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Assessing Hydrological Dynamics during the Monsoon Season in the Hooghly River, West Bengal, India: An Evaluation of Comprehensive Pollution Index and Water Quality index

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ABSTRACT

This study meticulously evaluates the water quality parameters of the Hooghly River during the period spanning 2022 to 2023, specifically during high tide, with a particular focus on the locales of Kamarhati, Panihati, and Khardah. A comprehensive analysis encompassed both physico-chemical and biological parameters. The application of Pollution indices, notably the Water Quality Index (WQI) and Comprehensive Pollution Index (CPI), elucidates the water quality status at the selected sampling locations. Elevated E. coli levels (Kamarhati: 10000, Panihati: 15000, Khardah: 20000), turbidity, and total suspended solids exceeded WHO and BIS standards, categorizing the river as slightly polluted (CPI: Kamarhati-0.67, Panihati-0.68, Khardah-0.59), rendering the water unsuitable for consumption (WQI > 100). Low dissolved oxygen levels (1.9-2.4 mg/l) and significant microbial contamination (coliform: 10000-20000 MPN) underline the urgent need for targeted interventions. While pH, temperature, and DO levels suggested a stable aquatic environment, elevated TDS, TSS, and E. coli concentrations signify potential pollution sources, necessitating immediate water treatment. Moderate levels of BOD and COD indicate a manageable organic pollutant load, and nitrate and nitrite within permissible limits are positive.

Key words: *Hooghly River, Pollution Indices, Water Quality, Monsoon Dynamic*

Introduction

Water, as the quintessential life-sustaining element permeating every cellular microcosm of organic entities, ecosystems, and the cosmos, assumes paramount significance. Beyond its fundamental role, freshwater serves diverse human needs, encompassing drinking, domestic, industrial, and agricultural applications. Rivers, essential sources of freshwater, play a vital role in sustaining and fostering civilization. Riverine ecosystems are acknowledged as highly dynamic ecosystems (Choudhury *et al.*, 2022). Water, vital for all life forms, is unfortunately scarce in freshwater sources like rivers, lakes, ponds, and groundwater (Roy *et al.*, 2019; Roy *et al.*, 2020). Despite India's abundant freshwater resources, escalating anthropogenic impacts, including pollution from urbanization and agriculture, coupled with excessive water extraction, have pushed rivers to a critical state. The unabated release of industrial effluents, sewage, and solid waste further worsens the situation.

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In natural water ecosystems, pH plays a crucial role in modulating compound toxicity (Ustaoðlu and Tepe, 2019). Parameters like Electrical Conductivity (EC) and Total Dissolved Solids (TDS) are vital for assessing salinity hazards and water suitability for agricultural irrigation (Singh *et al.,* 2020). Electrical Conductivity (EC) characterizes the capacity of an ionic solution to conduct electric current (Haldar *et al*., 2014). Widespread water pollution necessitates a shift to sustainable water resource management, aiming to restore aquatic ecosystems and maintain optimal environmental conditions. River water quality is a major concern due to substantial discharges from domestic, agricultural, municipal, and industrial effluents (Matta *et al.,* 2015). The pressing goal is to reinstate aquatic ecosystems to a state of equilibrium across various dimensions, fostering an environment conducive to optimal functioning. Water quality in rivers, impacted by discharges from various sources, is a significant concern, particularly for the Ganga and Hooghly rivers. These water bodies, crucial for sustenance and with religious importance, face pollution threats from domestic waste, sewage, industrial effluents, and ritualistic practices. This study employs the Water Quality Index (WQI) and Comprehensive Pollution Index (CPI) to evaluate temporal variations in water quality along the upper and lower stretches of the Hooghly River. Selected locations, important for economic and cultural activities, offer key insights into water pollution severity from domestic and industrial contributions.

Materials and Methods

Study Region

This research centers on ferry ghats along Kolkata's Hooghly River, specifically Kamarhati Pituri Ghat, Panihati Ferry Ghat, and Khardah Ferry Ghat. Sampling locations include Pilgrim areas, Ferry Ghats, and Industrial Areas along the eastern bank. The study scrutinizes the Hooghly River, a significant Ganga tributary. Figure 1 visually pinpoints our study area, providing insights into the Hooghly River ecosystem dynamics, particularly focusing on anthropogenic pressures on ferry ghats. The in depth analysis aims to enhance our understanding of the Hooghly River's current state and its ecological significance within the broader Ganga River system. Additionally, an ArcGIS 10.8-crafted map enhances precision for a comprehensive analysis of selected ferry ghats and their surroundings.

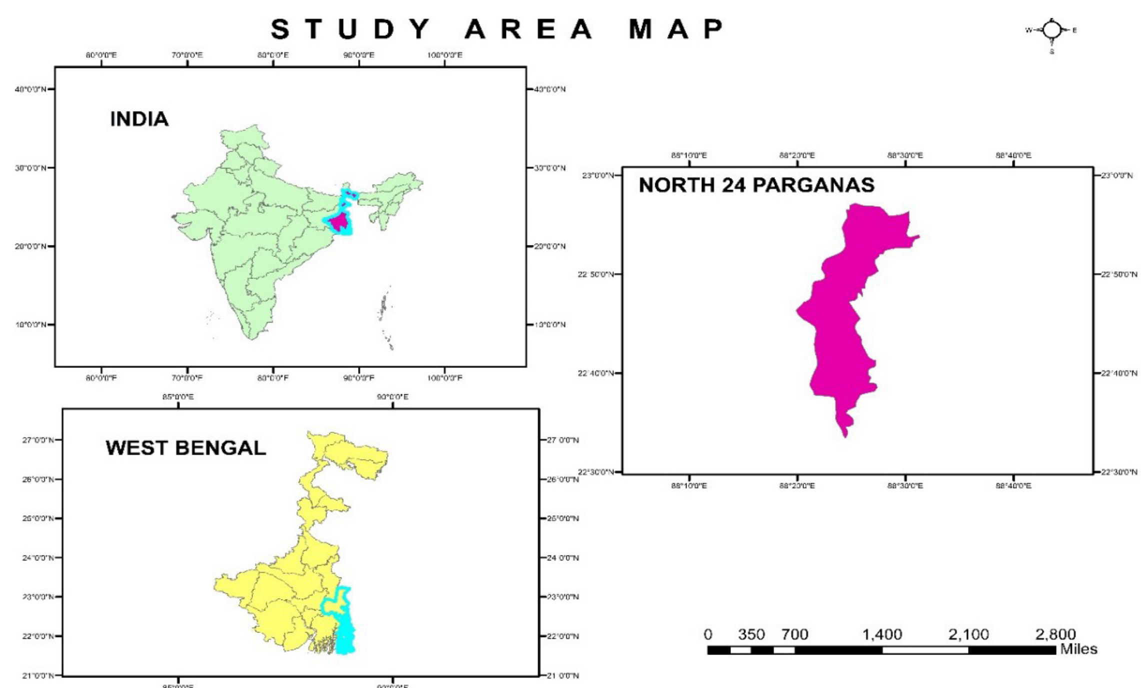

Fig. 1. Geographical overview of the Hooghly River (Study Area Map)

Table 1. Study area Locations

Sl.No.	Location	Latitude	Longitude
1	Kamarhati Puturi Ghat	22°4016°N	88l°22’29°E
2	Panihati Ferry Ghat	22°4016°N	88°21’56°E
3	Khardah Ferry Ghat	22°4210584° N	88° 22' 31.242°E

Sample Collection

In 2022-2023, monsoon sampling evaluated Hooghly River’s physico-chemical and biological parameters. Stringent protocols-maintained sample purity, ensuring accurate analysis of key parameters- pH, COD, BOD, DO, and turbidity. Robust statistical analyses provided precise insights into the river’s characteristics, assessing water quality and organic pollution load impact across 21 parameters. Findings adhered to APHA (2012), BIS (2012), and WHO standards, confirming stringent quality criteria.

Indexing Approach

In this research paper, we focus on analyzing water samples collected from selected locations along the Hooghly River. The study involves a comprehensive analysis of 21 physicochemical parameters present in the water, (Sharma *et al.,* 2020).

Assessment of Water Quality Index

Our study utilizes the refined Weighted Arithmetic Index (WQI) method by Brown *et al.* (1972) to assess water quality comprehensively. Following the approach outlined by Roy *et al*. (2022) and incorporating the National Sanitation Foundation’s (NSF) index by Bhutiani *et al.* (2016), our research captures the collective impact of physicochemical parameters, yielding a precise WQI through weighted factor assignment and arithmetic mean calculation.

Assessment of Comprehensive pollution Index

Water quality assessment involves calculating the Comprehensive Pollution Index (CPI), considering parameters like BOD5, COD, ammonia nitrogen, and total phosphorus. Researchers (Kumar *et al.*, 2015; Sidabutar *et al*., 2017; Yadav *et al.*, 2018; Wang *et al*., 2018) utilize CPI as a tool to gauge overall pollution load. Computed following the equation by Roy *et al.*, 2021, CPI determines water quality status.

Statistical

Analysis

SPSS was used for one-way ANOVA to analyze seasonal variations in element concentrations at a 95% confidence level. Excel calculated correlation coefficients, mean, and SD for water parameters, grain size, and element concentrations. The Karl Pearson coefficient measured variations across locations. Tables 6 and 7 present concise yet comprehensive data insights, aiding interpretation. The t-test assessed differences between locations, contributing to a thorough understanding of the dataset’s dynamics in Hooghly River water.

Results and Discussion

This study of the Hooghly River evaluated 21 physico-chemical and biological parameters at three locations, comparing results to BIS 2012 and WHO standards. Table 2 outlines the river’s physicochemical characteristics, while Table 3 summarizes key indices concisely, providing a comprehensive overview of water quality and district statistics. Table 4, the correlation coefficient table, offers insights into parameter interrelationships. Temporal trends and descriptive statistics reveal higher mean values in Panihati and Khardah compared to Kamarhati, indicating elevated water quality parameters in these locations. The correlation matrix exposes associations, such as *E.coli* with hardness and pH with Sulphate. Statistical significance levels support reliability assessment. Water analysis shows contamination, rendering it unsuitable for drinking and bathing. Elevated WQI values (208 to 216), driven by increased iron levels, turbidity, DO, and microbial load, exceed the desirable limit of 100. Conversely, CPI suggests slight pollution (0.61 to 0.7). Figure 2 reveals WQI levels surpassing permissible limits, crafted meticulously using Excel 2021. Figures 3 illustrate evolving conditions, depicting key parameters like DO, BOD, COD, nitrate, pH, and turbidity. Descriptive statistics for Kamarhati, Panihati, and Khardah show variability, with Kamarhati having a lower mean (754.807) than Panihati (1107.2814) and Khardah (1475.4057). A computed p-value (< 0.05) indicates statistically significant variations, rejecting the null hypothesis. The study explores Hooghly River water quality, considering various parameters. Temperature and pH (7.6-7.38) align with WHO standards. Chloride levels are negligible. Total Coliform count at 20,000 exceeds limits, necessitating immediate management. Dissolved Oxygen (DO) stays within specified limits, ensuring aquatic life support. Total Dissolved Solids (TDS) range from 93 mg/l to 135 mg/l, meeting standards. Elevated turbidity levels, attributed to runoff, surpass permissible limits. Electrical Conductivity remains acceptable (186 to 270). Biochemical Oxygen Demand (BOD) indicates a low organic pollutant load.

Despite general conformity to standards, heightened *E. coli* concentrations, especially in Khardah, raise health concerns, necessitating immediate action and thorough investigation. The study highlights the dynamic nature of water quality influ-

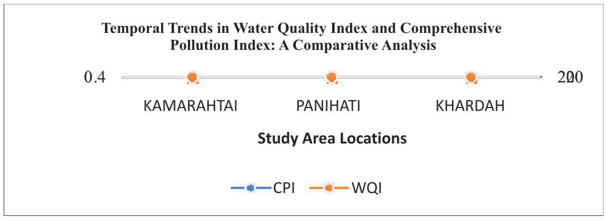

Fig. 2. Temporal Trends in WQI and CPI

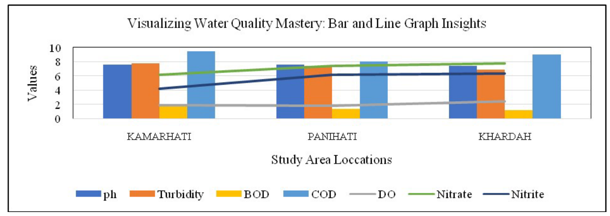

Fig. 3. Bar graph shows data distribution in study locations

Table 2. Assessment of Water Quality (2022-2023) at Three Varied Sites along the Hooghly River

Sl. No.	Parameters	Unit	Kamarhati		Panihati	Khardah	WHO	BIS
			Standard	Permissible	Acceptable			
1.	Alkalinity	mg/l	62	60	68	0.0	200	600
2.	Hardness	mg/l	101.2	106.12	110.2	500	200	600
3.	Chloride	mg/l	BDL	BDL	BDL	250	250	1000
4.	Chlorine	Mg/l	-	-	-	0.02	0.2	1
5.	Salinity	Ppt	BDL	BDL	BDL			
6.	pH	mg/l	7.6	7.57	7.38	6.5-8.5	6.5-8.5	6.5-8.5
7.	Temperature	°C	32.4	32.1	32.1	20-30	15	40
8.	TDS	mg/l	108	93	135	500	500	2000
9.	TSS	Mg/l	60	20	40	200	0	0
10.	ElectricalConductivity	mg/l	202	186	270	400	300	0.0
11.	Turbidity	mg/l	7.8	7.4	6.9	0.0	1	5
12.	DO	mg/l	1.9	1.8	2.4	5	<6	15
13.	BOD	mg/l	1.7	1.3	1.2	30	30	100
14.	COD	mg/l	9.5	8	9	250	120	250
15.	Nitrate	mg/l	6.2	7.4	7.8		No-Relaxation	45
16.	Nitrite	mg/l	4.2	6.1	6.3	1	0.1	10
17.	Phosphate	mg/l	BDL	BDL	BDL			
18.	Phosphorous	mg/l	-	-	-	0.025	25	0.0
19.	Sulphate	mg/l	24.8	25.15	27.4	200	200	400
20.	*E.coli*	MPN/100ml	10000	15000	20000	0.0	<200	<1000
21.	Iron	Ppm	0.7269	0.7328	0.7118	0.7	0.3	-

Table 3. Summary of different Indices

Sl No	Indices	Average Values	Remarks
1	Water Quality Index	211.43	Unfit For Consumption
2	Comprehensive Pollution Index	0.64	Slightly Polluted

*.Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).
BOD = Bio-chemical Oxygen Demand; COD = Chemical Oxygen demand; DO = Dissolved Oxygen; TH = Total Hardness;
TDS = Total Dissolved Solids.

Table 4. Exploring Correlation Coefficients among Physicochemical Parameters

Correlations												
	TA	pH	Temp	TDS	TSS	EC	Turbidity	DO	BOD COD Nitrite	Nitrate *E. coli*	Sulphate	Iron
TA	1											
pH	-0.900	1										
Temp	-0.892	0.605	1									
TDS	0.592	-0.884	-0.163	1								
TSS	-0.546	0.126	0.866	0.352	1							
EC	0.726	-0.953	-0.337	0.984	0.179	1						
Turbidity	-0.993	0.945	0.832	-0.682	0.444	-0.802	1					
DO	0.743	-0.960	-0.359	0.979	0.156	1.000*	-0.816	1				
BOD	-0.961	0.745	0.982	-0.346	0.756	-0.508	0.922	-0.529	1			
COD	-0.378	-0.064	0.756	0.523	0.982	0.362	0.266	0.339	0.619	1		
Nitrate	0.974	-0.778	-0.971	0.395 -	0.721	0.553	-0.941	0.573	-.999*	-0.577	1	
Nitrite	0.927	-0.671	-0.996	0.247	-0.820	0.417	-0.877	0.438	-0.995	-0.697	0.988	1
Sulphate	0.899	-1.000**	-0.604	0.885	-0.124	0.954	-0.944	0.961	-0.743	0.066	0.777	0.670
1												
E. coli	.999*	-0.922	-0.866	0.634	-0.500	0.762	-.998*	0.778	-0.945 -0.327	0.961	0.906	0.921
1												
Iron	-0.658	0.920	0.245	-0.996	-0.272	-0.995						

enced by seasons and human activities, emphasizing the necessity for robust policies, sewage treatment, and pollution control to mitigate health risks. Ongoing monitoring is vital, exposing generally poor water quality and indicating slight pollution, aligning with previous research (Yadav *et al*., 2015 and Kumar *et al.*, 2014).

Conclusion and Recommendation

The investigation reveals that water parameters in Kamarhati, Panihati, and Khardah generally approach WHO standards, but the CPI designates the river as slightly polluted, with specific areas showing moderate pollution. Elevated WQI values indicate water unsuitability for consumption, requiring urgent corrective measures. High CPI values result from elevated turbidity, BOD, and COD. Alarming E. coli levels, especially in Khardah, underscore the need for immediate action to prevent waterborne diseases. Urgent steps, including sewage treatment and controlling anthropogenic practices during the monsoon, are recommended. Despite some parameters exceeding standards, the Hooghly River isn’t immune to pollution, emphasizing the necessity for strict waste disposal policies. Declining water quality poses significant health hazards, necessitating prompt action to protect public health. The study stresses ongoing oversight, policy changes, and collaboration among communities, local government, and water management organizations for focused interventions ensuring water supply quality for current and future generations.

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Conflict of Interest: None

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