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Assessment of water quality status of river Kopili, in Karbi Anglong district of Assam using water quality index

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Abstract

River Kopili, regarded as one of the most important Southern bank tributaries of the mighty river Brahmaputra, is facing a tremendous pollution threat from its riparian areas, especially in its upper stretches due to anthropogenic activities. The Central Pollution Control Board (CPCB) in one of its report has placed the Kopili river in 4th rank among the 56 most polluted river of North-East region. The results of the present study showed that water quality index ^[1] of the river ranges from poor to unsuitable quality of water for drinking in almost all the five sampling stations. The water quality found to be deteriorated during winter season with an average WQI value of 81.88 as compared to pre-monsoon and monsoon season with an average value of 67.13 and 80.12 respectively. According to the water quality index, station 4 and 5 are recorded to be the most polluted stations among the study area. Thus, all the above analysis showed that the riverine ecosystem is moderately polluted, which may degrade further if proper management of the riverine ecosystem is not initiated timely, which is the need of the hour to sustain the environmental integrity of the river Kopili.

Keywords: Kopili river, Brahmaputra, environmental integrity, water quality index

Introduction

River is a lotic ecosystem flowing under the influence of gravity and confluence into the sea and some into lakes. Rivers are regarded as one of the most important resources in the world as well as in India in particular. Rivers are important pathways for the flow of energy, matter and organisms through the landscape ^[2]. Rivers also play a major role in assimilation or transportation of the municipal and industrial wastewater discharges continuously or occasionally or seasonally. Most of the ancient civilizations grew along the banks of the rivers. The water quality of a river is the composite of several interrelated compounds, which are subjected to local and temporal variations and also affected by the volume of water flow ^[3]. Surface water resources are more vulnerable to pollution than ground water resources ^[4] especially in developing countries where the heavy industrialization, increasing urbanization, and adaptation of modern agricultural practices play an important role in improving the living standard but at the same time cause severe environmental damage ^[5], and declining quality of life for many people ^[6]. Water pollution affects their physico-chemical characteristics and microbiological quality ^[7]. Therefore, constant monitoring of a river system is required to evaluate the effects of environmental factors on water quality for proper utilization and sustainable development of the resources.

Water Quality Indices (WQI) provides a single value to the water quality of a source on the basis of one or the other system which translates the list of constituents and their concentrations present in a sample into a single value. The application of WQI helps to understand the overall water quality status of individual sampling stations at a certain time ^[8] and its suitability for various beneficial uses. The concept of indices to represent gradation in water quality was first proposed by ^[9], since then numerous water quality indices have been formulated that can easily evaluate the overall water quality of an area promptly and efficiently. The general WQI developed by ^[1] has undergone much improved modification suitable for a different purpose.

Study area

Kopili is an inter-state river of North-East India flows through the states of Meghalaya and Assam. Kopili originates from the south-western slope of the Shillong peak and flows through southern Assam before its confluence with Brahmaputra. The geographical co-ordinates range of Kopili basin extends from longitude 91-93° E and latitude 25-27° N. The basin covers a total geographical area of 13,55,600 hectares. Its basin is bound by the Jayanti Hills in the West and the South Cacher and Mikir Hills in the East. Kharkor, Myntriang, Dinar, Longsom, Amring, Umrong, Longku and Langkri are its major tributaries in its upper reaches. Diyung, Jamuna, Umkhen-Borapani, Killing, Umtrew/Digar, Kolong etc. are its major tributaries in down stretch at Assam. The river flows for a total length of about 290 kilometers and has a catchment area of 16,420 square kilometers (6,340 sq. miles).

Materials and methods

Water samples were collected from five (5) different sampling sites viz. Dharma Nagar, 8 Kilo (S1), Kopili Dam (S2), 29 Kilo (Inside NEPCO Power Station) (S3), Panimur (S4) and Borowasling (S5) on monthly interval over a period of one year, i.e. January 2019 to December 2019 (Fig. 1).

Various physico-chemical parameters of water were assessed by following standard protocols of [10, 11]. A set of nine most important water quality parameters like pH, turbidity, dissolved oxygen, total alkalinity, total hardness, total dissolved solids, electric conductivity, biological oxygen demand (BOD₅) and chemical oxygen demand (COD) are selected to calculate the water quality index (WQI) of Kopili river at Karbi-Anglong district of state Assam. Calculation of WQI was carried out by following the 'weighted arithmetic index method' [1] using the following equation:

$$WQI = \sum W_i Q_i / \sum W_i$$

Where Q_i is the quality rating of i^{th} water quality parameter for a total of n quality parameter, W_i is the unit weight of n^{th} water quality parameter. The quality rating Q_i is calculated using the equation:

$$Q_i = [(V_{actual} - V_{ideal}) / (V_{standard} - V_{ideal})] \times 100$$

Where V_{actual} is the actual amount of n^{th} parameter present, V_{ideal} is the ideal value of the parameter [$V_i = 0$, except for pH ($V_i = 7$) and DO ($V_i = 14.6$ mg/l)],

$V_{standard}$ is the standard permissible value for the n^{th} water quality parameter.

Unit weight (W_i) is calculated using the formula

$$W_i = 1/S_i$$

Where 1 is the constant of proportionality. The water quality status (WQS) according to WQI is shown in Table 1.

Results and Discussions

Water Quality Parameters

All the physical and chemical water quality parameters recorded at various sites of Kopili river during pre-monsoon, monsoon and winter is shown in the table 2.

pH value expresses the intensity of the acidic or basic characters of water. The average pH values for pre-monsoon, monsoon and winter was found to be 4.62 ± 0.37 , 4.07 ± 0.83 and 3.69 ± 0.38 respectively. Highly acidic pH was recorded during the study period which may be due to the impact of unauthorized coal mining in the upper stretch of the river. Coal have high concentration of pyrites which in presence of water and oxygen undergo oxidation to produce sulphuric acid thereby increasing the acidity of the water. According to [12, 13] an ideal pH for fish culture practice ranged between 6.5 to 9. According to [14] the acidic pH death point for fish is 4.

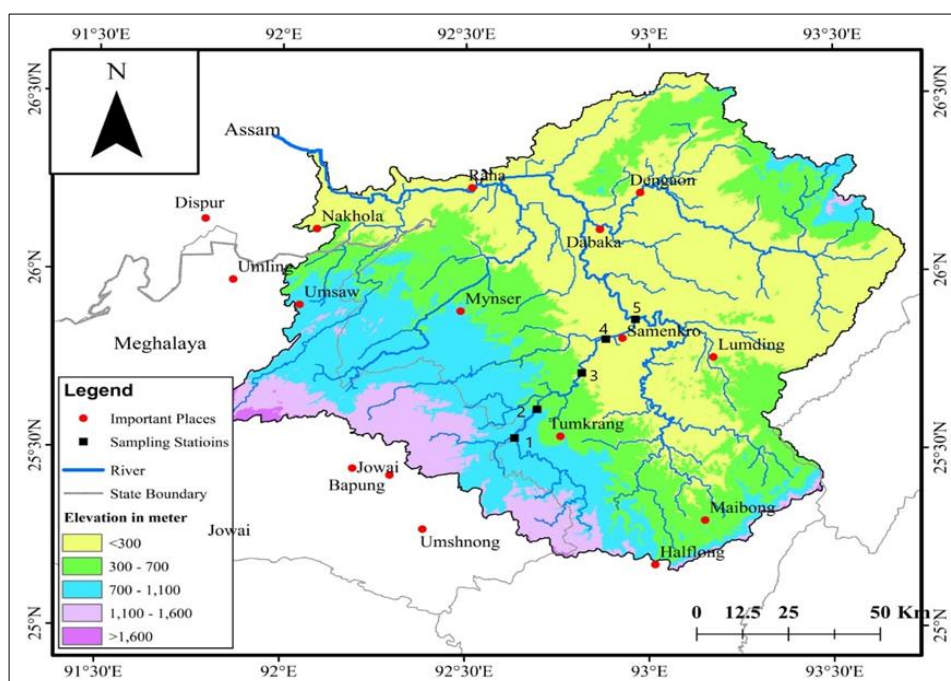


Fig 1: Map showing the study area

Turbidity is the presence or absence of clay silt, dissolved organic and inorganic matter, turbid water received from the catchment area, plankton and other microscopic organisms. Observed turbidity value of Kopili river in Karbi-Anglong district ranged between 0.41-1.46 NTU (± 0.37), 1.45-3.72

NTU (± 0.83) and 3.06-4.19 NTU (± 0.43) during pre-monsoon, monsoon and winter respectively. Turbidity was found to be maximum in the month of October 2019 which may be due to the bursting of hydroelectric dam of the river, which may carry a huge amount of sediment load from the

catchment areas. A nephelometer turbidity reading of 20-30 NTU is considered as suitable for fish culture [15]. So, it can be assumed that the river water is not conducive for fisheries point of view.

The amount of oxygen which is dissolved in a water body is known as dissolved oxygen (DO). The mean DO values ranged from minimum 7.25 mg/L (± 0.36) during monsoon season to a maximum 8.61 mg/L (± 0.39) during winter. Decreasing trend of DO during monsoon and pre-monsoon seasons can primarily be attributed to high temperature and decomposition process of organic matter in water [16, 17]. Maximum dissolved oxygen concentration in winter season may be due to the low surface water temperature and atmospheric temperature. The optimal range of dissolved oxygen for survival, growth, and reproduction of fish vary from 5-8 mg/L [14]. So, findings of present investigation with relation to DO amount is congenial for survival of fishes.

Total Alkalinity is a measure of the concentration of ions in water that would react to neutralize hydrogen ions. The mean concentration of alkalinity in water samples of Kopili river was observed to be 18.15 ± 1.23 , 17.65 ± 2.85 and 20.60 ± 1.56 during pre-monsoon, monsoon and winter season. This may be due to decrease rate of decomposition [18]. This may be due to the high temperature, low water level and addition of effluents in river basin [19, 20]. According to [14], alkalinity range of 20-40 mg/L favour medium level of fish production while a range of 40-90 mg/L favour high fish production. The present investigation indicated that the river Kopili can support medium level of fish production.

Total Hardness is associated with the capacity of water to precipitate soap. Hardness is due to the presence of divalent metallic cations like calcium, magnesium, strontium, ferrous ions and manganese ions [15]. Mean values of total hardness was minimum during monsoon (42.69 ± 1.74) and maximum during winter (43.99 ± 1.30) and the values were within the standard limit of 300 mg/L as per BIS. The hardness of water is not a pollution indicator parameter but indicates water quality mainly in terms of Ca^{2+} and Mg^{2+} . Water with less than 75 mg/L of CaCO_3 is considered soft and above 75 mg/L of CaCO_3 as hard [21]. Total hardness is found to be minimum during monsoon season which may be assumed that in the absence of free carbon dioxide some of the half-bound carbon (HCO_3) gets channelized in to bound form (CO_3), thus resulting in low bicarbonate values. The recommended ideal value of hardness for fish culture is in range the of 30-180 mg/L [22]. Findings of the present study with relation to total hardness of River Kopili (22.02-125.12 mg/L) indicated that it might sustain medium to high level of fish production.

Electrical Conductivity (EC) is a measure of the ability of water sample to carry current. Factors like temperature, ionic mobility and ionic valences influences the electrical conductivity [15]. Observed EC values for the water samples of Kopili river in the studied area ranged between 74.51-85.49 $\mu\text{S/cm}$ (± 3.78), 80.25-104.75 $\mu\text{S/cm}$ (± 8.71) and 89.00-95.75 $\mu\text{S/cm}$ (± 2.38) during pre-monsoon, monsoon and winter

season respectively, which is under the standard limit of ICMR (300 $\mu\text{S/cm}$). The increased in EC values of water indicates that there is a source of dissolved ions in the vicinity. Higher the value of dissolved solids, greater the number of ions in water. Increasing levels of conductivity is the products of decomposition and mineralization of organic materials. [23] recorded that conductivity of a waterbody must be within the range of 76-474 $\mu\text{S/cm}$ for any aquatic ecosystem to thrive. Based on this information Kopili riverine ecosystem may be considered for any kind of aquatic organism to grow.

Total Dissolved Solids (TDS) is the concentration of dissolved particles present in a water sample and BIS desirable limit for TDS is 500 mg/L. TDS values are within the desirable limit of BIS with a mean value of 77.02 mg/L (± 11.19) during pre-monsoon, 94.72 mg/L (± 7.00) during monsoon and 80.05 mg/L (± 0.64) during winter season. High values of TDS during monsoon were due to increase in sediment load from catchment such as agricultural fields and mixing of effluents released from nearby collieries with the river water. With the increasing temperature during monsoon months, organic matter mineralized faster which leads to increase in TDS values. [14] suggested that TDS less than 400 mg/L considered favorable for any riverine ecosystem to flourish.

Biological Oxygen Demand (BOD_3) is an empirical standardized laboratory test which measures oxygen requirement for aerobic oxidation of decomposable organic matter and certain inorganic materials in water, polluted waters and wastewater under controlled conditions of temperature and incubation period [11]. BOD_3 values are ranged from a minimum of 5.59 mg/L (± 2.23) during pre-monsoon season to a maximum of 8.06 mg/L (± 2.41) during monsoon season. This might be due to increase in organic load in the riverine ecosystem from the catchment areas as a result of heavy rainfall and flood like situation. [24] recorded higher values of BOD in monsoon compared to post monsoon. [25] reported values of biological oxygen demand of river Chambal was varied from 1.20 to 12.20 mg/L. Observed values clearly indicate that the river water is moderately polluted by organic wastes. The values of BOD are above the standards limit of 5 mg/l laid by WHO.

Chemical Oxygen Demand (COD) test determines the oxygen requirement equivalent of organic matter that is susceptible to oxidation with the help of a strong chemical oxidant. It is an important, rapidly measured parameters as a means of measuring organic strength for streams and polluted water bodies [11]. The mean concentration of COD in water samples was found to be 9.51 mg/L (± 3.79), 13.70 mg/L (± 5.78) and 10.40 mg/L (± 4.06) during pre-monsoon, monsoon and winter period. Maximum level of COD was observed during monsoon season which might be contributed due to the heavy organic load, agriculture run off carried by the river water from the surrounding catchment areas as a result of heavy rain.

Table 1: WQI range, status and possible usage of the water sample [9]

WQI	Water Quality Status (WQS)	Possible usage
0-25	Excellent	Drinking, irrigation and industrial
26-50	Good	Drinking, irrigation and industrial
51-75	Poor	Irrigation and industrial
76-100	Very Poor	Irrigation
Above 100	Unsuitable for drinking and fish culture	Proper treatment required before use

WQI analysis

For calculating WQI using "Weighted Arithmetic Index" involves the estimation of 'unit weight' assigned to each physicochemical parameter which are selected for the

calculation. To transfer different units and dimensions of the selected parameters are into a common scale using the assigning units. A maximum weightage of 0.25, 0.25 and 0.21 is assigned to turbidity, dissolved oxygen and BOD_3 (Table 2).

Table 3 shows the drinking water quality standards of each parameter used for the calculation of WQI. Tables 4, 5, 6, 7 and 8 represents the values observed for the selected physicochemical parameters from the five different sampling

stations during each season and their corresponding WQI values. Out of the ten (10) parameters DO, BOD₃ and COD were found to be the most influencing parameters in the WQI scores.

Table 2: Descriptive Statistics of Water Quality Parameters of Kopili River

Parameter	Pre-monsoon	Monsoon	Winter
Turbidity (NTU)	0.88 ± 0.37 (0.41-1.46)	2.25 ± 0.83 (1.45-3.72)	3.63 ± 0.43 (3.06-4.19)
pH	4.62 ± 0.22 (4.36-4.97)	4.07 ± 0.20 (3.85-4.4)	3.69 ± 0.38 (3.23-4.25)
Dissolved Oxygen (mg/L)	7.96 ± 0.30 (7.60-8.27)	7.25 ± 0.36 (6.71-7.61)	8.61 ± 0.39 (7.93-9.09)
Total Alkalinity (mg/L)	18.15 ± 1.23 (16.25-20.00)	17.65 ± 2.85 (13.75-17.00)	20.60 ± 1.56 (17.75-22.25)
Total Hardness (mg/L)	43.84 ± 1.83 (41.54-57.29)	42.69 ± 1.74 (40.28-45.04)	43.99 ± 1.30 (42.28-45.54)
Electric Conductivity (µS/cm)	80.00 ± 3.78 (74.51-85.49)	90.85 ± 8.71 (80.25-104.75)	92.50 ± 2.38 (89.00-95.75)
Total Dissolved Solids (mg/L)	77.02 ± 11.19 (64.05-90.79)	94.72 ± 7.00 (84.84-102.66)	80.05 ± 0.64 (79.5-81.00)
BOD ₃ (mg/L)	5.59 ± 2.23 (1.53-7.66)	8.06 ± 3.40 (1.70-11.23)	6.14 ± 2.41 (2.21-8.54)
COD (mg/L)	9.51 ± 3.79 (2.60-13.03)	13.70 ± 5.78 (2.89-19.10)	10.40 ± 4.06 (3.75-14.33)

Values are expressed in mean ± SD (the values in parentheses denotes the range of each parameter)

Table 8 depict the overall summery of WQI values of the water samples collected from the different five sampling stations for each season. Maximum values of WQI were recorded during monsoon season and minimum during winter in three sampling stations except stations 4 and 5 as depicted in Fig. 2. The unsuitability of Kopili river water during monsoon season may be due to the increase surface run-off from the catchment areas. A similar finding has also been reported by [26, 27, 28] in their studies of assessment of surface water quality status of different rivers. The result also showed that majority of water sample fall under poor (51<WQI<75) to very poor (76<WQI<100) and unsuitable water category (WQI>100). In case of the station 2, the WQI value falls under the category of drinking water (25<WQI<50); which is suitable for drinking, irrigation and industrial purpose, which

might be due to the availability of less water in that station due to the construction of Kopili Hydro-electric Dam.

The WQI values also showed a mixed pattern of change in all the studied five stations. The WQI value of upstream stations from 1-3 is lower than the downstream station i.e. 4 and 5. Which may be due to the less anthropogenic activities occurring in the vicinity of that stations. Similar findings also recorded by [29], who have observed better water quality status in upstream than downstream due to a decrease in water and accumulation of contaminants along the downstream of the river. Different anthropogenic activities like picnic spot, agricultural run-off, bathing and washing clothes are observed in the station 4 and 5, which may also be the contributing agent towards the deuteriation of water quality status of the river in the studied area.

Table 3: Standards of parameters used for WQI determination

Parameter	ICMR/BIS standard (V _s)	Unit Weight (W _i)
Turbidity	5	0.25
pH	8.5	0.15
DO	5	0.25
Total Alkalinity	120	0.01
Total Hardness	300	0.00
EC	300	0.00
TDS	500	0.00
BOD ₃	6	0.21
COD	10	0.13
Σ W _i = 1.00		

Table 4: Calculation of WQI at station 1

Parameter	Pre-monsoon			Monsoon			Winter		
	V _a	Q _i	W _i Q _i	V _a	Q _i	W _i Q _i	V _a	Q _i	W _i Q _i
Turbidity	0.70	13.90	3.48	1.47	29.35	7.34	3.23	64.60	16.15
pH	4.36	-176.00	-25.88	3.85	-210.33	-30.93	3.23	-251.33	-36.96
Dissolved Oxygen	7.60	200.00	50.00	6.71	225.43	56.36	7.94	190.57	47.64
Total Alkalinity	16.25	13.54	0.14	17.00	14.17	0.15	21.75	18.13	0.19
Total Hardness	43.04	14.35	0.06	44.29	14.76	0.06	45.54	15.18	0.06
Electric Conductivity	77.89	25.96	0.11	104.75	34.92	0.15	93.00	31.00	0.13
Total Dissolved Solids	88.79	17.76	0.04	102.39	20.48	0.05	81.00	16.20	0.04
BOD ₃	4.91	81.86	17.05	7.59	126.50	26.35	4.57	76.10	15.85
COD	8.35	83.50	10.44	12.90	129.03	16.13	7.76	77.63	9.70
	Σ W _i Q _i = 55.48			Σ W _i Q _i = 75.65			Σ W _i Q _i = 52.81		

Table 5: Calculation of WQI at station 2

Parameter	Pre-monsoon			Monsoon			Winter		
	V _a	Q _i	W _i Q _i	V _a	Q _i	W _i Q _i	V _a	Q _i	W _i Q _i
Turbidity	0.91	8.15	2.04	2.34	46.80	11.70	4.19	83.75	20.94
pH	4.42	-172.00	-25.29	3.92	-205.33	-30.20	3.41	-239.50	-35.22
Dissolved Oxygen	8.43	199.71	49.93	6.95	218.71	54.68	8.55	172.94	43.24
Total Alkalinity	17.75	14.79	0.15	16.00	13.33	0.14	20.50	17.08	0.18
Total Hardness	44.29	14.76	0.06	45.04	15.01	0.06	45.29	15.10	0.06
Electric Conductivity	82.58	27.53	0.11	85.50	28.50	0.12	94.00	31.33	0.13
Total Dissolved Solids	90.92	18.18	0.05	102.66	20.53	0.05	80.00	16.00	0.04
BOD ₃	1.53	25.49	5.31	1.70	28.33	5.90	2.21	36.76	7.66
COD	2.60	26.00	3.25	2.89	28.90	3.61	3.75	37.50	4.69
	$\sum W_iQ_i = 35.60$			$\sum W_iQ_i = 46.07$			$\sum W_iQ_i = 41.71$		

Table 6: Calculation of WQI at station 3

Parameter	Pre-monsoon			Monsoon			Winter		
	V _a	Q _i	W _i Q _i	V _a	Q _i	W _i Q _i	V _a	Q _i	W _i Q _i
Turbidity	1.11	22.15	5.54	2.26	45.15	11.29	3.97	79.30	19.83
pH	4.62	-176.00	-25.88	4.01	-200.00	-29.41	3.57	-228.50	-33.60
Dissolved Oxygen	8.19	200.00	50.00	7.61	199.72	49.93	8.85	164.43	41.11
Total Alkalinity	18.00	15.00	0.16	19.50	16.25	0.17	22.25	18.54	0.19
Total Hardness	47.04	15.68	0.07	42.04	14.01	0.06	44.04	14.68	0.06
Electric Conductivity	74.51	24.84	0.10	87.25	29.08	0.12	90.75	30.25	0.13
Total Dissolved Solids	64.05	12.81	0.03	93.98	18.80	0.05	79.50	15.90	0.04
BOD ₃	7.07	117.89	24.56	9.51	158.58	33.04	7.23	120.49	25.10
COD	12.03	120.25	15.03	16.18	161.75	20.22	12.29	122.90	15.36
	$\sum W_iQ_i = 69.60$			$\sum W_iQ_i = 85.46$			$\sum W_iQ_i = 68.21$		

Table 7: Calculation of WQI at station 4

Parameter	Pre-monsoon			Monsoon			Winter		
	V _a	Q _i	W _i Q _i	V _a	Q _i	W _i Q _i	V _a	Q _i	W _i Q _i
Turbidity	0.73	14.60	3.65	1.46	29.15	7.29	3.06	61.25	15.31
pH	4.74	-150.67	-22.16	4.20	-180.17	-26.50	3.98	-201.33	-29.61
Dissolved Oxygen	8.15	184.29	46.07	7.58	191.71	47.93	9.10	157.28	39.32
Total Alkalinity	18.75	15.63	0.16	13.75	11.46	0.12	17.75	14.79	0.15
Total Hardness	41.54	13.85	0.06	41.79	13.93	0.06	42.29	14.10	0.06
Electric Conductivity	85.49	28.50	0.12	80.25	26.75	0.11	89.00	29.67	0.12
Total Dissolved Solids	65.92	13.18	0.03	89.71	17.94	0.04	79.25	15.85	0.04
BOD ₃	6.78	112.99	23.54	10.26	171.08	35.64	8.17	136.18	28.37
COD	11.53	115.25	14.41	17.45	174.50	21.81	13.88	138.80	17.35
	$\sum W_iQ_i = 65.88$			$\sum W_iQ_i = 86.51$			$\sum W_iQ_i = 68.21$		

Table 8: Calculation of WQI at station 5

Parameter	Pre-monsoon			Monsoon			Winter		
	V _a	Q _i	W _i Q _i	V _a	Q _i	W _i Q _i	V _a	Q _i	W _i Q _i
Turbidity	1.46	29.25	7.31	3.73	74.55	18.64	3.69	73.80	18.45
pH	4.97	-135.33	-19.90	4.40	-173.33	-25.49	4.25	-183.00	-26.91
Dissolved Oxygen	8.27	180.86	45.21	7.41	205.43	51.36	8.63	170.71	42.68
Total Alkalinity	20.00	16.67	0.17	22.00	18.33	0.19	20.75	17.29	0.18
Total Hardness	43.29	14.43	0.06	40.29	13.43	0.06	42.79	14.26	0.06
Electric Conductivity	79.55	26.52	0.11	96.50	32.17	0.13	95.75	31.92	0.13
Total Dissolved Solids	75.41	15.08	0.04	84.85	16.97	0.04	80.50	16.10	0.04
BOD ₃	7.66	127.70	26.60	11.24	187.25	39.01	8.54	142.27	29.64
COD	13.03	130.25	16.28	19.10	191.00	23.88	14.33	143.30	17.91
	$\sum W_iQ_i = 75.89$			$\sum W_iQ_i = 107.81$			$\sum W_iQ_i = 82.18$		

Table 9: Summary of WQI of the Kopili river

Sampling Stations	Pre-monsoon		Monsoon		Winter	
	WQI	WQS	WQI	WQS	WQI	WQS
1	55.48	Poor	75.65	Poor	52.81	Poor
2	35.60	Good	46.07	Good	41.71	Good
3	69.60	Poor	85.46	Very Poor	68.21	Very Poor
4	65.88	Poor	86.51	Very Poor	71.12	Very Poor
5	75.89	Very Poor	107.81	Unsuitable	82.18	Very Poor
Average	60.49		80.30		63.21	

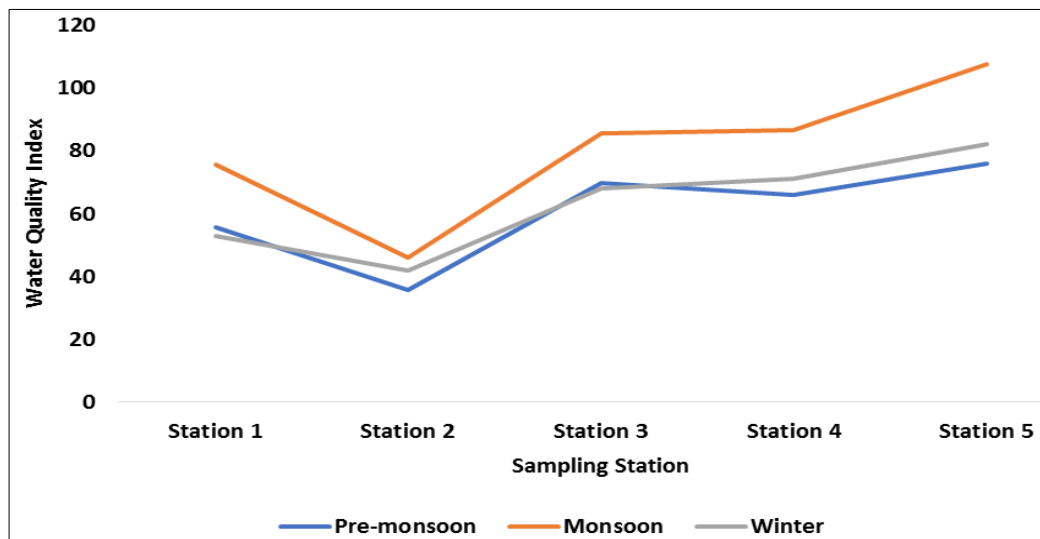


Fig 2: WQI rating of various sampling stations of Kopili river.

Conclusion

In this study water quality index provides us with a valuable information about the overall water quality status of Kopili river in Karbi-Anglong district of Assam. WQI highlights the salient features of various water quality parameters acting upon the general water quality of the river. As per the observation recorded the WQI value fall in poor to unsuitable quality of water in all the studied five stations. In the present study DO, BOD₃ and COD played a significant role in affecting the WQI of the river. This study shows the insight status of the suitability of the Kopili River water based on Water quality indices values. It also highlights the salient features of some important water parameters which include, Surface water temperature, pH, Turbidity, DO, BOD₃, COD etc. Based on the observed WQI values and other physico-chemical parameters it can be concluded that some effective measurements are urgently required to restore the environmental integrity of the Himalayan river.

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