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Original Article

Seasonal variability in water quality of the meghna river, Bangladesh: An assessment of key physicochemical parameters

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ABSTRACT

The goal of the current study was to assess the water quality in relation to its physical and chemical characteristics in the Gazaria, Kazipura to Doshadi of the Meghna River, Bangladesh. Six stations examined nine water quality parameters from October 2023 to September 2024 during the pre-monsoon (February –May), monsoon (June –September), and post-monsoon (October –January). According to EPA standard procedures, the physico-chemical parameters temperature, pH, dissolve oxygen (DO), electrical conductivity (EC), total dissolved solid (TDS), salinity, biological oxygen demand (BOD), chemical oxygen demand (COD), and turbidity were measured. The DoE standard was discovered to be surrounded by a few parameters, including salinity, pH, EC, TDSs, and COD. However, during seasonal fluctuations, the Meghna River's physiochemical parameters such as temperature, BOD, and turbidity exceeded the acceptable limit. The Meghna River' s water quality parameters investigation made it abundantly evident that there was a pollution load present. In order to preserve the river' s and the surrounding areas' healthy ecosystem and sound environment, the river' s water quality must be properly managed and monitored.

Keywords: Meghna River, physico-chemical, seasonal fluctuations, water quality.

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INTRODUCTION

Rivers play a crucial role in maintaining ecological balance, supporting biodiversity, and providing essential resources for human activities. In terms of water pollution, Bangladesh is one of the most polluted countries in the world.[1] Pollution from human activities and improper agricultural drainage from rivers pose serious hazards to water supplies.[2] Many of the companies and industries are located along the river system or on the banks of the Meghna.[3] Due to the careless disposal of household and industrial garbage as well as the interference of dishonest individuals, several rivers in this nation are biologically and hydrologically dead. Commercial and industrial operations, as well as the expansion of human populations, have resulted in an enormous inflow of pollutants entering surface water from a variety of sources.[4,5] Physical, chemical, and biological characteristics associated to all other hydrological parameters are the focus of water quality.[6]

One of the largest rivers of the country, the Meghna has an extensive estuary from which the Ganges-Padma, Brahmaputra-Jamuna, and Meghna itself flow.[7] Only 7% of the 1,720,000 km^2 catchment area that these three powerful river basins drain is in Bangladesh.[8] Together with the Padma, the present deltaic Meghna is Bangladesh's greatest river. This river is currently facing serious environmental issues and contamination of the water, which have resulted in a biological and hydrological standstill.[9] One of the most polluted nations is Bangladesh, where 1176 business entities currently release over 0.4 million m^3 of raw wastewater into the rivers daily.[10] Multiple research studies showed that the surface water quality of the country's rivers is becoming much more contaminated every single day and the diverse aspects of pollution makes it

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an urgent complicated issue.[11-13] The surface water monitoring that was done for this project gives resource managers and surge forecasters useful information.

Any given location or source's water quality can be evaluated using physical, chemical, and biological criteria and these parameters' values are detrimental to human health if they exceed specified boundaries.[14-16] Temperature, nutrients, alkalinity, turbidity, hardness, and dissolved oxygen (DO) are all factors that affect the health of the biota in a body of water. The majority of water bodies have small concentrations of several chemical characteristics. Regarding the Meghna's habitat structure, the downstream region encounters significant industry and urbanization, mechanical fishing, and fuel transportation, all of which contribute to the deterioration of the water quality. On both sides of the Meghna, a greater number of man-made activities have emerged, including villages, cities, ports, and industries (fertilizer manufacturers, thermal power plants). Due to all of these stressors, the downstream is now more vulnerable to water contamination, which has a negative impact on aquatic diversity.

This study serves as essential in providing information on the current condition of the Meghna River's water quality. Since water quality is determined by processes, monitoring and water quality maintenance benefit more from updated data. The study might then be utilized to build a database of continuous water quality. In order to assess the current state of the Meghna River's quality, a thorough experimental study was necessary. The goal of the current study was to evaluate the seasonal variability of the water's physio-chemical parameters and the connections between the various Meghna River water quality measurements. In order to manage the water quality of the Meghna River, this assessment will necessitate the enforcement of the current water policy, water usage, management implementation plans, and antidegradation statement.

MATERIALS AND METHODS

Study Area

A study on the Meghna River, one of the most contaminated rivers, was carried out. The study area was divided into 6 sampling station which were denoted St-1 (located: Gazaria_ Kazipura, Upper Meghna), St-2 (located: Char Abdullahpur, Meghna Branch) St-3 (located: Poschim Lalpur, Meghna Branch) St-4 (Kalir Bazar_Mollakandi, Meghna Branch) St-5 (located: Bishnupur, Meghna Branch) and St-6 (Located: Doshadi, Upper Meghna). The study area cover 60 km of Meghna river from Gazaria, Kazipara to Doshadi shown in [Figure 1].

Sampling and Methods

Six sampling stations provided water samples for physicochemical examination during the period from October 2023 to September 2024. Three distinct seasons were chosen for the sampling period: pre-monsoon (February –May), monsoon (June –September), and post-monsoon (October –January). 1000 ml plastic bottles were used to hold the samples that were taken from each sampling station. Total 24 water sample were collected for pre-monsoon, monsoon and post-monsoon respectively. First, the bottles were cleaned and washed with detergent solution and treated with 5% nitric acid (HNO_3) over night. The bottles were labeled with the appropriate identification number and screwed after sampling.

The environmental lab at the Institute of Water Modelling (IWM), in Dhaka, Bangladesh, collected, stored, and examined all water samples in accordance with EPA-approved procedures. The thermometer Celsius scale (made in Germany, measuring 100°C) was used in the field to measure the temperature of the water. A pH meter, an electronic digital device, was used to measure the pH. Total dissolved solid (TDS) was measured by Gravimetric Method and electrical conductivity (EC) assessed through standard procedure. Chemical parameter such as DO was measured by Winkler titration method, biological oxygen demand (BOD) was measured by through the dilution method and chemical oxygen demand (COD) determined using the Closed Reflux Colorimetric method and Turbidity measured using the Nephelometric method. The gathered information was put together, properly assembled, and then statistically examined. To display and analyze the gathered data, Microsoft Office Excel was utilized. Charts and tabular representations were used to present the study's findings.

RESULTS AND DISCUSSION

Managing the river environment requires regular monitoring of the water quality. Nine parameters were examined in the current study of the water quality of the Meghna River, and the results are as follows.

Temperature

When it comes to water quality management, temperature is crucial. All changes in the physicochemical characteristics of water are caused by it. In general, greater temperatures accelerate chemical processes. In the pre-monsoon season, the water's highest temperature was 28.6° C at St-6 and its lowest was 25.1° C at St-1. The highest and lowest recorded temperatures throughout the monsoon season were 33.1°C and 33.0°C at St-4 and St-1, respectively. Additionally, St-5 (30.1° C) and St-4 (20.7° C) had the greatest and lowest temperatures during the post-monsoon season, respectively. In all sampling stations, the monsoon season had the highest temperature of the three distinct seasons, followed by the pre-monsoon and post-monsoon seasons [Figure 2]. Mean water temperature in pre-monsoon, monsoon and post-monsoon season was 26.98 ± 1.02 , 31.5 ± 0.91, 25.6 ± 3.23 respectively [Table 1]. In all sampling stations, the monsoon season had

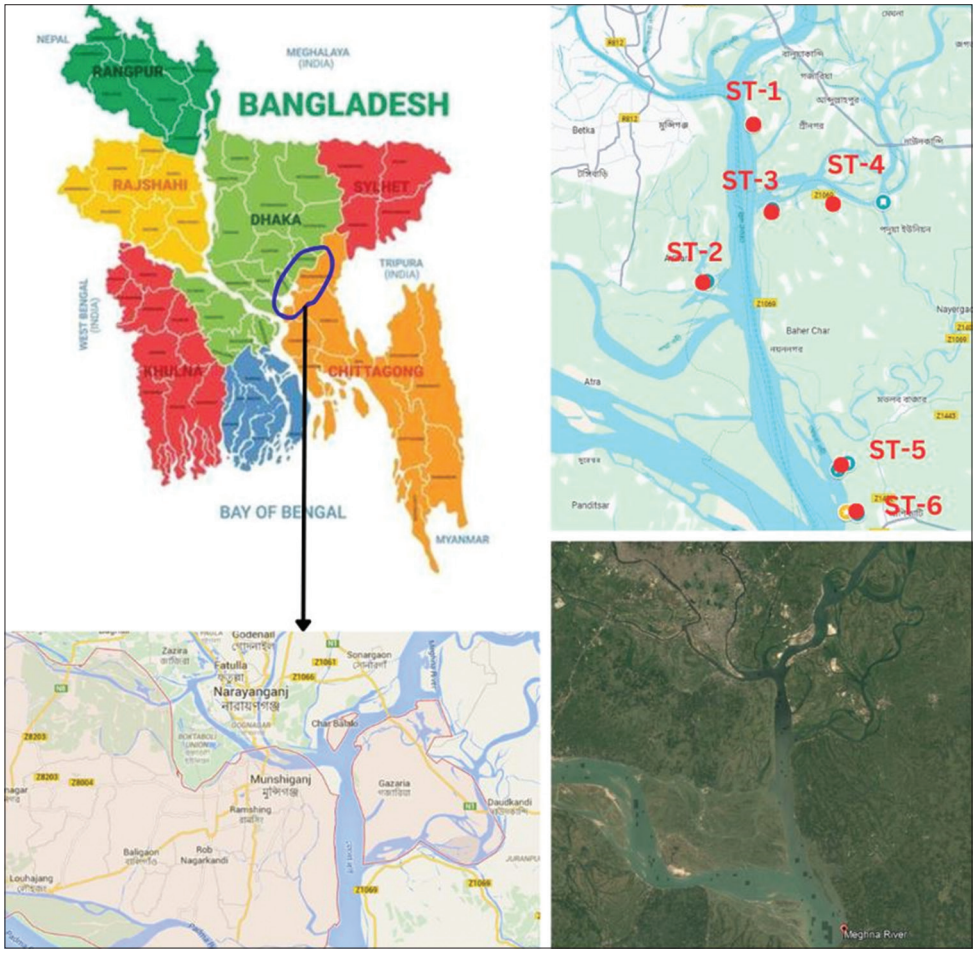

Figure 1: Study area and sampling point in the Meghna river

the highest temperature of the three distinct seasons, followed by the pre-monsoon and post-monsoon seasons. The study's findings showed that, aside from the monsoon season, water temperature was appropriate for aquatic biodiversity; this could be because of the monsoon season's unpredictable weather.

pH

Except from monsoon, Average pH value of pre-monsoon and post-monsoon was alkaline. St-6 and St-3 had the greatest pH (7.70) and lowest pH (6.69) during the pre-monsoon season, respectively. The highest and lowest pH values were recorded at St-1 (7.67) and St-4 (6.20) during the monsoon season, respectively, and St-1 (7.58) and St-5 (6.57), respectively, during the post-monsoon season [Figure 2]. The mean pH values for pre-monsoon, monsoon, and post-monsoon were 7.30 ± 0.25, 6.90 ± 0.35, and 7.10 ± 0.026, respectively [Table 1]. According to ECR (2023), the pH range of inland surface water is typically between 6.5 and 8.5. The investigation found that all sampling stations' pH levels fell within this range. Rapid pH changes are caused by the increase or loss of dissolved gases like CO_2 and O_2. pH measurement of a water sample's alkanity or acidity. So, Study area of water excluding monsoon season was alkaline.

DO

A high level of DO is necessary for healthy water. Without oxygen, all life cannot survive. For natural stream purification processes to support aerobic life forms, sufficient oxygen levels are necessary. In our study, during the pre-monsoon season, the highest and lowest DO levels were 7.54 mg/L at St-4 and 1.95 mg/L at St-6, respectively. The maximum and minimum levels during the monsoon season were 7.39 mg/L at St-1 and 4.20 mg/L at St-4, respectively [Figure 2]. The highest and lowest DO values throughout the post-monsoon season were 6.30 and 2.97 mg/L at St-2 and St-5, respectively [Figure 2]. The mean DO levels were 4.35 ± 1.75, 5.15 ± 1.00, and 4.46 ± 0.88 mg/l in the pre-monsoon, monsoon, and post-monsoon seasons, respectively [Table 1] and the standard level of DO for aquatic organism is ≥5.0 mg/L (ECR, 2023). The study's findings showed that the river water's DO level was decreased, which could have an impact on the aquatic life. The standard for DO is for optimal fish health, DO levels of 5 mg/L are advised; fish mortality has been documented at DO levels below this threshold, which is why the Meghna River's

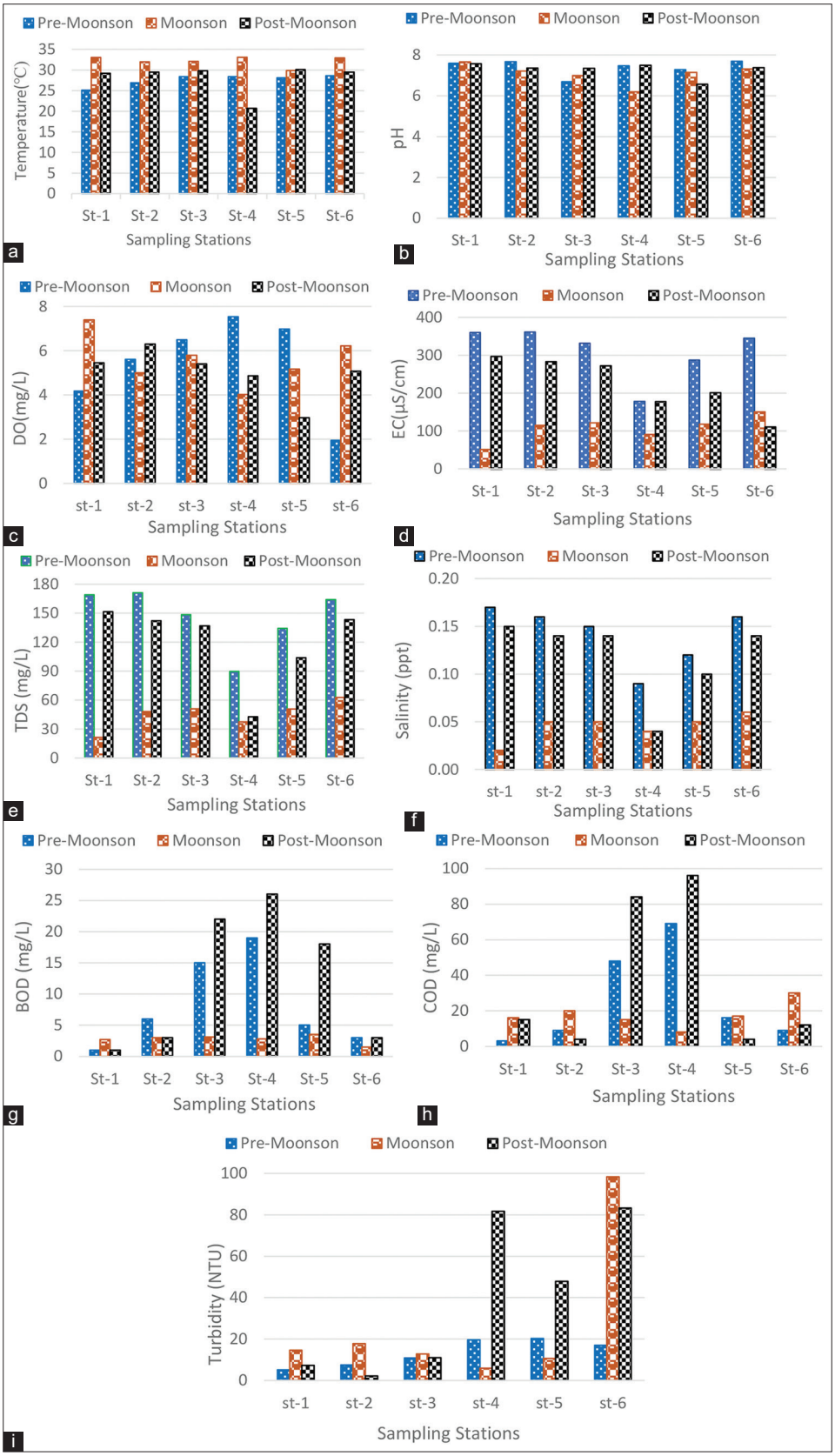

Figure 2: Seasonal variation of water quality at different points of Meghna River: (a)Temperature, (b)pH, (c)DO, (d)EC, (e)TDS, (f)Salinity, (g)BOD, (h)COD, (i)Turbidity

Table 1: Physico-chemical water quality parameters of the Meghna river (ranges of parameters are in parentheses)

Parameter	Season (Mean±SD, N=24)			Standard ECR,2023
	Pre-Monsoon	Monsoon	Post-Monsoon	
Temp. (°C)	26.98±1.02	31.52±0.92	25.60±3.24	20.0–30.0
	28.60–25.10	33.10–29.90	30.10–20.70	
pH	7.35±0.25	6.86±0.36	7.13±0.27	6.50–8.50
	7.85–6.69	7.67–6.20	7.58–6.57	
DO (mg/L)	4.35±1.75	5.15±1.00	4.46±0.88	≥ 5 mg/L
	7.54–0.94	7.39–2.17	6.30–2.91	
EC (µS/cm)	292.75±56.71	90.20±29.45	177.7±60.59	≤1200 µS/cm
	361.00–178.20	150.30–51.40	297.00–99.90	
TDS (mg/L)	139.89±26.96	38.01±12.72	84.62±33.49	≤ 1000 mg/L
	171.20–89.80	62.80–21.44	151.50–42.70	
Salinity (ppt)	0.14±0.03	0.04±0.01	0.08±0.03	≤ 0.5 ppt
	0.17–0.09	0.06–0.02	0.15–0.04	
BOD (mg/L)	7.33±6.53	2.25±0.53	5.48±7.05	≤ 6 mg/L
	19.00–1.00	3.50–1.50	26.00–1.00	
COD (mg/L)	23.88±23.35	17.17±5.65	20.79±27.60	≤ 200 mg/L
	69.00–3.00	31.00–8.00	96.00–3.00	
Turbidity (NTU)	11.48±6.40	24.02±31.34	28.18±25.97	≤ 10 NTU
	24.50–o 3.58	98.40–5.90	83.30–2.08	

DO: Dissolve oxygen; EC: Electrical conductivity TDS: Total dissolved solid; BOD: Biological oxygen demand; COD: Chemical oxygen demand

water during the pre-monsoon season, St-4, did not meet the safe limit. In the pre-monsoon and post-monsoon seasons, the Meghna River's DO content suggests an adverse habitat for aquatic life.

EC

The ions concentration in water is measured by the EC. The environment, water flow, and water sources all affect ion concentration. St-2 and St-4 had the greatest EC (361.0 µS/cm) and lowest EC (178.20 µS/cm) during the pre-monsoon season, respectively. The highest and lowest EC values were recorded at St-6 (150.30 µS/cm) and St-1 (51.40 µS/cm) during the monsoon season, respectively, st-1 (297.00 µS/cm) and St-6 (110.80 µS/cm) highest and lowest EC value respectively, during post-monsoon season [Figure 2]. The mean EC levels were 292.75 ± 56.71, 90.20 ± 29.45, and 177.76 ± 60.59 mg/l in the pre-monsoon, monsoon, and post-monsoon seasons, respectively [Table 1]. The EC values of the water of the Meghna is 202.8 µS/cm measured 2022.[17] The Meghna River's EC concentrations were significantly below the recommended range of 800 –1000 µS/cm for inland surface water, which is appropriate for aquatic environments (ECR, 2023). It could be the lack of carbonate mineral breakdown, waste water discharge, and runoff from cities and farms.

TDS

A measurement of the quantity of particle materials in solution is called TDSs, or TDS. This serves as a sign of nonpoint source pollution issues linked to different land use techniques. They measure the diffraction of light generated by particles in the water by directly measuring the concentration of those particles.[18] During the pre-monsoon season, St-1 had the highest TDS (169.0 mg/L) and St-4 had the lowest (89.8 mg/L). St-6 (62.8 mg/L) and St-1 (21.44 mg/L) had the highest and lowest TDS levels during the monsoon season, respectively, while St-1 (151.5 mg/L) and St-4 (42.70 mg/L) had the highest and lowest TDS levels during the post-monsoon season [Figure 2]. The pre-monsoon, monsoon, and post-monsoon seasons had mean TDS concentrations of 139.89 ± 26.9, 38.01 ± 12.72, and 84.62 ± 33.49 mg/L, respectively [Table 1]. TDS levels in river water were found to be low, with the standard level for aquatic environments or fisheries being ≤ 1000 mg/L (ECR, 2023). Because the density of total dissolved solids controls the flow of water into and out of an organism's cells, variations in the concentrations of dissolved solids can be detrimental. Aquatic life requires a steady level of minerals in the water. Excessive or insufficient concentrations might hinder growth and cause many fish or reefs to die.

Salinity

There are notable seasonal fluctuations in the salinity of Bangladesh's Meghna River, especially in its delta areas. St-1 and St-4 had the greatest salinity (0.17 ppt) and lowest salinity (0.09 ppt) during the pre-monsoon season, respectively. The highest and lowest salinity values were recorded at St-6 (0.06)

and St-1 (0.02) during the monsoon season, respectively, st-1 (0.15 ppt) and St-4 (0.04) highest and lowest salinity value respectively [Figure 2], during post-monsoon season. The mean salinity levels were 0.14 ± 0.03, 0.04 ± 0.01, and 0.08 ± 0.03 mg/l in the pre-monsoon, monsoon, and post-monsoon seasons, respectively [Table 1]. Regarding Aquatic Life, Ecosystems and freshwater organisms can be harmed by high salinity. The Meghna River in Bangladesh exhibits significant seasonal variations in salinity, particularly in pre-monsoon season and post-monsoon season. Seasonal variations in freshwater flow and tidal impacts are the main causes of these fluctuations. Fisheries, the river's ecological health, and its potential as a freshwater resource all depend on monitoring these salinity fluctuations.

BOD

When evaluating the water quality of rivers, such as Bangladesh's Meghna River, the Biochemical Oxygen Demand (BOD) is a crucial metric. BOD measures how much oxygen bacteria need to break down organic materials in water; higher BOD values signify higher pollution levels. In our study, During the pre-monsoon season, St-4 had the highest BOD (19 mg/L) and St-1 had the lowest (1 mg/L). St-5 (3.5 mg/L) and St-6 (1.5 mg/L) had the highest and lowest BOD levels during the monsoon season, respectively, while St-4 (26 mg/L) and St-1 (1 mg/L) had the highest and lowest BOD levels during the post-monsoon season [Figure 2]. The pre-monsoon, monsoon, and post-monsoon seasons had mean BOD concentrations of 7.33 ± 6.53, 2.25 ± 0.53, and 5.48 ± 7.05 mg/L, respectively [Table 1]. The Department of Environment's Surface and Ground Water Quality Report 2022 states that the Meghna River's BOD levels varied from 2.0 mg/L to 22 mg/L, while its DO levels ranged from 0.5 mg/L to 8.0 mg/L. These variations indicate that the water quality fluctuates, with some areas experiencing significant organic pollution. According to Bangladesh's environmental quality standards (EQS), surface waters should have a BOD level of ≤ 6 mg/L in order to sustain aquatic life and guarantee suitability for a variety of uses. BOD levels above this limit can cause oxygen depletion, which will negatively impact fish and other aquatic organisms.[19] In our study area was slightly polluted in pre-monsoon and post-monsoon season according to standard vaule of BOD.

COD

The amount of oxygen needed to oxidize organic and inorganic materials in water is measured by the COD, a crucial indication of water quality. Significant pollution can be indicated by elevated COD levels, which can have a negative impact on aquatic ecosystems. In the Meghna River, COD levels have been observed to vary across different studies and locations. During the pre-monsoon season, St-4 had the highest COD (69 mg/L) and St-1 had the lowest (3 mg/L). St-6 (30 mg/L) and St-4 (8 mg/L) had the highest and lowest COD levels during the monsoon season, respectively, while St-4 (96 mg/L) and St-2,5 (4 mg/L) had the highest and lowest COD levels during the post-monsoon season [Figure 2]. The pre-monsoon, monsoon, and post-monsoon seasons had mean COD concentrations of 23.88 ± 23.35, 17.17 ± 5.65, and 20.79 ± 27.60 mg/L, respectively [Table 1]. Samples taken from September 2015 to March 2016 had COD levels ranging from 2.5 to 5.9 mg/L.[20] COD levels over critical standards were recorded at some Meghna River stations, indicating specific regions of concern.[21] In this regard, Bangladesh's Environmental Quality Standards (EQS) state that surface waters should have a COD level of ≤ 200 mg/L in order to sustain aquatic life and guarantee its appropriateness for a range of applications. In terms of organic contamination, the Meghna River's measured COD levels are well within this range, indicating generally satisfactory water quality. However, it is essential to remember that seasonal variations, industrial discharges, and agricultural runoff can all affect the quality of water, and that regular monitoring is necessary to identify and efficiently control any sources of contamination.

Turbidity

Water bodies that contain suspended particles like silt, clay, and organic matter are said to have turbidity, a measure of water clarity. During the pre-monsoon season, St-5 had the highest Turbidity (20.20 NTU) and St-1 had the lowest (5.09 NTU). St-6 (98.40 NTU) and St-4 (5.96 NTU) had the highest and lowest Turbidity levels during the monsoon season, respectively, while St-6 (83.30 NTU) and St-2 (2.08NTU) had the highest and lowest Turbidity levels during the post-monsoon season [Figure 2]. The pre-monsoon, monsoon, and post-monsoon seasons had mean Turbidity concentrations of 11.48 ± 6.40, 24.02 ± 31.34, and 28.18 ± 25.97 mg/L, respectively [Table 1]. During the monsoon season Due to improved suspended load transfer, higher turbidity levels are caused by increased rainfall and river flow. Free-flowing rivers like the Meghna naturally follow this pattern.[22] Seasonal variations, upstream activity, and local environmental circumstances are some of the elements that affect these variances.

A [Table 2] that displays the link between several variables is called a correlation matrix. Between − 1 and +1 are the values, where: +1 indicates a perfect positive correlation, meaning that both variables rise in tandem. − 1 denotes a perfect negative correlation, meaning that when one rises, the other falls.0 → No correlation, meaning that there is no connection between the variables. The results of this investigation demonstrate a high degree of linear correlation between the parameters.

Strong Positive Correlations: A strong direct association is shown by values that are near +1.

EC and TDS (0.999): There is a nearly perfect correlation between EC and TDS . Because dissolved ions in water

Table 2: Pearson's correlation matrix of water quality parameters

Parameter	TEMP.	pH	DO	EC	TDS	Salinity	BOD	COD	Turbidity
TEMP.	1.000								
pH	-0.219	1.000							
DO	0.992	-0.219	1.000						
EC	-0.553	0.855	-0.553	1.000					
TDS	-0.559	0.858	-0.559	0.999	1.000				
Salinity	-0.565	0.861	-0.565	0.997	0.997	1.000			
BOD	0.331	0.230	0.331	0.168	0.177	0.202	1.000		
COD	0.520	0.003	0.520	-0.093	-0.088	-0.061	0.939	1.000	
Turbidity	0.195	-0.147	0.195	-0.195	-0.204	-0.205	-0.088	0.094	1.000

DO: Dissolve oxygen; EC: Electrical conductivity TDS: Total dissolved solid; BOD: Biological oxygen demand; COD: Chemical oxygen demand; Green color: Negative correlation; White color: No correlation; Yellow color: Positive correlation

contribute to conductivity, EC rises as TDS does. Because dissolved salts contribute to salinity, TDS and salinity are strongly correlated (0.997). This implies that the number of dissolved solids in the Meghna River affects its salinity. A strong correlation exists between the COD and biological oxygen demand (BOD) (0.939). They both show the amount of organic contamination. BOD and COD both rise as organic matter does. Temperature and DO (0.992): According to this robust link, DO levels rise in tandem with temperature. However, because warmer water holds less oxygen, DO typically declines with increasing temperatures, according to science. This could suggest sampling or seasonal influences. Strong Negative Correlations: When two variables have values near − 1, one is rising while the other is falling. DO and EC (− 0.553), DO and TDS (− 0.559), and DO and Salinity (− 0.565): DO is decreased by higher dissolved solids and salinity. Water that is saline or dirty holds less oxygen for aquatic life, thus this makes sense. Temperature and Salinity (− 0.565), Temperature and TDS (− 0.559): TDS and salinity levels decrease with increasing temperature. This might be because hotter months (like the monsoon) have diluting effects. These numbers suggest a weak or nonexistent correlation. COD has no effect on acidity, as indicated by the nearly zero association between pH and COD (0.003). Water clarity, or turbidity, shows low correlation with organic pollution, indicating that suspended particles are not principally organic (turbidity and BOD − 0.088, turbidity and COD 0.093).

CONCLUSION

The results of this study give environmentalists, water resource managers, and researchers useful information to help them implement suitable techniques for enhancing water quality management initiatives. The explanation given is that during the study year, pH, EC, TDS, salinity, and COD all stayed within the acceptable range. This indicates that the environmental quality requirements for surface water, such as the Meghna River, established by the Department of Environment (DoE), Bangladesh, were not exceeded by these water quality parameters. Aquatic ecosystem health is ensured by a constant pH. Excessive pH level can damage aquatic life, including fish. A balanced mineral content, which means no excessive pollution from industrial or agricultural discharge, is indicated by a consistent EC within the safe level. As long as TDS stays below the limit, there may not be any serious sewage, industrial, or salt intrusion contamination. Excessive TDS can harm aquatic life and leave water unsafe for human consumption. The Meghna River's freshwater status is maintained by its low salinity. Elevated salinity can lower agricultural yield and damage freshwater fish. However, according to ECR 2023, some stations exceed the allowable DO level during the monsoon and post-monsoon seasons. In Contrast, according to the explanation above, In Meghna river during pre-monsoon and post-monsoon, the physiochemical characteristics such as BOD were Exceed the safe range. River water levels decline during the pre-monsoon season as a result of less rainfall. Because contaminants are less diluted when there is less water, BOD concentrations rise. Wastewater, fertilizers, and surplus organic matter are washed into the river during monsoon rains. The BOD levels rise above the acceptable threshold due to the abrupt inflow of organic material, which accelerates microbial breakdown. Uncontrolled pollution discharge degrades rivers' ecological quality. Therefore, in order to help the government, create and execute relevant policy guidelines, it is vital to regularly assess the water quality of the Meghna River in order to safeguard and improve its surface water quality.

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