCLUSION

The findings of this study reveal a complex and concerning picture of groundwater quality in the Rooma area of Kanpur. While some physico-chemical parameters, such as pH, TDS, and chloride, remained within acceptable limits, several

critical indicators—particularly total hardness, alkalinity, and arsenic levels—consistently exceeded safe thresholds. This indicates a growing chemical burden in the local aquifer, likely driven by unregulated industrial activity and inadequate environmental safeguards.

What makes the situation more alarming is the biological assessment, which, although showing relatively low levels of microbial contamination, exposed seasonal spikes in bacterial load—especially during and after the monsoon season. Even these low or moderate microbial presences are unacceptable in drinking water, especially for vulnerable populations like children and the elderly. Such contamination hints at leakages from sanitation systems, surface runoff, or poor infrastructure hygiene, all of which reflect systemic neglect.

The recurring presence of arsenic in elevated concentrations, along with episodic increases in fluoride, poses a long-term public health threat. These toxic elements are linked to irreversible conditions, including skin disorders, bone deformities, and various cancers. If left unchecked, continued reliance on this water source without treatment could silently fuel chronic health crises in the region.

While the groundwater in Rooma remains a vital lifeline for the local community, its quality is under serious stress from both industrial pollutants and microbial threats. Microbial safety is moderate but unstable, warranting seasonal chlorination or UV treatment. High arsenic levels demand immediate community-level awareness and installation of arsenic filters or alternative water sources. Policy-level interventions for industrial waste regulation and source-wise water quality zoning are urgently needed. In addition, there is an urgent need for regular, multi-parameter monitoring, community-level awareness, and sustainable water management strategies. Safe drinking water should not be a privilege—it is a basic right. For Rooma, that right can only be protected through science-backed policies, better infrastructure, and community participation in safeguarding this essential resource.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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