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Quality characterization of an urban stretch of Ranikhola River using water quality index

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ABSTRACT

One of the largest rivers in Sikkim is the Ranikhola River, which provides water for domestic, industrial, and agricultural use as well as supporting a variety of livelihoods and, most importantly, draining the entire city. The present study aimed to develop the Water Quality Index (WQI) via the Weighted Arithmetic Water Quality Index Method (WAWQI) for an urbanized stretch of the Ranikhola river. Three sample stations were examined along the stretch for a hydrological year, 2018, during which the study was carried out for three seasons namely pre-monsoon (PRM), monsoon (MON), and post-monsoon (POM).The study constituted of physicochemical parameters like pH, conductivity, dissolved oxygen (DO), nitrate, biochemical oxygen demand (BOD), and total coliform. The maximum average seasonal WQI value was observed during pre-monsoon (PRM) at station 1 i.e 53.07 and the minimum at station 3 i.e 40.30. Consequently, the maximum WQI value during monsoon (MON) was observed at station 1 i.e 66.97, and the minimum at station 3 i.e 41.59. Maximum WQI value during post-monsoon (POM) was also observed to be maximum at station 1 i.e 61.67 and minimum at station 3 i.e 38.71 respectively. Comparatively poor water quality was observed at the upstream sampling station than at the downstream station. Conclusively, sites 1 and 2 showed poor water quality for all seasons, while station 3 shows relatively good water quality status in all the seasons. The research emphasizes the necessity for adequate water management measures throughout the Ranikhola river stretch, including proper water treatment, conservation, and assessment.

1. Introduction

Water is a precious important life-sustaining natural resource available on earth. To attend to the ever-increasing human needs, estimating the available freshwater is important. Rivers are the main contributor to water resources for domestic, agricultural, and industrial operations. However, the severity of threats and degradation to rivers increases at an alarming rate due to anthropogenic influences, improper waste deposits, and natural processes (Carpenter et al., 1998, Wang et al., 2008). Water pollution has become a major problem worldwide. If not taken into consideration, scarcity of water resources, especially for drinking will be the outcome in near future (Cheng et al., 2009, Vorosmarty et al., 2010). As stated by the World Health Organisation (WHO, 2017), 80% of human diseases are water-borne which also means that human health is vulnerable to manifold diseases (Panigraha et al., 2012). Acknowledging and monitoring the status and trends of water used for different purposes is therefore a necessity. The water's quality is monitored by its biological, chemical, and physical properties and categorized according to its prescribed limits, considered unsafe or unfit if it exceeds the certain prescribed limit (ICMR 1975; BIS 2003). As a result, the Water Quality Index (WQI) may be used to categorise the quality of water and its various uses.

WQI by definition is a process that describes the quality of water by combining various parameters into a single numeric value. It disintegrates bulk information of various water quality parameters and forms a single value for easy representation and understanding (Semiromi et al., 2011). WQI helps us in assessing whether the water is susceptible tobeing consumed by humans and suitable for other uses. It can give us insight into the quality of water of a

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particular sampling station at any time/season (Yogendra and Puttaiah 2008). WQI is considered the most efficient way to approach the water quality status. It is one of the most widely used tools for assessing surface as well as groundwater and plays a crucial part in managing water resources (Debels et al., 2005; Lumb et al., 2011; Mohebbi et al., 2013; Sutadian et al., 2016).

The idea of using indices for the representation of water quality standards was initially introduced by Horton using 10 variables in 1965 and later advanced by Brown et al., (1970).Many authors have formulated various techniques for calculating WQI (Debels et al., 2005, Tsegaye et al., 2006). Several methods formulated worldwide are the US National Sanitation Foundation Water Quality Index (NSFWQI) (Brown et al., 1970), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), British Columbia Water Quality Index (BCWQI), Oregon Water Quality Index (OWQI) (Debels et al., 2005), etc. Workers like Debels et al., (2005), Wu et al., (2018),Sener et al., (2017), and Ewaid (2020), etc have evaluated and developed WQI for different rivers worldwide. It has also been widely used on different rivers in India by workers like Yogendra and Puttaiah (2008), Kumar et al., (2011), Sharma and Kansal (2011), Shah and Joshi (2017), etc. Similarly, workers like Singh et al., (2016), Bora and Goswami (2017), Lkr et al., (2020) have also conducted the study of water quality status on different rivers from the North - Eastern part of India.

Sikkim is a small hilly state which lies inthe North-Eastern part of India, covering a comprehensive geographic area of 7096 km^2. The area lies between 27° 04′ 46′′and 88° 55′ 25′′ north latitude 88° 00′ 58′′ & 88° 55′ 25′′ east longitude in Eastern Himalaya (Subba, 2008). Its northern boundary is with Tibet, while its eastern, western, and southern borders are with Bhutan, Nepal and West Bengal. Ranikhola River in the Sikkim state of India is one of the rivers playing a significant role and is a tributary of the Teesta River. Ranikhola River is a significant source of supply of water for the local inhabitants for drinking as well as other purposes. This river has been a life-sustaining natural resource for downstream and nearby settlements. The river is subjected to many points and non-point source pollution as all the effluent coming from nearby industries, garbage disposal, road construction, debris from soil erosion/landslide, households, etc, drains into it.Several development projects, including the building of the NH31A road, bridges, mega hydropower project, agricultural operations, and industry (pharmaceuticals manufacturing unit), have become the greatest threat to the Ranikhola River.(Mallick and De,2018) Henceforth, to study the pollution level, and water quality status and to insight into the condition of the river, the Weighted Arithmetic Water Quality Index (WAWQI) method has been used in this study.

1.1.1 The Study Area

Ranikhola River in Sikkim state of India is one of the tributaries of the Teesta River. It is located on the southern mountain range of the East side of the Himalayas and flows through the east district of the state. It originates from the South Western slopes of Lingzung, 2865 m above sea level, and flows towards Teesta River near Singtam, flows further towards West Bengal through Bangladesh, and then enters the Bay of Bengal. The Ranikhola watershed covers an area of 254 km^2 between the latitudes 27° 13′ 9 N to 27° 23′ 51N and longitude 88° 29′ 31E to 88° 43′ 18 E (Mishra et al., 2019). The watershed has very steep slope areas and is mostly forest covered with temperatures ranging normally between 4 - 26°C. The Ranikhola River channel has big boulders and rocks (Yadav et al., 2017). Ranikhola is a rainfed perennial river and is among the minor rivers in the East district playing an important role. This basin is of great importance as it sustains many towns. Ranikhola confluence with Teesta, which is a source of drinking water for the people downstream. The sampling stations and salient features of the sampling stations along with their topographical description are presented in Fig. 1 and Table 1.

Table 1. Sampling stations along with salient features

Sl	Station	Station code	Features of the sampling station	Elevation (msl)	Coordinates
1	Adampool	1804	Mostly forest-covered area with some residential sites.	909 m	27° 18′ 25’’ N 88° 35′ 05’’ E
2	Ranipool	1805	Forest cover, residential sites, and pharmaceutical sites are located.	829 m	27° 17′ 30′′ N 88° 35′ 31′′ E
3	Singtam-Teesta	1807	City area with industrial sites	466 m	27° 14′ 48′′ N 88° 28′ 39′′ E

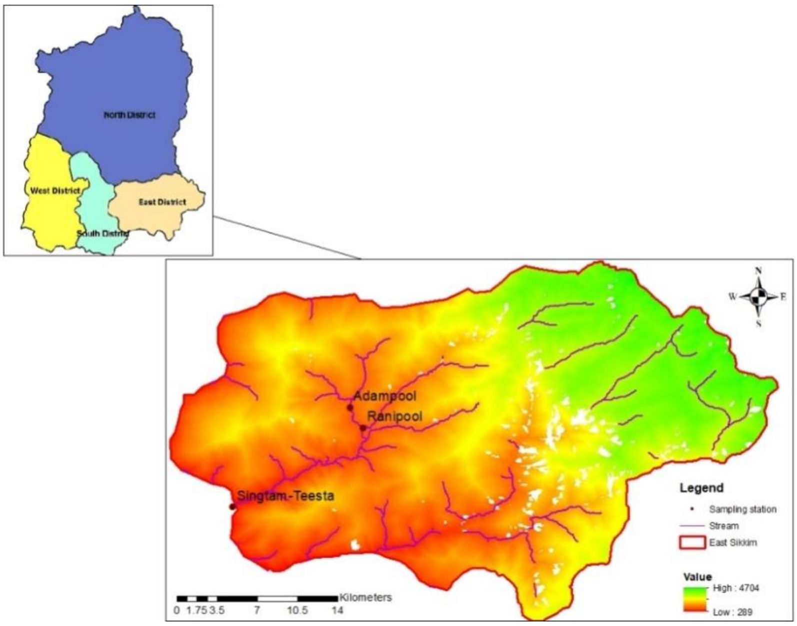

Figure 1. Map showing East Sikkim district and sampling stations

2. Material and methods

Three sampling stations namely Adampool (1804), Ranipool (1805), and Singtam-Teesta (1807) along an urbanized stretch of Ranikhola River were selected for this study. Secondary water quality data of all three sampling stations were collected from the State Pollution Control Board, Government of Sikkim. The selected physio-chemical parameters for the study are pH, Dissolved Oxygen (DO), Conductivity, Nitrate, Biochemical Oxygen Demand (BOD), and Total Coliform. The observed data were collected for a hydrological year (2018) and were grouped into three seasons i.e Pre-Monsoon (PRM), Monsoon (MON), and Post-Monsoon (POM) for predicting the quality of the water seasonally. Water Quality WQI was calculated withthe Weighted Arithmetic Water Quality Index Method (WAWQI) formulated by Brown et al., (1972). WQI score to predict the quality rating and categorize the quality of water into their probable usage is presented in Table 2. The equation for WAWQI calculation is given as:

i. Quality rating or sub-index (q_n) will be determined using the subsequent expression. (Tyagi et al., 2013)

$$\mathbf{q_n = 100\ [V_n - V_{io}] / [S_n - V_{io}]} \quad (1)$$

q_n = the nth water quality parameter's quality rating.

V_n = the nth parameter's estimated value at the specified sampling location.

S_n = Standard permissible value of the nth parameter given by WHO / BIS (Table 3)

V_{io} = In pure water, the ideal value of nth parameter (0 for all parameters except pH and DO where pH is 7.0 and DO is 14.6 mg/L respectively).

ii. Unit weight (Wn) is derived using a value that is inversely proportional to the recommended standard value (Sn) for the associated parameter.

$$\mathbf{W_n = K / S_n} \quad (2)$$

W_n = nth parameters unit weight

S_n = nth parameters Standard value given by WHO / BIS (Table 3)

K = constant for proportionality.

iii. K is derived by

$$\mathbf{K = \frac{1}{\sum(\frac{1}{Sn})}} \quad (3)$$

Table 2 Water quality status categorization as per the WQI score

WQI Value	Water Quality Status	Probable usage
0 - 25	Excellent	Drinking, Irrigation and Industrial purpose
26 - 50	Good	Drinking, Irrigation and Industrial purpose
51 - 75	Poor	Irrigation and Industrial purpose
76-100	Very poor	Irrigation purpose
Above 100	Unsuitable for drinking	Proper treatment before any usage

** Brown et al., (1972)

** Except for pH and conductivity, other parameters are in mg/l.

Table 3. Standard value (S_n) according to WHO, BIS and unit weight (W_n)

Parameters	WHO standards	BIS standards	Unit weight (W_n)
pH	6.5 – 8.5	6.5 - 8.5	0.231
Cond. (µmhos/cm)	250	300	0.007
NO_3-N (mg/l)	45	45	0.044
DO (mg/l)	5	6	0.327
BOD (mg/l)	5	5	0.392
T. Coliform (MPN/100ml)	10	0	0
			$\sum W_n = 1$

3. Results and Discussion

1.3.1 Physico-chemical parameters of the sampling stations

The seasonal mean values of physicochemical parameters acquired from the three sampling stations for all seasons (PRM, MON, POM) are given in Table 4.

pH value is an indicator of the acidic or alkalinity nature of water. pH ranges from 1–14 with neutral at 7, 1 - 6 as acidic, and 8 - 14 as alkaline. pH is one of the major criteria for determining the acceptability of the quality of water for various uses. The mean value of pH observed in our study during PRM, MON, and POM seasons were 6.67 ± 0.747, 6.31 ± 0.27, and 6.34 ± 0.47 respectively. The pH of natural water often falls between 6 and 8(Thakre et al., 2010), which is comparable to the pH value range we found in our study throughout the three seasons. Electrical conductivity (EC) describes the number of dissolved ions present in water. Electrical conductivity (EC) can greatly alter the taste and purity of water (Pradeep, 1998).

Low electrical conductivity is an indication of good water quality status (Sharma and Kumar, 2017). The mean values of EC obtained during PRM, MON, and POM were 194.17 ± 24.75 µmhos/cm, 231.25 ± 8.84 µmhos/cm, and 170 ± 32.99 µmhos/cm respectively. The maximum value of EC in our study was observed during MON i.e 231.25 ± 8.84 µmhos/cm whereas, the minimum value was observed during POM i.e 170 ± 32.99 µmhos/cm.

Biochemical Oxygen Demand (BOD) is also an important and widely used indicator of pollutants and measurement in water. BOD defines the oxygen content that is required by aerobic microbes to break down organic matter in water. It indicates organic pollution; a higher value of BOD means a higher pollution level (Patil et al., 1983). The mean BOD observed during PRM, MON, and POM were 2.82 ± 0.35 mg/l, 3.23 ± 0.35 mg/l and 2.39 ± 0.45 mg/l respectively. The maximum value of BOD in our study was observed during MON i.e 3.23 ± 0.35 mg/l, while the minimum value during POM i.e 2.39 ± 0.45 mg/l.

Dissolved Oxygen (DO) defines the total oxygen present in water. DO is an important criterion to be considered for evaluating the state of the water quality. The ideal value of DO according to WHO (2017) and BIS (2003) is 5 and 6 respectively (Sharma and Kumar, 2017). If the value of DO falls below the ideal value, it hampers the aquatic ecosystem even leading to the mass killing of fish. The seasonal mean of DO observed during PRM, MON, POM was 9.52 ± 0.35 mg/l, 10.16 ± 2.60 mg/l, and 9.17 ± 1.41 mg/l respectively. In this study, DO value was maximum during MON i.e 10.16 ± 2.60 mg/l and minimum at PRM i.e 9.17 ± 1.41 mg/l. The DO value is seen to be higher than the ideal value which is an important indicator for the aquatic ecosystem to thrive. If DO in a water body is greater than 4 mg/l, it ensures healthy water and good quality water (Prasad and Bose, 2001).

Nitrate present in the surface water is the outcome of an increase in waste disposals, change of land use, etc. Excess nitrate in water could lead to health issues like blue baby disease and also hamper aquatic ecosystems caused by eutrophication (WHO, 1998). The seasonal mean of nitrate was observed to be 2.8 ± 0.38 mg/l, 2.42 ± 0.62 mg/l, and 2.7 ± 1.23 mg/l for PRM, MON, and POM respectively. The detected nitrate value in this study is very less compared to the permissible limit by WHO (2017), which is 45 mg/l. The maximum value of nitrate in this study was observed during PRM i.e 2.7 ± 1.23 mg/l and the minimum during MON i.e 2.42 ± 0.62 mg/l.

Total coliform is the determination of bacteria found in surface water, also in human and animal waste. According to BIS (2003), the maximum allowable concentration of total coliform in 100 millilitres of water is 0, for drinking water. The values of total coliform observed during PRM, MON, and POM were 155 ± 14.14, 181.87 ± 53.92, and 140 ± 28.28 respectively. The highest value of total coliform in this study was observed during MON i.e 181.87 ± 53.92 and minimum during POM i.e 140 ± 28.28.The presence of total coliform above the permissible range indicates that other pathogenic organisms of fecal origin may be present in water as pathogenic organisms and coliforms arise from same source.

1.3.2 Analysis of WQI

The first step in the WQI calculation using the "Weighted Arithmetic Index" method is assigning "unit weight" to all the selected physicochemical parameters for the calculation. After each of the selected parameters has been given a unit weight, the dimensions and units of the chosen parameters are converted to a standard scale. The standard permissible values and unit weights assigned to all the selected parameters for the calculation of WQI for drinking water are presented in Table 3. The maximum unit weight of 0.392 was given to BOD, 0.327 to DO, and similarly, 0.231 to pH. The values from the three sampling stations' physicochemical parameters during PRM, MON, and POM with their respective WQI value are presented in Table 5, 6, and 7 with graphical representation in Fig. 2, 3 and 4. Parameters like DO, BOD, and pH were observed to have the highest influence on the WQI score, which means they play a significant role in determining the overall WQI score. The overall seasonal WQI score and status in all the sampling stations are presented in Table 8.. As presented in Table 8, in station 1 (1804) the maximum WQI value was observed during MON (65.22, poor) followed by POM (61.67, poor) and the least value during PRM (53.07, poor). For station 2 (1805), the maximum WQI value was observed during MON (66.97, poor), followed by PRM (52.96, poor) and POM (51.33, poor). Similar cases were observed by various researchers like Bora and Goswami (2017) and Lkr et al., (2020) during their assessment of the quality of surface watersin Assam and Nagaland. Similarly, for station 3 (1807), the maximum value of WQI was observed during MON (41.59, good), followed by PRM (40.30, good) and POM

Table 4. Seasonal range, mean and SD of water quality parameters

Parameters	Pre-Monsoon Range	Mean and SD	Monsoon Range	Mean and SD	Post Monsoon Range	Mean and SD
pH	6 - 7	6.5 ± 0.71	6.125 – 6.5	6.31 ± 0.27	6 – 6.67	6.34 ± 0.47
EC	176.67 – 211.67	194.17 ± 24.75	225 – 237.50	231.25 ± 8.84	146.67 – 193.33	170 ± 32.99
NO_3-N	2.53 – 3.07	2.8 ± 0.38	1.98 – 2.85	2.42 ± 0.62	1.83 – 3.57	2.7 ± 1.23
DO	9.27 – 9.77	9.52 ± 0.35	8.33 – 12	10.16 ± 2.60	8.17 – 10.17	9.17 ± 1.41
BOD	2.47 – 3.17	2.82 ± 0.35	2.98 – 3.48	3.23 ± 0.35	2.07 – 2.70	2.39 ± 0.45
T. Coliform	145 – 165	155 ± 14.14	143.75 - 22	181.87 ± 53.92	120 – 160	140 ± 28.28

(38.71, good). The WQI value of this study shows that the maximum WQI score in all cases was observed during MON. The main contributing factor for the highest value of WQI value during the MON season maybe due to the increase in the discharge rate of water and higher surface runoff ultimately leading to more pollutants being carried into the river water. Furthermore, the Himalayan region is significant to incessant and heavy spells of monsoon rainfall especially from May to early October, with July being the wettest month. The annual rainfall of this region is 2525 mm, with 135 rainy days in a year (Das et al., 2018). This often leads to multiple landslides consequently, deteriorating the quality of water. Similar scenarios have been observed in a case study of the Cauvery River by Sebestian and Yamakanamardi (2013).

Water Quality Index value in sampling stations 1 (1804) and 2 (1805) shows poor water quality (50 < WQI < 75) for all seasons. Whereas, station 3 (1807) shows good water quality status (25 < WQI < 50) for all three seasons. Variation in WQI value for all stations season-wise is presented in fig 5. The water quality for stations 1 (1804) and 2 (1805) shows a higher WQI score, indicating that the pollution level of water is higher for upstream locations compared to downstream locations i.e station 3 (1807). The high WQI value in station 1 maybe because of an increase in human-made activities in and around the sampling stations and pollution load coming in from the city area. In addition to that, there are problems related to improper waste disposal and lack of proper management of water. Likewise, the high WQI value in station 2 is directly influenced by an increase in settlement, developmental projects, urbanization, etc. The location of small-scale industries at Samlik-Marchak near Ranipool, the location of a crematorium at Jalipool, and non-point sources of pollution from residential houses, commercial places, etc contribute to it.

In this study, we have observed that the pollution trend decreases from station 1 to station 3. Self-purification may also include increase in DO because of aeration, dilution from incoming tributaries, sedimentation of dissolved solids and filtering during water flow. A similar case of a decrease in pollution trend from upstream to downstream has also been observed by researchers like Bora and Goswami (2017) for the assessment of water quality in Kolong River, Assam, and Lkr et al., (2020) in the analyses of the Doyang River's water quality in Nagaland. The noticeable decrease in the trend of pollution level in station 3 as compared to upstream stations maybe due to the merging of other streams beyond station 2, thereby increasing the self-purification level of the river. Also, there is no major detectable pollution contributing factors in terms of urbanization and settlement compared to the upstream sampling stations area. Apart from that, the location of dense forest-covered areas, open forests, and protected areas like Martam Reserved Forest, Bhusuk Reserved Forest, and Assam Forest (Mishra et al., 2019) also play anessential role in improving the quality of water. The seasonal average WQI score and WQI status aredisplayed in Table 9. From Table 9, it was evident that the seasonal average score during PRM, MON, and POM was 48.78 (good), 57.93 (poor), and 50.57 (poor) respectively. This is an indication that both MON and POM relate to bad water quality, stating that water may only be used for industrial and agricultural purposes. Meanwhile, the water quality status of PRM falls under good water quality status and specifies that water is useful for various purposes including industrial and agricultural use (Fig. 6). This seasonal categorization of water quality status for the study area is as per the indices given by Brown et al.,1972.

Table 5. WQI calculation at station 1 (1804)

Parameters	**Pre-Monsoon (PRM)**			**Monsoon (MON)**			**Post-Monsoon (POM)**		
	V_n	Q_n	W_n* Q_n	V_n	Q_n	W_n* Q_n	V_n	Q_n	W_n* Q_n
pH	6.50	33.30	7.68	6.13	58	13.38	6	66.70	15.39
EC	176.67	58.89	0.39	225	75	0.49	146.67	48.89	0.32
NO_3-N	3.07	6.82	0.30	2.85	6.33	0.28	3.57	7.93	0.35
D.O	9.37	60.80	19.87	8.33	72.90	23.82	8.17	74.80	24.44
B.O.D	3.17	63.33	24.84	3.48	69.50	27.25	2.70	54	21.18
T. Coliform	165	0	0	220	0	0	160	0	0
∑ W_n* Q_n	53.07			65.22			61.67		
WQI	53.07			65.22			61.67		

Table 6. WQI calculation at station 2 (1805)

Parameters	Pre-Monsoon (PRM)			Monsoon (MON)			Post-Monsoon (POM)		
	V_n	Q_n	W_n* Q_n	V_n	Q_n	W_n* Q_n	V_n	Q_n	W_n* Q_n
pH	6.33	45	10.27	6.25	50	11.53	6.33	44.50	10.27
EC	191.67	63.89	0.42	232.50	77.50	0.51	153.33	51.11	0.33
NO_3-N	2.53	5.62	0.24	2.33	5.17	0.23	2.83	6.30	0.27
D.O	9.77	57	18.63	8.45	71.50	23.37	9	65.10	21.28
B.O.D	2.97	59.4	23.29	3.35	67	26.27	2.43	48.67	19.09
T. Coliform	145	0	0	167.50	0	0	133.33	0	0
∑ W_n* Q_n	52.96			66.97			51.23		
WQI	52.96			66.97			51.33		

Table 7. WQI calculation at station 3 (1807)

Parameters	Pre-Monsoon (PRM)			Monsoon (MON)			Post-Monsoon (POM)		
	V_n	Q_n	W_n* Q_n	V_n	Q_n	W_n* Q_n	V_n	Q_n	W_n* Q_n
pH	7	0	0	6.50	33.30	7.68	6.67	22	5.08
EC	211.67	70.56	0.46	237.50	79.17	0.52	193.33	64.44	0.42
NO_3-N	2.07	4.60	0.20	1.98	4.39	0.19	1.83	4.07	0.18
D.O	9.27	62	20.26	12	30.20	9.87	10.17	51.50	16.83
B.O.D	2.47	49.40	19.37	2.98	59.50	23.33	2.07	41.33	16.21
T. Coliform	155	0	0	143.75	0	0	120	0	0
∑ W_n* Q_n	40.30			41.59			38.71		
WQI	40.30			41.59			38.71		

Table 8. Value of WQI and its status for the three sampling stations

Sampling station	Pre-Monsoon (PRM)		Monsoon (MON)		Post-Monsoon (POM)	
	WQI	Status	WQI	Status	WQI	Status
1804	53.07	Poor	65.22	Poor	61.67	Poor
1805	52.96	Poor	66.97	Poor	51.33	Poor
1807	40.30	Good	41.59	Good	38.71	Good

Table 9. Seasonal mean of WQI score and WQI status

Season	WQI score	WQI status
Pre-Monsoon (PRM)	48.78	Good
Monsoon (MON)	57.93	Poor
Post-Monsoon (POM)	50.57	Poor

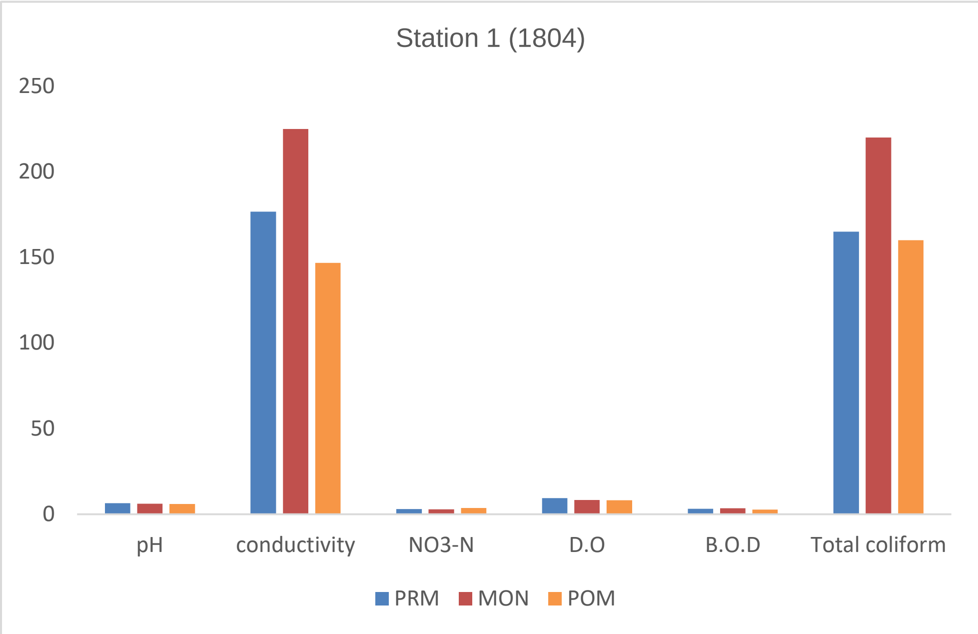

Figure 2. Average water quality data for station 1 (1804

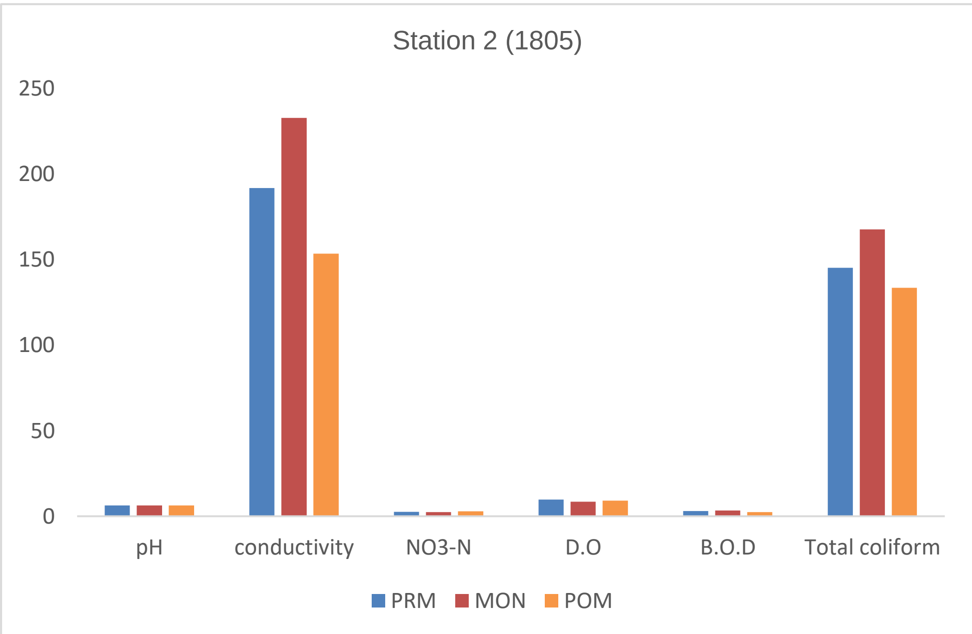

Figure 3. Average water quality data for station 2 (1805)

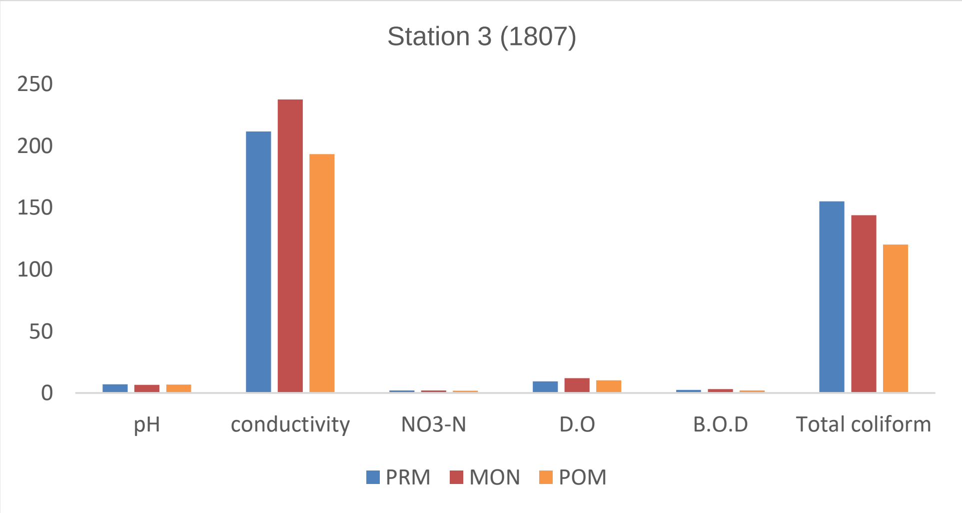

Figure 4. Average water quality data for station 3 (1807)

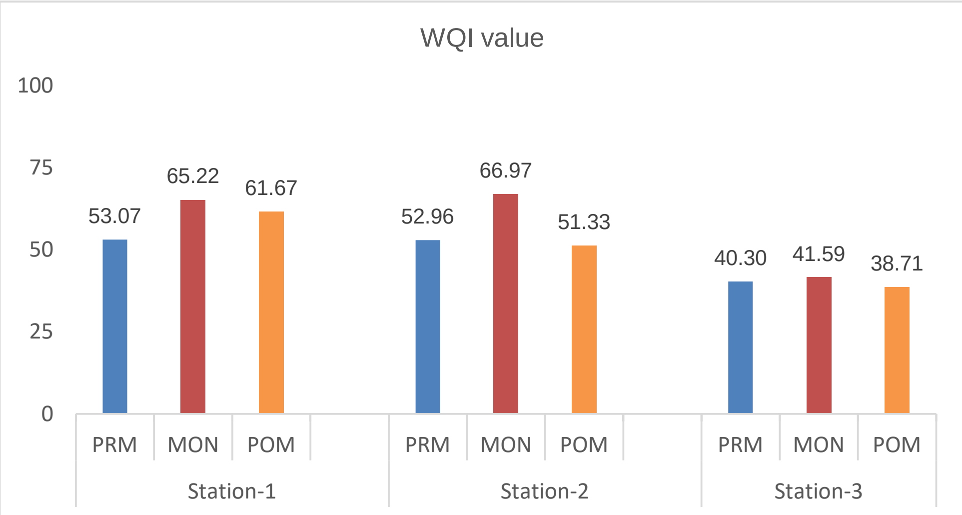

Figure. 5 WQI score from the three sampling stations for all seasons

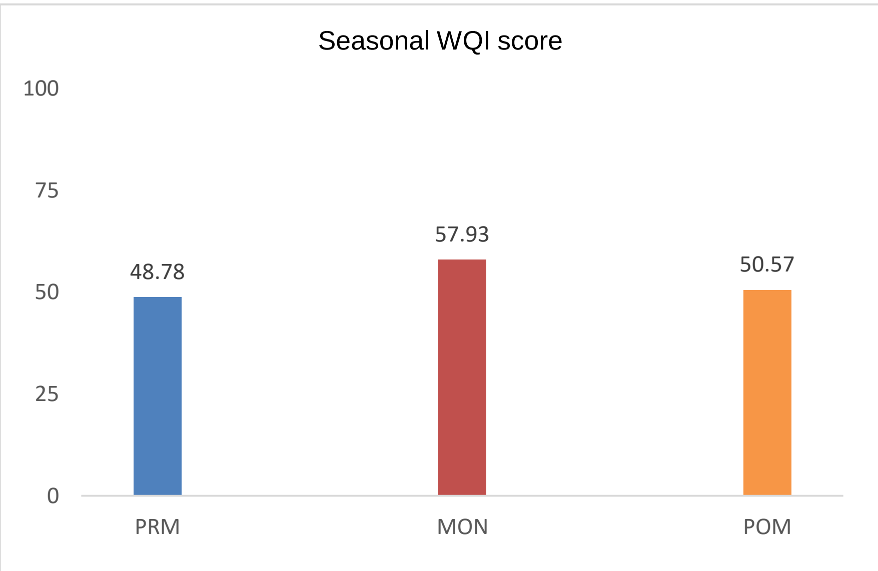

Figure 6. Seasonal WQI score of all sampling stations

4. Conclusions

The present study gives us a clear idea about the pollution status of water for the selected sampling stations along the stretch of Ranikhola River in the form of the WQI with the following points.

1. It was observed that during PRM, two stations upstream i.e station 1 (1804) and 2 (1805) shows "Poor" water quality status while downstream station 3 (1807) score "Good" condition of WQI. Similarly, for MON, two upstream stations fall under "Poor" while the downstream station falls under the "Good" category. In POM season, except for station-3, all stations score "Poor" condition quality of water. We also notice that the increase/decrease of WQI score is comparatively lesser in PRM and POM but the highest noticeable WQI score is during the MON season.
2. The average overall WQI rating seasonally shows that the water quality status during PRM falls under "Good" while MON and POM fall under "Poor" conditions. It is also quite obvious that the most significant parameters influencing the overall status of WQI are pH, DO, and BOD.
3. Proper information and conservation rules must be made known to all the residents residing especially in catchment areas. Careful agricultural waste disposal, proper practices of land use, proper waste disposal, and protection of riparian zones must be practised at all possible costs.
4. Water Quality Index could go a long way in managing and controlling the pollution level of the river and this study will help in enlightening the remedies to be taken to improve the water quality status along the stretch of Ranikhola River

5. Acknowledgements

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