Bangladesh J. Environ. Sci., Vol. 46, 176-184, 2024 **@ BAED ISSN 1561-9206**

IMPACTS OF POLLUTION AND WATER MANAGEMENT ON PHYSICOCHEMICAL PARAMETERS AND WATER QUALITY INDEX OF THE MEGHNA RIVER AT BHAIRAB, BANGLADESH

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ABSTRACT

This study assesses the physicochemical parameters of surface water in the Meghna River at Bhairab Bazar, Kishorganj district, focusing on the Water Quality Index (WQI) to evaluate water pollution levels and overall water quality suitability for various uses. Water samples were collected seasonally from three distinct locations between February and July 2022 to analyze the distribution of parameters including temperature, total dissolved solids (TDS), electrical conductivity (EC), pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), hardness, and alkalinity during both dry and wet seasons. Mean TDS values were recorded at 239.67 ± 5.033 ppm in the dry season and 180 ± 9.165 ppm in the wet season, both of which fall below the Asian Development Bank's standard limit of 400 ppm for aquaculture. Statistical analysis demonstrated significant differences in TDS ($p < 0.05$) as well as strong correlations for EC and DO ($p < 0.01$) between seasons. The WQI results indicate that the river water is heavily polluted and classified as unsuitable for drinking, with values exceeding 300 in both seasons. These findings suggest a degradation in water quality, likely attributable to anthropogenic activities, particularly the direct discharge of domestic effluents. The study highlights the urgent need for effective management strategies and continuous monitoring to mitigate further deterioration of the river's water quality.

Key words: Water quality index, physico-chemical parameters, pollution, Meghna river

Introduction

The Meghna River is one of the most important rivers in Bangladesh, playing a crucial role in irrigation, fishing, transportation, recreation, and various other activities. However, water quality in the Meghna River is continually changing due to the release of inadequately treated industrial waste containing contaminants and hazardous substances into the water bodies, either directly or indirectly (Ahmed, *et al.,* 2015). As a result, the river is inundated with millions of liters of sewage, household waste, industrial effluents, and agricultural runoff. These pollutants introduce a range of hazardous heavy metals, toxic compounds, pesticides, and various other chemicals from different sectors (Rasel, *et al.,* 2013). Such contamination adversely affects water quality, making it difficult for aquatic species to thrive and posing risks to public health and agricultural activities. Continuous monitoring of pollutant levels in the river is essential to safeguard public health and prevent consumption of contaminated water. The Water Quality Index (WQI) is a highly effective method for evaluating the quality of both surface and groundwater, serving as a valuable tool for policymakers focused on water resource management. Numerous researchers have developed mathematical models and tools to facilitate comprehensive water quality assessments (Brown *et al.,* 1970). Consequently, this study aims to monitor the physicochemical water quality parameters of the Meghna River using the Water Quality Index (WQI) and assess their suitability for supporting aquatic life, including fisheries.

Materials and Methods

Study area: The Meghna River forms within Bangladesh in the Kishoreganj District, just above the town of Bhairab Bazar, through the confluence of the Surma and Kushiyara Rivers, both originating as the Barak

River in the hilly regions of eastern India. Water samples were collected seasonally from three key sites along the Meghna River: Bhairab Bazar (ST-1), Char Sonarampur (ST-2), and Kalipur (ST-3) between February and July 2022. These sites were chosen due to their high levels of pollution from various waste sources, including residential, commercial, and industrial discharges. The locations of these sampling sites are illustrated in Fig. 1.

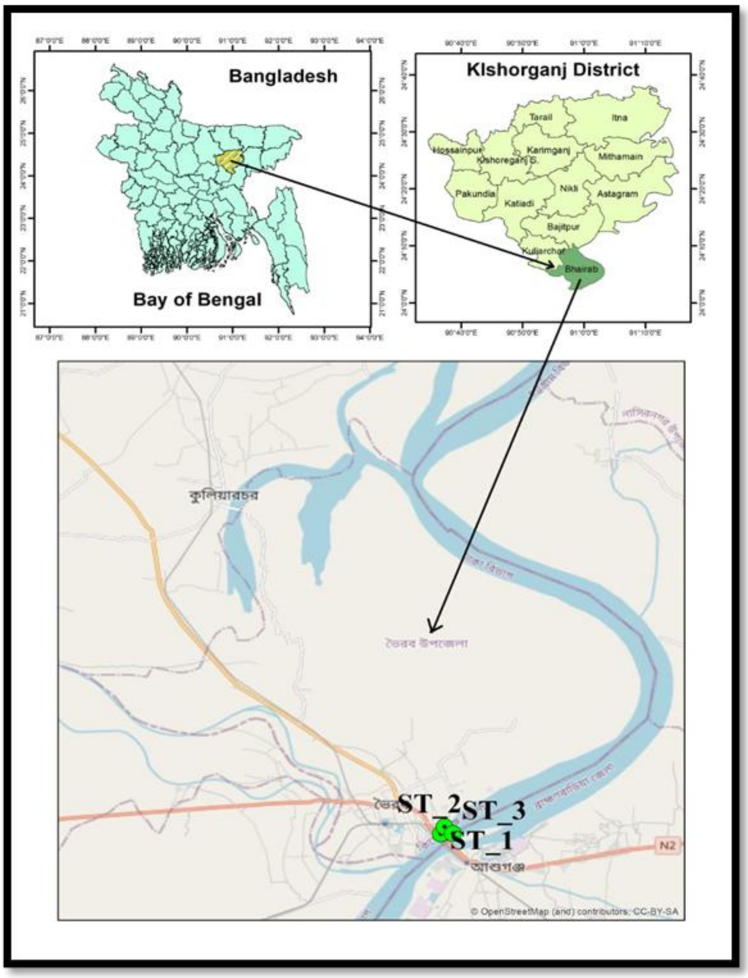

Fig. 1. Map showing the study area of the Meghna River at Bhairab, Kishoreganj

Sample collection: Water samples were collected during the dry season (February 2022) and the wet season (July 2022). Samples were taken in pre-rinsed 500 ml plastic bottles, with collection points spaced approximately 1000 meters apart. After collection, each bottle was securely sealed and labeled with the corresponding identification number.

Sample analysis: Water temperature was measured with a thermometer, and pH was assessed using a calibrated pH meter. Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were evaluated with digital TDS and EC meters, respectively. Dissolved Oxygen (DO) levels were measured using a DO meter, while Biological Oxygen Demand (BOD) was analyzed in a BOD incubator. Hardness was determined through EDTA titration, and alkalinity was measured by titration with 0.1 N HCl.

Water quality index (WQI) model: This index makes it possible to determine whether water is suitable for human consumption. There are three steps are included in the WQI index calculating process (Conesa Fernández-Vitoria, 2009). In the first step, each of the parameters was assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes.

In the second step, the relative weight (Wi) is computed from the following equation:

$$Wi = \frac{wi}{\sum_{n=1}^{n} wi}$$

Where,
Wi is the relative weight,
wi is the weight of each parameter and n is the number of parameters.

In the third step, A quality rating scale (Qi) for each parameter is calculated through dividing its concentration in each water sample by its respective standard as per the proposed guidelines and the result is multiplied by 100 using the following equation:

$$qi = \frac{ci}{si} \times 100$$

While the quality rating for pH and DO was calculated on the basis of the following formula:

$$qi_{\text{pH, DO}} = \frac{ci-vi}{si-vi} \times 100$$

Where,
qi = the quality rating
ci = value of the water quality parameters obtained from the analysis
si = standard value
vi = ideal value for pH (7.0), and DO (14.6)

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation:

$$SIi = Wi \times qi$$

$$WQI = \sum_{i=1}^{n} SIi$$

Where,
SIi is the sub-index of ith parameter
qi is the rating based on concentration of ith parameter
n is the number of parameters

Table 1. Water quality index model (WQI) and scales (Brown, *et al.*, 1972; Menberu, *et al.*, 2021; Smith, 1990)

Water quality index value	Rating of the water quality
<50	Excellent water
50–100	Good water
100–200	Poor water
200–300	Very poor water
>300	Water unsuitable for drinking

Results and Discussion

Temperature: During the dry season, the water temperature ranged from 25.5 to 29 ºC, whereas in wet season, it varies from 29.5 to 32.5 ºC, at three sampling stations. The highest temperature has been observed at station 1 (32 ºC) in the wet season, whereas the lowest value of temperature was recorded at station 3 (26.3 ºC) during the dry season (Fig. 2). Temperature recorded in the river water shows that it varies with the season. In a study conducted by Meghla, *et al.*, (2013) found highest temperature of 31.5 ºC during wet season and lowest temperature of 23.1 °C during dry season, which is relatively similar to the present study.

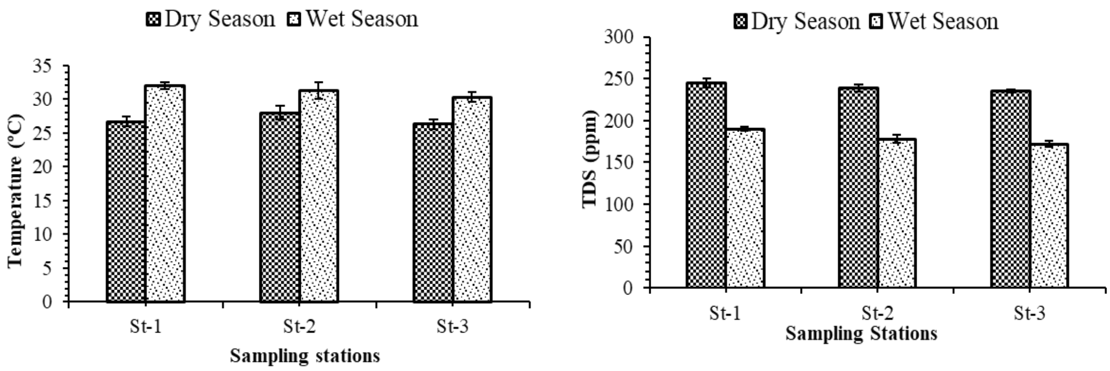

Fig. 2. River Water Temperature and TDS Levels at different Sampling Stations in Dry and Wet Seasons

Total dissolved solid (TDS): In dry season, the TDS values were ranged from 233 to 250 ppm, where as it varies from 168 to 192 ppm in wet season, at three sampling stations. The highest TDS value has been observed at station 1 (245 ppm) in the dry season, whereas the lowest value of TDS was recorded at station 3 (172 ppm) during the wet season (Fig. 2). The highest TDS values were found in dry season compared to wet season in all stations. This might due to the lower concentration of pollutant with higher amount of rainfall in wet season.

Electrical conductivity (EC): Among the three sampling stations, in dry season, the EC values were ranged from 460 to 480 µS/cm, whereas it varies from 219 to 250 µS/cm in wet season. The highest EC value has been observed at station 1 (475 µS/cm) in the dry season, whereas the lowest value of EC was recorded at station 3 (223 µS/cm) during the wet season (Fig. 3). The highest EC values were found in dry season compared to wet season in all stations. This might due to the total volume of water decreases in dry season, as a result the conductivity increases.

pH: During the dry season, the pH value varied from 7.51 to 7.92, whereas it ranged from 7.65 to 7.98 in wet season, at all sampling sites. The maximum pH value has been observed at station 3 (7.91) in the wet season, whereas the minimum value of pH was recorded at station 3 (7.67) during the dry season (Fig. 3). There was a small difference between pH values during the both seasons. In comparison to the dry season, the pH of every sampling location was higher in the wet season. This might due to the lower concentration of pollutant with higher amount of rainfall in wet season.

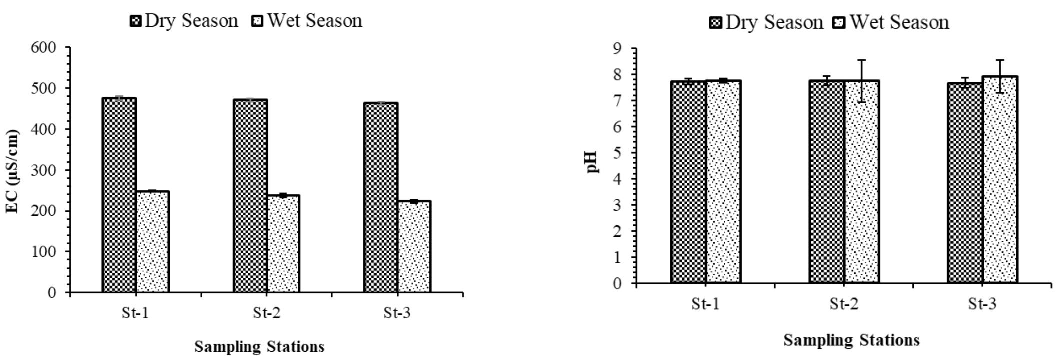

Fig. 3. The values of EC and pH at different sampling stations during dry and wet season

Dissolved oxygen (DO): Among the three sampling stations, in dry season, the DO values were ranged from 1.2 to 2.1 ppm, whereas it varies from 1.91 to 1.99 ppm in wet season. The highest DO value has been observed at station 3 (1.98 ppm) in the wet season, whereas the lowest value of DO was recorded at station 1 (1.40 ppm) during the dry season (Fig. 4). The highest DO values were found in wet season compared to dry season in all stations. The reason for this is that the bacteria are consuming the oxygen present in the water. When wastewater has a considerable amount of organic content in the dry season, microorganisms become more active and use dissolved oxygen for their biological decomposition of organic matter (Parveen, *et al.*, 2017).

Biological oxygen demand (BOD): During the dry season, the BOD ranged from 9 to 18 ppm, whereas in wet season, it ranged from 8 to 15 ppm, at three sampling stations. The maximum BOD has been observed at station 1 (16 ppm) in the dry season, whereas the minimum value of BOD was recorded at station 3 (9 ppm) during the wet season (Fig. 4). BOD recorded in the river water shows that it varies with the season. Due to the considerable dilution of rainfall in the rainy season, it is obvious that BOD concentration was lower in all the stations during the wet season. For good water quality, BOD should be between 5 and 6 mg/l (Huq, and Alam, 2005). The Meghna River's higher BOD is a result of pollution from several organic and chemical pollutants.

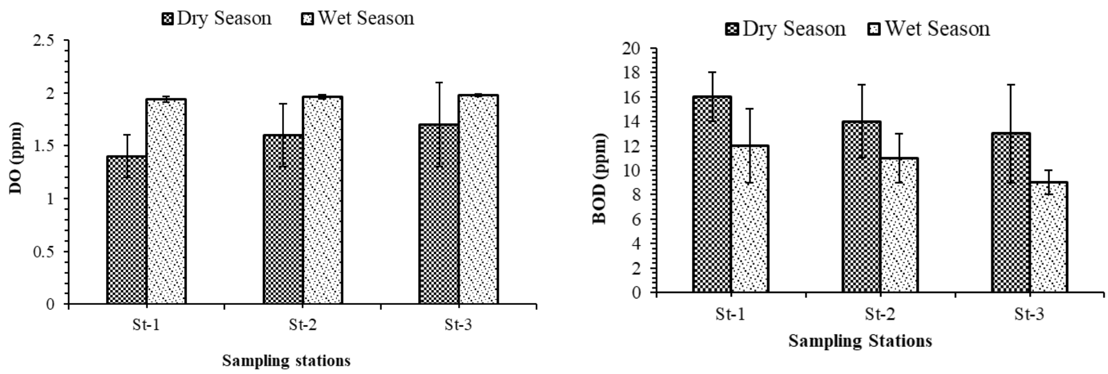

Fig. 4. The values of DO and BOD at different sampling stations during dry and wet season

Alkalinity: Among the three sampling stations, in dry season, the alkalinity values were ranged from 130 to 149 ppm, whereas it varies from 117 to 132 ppm in wet season. The highest alkalinity value has been observed at station 3 (145 ppm) in the wet season, whereas the lowest value of DO was recorded at station 1 (117 ppm) during the dry season (Fig. 5). The highest alkalinity values were found in dry season compared to wet season in all stations. It indicates that the Meghna River water contains higher amounts of carbonates and bi-carbonates enriched compounds during the dry season.

Hardness: During the dry season, the hardness ranged from 164 to 181 ppm, whereas in wet season, it ranged from 120 to 140 ppm, at three sampling stations. The maximum harness has been observed at station 3 (178 ppm) in the dry season, whereas the minimum value of hardness was recorded at station 1 (123 ppm) during the wet season (Fig. 5). Hardness recorded in the river water shows that it varies with the season. Wet season showed a lower amount of hardness concentration in all of the studied stations compared to dry season. There may be a decrease in river water flow as a result of oil spills from boats, unethical industrial effluent drainage, the dumping of municipal refuse, etc (Meghla, *et al.*, 2013).

Comparison of physicochemical parameters values with standard levels: The mean values of all investigated water quality parameters were compared with standard levels to determine the suitability of water for drinking, irrigation, and fisheries (Table 2). During the both season the water temperature was exceeded the standard limit. This is because higher level of pollutants in water. The values of TDS and EC were lower than the standard levels in the both seasons, indicating that there was a little higher free ionic load or inorganic pollutant concentrations in waterbody that recommended that there is a normal condition for fish culture and irrigation. The pH was within the range of standard value. The BOD level exceeded the standard level, indicating that this river water was polluted with the organic chemicals and bacterial pollutants, which decreased the DO content compared to the standard levels during the both season due to the decomposition of different organic wastes by micro-organisms. As a result, the water is not suitable for drinking water purpose, for fresh water fishes, and for irrigation purposes. The alkalinity was within the range of standard level and the hardness lower than the permissible limit, which is almost suitability for fish production and irrigation.

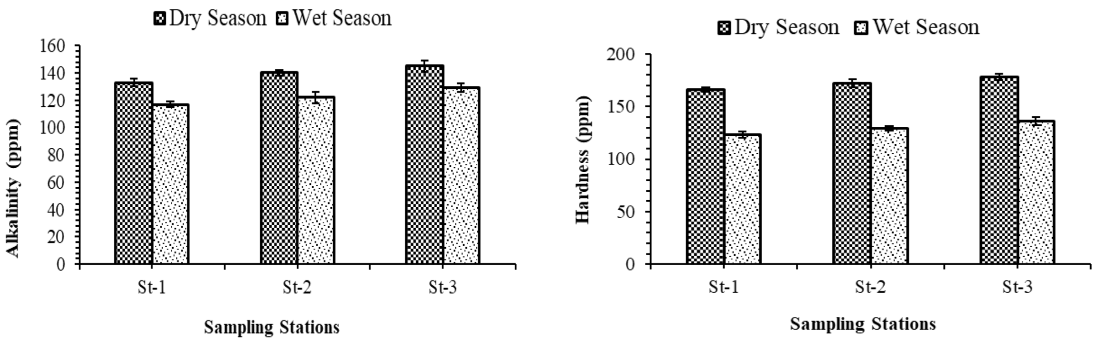

Fig. 5. The values of alkalinity and hardness at different sampling stations during dry and wet season

Table 2. Comparison of investigated values with standard levels for drinking, irrigation and fisheries

Parameters	Investigated seasonal water quality (Mean values)		Standard levels			References
	Dry	Wet	Drinking	Irrigation	Fisheries	
Temperature (ºC)	27	31.2	25	-	25	ECR (2023), EPA (2018)
TDS (ppm)	239.67	180	1000	2000	<400	ADB (1994)
EC (µS/cm)	469.67	236	-	750	800-1000	ADB (1994), EQS (1997)
pH	7.71	7.80	6.5-8.5	6.5-8.5	6.5-8.5	ECR (2023), EQS (1997)
DO (ppm)	1.57	1.96	6	5	4.0-6.0	ECR (2023), EQS (1997)
BOD (ppm)	14.33	10.67	-	10 or less	(-) or below 2	ECR (2023), EQS (1997)
Alkalinity (ppm)	139.33	122.67	-	-	80-200	Bhatnagar, *et al.,* (2004)
Hardness (ppm)	172	129.33	-	200-500	-	ECR (2023)

Correlation matrix (CM): A correlation matrix was used to identify the correlation of physicochemical parameters. A significant correlation was observed in the water samples during the dry and wet season in the Meghna River (Table 3-4). During the both season, temperature shows a positive correlation with TDS and EC, where it shows a negative correlation with DO, alkalinity and hardness. TDS shows significantly positive correlation with EC ($r = 0.712$, $p < 0.05$) in the dry season, but it has a strongly significant positive correlation with EC ($r = 0.966$, $p < 0.01$) in the wet season, and it has also strongly significant negative correlation with DO ($r = -0.842$, $p < 0.01$), as well as significantly negative correlation with hardness ($r = 0.753$, $p < 0.05$) in that season. During the dry season EC shows no significant correlation with other parameters but it shows strongly significant negative correlation with DO (r = -0.820, $p < 0.01$) and hardness (r = -0.819, $p < 0.01$), and also has significantly negative correlation with alkalinity (r = -0.744, $p < 0.05$) in wet season. pH only shows significant positive correlation with hardness (r = 0.724, $p < 0.05$) in wet season. In the dry season, DO has a significantly positive correlation with alkalinity (r = 0.787, $p < 0.05$) and hardness (r = 0.783, $p < 0.05$), but in the wet season it shows negative correlation with BOD. BOD significantly negative correlates with hardness (r = -0.673, $p < 0.05$) in wet season. Alkalinity has a strongly significant correlation with hardness (r = 0.975, $p < 0.01$) in dry season, but it shows significantly positive correlation with hardness (r = 0.787, $p < 0.05$) in wet season.

Table 3. Correlation coefficient of physicochemical water quality parameters of the Meghna River in dry season

Parameters	Temp	TDS	EC	pH	DO	BOD	Alkalinity	Hardness
Temp	1							
TDS	0.246	1						
EC	0.295	0.712*	1					
pH	0.616	0.340	-0.027	1				
DO	-0.039	-0.061	-0.200	0.053	1			
BOD	-0.039	0.636	0.460	0.100	0.611	1		
Alkalinity	-0.120	-0.553	-0.613	-0.027	0.787*	0.007	1	
Hardness	-0.111	-0.551	-0.587	-0.107	0.783*	0.014	0.975**	1

* Correlation is significant at the 0.05 level (2-tailed) **. Correlation is significant at the 0.01 level (2-tailed)

Table 4. Correlation coefficient of physicochemical water quality parameters of the Meghna river in wet season

Parameters	Temp	TDS	EC	pH	DO	BOD	Alkalinity	Hardness
Temp	1							
TDS	0.586	1						
EC	0.641	0.966**	1					
pH	-0.229	-0.436	-0.590	1				
DO	-0.300	-0.842**	-0.820**	0.279	1			
BOD	0.521	0.595	0.624	-0.528	-0.214	1		
Alkalinity	-0.557	-0.647	-0.744*	0.604	0.518	-0.195	1	
Hardness	-0.521	-0.753*	-0.819**	0.724*	0.471	-0.673*	0.787*	1

* Correlation is significant at the 0.05 level (2-tailed) **. Correlation is significant at the 0.01 level (2-tailed)

Water quality index (WQI) model: WQI model of Meghna River was established from various physicochemical parameters in two seasons (dry and wet season). The values of various physicochemical parameters for the calculation of water quality index were used to get WQI. Season wise WQI calculations are presented in the Table 5. According to Table 1, which presents the water quality classifications based on WQI criteria, indicating that all seasonal samples from the Meghna River fall into the "unsuitable for drinking" category, with WQI values exceeding 300 during both the dry and wet seasons. Furthermore, WQI values were consistently higher in the dry season compared to the wet season across all sampling stations (Table 5). This indicates a significant decline in water quality, particularly from the wet season to the dry season, which can be attributed to the direct discharge of industrial effluents and domestic sewage into the river. The WQI results clearly indicate that the water in the Meghna River is highly polluted, making it unsuitable for both public consumption and irrigation. The analysis of physicochemical parameters alongside the WQI offers critical insights that can inform targeted strategies for pollution control and water management in the region. Elevated pollutant levels and imbalanced physicochemical parameters may pose significant risks to native fish and other aquatic species, underscoring the necessity of restoration projects and conservation initiatives.

Table 5. Calculation of WQI of water samples by water quality index model in dry and wet season of the Meghna river

Parameters	Weight (wi)	Relative weight (Wi)	Dry season			Wet season		
			S1	S2	S3	S1	S2	S3
Temperature (°C)	1	0.029	3.10	3.25	3.05	3.71	3.63	3.52
TDS (ppm)	2	0.052	1.28	1.24	1.22	0.99	0.93	0.89
EC (µS/cm)	2	0.052	9.88	9.80	9.63	5.16	4.93	4.64
pH	4	0.103	14.63	15.66	13.80	15.66	15.25	18.75
DO (ppm)	4	0.103	15.8	15.57	15.45	15.16	15.14	15.12
BOD (ppm)	3	0.077	616	539	500.5	462	423.5	346.5
Alkalinity (ppm)	2	0.052	5.76	6.07	6.28	5.07	5.29	5.59
Hardness (ppm)	3	0.077	4.26	4.42	4.57	3.16	3.31	3.49
∑wi	21	-	-	-	-	-	-	-
∑Wi	-	0.045	-	-	-	-	-	-
WQI= ∑SIi			670.72	591.01	554.5	510.91	471.98	398.5
Guideline used			Bhatnagar, *et al.*, (2004), WHO (2011)					
Status			Water is unsuitable for drinking (all stations)					

These findings highlight an urgent need to identify and mitigate specific pollution sources, potentially improving resource allocation for industrial, agricultural, and domestic waste management practices along the river**.** Such insights could further support the establishment of stricter pollution control policies. Enhanced standards for effluents and more rigorous regulations on industrial and agricultural activities near the river may be implemented to safeguard the aquatic environment. This comprehensive understanding of the Meghna River's water quality, therefore, serves as a foundational step for sustainable ecosystem and water resource management strategies.

Conclusion

The Water Quality Index (WQI) analysis confirms that the Meghna River is unsuitable for drinking, irrigation, and aquaculture in all seasons. Addressing this critical issue requires dedicated and proactive measures to prevent and minimize pollutant discharges, along with comprehensive pollution management strategies to preserve the health and sustainability of this critical river system.

Acknowledgement

The authors are thankful to the Department of Environmental Science and Resource Management at Mawlana Bhashani Science and Technology University for immense cooperation through providing instruments and Laboratory facilities.

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