Drink-fit Analysis of Gomti River Water: Impact of Seasons and Flow Dynamics

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Abstract: The river Gomti is a lifeline for Lucknow, playing a vital role in the city's socio-economic and cultural fabric. The river's water quality undergoes dynamic changes throughout the year due to seasonal variations and anthropogenic activities. Research was carried out to investigate the water quality of Gomti River during the pre-monsoon, monsoon, and post-monsoon periods to understand the temporal variations and identify potential environmental challenges in approximately 14 Km. The samples were collected from 9 major points. To understand the water quality, physicochemical parameters were identified via the examination of pH, temperature, turbidity, total dissolved solids, Total hardness, chloride, fluoride, DO, BOD, COD, E.Coli and Total Coli. Data has been compared with existing data and qualitative correlation has been found between season dynamics with E.Coli concentration. The research survey has determined that a significant portion of pollution in the Gomti River originates from numerous drains discharging untreated industrial and domestic waste directly into the river. As a result, the physico-chemical and microbiological quality of the Gomti River is poor, rendering it unsafe and unsuitable for any use. The findings showed that the River Gomti water needs emergent river restoration initiatives by the local communities, the policymakers, and environmental agencies residing in Lucknow city for the sustainable water resource management and environmental conservation of River Gomti.

Keywords: Water quality assessment, physicochemical parameters, sustainable water resource management, environmental conservation.

1.0 Introduction

Water, essential for life, is critical for maintaining ecosystems, human health, and economies. Rivers, as vital freshwater sources, support biodiversity and agriculture but are threatened by pollution, impacting their quality and balance.[1-11] In this regard, the Gomti River in Lucknow City, Uttar Pradesh, India, renowned for its cultural significance and vital role in sustaining livelihoods, faces growing pollution from urban runoff, drainage effluents, and agricultural runoff.[12-21] Addressing these issues requires comprehensive water quality assessments across different seasons. This research aims to evaluate the Gomti River's water quality during pre-monsoon, monsoon, and post-monsoon periods, providing insights into the spatio-temporal variability of pollutants and their effects on environmental and human health. Through detailed analysis of water quality data, the study seeks to inform evidence-based management strategies to preserve the river's ecological integrity and usability. By highlighting the complex relationship between human activities and water quality changes,[22-25] this research underscores the need for sustainable river management practices.The findings are expected to guide policymakers, stakeholders, and local communities in protecting the Gomti River, contributing to the global effort to ensure water security and environmental resilience.

2.0 Methodology

2.1 Study Area

The Gomti River, also known as Gumti or Gomati, is an alluvial tributary of the Ganges, linked to Hindu mythology as sage Vashist's daughter. Bathing in it during Ekadashi is believed to cleanse sins. Originating from GomatTaal, formerly FulhaarJheel near MadhoTanda in Pilibhit, India, it flows 900 km through Uttar Pradesh, meeting the Ganges in Ghazipur. Cities like Lucknow, LakhimpurKheri, Sultanpur, and Jaunpur lie along its banks. After 240 km, the Gomti enters Lucknow city, where it meanders for approximately 14 km. Presently the river, crucial for water supply in Lucknow, faces pollution from sewage, industrial effluents, and agricultural runoff, alongside urbanization and encroachments.[26-30] Despite these issues, it remains culturally significant. Figure 1 shows the area map of our sampling locations.

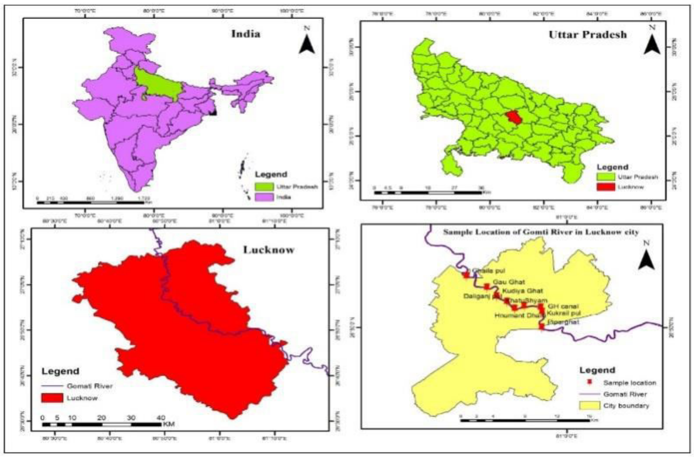

Figure 1: Area Map of Sampling Locations in the Gomti River, Lucknow City, Uttar Pradesh, India

2.2 Site Description

The research zone encompasses a segment of the Gomti River within Lucknow city, Uttar Pradesh, spanning from latitude 26.88682 to 80.899846 N and longitude 26.902311 to 80.874136 E.[19-27]Nine distinct sites have been chosen for sampling and analysis to conduct a comprehensive examination of the physicochemical and biological aspects during pre-monsoon, monsoon and post-monsoon in the middle of the Gomti River in Lucknow city. Coordinates of each sample point location were recorded in the field through handset GPS. Work Plan of the study is shown inFigure 2.

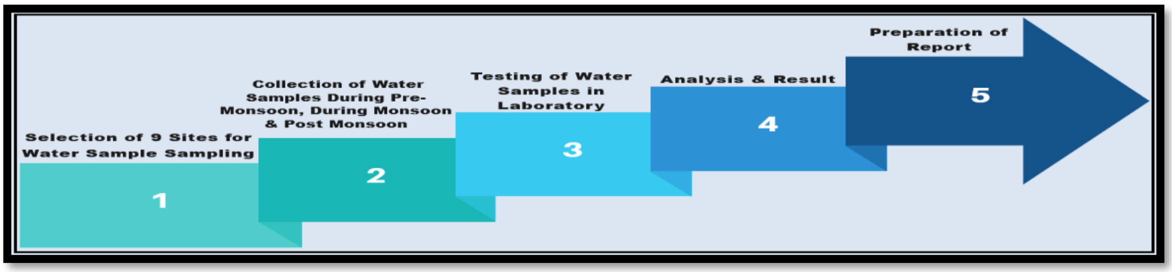

Figure 2: Flow Chart of the Work Plan During Study

Table 1: 9 Different SampleCollection Sites within The Study Area Gomti River

1 Ghaila Pul	4 Daliganj Pul	7 Kukrail
2 Gaughat	5 Hanumat Dham	8 Gh Canal
3 Kudiaghat	6 Khatushayam	9 Pipraghat

2.3 Sample Collection and Methodical Procedures

Water samples were collected during pre-monsoon, monsoon, and post-monsoon periods from nine sites in the Gomati River using pre-cleaned 1000mL tarson containers. Heavy brackets were used to submerge the buoyant glass or polyethylene bottles. A sampler collected water from specific depths by removing the stopper once at the desired depth. Once lowered to the desired depth, the sampler's stopper was removed with a jerk. To prevent air interaction, samples were sealed tightly, maintaining stability and minimizing chemical changes. By doing so, it prevents alterations in carbon dioxide levels, maintains the stability of hydrogen carbonates without converting them into precipitable carbonates, reduces the oxidation of iron, thus preventing color changes, and so forth. Dissolved oxygen, sulfides, residual chlorine, nitrite, and pH were fixed on-site. Other samples were preserved promptly for further testing. Heavy metals such as manganese (Mn), cadmium (Cd), lead (Pb), chromium (Cr), etc. were not tested due to the limitations of the laboratory. The APHA-AWWA-WPFC (23rd edition) guidelines were followed to ensure accurate sampling and analysis, excluding heavy metals due to lab limitations. The sampling location sites are shown in Figure 2 & Table 1.
Each sample bottle was tightly capped to prevent leakage and contamination during handling and transport. Bottles were labeled with date, location, and water source for accurate identification during analysis. Samples were kept cold and transported to the

lab, where they were stored at 4°C until final analysis. Twelve parameters were measured, including pH, temperature, turbidity, TDS, COD, DO, total hardness, chloride, fluoride, BOD, E. Coli, and total coliforms. In-situ measurements of pH, temperature, and DO were taken with a multiparameter instrument and DO meter. Physicochemical tests were performed within 48 hours, including turbidity, BOD, COD, TDS, and chloride titration. The turbidity of each sample was examined using a digital turbidity meter (Model—Metzer-M) immediately after it was escorted into the research laboratory. The TDSs was measured via a gravimetric analysis at temperatures ranging from 100 ◦C to 110 ◦C. EDTA titration was used to determine the total hardness. Results were compared to Indian drinking water standards (BIS 2012).) Table 2 & 3.

Table 2: Water Quality Parameters Collected from Sample Sites

Water Quality Parameters Collected From Ghaila – Pipraghat During Pre-Monsoon, Monsoon & Post- Monsoon

pH	Temperature	Turbidity
TDS	Hardness	Chloride
Fluoride	DO	BOD
COD	E. Coli	Total Coli

Table 3: The Drinking Water Guidelines Recommended by the Bureau of Indian Standards

S. No.	Parameter	Permissible Limit	S. No.	Parameter	Permissible Limit
1.	pH	6.5 - 8.5	7.	Fluoride	1-1.5 mg/l
2.	Temperature	20^0 C	8.	DO	above 3 mg/L
3.	Turbidity	1-5 NTU	9.	BOD	below 2 mg/L
4.	Total Dissolved Solids	500 mg/l	10.	COD	200 mg/L
5.	Total Hardness	50 - 300 mg/l	11.	E Coli	0 CFU/100 ml
6.	Chloride	250 mg/l	12.	T. coliform	0 CFU/100 ml

3.0 ResultsandDiscussion

The laboratory analyses of the water quality samples taken from the sample sites during pre, during and post-monsoon are summarized below along with tables4 & 5.

Table 4: Various Physio-Chemical and Biological Parameters Analyzed at the Global Environmental Consultancy and Research Centre in Lucknow, Uttar Pradesh, India

		GHAILA	GAUGHAT	KUDIAGHAT	DALIGANJ	HANUMAT DHAM	KHATUSHAYAM	KUKRAIL	GH CANAL	PIPRAGHAT
pH	Pre	7.82	7.87	7.69	6.72	7.49	7.47	7.41	7.55	7.7
	Monsoon	7.68	7.59	7.79	7.87	7.48	8.16	7.46	7.6	8.32
	Post	7.23	7.23	7.11	7.02	6.96	7.13	7.03	7.11	7.32
Temperature	Pre	25.2	25	24.8	25.0	25.1	25.3	25.2	25.1	25.1
	Monsoon	25.8	25.8	25.1	25.9	25.4	26.3	26	25.5	25.6
	Post	18.2	16.2	17.5	16.8	17.6	18.1	16.3	17.1	16.9
Turbidity	Pre	3.0	2.0	3.0	3.0	4.0	4.0	4.0	8.0	3.0
	Monsoon	4.0	3.0	4.0	5.0	3.0	3.0	5.0	6.0	5.0
	Post	3.0	4.0	5.0	3.0	4.0	5.0	6.0	3.0	4.0
Total Dissolved Solids	Pre	260.0	280.0	380.0	400.0	400.0	380.0	340.0	680.0	430.0
	Monsoon	160.0	160.0	320.0	160.0	280.0	240.0	320.0	280.0	280.0
	Post	200.0	180.0	340.0	220.0	300.0	260.0	340.0	300.0	260.0
Total Hardness	Pre	202.0	208.0	252.0	250.0	300.0	270.0	248.0	312.0	248.0
	Monsoon	101.0	98.9	105.0	105.0	38.3	64.6	109.0	50.5	38.3
	Post	208.0	182.0	202.0	210.0	206.0	180.0	200.0	190.0	184.0
Chloride	Pre	12.5	13.5	20.0	25.0	29.0	25.0	22.5	45.0	35.0
	Monsoon	10.0	9.0	11.0	11.9	30.1	15.7	19.6	18.1	30.1
	Post	21.5	16.5	35.5	19.5	16.5	13.5	22.0	28.5	14.0

Table 5: Various Physio-Chemical and Biological Parameters Analyzed at the Global Environmental Consultancy and Research Centre in Lucknow, Uttar Pradesh, India

Fluoride	Pre	0.3	0.4	0.6	0.5	0.6	0.3	0.4	0.4	0.5
	Monsoon	0.5	0.6	0.7	0.6	0.5	0.4	0.6	0.5	0.7
	Post	0.6	0.5	0.4	0.7	0.6	0.5	0.7	0.5	0.6
DO	Pre	3.8	3.6	3.2	3.8	3.1	3.1	3.4	3.1	3.2
	Monsoon	4.2	4	4.4	4.2	3.8	3.6	3.2	4	3.8
	Post	3.8	4.0	3.6	4.2	4.0	3.2	4.2	4.4	3.8
BOD	Pre	15.0	12.4	13.7	15.1	18.4	14.4	12.9	16.8	16.0
	Monsoon	39.5	37.8	37.6	42.2	38.2	37.5	42.2	35.2	35.5
	Post	18.6	20.8	21.1	28.5	20.6	26.3	24.1	21.2	29.7
COD	Pre	68.4	62.0	72.0	75.6	92.0	76.0	68.0	84.0	80.0
	Monsoon	194.4	205.2	194.4	205.2	219.6	216.0	205.2	208.8	216.0
	Post	70.6	76.0	84.0	96.0	72.0	92.0	88.0	80.6	99.8
E Coli	Pre	300.0	75.0	200.0	490.0	365.0	20.0	240.0	450.0	495.0
	Monsoon	400.0	150.0	250.0	600.0	400.0	100.0	280.0	480.0	520.0
	Post	600.0	100.0	400.0	280.0	480.0	150.0	250.0	520.0	400.0
T. coliform	Pre	450.0	200.0	250.0	500.0	480.0	95.0	364.0	630.0	669.0
	Monsoon	550.0	300.0	400.0	660.0	520.0	250.0	400.0	700.0	740.0
	Post	660.0	250.0	520.0	400.0	700.0	300.0	400.0	740.0	550.0

3.1 *pH:*

pH measures water acidity or alkalinity, ranging from 0 to 14. A pH of 7 is neutral, below 7 is acidic, and above 7 is alkaline. Pre-monsoon pH levels range from 6.72 to

7.87, indicating slightly acidic to neutral conditions. Monsoon pH increases to 7.46 to 8.32, suggesting alkalinity due to increased water flow and dilution. Post-monsoon pH stabilizes between 6.96 and 7.32, returning to slightly acidic to neutral (Figure 3& 4). These variations reflect seasonal changes influenced by precipitation, runoff, and organic matter decomposition. Regular pH monitoring is crucial for assessing water quality and ecosystem health in the Gomti River.

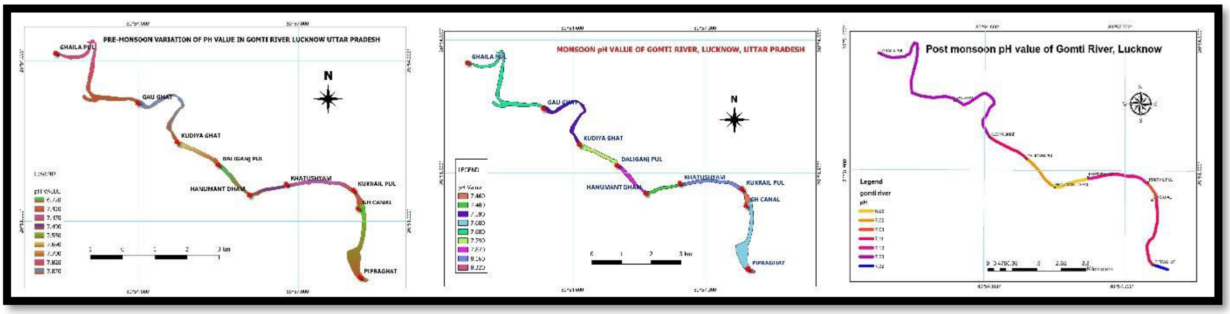

Fig 3: Pre-Monsoon, Monsoon &Post-Monsoon pH Value of Gomti River, Lucknow, Uttar Pradesh, Source-Field Work

3.2 *Temperature*:

Gomti River's surface water temperature ranges from 16.2°C to 26.3°C during pre-monsoon, monsoon, and post-monsoon periods, exceeding BIS standards during pre-monsoon and monsoon due to increased solar radiation and air temperature. Post-monsoon temperatures drop below the standard (Figure 5). These fluctuations may impact water quality and aquatic ecosystems, affecting organisms, though they pose no direct health risk to humans.

3.3 *Turbidity:*

Turbidity measures water clarity, affected by particles like sediment and organic matter. Pre-monsoon turbidity ranges from 2.0 to 8.0 NTU. Monsoon and post-monsoon levels range from 3.0 to 6.0 NTU (Figure 6). These variations indicate different levels of suspended particles across seasons. High turbidity can reduce light penetration, impacting photosynthesis and aquatic habitats, necessitating continuous monitoring.

3.4 Total Dissolved Solids:

Total Dissolved Solids (TDS) indicate inorganic and organic substances in water. Pre-monsoon TDS levels range from 260.0 to 680.0 mg/L, indicating potential water quality concerns. Monsoon levels decrease to 160.0-320.0 mg/L due to dilution from precipitation. Post-monsoon levels stabilize at 180.0-340.0 mg/L (Figure 7). TDS variations, influenced by precipitation and runoff, affect water taste, appearance, and suitability for drinking and irrigation, impacting water quality and aquatic life.

Fig 6-15: Graph of Different Parameters Collected at Nine Sites During Pre-Monsoon, Monsoon & Post-Monsoon

3.5 *Total Hardness:*

Total Hardness in the Gomti River varies seasonally. Pre-monsoon levels range from 202.0 to 312.0 mg/L, indicating high hardness. Monsoon levels decrease due to rainfall dilution, while post-monsoon levels rise to 180.0-210.0 mg/L (Figure 8). Seasonal changes are influenced by precipitation, runoff, and geology. High hardness indicates high dissolved minerals, primarily calcium and magnesium, unsuitable for various uses.

3.6 Chloride:

Chloride, a vital nutrient for humans and aquatic life, varies in the Gomti River. Pre-monsoon levels range from 12.5 to 45.0 mg/L, within acceptable limits. Monsoon levels decrease to 9.0-30.1 mg/L due to rainfall dilution. Post-monsoon levels rise to 13.5-35.5 mg/L, influenced by water flow changes and pollutants (Figure 9). High concentrations suggest industrial effluents, posing health and environmental risks.

3.7 Fluoride:

Fluoride, a naturally occurring mineral in water, varies in the Gomti River. Pre-monsoon levels range from 0.3 to 0.6 mg/L, staying within acceptable limits. Monsoon and post-monsoon levels slightly increase to 0.4 to 0.7 mg/L (Figure 10), influenced by water flow changes and mineral leaching. High levels can cause dental and skeletal fluorosis.

3.8 Dissolved Oxygen:

Pre-monsoon DO levels range from 3.1 to 3.8 mg/L, indicating oxygen depletion likely due to organic matter decomposition and low water flow. Monsoon levels slightly increase to 3.2 to 4.2 mg/L due to enhanced aeration from rainfall-induced turbulence.

Post-monsoon levels stabilize at 3.2 to 4.4 mg/L (Figure 11). DO levels are critically low, with the highest upstream and significant declines downstream, suggesting heavy pollution from various discharges and human activities throughout the year.

3.9 Biological Oxygen Demand:

Biological Oxygen Demand (BOD) measures the oxygen consumed by microorganisms decomposing organic matter in water. Pre-monsoon BOD levels range from 12.4 to 18.4 mg/L, monsoon levels from 35.2 to 42.2 mg/L, and post-monsoon from 18.6 to 29.7 mg/L (Figure 12). Elevated BOD levels deplete oxygen, indicating ongoing pollution from sewage, agricultural runoff, and industrial effluents, threatening water quality and aquatic health. Effective pollution control measures are essential to mitigate these environmental impacts.

3.10 Chemical Oxygen Demand:

Chemical Oxygen Demand (COD) measures the oxygen needed to oxidize organic and inorganic compounds in water. Pre-monsoon COD levels range from 62.0 to 92.0 mg/L, monsoon levels rise to 194.4-219.6 mg/L, and post-monsoon levels range from 70.6 to 99.8 mg/L (Figure 13). High COD indicates pollutants and toxic substances from industrial effluents, agricultural runoff, and sewage discharge, harming water quality and aquatic ecosystems.

3.11 E. Coli:

Escherichia coli (E. coli) indicates fecal contamination in water. Pre-monsoon levels range from 20.0 to 495.0 CFU/100 ml, monsoon levels from 100.0 to 520.0 CFU/100 ml, and post-monsoon from 150.0 to 600.0 CFU/100 ml (Figure 14). These increases, due to runoff, suggest continued sewage and agricultural contamination, posing health risks. The elevated E. coli levels indicate ongoing contamination from sewage discharge and agricultural runoff. E. coli levels in the Gomti River are alarmingly high, revealing fecal matter and potential pathogens, which signify poor water quality and health risks throughout different seasons (Figures 14 & 16).

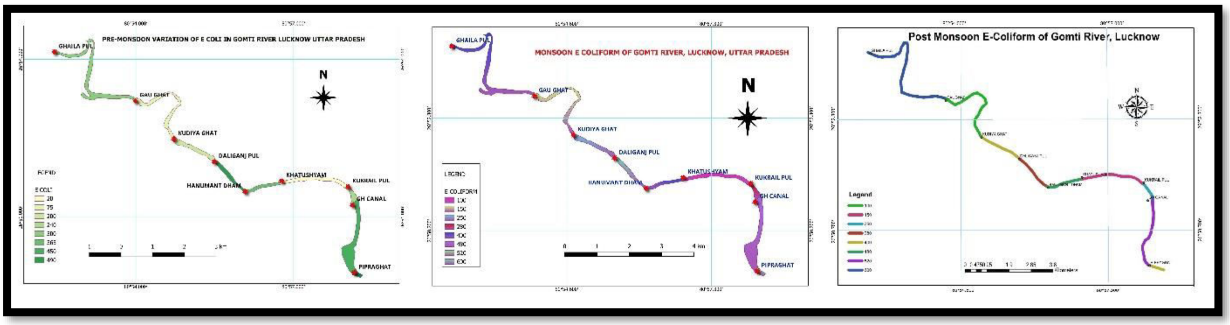

Fig. 16: Pre-Monsoon, Monsoon & Post-Monsoon E. Coliform of Gomti River, Lucknow, Uttar Pradesh

3.12 Total Coli:

Total Coliforms are a group of bacteria commonly found in the intestines of warm-blooded animals and are used as indicators of faecal contamination in water which are increasing due to sewage and runoff. Pre-monsoon levels ranged from 95.0 to 669.0 CFU/100 ml, monsoon from 250.0 to 740.0 CFU/100 ml, and post-monsoon from 250.0 to 700.0 CFU/100 ml (Figure 15). High levels indicate poor water quality and health risks. Across different seasons elevated levels of Total Coliforms suggest the presence of fecal matter and potential pathogens, indicating poor water quality and posing risks to human health carried by sewage discharge agricultural runoff and open defecation.

Table 6 Contamination Profiles of Water by E.Coli from vulnerability proxies[h]

Vulnerability proxy								
Wastewater input								
Receiving water						Human or bovine source		
Surface water (x^a)	Water contamination profile	Conductivity ($\mu S \cdot cm^{-1}$)	Salinity (min - max)	SPM (g-liter^{-1}	DOM (mg · liter $^{-1}$)	Distance from the closet discharge	Amt of rainfall 9mo	e.coli density [SD] 9CFU-100ML^{-1}) (min-max)^C
Creek water (1)	1	345	0	0.01	0.1	400 m	0	$6.2[\pm0.6]*10^2$(NR)
	2	557	0	0.07	ND		50^e	$4.0[\pm0.7]*10^2$(NR)
River (4)	3	531	0	1.1	< 0.5	6 km upstream	10^g	$2.0[\pm0.3]*10^2$ ($2.0*10^2$ – $4.0*10^3$)
anthropized(8)	4	7,500	0.3 (0-25)	0.74	3.16	1 km	10^g	$1.5[\pm0.2]*10^2$($3.0*10^1$-$5.0*10^4$)

[a] x, Strahler stream order.

[b] Treated effluent from wastewater treatment plant.

[c] Min-max (minimum-maximum) data were collected during 4 years of bimonthly sampling.

[d] There was one malfunctioning septic tank located 400 m from the samplinog point.

[e] Rainfall event on day of sampling.

[f] Confluence river-estuary sampling during low tide.

[g] Three days before sampling river-estuary confluence.

[h] SPM, suspended particulate matter; DOM, dissolved organic matter; NR, not relevant; ND, not determined.

This table indicates the concentration of E.*Coli*in various water bodies under multiple parameter variations.This table indicates data and concentration of E.*Coli,* under various parameters. Comparing with our dataand data found in this paper [23-24]. We find that Ph is higher than what is required for survival of E.*Coli*at all locations pre-, post, and during monsoon. *E.Coli*concentration increases in post-monsoon. Concentration will drop drastically during monsoon even when compared with pre-monsoon period.

A similar trend is seen for TDS, turbidity, and hardness. This trend is inverse for temperature.

4.0 Conclusion

The experimental findings revealed seasonal variations in pH and temperature levels. Dissolved oxygen levels across all samples were below the required standard value. TDS, total hardness, chloride, fluoride, BOD, COD, E. coli, and T. coliform data exceeded the standard limits for river water due to an increase in organic pollutants as the river passes through the city. Deteriorating water quality and river health are primarily attributed to untreated discharge from industries, domestic sewage and Rapid urbanization which exacerbates river water pollution. During summer, water quality significantly declines due to reduced river flow, while monsoon runoff carries faecal matter and pollutants from various sources.

Mitigating steps, including proper management of sewage and industrial waste discharge, are imperative. The river's highly polluted state necessitatesregular monitoring of parameters' variations for understanding seasonal trends, assessing water suitability environmental surveillance, public awarenessgauging impacts on ecosystems and human health and conventional treatments before beneficial use. Removing silt from the riverbed and revitalizing methods could help maintain minimum dilution flow. Urgent action is needed to mitigate contamination sources, improve sanitation practices to reduce contamination sources and manage water resources for public health and GomtiRiver water safety.The analysis underscores that there is an urgent need to safeguard the Gomti River through these actions which will not only enhance the quality of river water but also safeguard aquatic ecosystems, and ensure the preservation of the Gomti River's ecological integrity for present and future generations.

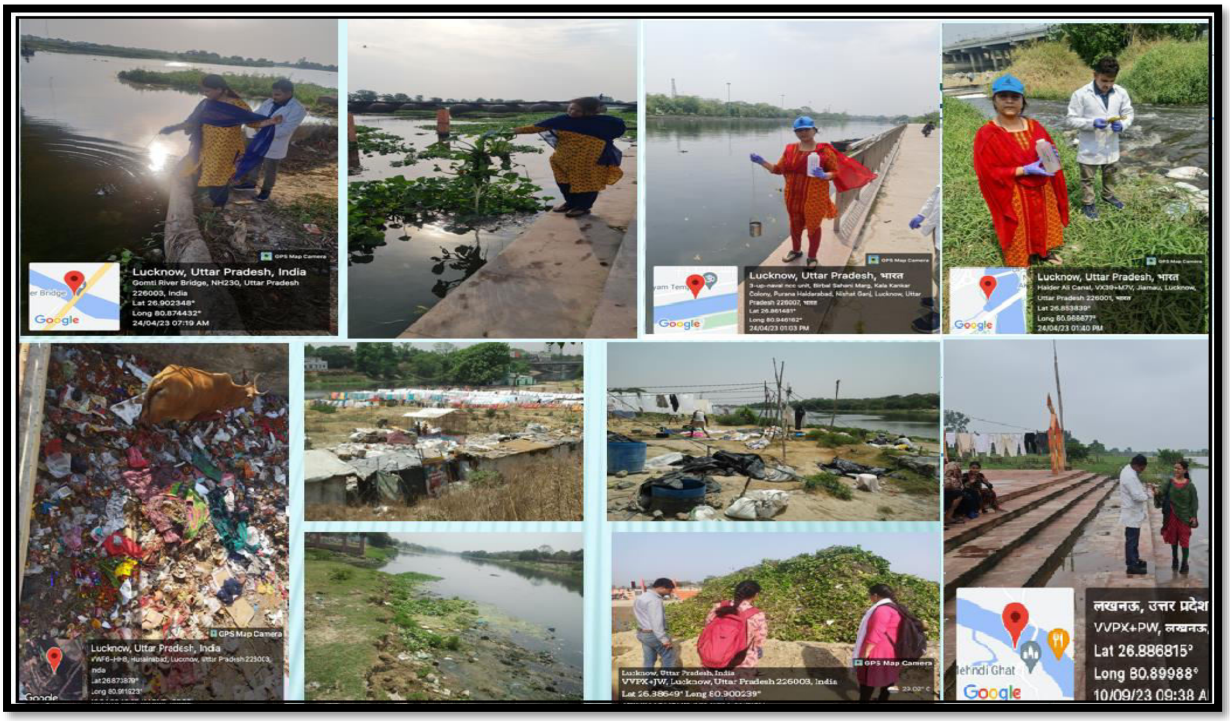

Figure : 17 Field Survey

Data Availability Statement The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflict Of Interest
The author declares no potential conflicts of interest concerning this article's research, authorship, and/or publication.

Ethics
There are no ethical issues with the publication of this manuscript.

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