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Meghna River's Physicochemical Parameters and Water Quality Index at Munshiganj, Bangladesh: Impact of Pollution and Water Management

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Abstract

Using the Water Quality Index (WQI) to evaluate water pollution levels and overall water quality suitability for different purposes, this study evaluates the physicochemical properties of surface water in the Meghna River in Munshiganj district. Between January and October 2023, seasonal water samples were taken from three different locations to examine the distribution of various parameters during the dry and wet seasons. These parameters included temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), and turbidity. In the dry season, mean BOD values were 7.7 ± 2.52, while in the wet season, mean turbidity values were 56.8 ± 7.59 NTU. Both of these values exceeded the standard limits of < 6 mg/L and ≤ 10 NTU for drinking water purposes set by the Environment Conservation Rule (ECR 2023). The results of statistical analysis showed both strong connections and considerable differences between the parameters. With values above 200 in both dry and wet (except from St-3) seasons, the WQI data show that the river water is highly contaminated and categorized as Very Poor water. These results point to a decline in water quality that is most likely caused by human activity, specifically the direct release of household wastewater. The study emphasizes the critical necessity for ongoing monitoring and efficient management techniques to prevent future degradation of the river's water quality.

Keywords: Physicochemical, Wet Season, Dry Season, Water Quality Index, Meghna River

Introduction

The Meghna River is one of the most significant rivers in Bangladesh, being essential for transportation, recreation, fishing, irrigation, and many other uses[1], [2]. The river has been exploited beyond its carrying capacity as a result of population growth and rapid industrialization[3]. Because to mixed industrialization, the quality of the water is constantly declining. Numerous studies have examined a number of characteristics pertaining to the river's water quality[4], [5], [6], [7]. Because of unplanned industrialization, water quality is progressively declining. Industrialization primarily refers to socio-economic activities that are primarily in charge of changing the structure of society through massive production[8], [9], [10]. The wildlife of the surrounding areas is endangered by the massive amounts of

wastewater produced by these industries[11]. Additionally, the Bangladeshi rivers are a pathway that discharges the highest silt load in the world[12]. When people use polluted water for an extended period of time, they can develop a number of acute and long-term health issues[13].
Physical, chemical, and biological factors can be used to evaluate the water quality of any given location or source[14]. One of the best methods to characterize the quality of water is to use the Water Quality Index (WQI), which has been used to describe the acceptability of water sources for human use[15], [16]. The index of water quality Large volumes of water characterization data are combined using the WQI numerical tool to produce a single value that represents the water quality rate[17]. Assessing the water quality index is crucial for preventing and controlling river pollution as well as for obtaining accurate data on water quality for efficient management[18]. Safe and drinkable water is vital for a healthy lifestyle. Obtaining a sufficient amount of clean, safe drinking water is a basic human necessity. Water Quality Indexes (WQI), which evaluate water quality based on computed indices, are among the best methods for communicating water quality[19]. Freshwater quality assessment is crucial because to the high demand and susceptibility to pollution in emerging nations, as well as the worry that it will soon be depleted[20]. Due to the numerous chemicals, fertilizer, iron and steel, leather, paint, clothing, food, cosmetics, toiletry, and pharmaceutical companies located on its banks or in its hinterland, Munshiganj is the most polluted district. In order to address this issue, we must research the extent of the current pollution in the Meghna River and obtain accurate information on the current state of affairs. Numerous research have been conducted on the Meghna River's silt and water quality[21], [22], [23]. However, no specific research based on WQI was done. Assessing the Meghna River's water quality for the Munshiganj district using the water quality index (WQI) is the primary goal of this study. The weighted arithmetic method is employed in this work to determine WQI. This study may raise user awareness while also assisting planners and policymakers in understanding and preserving water quality for various applications and aquatic life.

Materials and Methods

Study Area

A study was conducted on the Meghna River, which is among the most polluted waterways. The Meghna River bank, Tetoitola, Gazaria (ST-1), the PB-300 facility, Jamaldi (ST-2), and Notun Char, Hosaindi (ST-3) were the three main locations where water samples were taken periodically between January 2023 and October 2023. The high levels of pollution from several waste sources, such as discharges from homes, businesses, and industries, led to the selection of these locations. Figure 1 shows the locations of these sampling locations.

Figure 1: Map shows the Meghna River study area in Munshiganj, Dhaka

Sample Collection

During the wet season (October 2023) and the dry season (January 2023), water samples were taken. The collection locations were roughly 1500 meters apart, and samples were collected in 1000 ml plastic bottles that had been previously cleaned. Each bottle was firmly sealed and given the appropriate identification number after being collected. Following EPA-approved protocols, the environmental lab at the European University of Bangladesh in Dhaka, Bangladesh, gathered, preserved, and analyzed every water sample. In the field, the water's temperature was measured using a thermometer with a Celsius scale (manufactured in Germany) that reads 100°C. The pH was measured using an electronic digital equipment called a pH meter. Digital TDS and EC meters were used to measure electrical conductivity (EC) and total dissolved solids (TDS), respectively. A DO meter was used to detect the levels of dissolved oxygen (DO), and a BOD incubator was used to examine the biological oxygen demand (BOD). Turbidity was measured using the Nephelometric method, and Chemical Oxygen Demand (COD) was calculated using the Closed Reflux Colorimetric method.

Water quality index (WQI) model

The suitability of water for human consumption can be ascertained thanks to this indicator. The WQI index calculation process consists of three parts[24]. First, a weight (wi) was given to each of the parameters based on how important they were to the overall quality of the drinking water. The following formula is used to calculate the relative weight (Wi) in the second step:

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

where n is the number of parameters, wi is the weight of each parameter, and Wi is the relative weight. According to the suggested recommendations, the third stage involves calculating a quality rating scale (Qi) for each parameter by dividing its concentration in each water sample by the corresponding standard. The result is then multiplied by 100 using the following formula:

$$qi=\frac{ci}{si}x100$$

However, the following formula was used to determine the pH and DO quality ratings:

$$qi_{\text{pH, DO}}=\frac{ci-vi}{si-vi}x100$$

where qi is the ranking for quality. Si is the standard value, and ci is the value of the water quality parameters derived from the analysis. vi is the ideal amount for DO (14.6) and pH (7.0). In order to calculate the WQI, the SI is first calculated for each chemical parameter. The WQI is then calculated using the following formula:

SIi=Wi x qi

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

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

Table 1: shows the scales of the Water Quality Index model (WQI)[1], [9]

Index value for Water Quality	Water quality rating
<50	Excellent quality
50-100	Good Water
100-200	Poor Water
200-300	Very poor water
>300	Water unsuitable for drinking

Results and Discussion

Regular water quality monitoring is necessary for managing the river ecology. The present investigation of the water quality of the Meghna River looked at eight (8) factors, and the findings are as follows:

Temperature

Temperature has a critical role in managing water quality. It is the cause of all alterations in the physicochemical properties of water. Higher temperatures generally speed up chemical reactions. At three sampling locations, the water temperature varied between 20.2 and 20.9 ºC during the dry season and between 28.3 and 28.8 ºC during the wet season. While station 3 recorded the lowest temperature of 20.2 ºC during the dry season, station 1 recorded the maximum temperature during the wet season (28.8 ºC) (Figure 2). River water temperature readings indicate that it fluctuates with the season. In both the dry and wet seasons, the average water temperature was 20.50 ± 0.36 and 28.6 ± 0.25, respectively [Table 2].

pH

The pH values at all sampling sites ranged from 6.89 to 7.77 during the dry season and from 8.54 to 9.25 during the wet season. Station 2 indicated the lowest pH value (7.77) during the dry season, while station 3 recorded the highest pH value (9.25) during the wet season (Figure 2). According to Table 2, the average pH values for the dry and wet seasons were 7.30 ± 0.44 and 6.86 ± 0.36, respectively. As per ECR (2023), inland surface water generally has a pH range of 6.5 to 8.5. The pH levels at every sampling station were found to be within this range. The rise or fall of dissolved gases such as CO_2 and O_2 results in abrupt pH shifts.

Dissolved Oxygen (DO)

Water must have a high dissolved oxygen content to be considered healthy. All living can't survive without oxygen. Adequate oxygen levels are required for aerobic living forms to be supported by natural stream cleaning processes. The DO values at all sampling sites ranged from 9.65 mg/L to 8.42 mg/L during the dry season and from 7.87 mg/L to 5.90 mg/L during the wet season. Station 2 indicated the highest DO value (9.65 mg/L) during the dry season, while station 1 recorded the highest DO value (9.25 mg/L) during the wet season (Figure 2). According to Table 2, the average DO values for the dry and wet seasons were 9.50 ± 0.67and 6.70± 1.02, respectively. In all sites, the rainy season had the highest DO values as compared to the dry season. This is because the oxygen in the water is being used by the bacteria. During the dry season, when wastewater contains a significant amount of organic matter, bacteria become more active and use dissolved oxygen to break down organic matter biologically.

Biological oxygen demand (BOD)

One important indicator for assessing the water quality of rivers, like the Meghna River in Bangladesh, is the Biochemical Oxygen Demand (BOD). Higher BOD values indicate higher pollution levels because they quantify the amount of oxygen bacteria require to decompose organic compounds in water. In our study, The BOD values at all sampling sites ranged from 10.00 mg/L to 5.00 mg/L during the dry season and from 3.20 mg/L to 2.90 mg/L during the wet season. Station 2 indicated the highest BOD value (10.00 mg/L) during the dry season, while station 2 recorded the highest BOD value (3.20 mg/L) during the wet season (Figure 2). According to Table 2, the average BOD values for the dry and wet seasons were 7.7 ± 2.52 and 3.0 ± 0.15, respectively. According to the Department of Environment's Surface and Ground Water Quality Report 2022, the Meghna River's dissolved oxygen (DO) levels ranged from 0.5 mg/L to 8.0 mg/L, while its BOD levels ranged from 2.0 mg/L to 22 mg/L. a sign of our research, these discrepancies show that the water quality varies, with considerable organic pollution in some places. Bangladesh's Environmental Quality Standards (EQS) state that surface waters must have a BOD level of ≤ 6 mg/L to support aquatic life and ensure that they are suitable for a range of applications. Numerous organic and chemical contaminants are responsible for the Meghna River's elevated BOD.

Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD), a critical indicator of water quality, measures the quantity of oxygen required to oxidize organic and inorganic components in water. Elevated COD levels can indicate significant pollution, which can negatively affect aquatic ecosystems. COD levels in the Meghna River have been shown to differ between research and sites. At every sampling location, the COD levels varied from 15.0 mg/L to 12.00 mg/L during the wet season and from 53.00 mg/L to 20.00 mg/L during the dry season. According to Figure 2, station 3 recorded the greatest COD value (14.0 mg/L) during the wet season and the highest COD value (35.00 mg/L) during the dry season. The average COD values for the wet and dry seasons were 13.7 ± 1.53 and 24.30 ± 9.29, respectively, as shown in Table 2. According to Bangladesh's Environmental Quality Standards (EQS), surface waters must have a COD level of less than 200 mg/L in order to support aquatic life and ensure that they are suitable for a variety of uses. The Meghna River's observed COD levels fall well within this range in terms of organic pollution, suggesting generally acceptable water quality.

Electrical conductivity (EC)

Between the three sampling stations, the EC values varied from 150.3 to 51.40 µS/cm during the wet season and from 361 to 178.2 µS/cm during the dry season. Station 2 recorded the lowest EC value (228 µS/cm) during the wet season, while station 3 recorded the highest EC value (232 µS/cm) during the dry season (Figure 2). In comparison to the rainy season, the dry season had the greatest EC values across all stations. This may be the result of a decrease in the overall amount of water during the dry season, which raises conductivity.

Total Dissolved Solid (TDS)

Total dissolved solids, or TDS, is a measurement of the amount of particle materials in solution. This indicates nonpoint source pollution problems associated with various land use practices. The TDS values at all sampling sites ranged from 124.40 mg/L to 130.60 mg/L during the dry season and from 82.80 mg/L to 86.70 mg/L during the wet season. Station 1 indicated the highest TDS value (130.60 mg/L) during the dry season, while station 1 recorded the highest TDS value (86.70 mg/L) during the wet season (Figure 2). According to Table 2, the average TDS values for the dry and wet seasons were 127.60 ± 3.10 and 84.7 ± 1.95, respectively. In all sites, the dry season had the highest TDS values as compared to the wet season. Changes in the dissolved solids concentrations may be harmful. A constant concentration of minerals in the water is necessary for aquatic life. Concentrations that are too high or too low could stunt growth and kill a lot of fish or reefs.

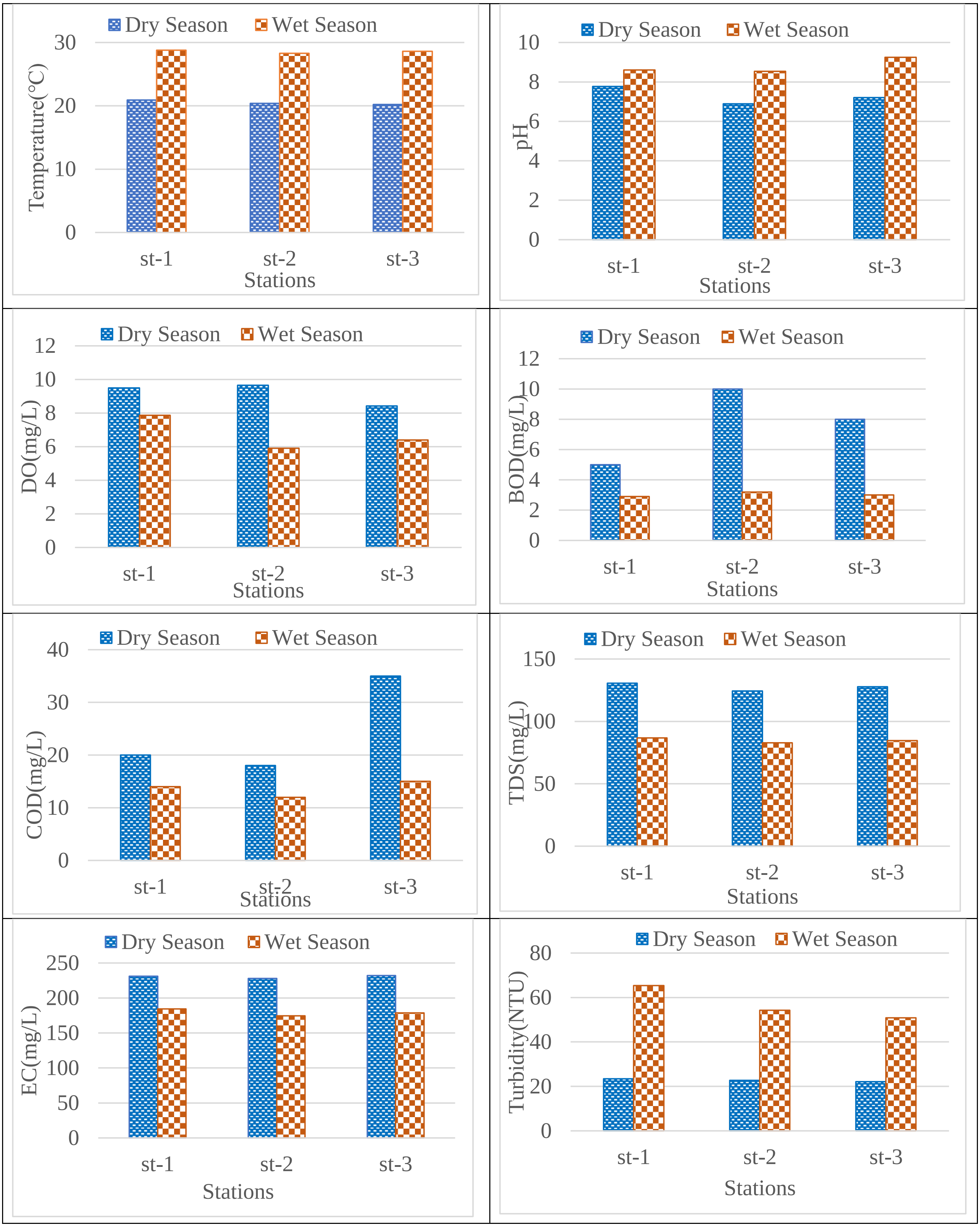
Turbidity

Turbidity levels ranged from 23.40 to 22.70 NTU during the dry season and from 65.40 to 50.90 NTU during the wet season at each sampling location. Station 1 had the highest turbidity value (23.40 NTU) during the rainy season and the highest turbidity value (15 NTU) during the dry season, as shown in Figure 2. Table 2 indicates that the average turbidity readings for the wet and dry seasons were 22.7± 0.65 and 56.8± 7.59, respectively.

Table 2: Meghna River physico-chemical water quality details (parameter ranges are in bracket)

Parameter	Season (Mean ± SD)		Standard ECR,2023
	Dry Season	Wet season	
TEMP. (°C)	20.50 ± 0.36	28.6 ± 0.25	20.0 to 30.0
	(20.20 to 20.90)	(28.3 to 28.8)	
pH	7.30 ± 0.44	6.86 ± 0.36	6.50 to 8.50
	(6.89 to 7.77)	(8.54 to 9.25)	
DO (mg/L)	9.50 ± 0.67	6.70± 1.02	≥ 5 mg/L
	(9.65 to 8.42)	(7.87 to 5.90)	
EC (µS/cm)	230.30 ± 2.08	179.20 ± 5.02	≤1200 µS/cm
	(361.00 to 178.20)	(150.30 to 51.40)	
TDS (mg/L)	127.60 ± 3.10	84.7 ± 1.95	≤ 1000 mg/L
	(130.60 to 124.40)	(86.70 to 82.80)	
BOD (mg/L)	7.7 ± 2.52	3.0 ± 0.15	≤ 6 mg/L
	(10.00 to 5.00)	(3.20 to 2.90)	
COD (mg/L)	24.30 ± 9.29	13.7 ± 1.53	≤ 200 mg/L
	(35.00 to 20.00)	(15.00 to 12.00)	
Turbidity (NTU)	22.7 ± 0.65	56.8 ± 7.59	≤ 10 NTU
	(23.40 to 22.70)	(65.40 to 50.90)	

Figure 2: Seasonal variation of water quality parameter at different points of Meghna River



Physicochemical parameter values are contrasted to standard levels

The acceptability of water for drinking, irrigation, and fishing has been determined by comparing the mean values of all examined water quality parameters with standard levels (Table 3). Throughout the rainy season, the water's temperature above the usual threshold. This results from increased levels of contaminants in the water. The pH & DO level was within the acceptable range. Although the BOD level was under the legal limit for fisheries, it was above the tolerable range, indicating that the river water had been polluted with organic compounds and microbial pollutants. The EC and TDS are within the standard limit It shows that the river water quality is appropriate for a number of applications, such as irrigation, drinking (after treatment), and the sustainability of aquatic life. Excessive levels of EC and TDS may be a sign of saline intrusion, industrial discharge, or agricultural runoff pollution. Turbidity exceeds the standard limit it indicates that the water is murky or hazy due to an excessive number of suspended particles. This may have serious effects on the environment, ecology, and human health.

Table 3: Examined values compared to drinking, irrigation, and fisheries standard levels

Parameters	**Investigated seasonal water quality (mean values)**		**Standard levels**			**Reference**
	Dry	**Wet**	**Drinking**	**Irrigation**	**Fisheries**	
Temperature(°C)	20.5	28.6	25	-	25	ECR (2023), EPA (2018)
pH	7.3	8.8	6.5 – 8.5	6.5 - 8.5	6 - 9	ECR (2023)
DO (mg/L)	9.2	6.7	6	-	$\geq$5	ECR (2023)
BOD (mg/L)	7.7	3.0	-	$\leq$12	$\leq$6	ECR (2023)
COD (mg/L)	24.3	13.7	-	100	50	ECR (2023)
EC (µS/cm)	230.3	179.2	-	2250	800 -1000	ECR (2023), EQS
TDS (mg/L)	127.6	84.7	1000	1000	1000	ECR (2023), EQS
Turbidity (NTU)	22.7	56.8	5	-	-	ECR (2023)

Correlation matrix

To determine the relationship between the physicochemical parameters, a correlation matrix was employed. Water samples from the Meghna River's dry and wet seasons showed significant correlation (Table 4-5). For dry season (Table 4), Temperature is strongly positively correlated with turbidity (0.98), pH (0.79), TDS (0.65), and EC (0.81). This shows that the dissolved solids, electrical conductivity, and suspended particles in the water tend to increase along with the temperature. BOD and pH have a very strong negative connection (-0.99), suggesting that larger levels of organic pollution are linked to more acidic environments. A small positive correlation (0.04) between dissolved oxygen (DO) and pH suggests that changes in pH have minimal impact on oxygen levels. According to the investigation, turbidity, temperature, and TDS all have a significant impact on dissolved oxygen levels, pH, and electrical conductivity. While BOD and COD levels are lower at higher temperatures, turbidity and TDS levels are higher. Chemical and organic contaminants have a detrimental impact on DO levels, which emphasizes how crucial effective wastewater treatment is. The lack of a clear correlation between turbidity and organic contamination suggests that the Meghna River's suspended particles are more mineral-based than organic.

Table 4: correlation coefficient between the Meghna River's physicochemical water quality measures during the dry season

	Temp	pH	DO (mg/L)	BOD (mg/L)	COD (mg/l)	TDS (mg/l)	EC (mg/L)	Turbidity (NTU)
Temp	1							
pH	0.797017	1						
DO (mg/L)	0.638566	0.044162	1					
BOD (mg/L)	-0.77145	-0.99915	-0.00296	1				
COD (mg/l)	-0.64177	-0.04832	-0.99999	0.007128	1			
TDS (mg/l)	0.652098	0.977614	-0.16703	-0.98545	0.162918	1		
EC (mg/L)	0.8146	0.603957	-0.76957	-0.63628	0.766899	0.758135	1	
Turbidity (NTU)	0.980426	0.662505	0.777584	-0.63108	-0.7802	0.490067	-0.19689	1

For wet season (Table 5), There is a substantial positive association between temperature (Temp) and turbidity (0.65), DO (0.92), COD (0.73), TDS (0.99), and EC (0.98). suggesting that dissolved oxygen, conductivity, and suspended particles all rise with temperature. Its substantial negative connection (-0.99) with BOD raises the possibility that organic pollution could be reduced by warmer temperatures. Higher dissolved solids and suspended particles enhance oxygen transport, as seen by the substantial positive correlations observed between dissolved oxygen (DO), turbidity (0.89), TDS (0.97), and EC (0.98). It confirms that organic pollution lowers oxygen levels because of its high negative correlation (-0.89) with BOD. The chemical oxygen demand (COD) exhibits a weak negative association with turbidity (-0.03) but a positive correlation with temperature (0.73) and pH (0.80). Higher temperatures decrease organic pollutants while increasing turbidity, electrical conductivity, and dissolved oxygen. High BOD levels have a detrimental effect on dissolved oxygen. Overall water quality is influenced by the strong relationship between TDS and EC. Mineral content has a stronger correlation with turbidity than organic contamination.

Table 5: correlation coefficient between the Meghna River's physicochemical water quality measures during the wet season.

	Temp	pH	DO (mg/L)	BOD (mg/L)	COD (mg/l)	TDS (mg/l)	EC (mg/L)	Turbidity (NTU)
Temp	1							
pH	0.190063	1						

DO (mg/L)	0.924172	-0.19936	1					
BOD (mg/L)	-0.99718	-0.26325	-0.89288	1				
COD (mg/l)	0.737043	0.803611	0.422999	-0.78571	1			
TDS (mg/l)	0.991592	0.061424	0.96583	-0.97908	0.643393	1		
EC (mg/L)	0.976221	-0.02728	0.985	-0.95719	0.573009	0.996064	1	
Turbidity (NTU)	0.652208	-0.62026	0.892306	-0.59344	-0.03161	0.744815	0.801025	1

The 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. Table 1 shows the water quality classifications based on WQI criteria. It shows that nearly all seasonal samples from the Meghna River, with the exception of the dry season (st-3), fall into the "Poor water quality" category, with WQI values surpassing 200 in both the dry and wet seasons. Additionally, this shows a notable drop in water quality, especially from the wet season to the dry season, which is caused by the direct release of household and industrial wastewater into the river.

Table 6: Using the water quality index model to calculate the WQI of water samples during the Meghna River's dry and wet seasons

parameter	**Dry season**			**Wet season**		
	St-1	St-2	St-3	St-1	St-2	St-3
Temperature(°C)	20.9	20.4	20.2	28.8	28.3	28.6
pH	7.77	6.89	7.21	8.60	8.54	9.25
DO (mg/L)	9.50	9.65	8.42	7.87	5.90	6.40
BOD (mg/L)	5.0	10.0	8.0	2.90	3.20	3.0
COD (mg/L)	20.0	18.0	35.0	14.0	12.0	15.0
EC (µS/cm)	231	118	232	184	174	178
TDS (mg/L)	130	124	127	86.7	82.8	84.7
Turbidity (NTU)	23.4	22.7	22.0	65.4	54.24	50.90
WQI	212.78	265.94	255.12	235.55	200.43	199.19
Status	**Very poor water**					

The WQI results clearly show that the Meghna River's water is extremely contaminated, deeming it unfit for irrigation and public use. Critical insights that might guide focused approaches for regional water management and pollution control are provided by the examination of physicochemical characteristics in conjunction with the WQI. Significant dangers to native fish and other aquatic species may arise from elevated pollutant levels and unbalanced physicochemical characteristics, highlighting the need for conservation and restoration operations.

Conclusion

The findings of this study provide researchers, water resource managers, and environmentalists with valuable information to aid in the implementation of appropriate strategies for improving water quality management programs. The results of our study show how vital it is to pinpoint and reduce particular sources of pollution, which could enhance the distribution of resources for residential, commercial, and agricultural waste management techniques along the river. The implementation of more stringent pollution control regulations may be further supported by such findings. To protect the aquatic ecosystem, more rules on industrial and agricultural operations close to the river and improved effluent standards could be put into place. Thus, a thorough grasp of the water quality of the Meghna River forms the basis for plans for managing water resources and ecosystems in a sustainable manner. According to the Water Quality Index (WQI) analysis, the Meghna River is nearly unfit for irrigation, drinking, and aquaculture throughout the year. In order to address this pressing issue and maintain the sustainability and well-being of this vital river system, comprehensive pollution control techniques must be implemented in addition to committed and proactive steps to prevent and minimize pollutant discharges.

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