

ASSESSMENT OF THE PHYSICOCHEMICAL PARAMETERS AND THE WATER QUALITY INDEX AT THE UPSTREAM PART OF THE SANGU AND MATAMUHURI RIVERS OF BANGLADESH

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Abstract

This study assessed 16 water quality parameters in situ at 4 locations in the upstream valley of each Sangu and Matamuhuri Rivers. Water Temperature (WT), pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Dissolved Oxygen (DO) were measured by direct probe method. Total Alkalinity (TA), Chloride (Cl⁻), Total Hardness (TH), and Carbon-di-oxide (CO₂) were measured by titration method, and Turbidity, Total Suspended Solids (TSS), Ammonia (NH₃), Nitrite (NO₂⁻), Nitrate (NO₃⁻), Sulfate (SO₄²⁻), and Orthophosphate (PO₄³⁻) were measured by colorimetric method. The Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) was used to calculate the water quality index (WQI). Water quality parameters pH, EC, TDS, DO, TA, Cl⁻, TH, CO₂, NO₂⁻, NH₃, NO₃⁻, and SO₄²⁻ were found within the range of standard values for drinking water in all the points of both the rivers, whereas, the WT was found slightly low (19.9°C) from the standard values (20-30°C) at one point of the Matamuhuri River. CO₂ and PO₄³⁻ were higher than the standard values at all sampling points of both rivers, with a mean value of 26.15 mgL⁻¹ having a standard deviation (SD) of 1.61 and 0.19 mgL⁻¹ (SD 0.05) for Sangu River and 24.15 mgL⁻¹ (SD 4.49) and 0.21 mgL⁻¹ (SD 0.03) for Matamuhuri River respectively. The turbidity was higher at all the points of the Sangu River, whereas at two points of the Matamuhuri River. TSS was higher at two and one points of the Sangu and Matamuhuri Rivers, respectively. The CCMEWQI of the Sangu and Matamuhuri Rivers was calculated at 82.95 and 81.08, respectively. The water quality, according to the CCMEWQI for both the Sangu and Matamuhuri Rivers, was in the “good” category of the index.

Keywords: Sangu, Matamuhuri, Physicochemical, Water Quality Index, WQI, CCMEWQI.

Introduction

The water quality parameters control the quality of the ecosystem and biodiversity of any aquatic environment (Mukherjee, *et al.*, 2023). The traditional approach of reporting the water quality of a point or a water body parameter by parameter in compliance with the guideline provides a wealth of information but has its complexity of understanding by general peoples and somewhat policymakers. A WQI reduces the multivariate nature of the data, combines all the parameters mathematically, compares them with their guideline values, and provides a readily understandable form of value with insight into water quality and human influences. WQI is a helpful tool to state the suitability of the water for humans, aquatic life, and wildlife (CCME, 2017).

Bangladesh, a land of rivers having about 700 rivers (Hossen, *et al.*, 2019), is divided into four major river networks such as i) the Brahmaputra-Jamuna River system, ii) the Ganges-Padma River system, iii) the Surma-Meghna River system, and iv) the Chittagong region hilly river system. The first three systems are interconnected, but the Chittagong hilly river system is completely separate and disconnected from the other systems and has a flow direction from south to north to fall into the Bay of Bengal (Rahman, *et al.*, 1990).

The total area of 13295 km² of the Chittagong Hill Tracts (CHTs) is comprised of seven valleys formed by the rivers Feni, Karnafuli, Chengi, Maini, Kassalong, Sangu, and Matamuhuri and their tributaries (Gain, 2000; Khan and Haque, 2003). Sangu and Matamuhuri are the two main rivers of the Bandarban districts, flowing parallel through the Sangu-Matamuhuri wildlife sanctuary, separated by the Chimbuk range. Sangu River is named after the Sangu chara, the largest one of the three charas which combined near the 62 and 63 nos. pillars of the Bangladesh-Myanmar border. These three charas formed the Sangu River, which flows through Thanchi and Bandarban Sadar upazilas and falls to

the Bay of Bengal at Juidondi, Dohajari union of Chandanaish upazila of Chittagong district (Charlie, 1945). Matamuhuri is a transboundary river that originates in the north Arakan hills of Myanmar, enters Bangladesh at the Poyamuhuri union of Alikadam upazila, and falls to the Bay of Bengal near the Matarbari of Cox's Bazar district.

The annual runoff discharge of the Sangu and Matamuhuri watersheds is about 2167.77 and 1490.61 million cubic meters, respectively, of which 84% and 79% discharge are in the wet season (Rudra and Alam, 2023). These rivers and their streams are the only water sources in the valleys' upland. These once-vibrant rivers are facing unusual siltation, navigability crisis, excess water in monsoon, and water scarcity in the dry season, which leads to drinking water, irrigation, and fishing crisis due to deforestation, stone extraction, changing cropping practices, and climate change (Rudra and Alam, 2023; Islam, *et al.*, 2017). These hilly rivers are dependent on the forest for their survival, and deforestation can degrade the rivers to a great extent (Shachi, 2018).

CCMEWQI has been adopted by the United Nations Environment Programme in various forms and used to rate water quality worldwide. The Egyptian WQI is based on the CCMEWQI (Khan *et al.*, 2008). New Zealand used this for marine water quality assessment (Walker and Vaughan, 2013), Brazil used it for shrimp culture (Ferreira *et al.*, 2011), USA used it in several states (Bya.org, 2003; IDNR, 2011), India and Vietnam used it for surface water monitoring (Darapu *et al.*, 2011; Hanh *et al.*, 2011).

Several studies have been conducted in the downstream reaches of the Sangu and Matamuhuri Rivers. Haque *et al.* (2020) investigated the relationship between WT and macrobenthos at the estuary of the Sangu River. Perkins (1976) showed the dependence of the benthic community on the salinity, DO, WT, etc. Other physical and nutrient parameters also determine the quality of the aquatic

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environments (Blaber and Blabar, 1980; Cyprus and Blaber, 1992; Jones, et al., 1996; Fraser, 1997; Young, et al., 1997; Akin, et al., 2005; Jaureguizar, et al., 2003; Simier, et al., 2004; Vivier, et al., 2010; Nabi, et al., 2011). Nabi et al. (2015) showed that DO and salinity are the most important parameters for the aquatic environment at the estuary of the Matamuhuri River. Knowing the water quality at the upstream of the rivers is crucial as these are the only water sources. So far, research has yet to be conducted on the water quality at the upstream valleys of the Sangu and Matamuhuri Rivers. This study aims to determine the physicochemical and nutrient parameters of the upstream part of the Sangu and Matamuhuri Rivers within the range of the Santu-Matamuhuri Wildlife Sanctuary and calculate the WQI of each sampling point and the overall study reach of the rivers by CCMEWQI.

Methodology

Sampling parameters

Sampling was done at 4 points of each of the Sangu and Matamuhuri rivers. Sampling started from downstream and completed upstream. The names of the sampling points and the coordinates are shown in **Table 1**. All the sampling points are shown in **Fig. 1**. Samples were collected 6 cm below the water surface.

Water quality parameters

All the water quality parameters were measured in situ at the sampling site. WT, pH, EC, TDS, and DO were measured

using a portable HACH HQ30d multi-parameter meter. TA, Cl⁻, TH, and CO₂ were measured by titration method using a digital titrator associated with the HACH ff2 aquaculture kit. Turbidity, TSS, NO₂⁻, NH₃, NO₃⁻, PO₄³⁻, and SO₄²⁻ were measured by using a portable HACH DR900 colorimeter. In all the cases, appropriate reagents listed in the manufacturer's (HACH) method were used and the methods were followed accordingly. The details of the methods are given in **Table 2**.

Table 1. Location and Coordinates of the Sampling points.

River	Location	Longitude	Latitude
Sangu	Ma Lung Gya	21°24.26'	92°36.23'
	Licri	21°24.44'	92°35.20'
	Choto Yang Bong	21°26.20'	92°34.51'
	Mo Reng Yang	21°32.13'	92°33.16'
Matamuhuri	Machkum	21°24.53'	92°29.19'
	Chaillatoli	21°24.95'	92°28.36'
	Sindumukh	21°25.79'	92°28.34'
	Indumukh	21°26.13'	92°28.42'

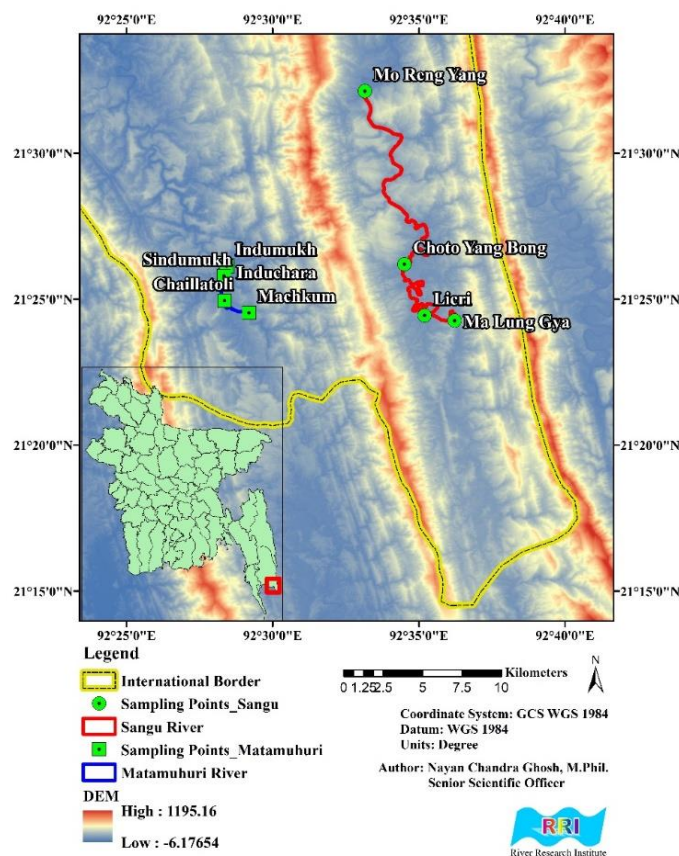


Fig. 1. Sampling points of Sangu and Matamuhuri Rivers.

Water Quality Index (WQI)

We used CCMEWQI (CCME, 2017) to calculate the water quality index of the Sangu and Matamuhuri rivers. The calculation of CCMEWQI is based on three factors, the number of parameters whose guidelines are not met (scope), the frequency with which the guidelines are not met (frequency), and the deviation of each parameter from the standard guideline (amplitude). These three factors are combined as the summation of three vectors to obtain a single water quality value of 0 – 100, where 0 – 44 is considered poor, 45 – 64 is considered marginal, 65 – 79 is considered fair, 80 – 94 is considered good, and 95 – 100 is considered excellent (CCME, 2017).

The “scope” is the percentage of parameters that do not meet the guidelines at least once during the considered period and is calculated by Eq. (1)

$$F_1 = \left(\frac{\text{Number of failed parameters}}{\text{Total number of parameters}} \right) \times 100 \quad \text{Eq. (1)}$$

The “frequency” is the percentage of individual tests that do not meet the guidelines and is calculated by Eq. (2)

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \times 100 \quad \text{Eq. (2)}$$

The “amplitude” is the amount by which the failed test values deviate from the standard guideline and is calculated by three different steps.

The first step is called “excursion”, which is the number of times by which an individual concentration is greater than (or less than, if the guideline is a minimum) the guideline. For the cases where the concentration must not exceed the guideline, it is calculated by Eq. (3a)

$$\text{excursion}_i = \left(\frac{\text{FailedTestValue}_i}{\text{Objective}_i} \right) - 1 \quad \text{Eq. (3a)}$$

For the cases where the concentration must not fall below the guideline, it is calculated by Eq. (3b)

$$\text{excursion}_i = \left(\frac{\text{Objective}_i}{\text{FailedTestValue}_i} \right) - 1 \quad \text{Eq. (3b)}$$

The collective amount by which individual tests are out of compliance is called the “normalized sum of excursions or nse” and is calculated by Eq. (4)

$$\text{nse} = \frac{\sum_{i=1}^n \text{excursion}_i}{\text{Number of tests}} \quad \text{Eq. (4)}$$

where “Number of tests” represents the tests meeting and not meeting guidelines.

The “amplitude” is then calculated by an asymptotic function that scales the normalized sum “nse” to yield a range between 0 – 100 and is given by Eq. (5)

$$F_3 = \left(\frac{\text{nse}}{0.01\text{nse}+0.01} \right) \quad \text{Eq. (5)}$$

Once all three factors are calculated from Eq. (1), (2), and (5), the CCMEWQI is calculated by Eq. (6)

$$\text{CCMEWQI} = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right) \quad \text{Eq. (6)}$$

The divisor 1.723 normalizes the resultant values to a range between 0 – 100 (CCME 2017).

The standard guidelines used for calculating the CCMEWQI are the DoE standard (ECR, 2023) for drinking water for the parameters WT, pH, DO, TDS, TH, Cl⁻, Turbidity, TSS, NH₃, NO₂, NO₃, SO₄²⁻, and PO₄³⁻; DoE standard (ECR, 1997) for drinking water for EC; Arthur (2022) for alkalinity and Advanced BioTech (2023) for CO₂.

Table 2. Details of the Water Quality Measurement Methods.

Parameter	Method	Range	Source
WT	USEPA Electrode Method	-10-110°C	HACH 8156, (2021)
pH	USEPA Electrode Method	0-14	HACH 8156, (2021)
EC	USEPA Direct Measurement Method	0.01– 200,000 μS/cm	HACH 8160, (2021)
TDS	USEPA Direct Measurement Method	0-50,000 mgL ⁻¹	HACH 8160, (2021)
DO	Direct Measurement Method	0.1-20.0 mgL ⁻¹	HACH 10360, (2021)
TA	Titration Method	10-400 mgL ⁻¹	HACH 8203, (2018)
Cl ⁻	Titration Method	10-100 mgL ⁻¹	HACH 8207, (2015)
TH	Titration Method	10-4000 mgL ⁻¹	HACH 8213, (2015)
CO ₂	Titration Method	0-100 mgL ⁻¹	HACH 8205, (2015)
Turbidity	Absorptometric Method	21-1000 FAU	HACH 8237, (2013)
TSS	Photometric Method	5-750 mgL ⁻¹	HACH 8006, (2014)
NO ₂	USEPA Diazotization Method	0.005 - 0.350 mgL ⁻¹	HACH 8507, (2019)
NH ₃	Salicylate Method	0.01 - 0.80 mgL ⁻¹	HACH 8155, (2018)
NO ₃	Cadmium Reduction Method	0.3 - 30.0 mgL ⁻¹	HACH 8039, (2019)
PO ₄ ³⁻	USEPA PhosVer 3 (Ascorbic Acid) Method	0.02 - 2.50 mgL ⁻¹	HACH 8048, (2017)
SO ₄ ²⁻	USEPA SulfaVer 4 Method	2 - 70 mgL ⁻¹	HACH 8051, (2013)

Results and Discussions

The spatial variation of all the water quality parameters of the Sangu and Matamuhuri Rivers are shown in **Fig. 2** and **Fig. 3** respectively. The Numerical values of the water quality parameters along with the mean, SD, and drinking water standard are shown in **Table 3**.

The mean WT of the Sangu River was determined at 24.05°C (SD 0.93), whereas the Matamuhuri River's mean WT was 21.4°C (SD 1.38). Both the rivers' values are within the DoE standard range of 20-30°C (ECR, 2023) except the Machkum Point of Matamuhuri River. The Machkum point of the river is a very narrow strip (about 6m in width) of the Matamuhuri River, with a right-angled, very high sedimentary rocky riverbank. It is also a point of comparatively high depth of

around 6-8m, whereas the other points are about 1-2m deep. The banks are covered with tall trees, rarely allowing sunlight onto the river. The low sunlight exposure along with high water depth increases the water heating time, making the water relatively cooler than the other points.

The mean DO concentrations of the Sangu and Matamuhuri rivers are 7.89 mgL^{-1} (SD 0.46) and 9.36 mgL^{-1} (SD 0.17), respectively. Both rivers' points have a value of DO concentrations above the DoE standard $>6 \text{ mgL}^{-1}$ for drinking water and aquaculture (ECR, 2023). The higher average DO level of the Matamuhuri River indicates that it possesses more healthier ecology than the Sangu River. The higher SD of the Sangu River suggested that the distribution of DO among the sampling points is more varying than in the Matamuhuri River. Both rivers have an increasing trend as the river progresses, but Sangu has a higher increasing slope than Matamuhuri, as shown in Fig. 2 and Fig. 3. This may be because the measuring points of the Sangu River were nearer the origin of the river than the Matamuhuri River. As the rivers progress, more and more interventions and human and natural influences come into play in the DO concentration variation.

The pH value also shows a similar trend to the DO concentrations and can be incorporated into the same facts. The mean pH of the Sangu River was 7.89 (SD 0.20); in the Matamuhuri River, it was 8.34 (SD 0.11). Both rivers possess pH values within the DoE standard range of 6.5-8.5 (ECR, 2023). A higher pH of Matamuhuri River indicates that it is more suitable for aquatic life.

Although the pH of the Matamuhuri River was higher than the Sangu River, the acid-neutralizing capacity, i.e., TA of the Sangu River, is higher than the Matamuhuri River. This usually happens when water has a high concentration of dissolved acid-neutralizing (alkali) substances such as carbonate, bicarbonate, and hydroxide ions (Arthur, 2022). The mean TA concentrations of the Sangu River were found to be 119 mgL^{-1} (SD 15.03), whereas the Matamuhuri River was 101 mgL^{-1} (SD 4.64). The higher SD of the Sangu River shows variability among points, whereas the Matamuhuri River shows a more consistent distribution of alkalinity. Both rivers have alkalinity within the standard range of 20-250 mgL^{-1} (Arthur, 2022).

The distribution of EC and TDS concentrations in the Sangu and Matamuhuri Rivers has a similar trend. EC and TDS of the Sangu River have a nearby value for the Ma Lung Gya, Licri, and Choto Yang Bong points but have a higher value in the Mo Reng Yang point. The upstream of Mo Reng Yang has a deep and wide portion of the Sangu River called Andharmanik, named after the word "Andhar", which means darkness. This is a section of high ecological health and geological formation of sedimentary rocky steep bank, which may have influenced the EC and TDS values of these points. The mean EC value for the Sangu River was $168.78 \text{ }\mu\text{S/cm}$ (SD 15.15), whereas for the Matamuhuri River was $203.73 \text{ }\mu\text{S/cm}$ (SD 5.72). On the other hand, the mean TDS value for the Sangu River was 79.68 mgL^{-1} (SD 6.59), whereas for the Matamuhuri River was 96.90 mgL^{-1} (SD 2.85). The higher SD of the Sangu River is due to the high value of the Mo Reng Yang point. Both rivers have the EC and TDS values within the standard range of $1200 \text{ }\mu\text{S/cm}$ (ECR, 1997) and 1000 mgL^{-1} (ECR, 2023), respectively.

The Cl^{-} concentration of both rivers shows a varying type of spatial distribution. In the Sangu River, the mean value of Cl^{-}

concentration was 10 mgL^{-1} (SD 3.32), while the Matamuhuri River had 13.25 (SD 2.86). Both rivers have chloride values within the DoE standard of 250 mgL^{-1} (ECR, 2023) and have an increasing trend with the rivers' progress. Both rivers have a nearby value and low concentrations compared to the standard value. Maintaining low chloride concentration is very important for various freshwater fishes, aquatic microorganisms, aquatic plants, etc.

The mean TH concentration in the Sangu River was 70.25 mgL^{-1} (SD 6.06), and in the Matamuhuri River was 81.0 mgL^{-1} (SD 3.54), well within the DoE standard 500 mgL^{-1} (ECR, 2023). Sangu River shows a high value of TH at the Mo Reng Yang point whereas, the Matamuhuri River shows a lower concentration at the Machkum point. The deviation of TH content in both these points can be explained by the unique nature of the sampling points described in the previous sections. The low value in the Machkum might facilitate the high fish yield in that area. According to the locals, the Machkum word came from two different words, "Mach" means fish, and "Kum" means home.

The distribution of CO_2 in the Sangu River is reasonably consistent, whereas it varies in the Matamuhuri River. The mean CO_2 concentration in the Sangu River was 26.15 mgL^{-1} (SD 1.61), whereas, in the Matamuhuri River, it was 24.15 mgL^{-1} (SD 4.49). In both cases, the values exceed the standard limit of 10 mgL^{-1} (Advanced BioTech, 2023). As the rivers are in the hilly regions and lie in the Sangu-Matamuhuri wildlife sanctuary, the aquatic life is somewhat preserved. Hence, CO_2 concentration may possess a higher value due to the influence of organic matter and aquatic respiration.

Turbidity is a parameter dependent on that point's natural and human events. The Sangu River has high but relatively consistent turbidity within the measuring reach, having a mean value of 12 FAU (SD 2.35). The Matamuhuri River has low but widespread turbidity with a mean value of 7.5 FAU (SD 6.87). The very low turbidity at the Machkum point of the Matamuhuri River may be due to the unique characteristics of that point described previously. At the same time, zero turbidity at the Indumukh point may be because the measuring point and its upstream up to about a kilometer extent has a gravel riverbed that inhibits the sand and silt from mixing with the water and also filters the sediments coming from upstream. On the other hand, in Chaillatoli Point, the riverbed is made of fine sand and silt, and there were numerous human activities on the measuring instance, which led the water to be highly turbid. All the points of the Sangu River exceed the DoE standard 5 mgL^{-1} (ECR, 2023), while for Matamuhuri River, Chaillatoli and Sindumukh points the value exceeds the standard. Although the colorimeter gives turbidity values, these values are lower than the measuring range of the method used in this study and hence cannot be used to calculate the WQI. The mean TSS concentration of the Sangu River was 10.75 mgL^{-1} (SD 1.48), which is much more consistent among the points. TSS concentration of the Matamuhuri River showed a similar trend as turbidity with a mean concentration of 9.50 mgL^{-1} (SD 6.87). The Ma Lung Gya and Mo Reng Yang points of the Sangu River and the Chaillatoli point of the Matamuhuri River exceed the DoE standard of 10 mgL^{-1} of TSS for drinking water (ECR, 2023).

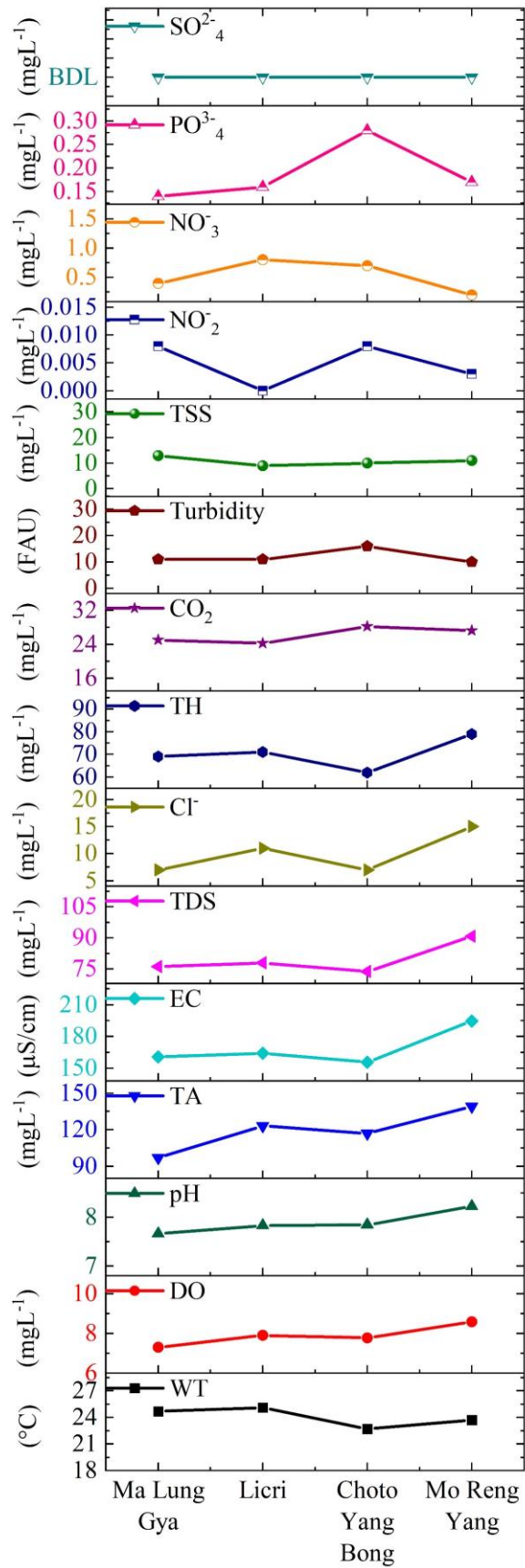


Fig. 2. Spatial variation of water quality parameters of the Sangu River.

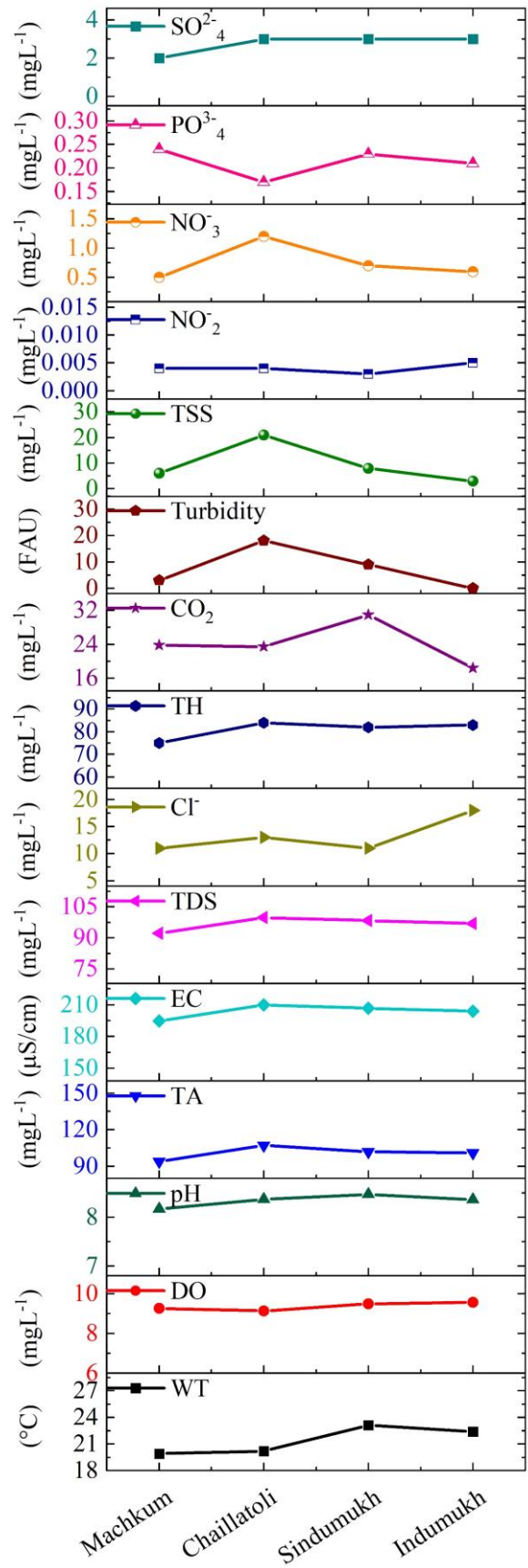


Fig. 3. Spatial variation of water quality parameters of the Matamuhuri River.

Table 3. Water quality parameters of the Sangu and Matamuhuri Rivers.

River	Location	WT (°C)	DO (mgL ⁻¹)	pH	TA (mgL ⁻¹)	EC (µS/cm)	TDS (mgL ⁻¹)	Cl ⁻ (mgL ⁻¹)	TH (mgL ⁻¹)	CO ₂ (mgL ⁻¹)	Turbidity (mgL ⁻¹)	TSS (mgL ⁻¹)	NO ₂ (mgL ⁻¹)	NH ₃ (mgL ⁻¹)	NO ₃ (mgL ⁻¹)	PO ₃₋₄ (mgL ⁻¹)	SO ₂₋₄ (mgL ⁻¹)
Sangu	Ma Lung Gya	24.7	7.3	7.66	97	160.6	76.2	7	69	25	11	13	0.008	BDL*	0.4	0.14	BDL*
	Licri	25.1	7.9	7.83	123	164.2	77.9	11	71	24.2	11	9	0	BDL*	0.8	0.16	BDL*
	Choto Yang Bong	22.7	7.78	7.85	117	155.8	73.8	7	62	28.2	16	10	0.008	BDL*	0.7	0.28	BDL*
	Mo Reng Yang	23.7	8.59	8.22	139	194.5	90.8	15	79	27.2	10	11	0.003	BDL*	0.2	0.17	BDL*
	Average	24.05	7.89	7.89	119	168.78	79.68	10.00	70.25	26.15	12.00	10.75	0.005	--	0.53	0.19	--
	Standard Deviation	0.93	0.46	0.20	15.03	15.15	6.59	3.32	6.06	1.61	2.35	1.48	0.003	--	0.24	0.05	--
Matamuhuri	Machkum	19.9	9.26	8.17	94	194.5	92.3	11	75	23.8	3	6	0.004	BDL*	0.5	0.24	2
	Chaillatoli	20.2	9.13	8.37	107	209.8	99.9	13	84	23.4	18	21	0.004	BDL*	1.2	0.17	3
	Sindumukh	23.1	9.48	8.47	102	206.7	98.4	11	82	31	9	8	0.003	BDL*	0.7	0.23	3
	Indumukh	22.4	9.57	8.36	101	203.9	97	18	83	18.4	0	3	0.005	BDL*	0.6	0.21	3
	Average	21.40	9.36	8.34	101	203.73	96.90	13.25	81.00	24.15	7.50	9.50	0.004	--	0.75	0.21	2.75
	Standard Deviation	1.38	0.17	0.11	4.64	5.72	2.85	2.86	3.54	4.49	6.87	6.87	0.001	--	0.27	0.03	0.43
Standard for Drinking Water		20-30	>6	6.5-8.5	20-250	1200	1000	250	500	10	5	10	10		45	0.1	250

(Note: *BDL → Below Detection Limit.)

The NO₂ concentration of both rivers is within the DoE standard 10 mgL⁻¹ (ECR, 2023) and found in very low concentrations. The mean NO₂ concentration of the Sangu River is 0.005 mgL⁻¹ (SD 0.003), while in the Matamuhuri River, the concentration is 0.004 mgL⁻¹ (SD 0.001). The SD value shows that the nitrite distribution is more widespread in the Sangu River than in the Matamuhuri River. Still, the concentrations are very low than the standard, so it does not affect the water. The NH₃ concentration of both rivers was measured and found to be Below the Detection Limit (BDL) of the method (<0.01 mgL⁻¹) at all the points of both rivers.

The NO₃ concentration has also shown a very low value compared to the DoE standard 45 mgL⁻¹ (ECR, 2023) in both rivers. The Sangu River has a lower mean concentration of 0.53 mgL⁻¹ (SD 0.24) than the Matamuhuri River of 0.75 mgL⁻¹ (SD 0.27). Still, the distribution is very similar in both rivers, as the SD values indicate. The very low presence of NO₂, NH₃, and NO₃ indicates no nitrogen contamination in both rivers.

While there was no contamination by nitrogen, the PO₃₋₄ concentration, as an indicator of contamination from agriculture and livestock, was higher at all the points of both rivers than the DoE standard of 0.1 mgL⁻¹ (ECR, 2023). The mean PO₃₋₄ concentration of the Sangu and Matamuhuri rivers was measured at 0.19 mgL⁻¹ (SD 0.05) and 0.21 mgL⁻¹ (SD 0.03), respectively. The distributions of the PO₃₋₄ are reasonably consistent in both rivers. Both rivers flow through hilly areas where indigenous people cultivate their ways at hills, and livestock is essential to their livelihood. This leads to the washout of agriculture and livestock contaminants to the river by rain and other measures, which may explain the high PO₃₋₄ concentration of these rivers.

The SO₂₋₄ concentration of the Sangu River was BDL (<2 mgL⁻¹) at all the points and a mean concentration of 2.75 mgL⁻¹ (SD 0.43) was found at the Matamuhuri River which is within the DoE standard of 250 mgL⁻¹ for drinking water (ECR, 2023). The distribution of SO₂₋₄ is reasonably consistent in the Matamuhuri River.

The CCMEWQI was measured based on 15 parameters out of 16 measured parameters, leaving turbidity out of the calculation due to the non-reliability of the method. The WQI of the Sangu River is calculated to be a “good” category at all points throughout the reach studied as shown in Fig. 4. The highest WQI in the Licri point is 87.33, while the lowest in the Mo Reng Yang point is 81.88. The overall WQI upstream of the Sangu River is calculated to be 82.95. The deviation of the WQI from the excellent criterion is due to the high value of CO₂, TSS, and PO₃₋₄.

The CCMEWQI of the Matamuhuri River also shows a “good” category of water in all the measured points. The highest WQI found at the Indumukh point is 87.45, while the lowest at the Machkum point is 81.56. The overall WQI of the study reach of the Matamuhuri River is calculated to be 81.08 as shown in Fig. 5. The WQI of the Matamuhuri River deviated from the excellent criterion due to the deviation of the WT, CO₂, TSS, and PO₃₋₄ parameters from the standard value. Among them, TSS was measured very high at Chaillatoli Point due to human interference.

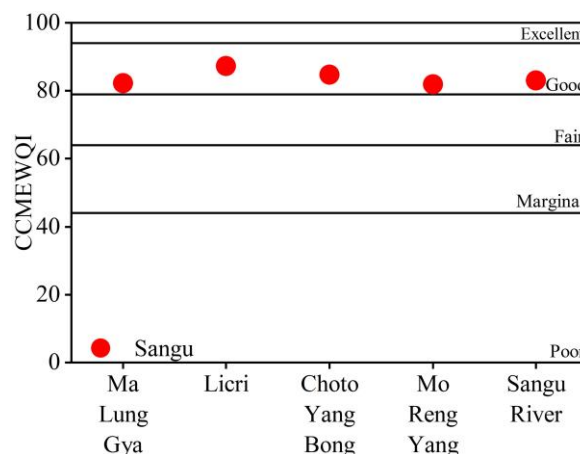


Fig. 4. CCMEWQI of Sangu Rivers.

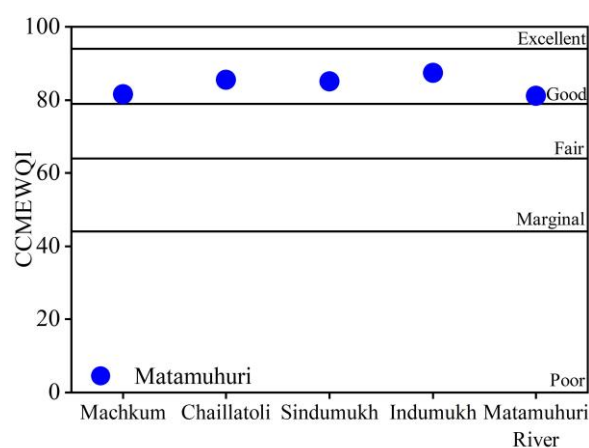


Fig. 5. CCMEWQI of Matamuhuri Rivers.

Conclusions

Sixteen water quality parameters have been measured in this study at 4 points of both rivers, and 15 parameters were used to calculate the CCMEWQI. Among them, at the Sangu River, three parameters, CO₂, TSS, and PO₃₋₄, were found higher than the standard guideline, while at the Matamuhuri River, four parameters, WT, CO₂, TSS, and PO₃₋₄, were found to deviate than the standard guideline. WQI was calculated by the CCMEWQI method and found to be “good” category in both rivers, with a value of 82.95 and 81.08 for the Sangu and Matamuhuri, respectively.

Recommendations

The study was at a very remote location where resources are hard to find and access to various points is also very limited. A more comprehensive study of seasonal water quality assessment, along with more parameters, including biological pollutants and heavy metal determination, would give a better estimation of the WQI of these rivers.

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