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ASSESSMENT OF WATER QUALITY INDEX OF A STRETCH OF RANIKHOLA RIVER, EAST SIKKIM

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ABSTRACT

The study was conducted to assess the Water Quality Index (WQI) of a stretch of the Ranikhola river of East Sikkim. The WQI values were calculated using weighted arithmetic water quality index method. The overall Water Quality Index value degraded as the river traverses from the upstream section (L1) towards the downstream section (L5). The WQI values of the five sampling stations (L1-L5) for Post Monsoon seasons were recorded as 10.45, 52.64, 53.05, 56.43 and 57.86 respectively with an average value of 46.08. Likewise, the Monsoon season recorded values were 25.27, 42.15, 53.05, 57.22 and 54.60 respectively with an average value of 46.45. The presence of densely populated residential homes in the adjoining areas of sampling stations L2 to L5 and sand mining activities has influenced the physico-chemical parameters of water samples. WQI values at these stations deteriorate as the river flows from upper reaches to urbanized/ downstream area. The main causes of deterioration in water quality are anthropogenic activities, soil erosion, discharge of untreated sewage, and polluted urban runoffs. The present water quality status indicates the necessity to adopt suitable management policy, regulate human activities and implement conservation efforts along the stretch of the Ranikhola river.

INTRODUCTION

The Ranikhola, a tributary to the Tista river drains a considerable part of the eastern district of Sikkim. It originates from the South-Western slopes of Lingzung (23º12' N; 88º 32'), 2865 m. above sea level and flows through a conspicuous gorge valley negotiating a series of elongated rides and interlocking spurs in its incised and gently meandering course downstream. The river flows through a varied land use pattern like forests, farmlands, settlement, roads *etc.*, as the agricultural land use and human settlements are developed in response to the steep slopes of the land, amount of rainfall and environmental conditions.

River water bodies suffer water quality deterioration because of human activities, industrialization, poor sanitation facilities, discharge of untreated sewage and waste disposal. Sewage is the main source of fresh water pollution (Gupta *et al.*, 2017; Manoj and Padhy, 2015). Urbanization without proper planning can severely impact the quality of water causing deterioration in the downstream reaches of the river. Indiscriminate discharge of untreated domestic and industrial effluents has led inevitably, to alterations in the quality and ecology of rivers and this brings new challenges not only to water resource managers but also to aquatic ecologists (Kamboj and Kamboj, 2019). The assessment of quality of river water is done using various physico-chemical and biological parameters. The different ways and techniques to protect river water have been reported in the literature by several research teams (Yisa and Jimoh, 2010; Shah *et al.*, 2015). One approach for determination of the quality of river water is water quality index (WQI), it is found to be an efficient and useful method for assessing water quality. This method gives an idea about the overall quality of water to the concerned policymakers (Tyagi *et al.*, 2013). The use of a WQI was initially proposed by Horton (1965) and Brown *et al*. (1970). Since then, several different methods for the calculation of WQI's has been developed. The different water quality indices used worldwide are US National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), British Columbia Water Quality Index (BCWQI), Oregon Water Quality Index (OWQI), Weighted Arithmetic Water Quality Index (WAWQI) (Nayak and Patil, 2015; Sutadian *et al.*, 2016). Bhargava *et al*. (1985) introduced the water quality index concept in India and gave an index scale ranging from 0 to 100 for highly polluted to unpolluted water (Lumb *et al.*, 2011). There is limited literature on investigations on the water quality status of the Ranikhola river of the east district of Sikkim. In this context, a study was carried out to assess the water quality status for two seasons (Post Monsoon and Monsoon) in a stretch of Ranikhola river with the following objectives to analyse the physico-chemical properties and to develop a water quality index using weighted arithmetic water quality index.

MATERIALS AND METHODS

Sampling spots were from both at the upstream and downstream part of the possible discharge points. The samples were collected from a well-mixed section of the river at about 30 cm below the water surface : from five locations along the urbanized stretches of Ranipool area of the river, *viz*., (L1) Adam pool (reference), (L2) Jalipool, (L3) Staff quarters (CAEPHT), (L4) Smile land and, (L5) Boys Hostel (CAEPHT). The geographical locations of sampling sites are presented in Fig:1.

Adam Pool (Sampling Site 1)

The sampling site is located at a latitude of N 27º18.647′ and longitude of E 88º35.106′ (elevation 934 m). This serves as the reference sampling location before the river water enters the Ranipool town area. There is no major anthropogenic input at this point.

Jalipool (Sampling Site 2)

The sampling site is located at a latitude of N 27º17.409′ and longitude of E 88º35.731′ (elevation 838 m). This site corresponds to another sub-tributary joining the river water coming from Site 1.

Staff Quarters, CAEPHT (Sampling Site 3)

This site is located at a latitude of N 27º17.421′ and longitude of E 88º35.558′ (elevation 836 m). It is located at the downstream point of Site 1 after the river water passes through the Ranipool town area. Major anthropogenic activities occur at this location.

Smile land (Sampling Site 4)

This part is located at a point downstream of the confluence of site 1 and 2, located at a latitude of N 27º16.754′ and longitude of E 88º35.734′ (elevation 782 m).

Fig.1: Sampling point locations along the Ranikhola Stretch (L1, L2, L3, L4 and L5)

CAEPHT Boy's Hostel ((Sampling Site 5)

This site is located at a latitude of N 27º17.287′and longitude of E 88º35.522′ (elevation 825 m). The inflow coming from sampling location 1 and 2, passing through site 3 directly converge at this location.

Physicochemical Analysis

The river water samples were collected from the selected five locations (L1–L5) as per standard sampling methods (IS: 2498, 1966 – Part-I). The first set of samples were collected from the sampling sites on 8th October 2019 post -Monsoon (PMON) followed by another collection of samples on 2nd July 2020 during monsoon (MON) for the laboratory analysis of the parameters. The water samples were observed for analysis of parameters like pH, electrical conductivity (EC), presence of carbonates and bicarbonates (total alkalinity), sodium, potassium, chloride and total dissolved solids (TDS). The physical parameters such as pH, EC and TDS were measured using pH meter, Electrical conductivity meter and EC probe respectively from the collected water sample in the laboratory. The Standard procedure as prescribed by Trivedy and Goel (1986) and APHA (2005) was followed for analysis of the chemical parameters of the water sample.

Water Quality Index Determination

Water quality index (WQI) is a valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues (Tyagi *et al.*, 2013). The calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (1965) and developed by Brown *et al.* (1972). The weighted arithmetic water quality index (WQI) is in the following form:

$$WQI = \sum_{i=1}^{n} w_i q_i / \sum_{i=1}^{n} w_i \text{.........(1)}$$

Where n is the number of variables or parameters, w_i is the relative weight of the ith parameter and q_i is the water quality rating of the i^{th} parameter. The unit weight (wi) of the various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters. According to (Brown *et al.*, 1972), the value of q_i is calculated using the following equation:

$$q_{i=100}[(Vi - V_{id})/(S_i - V_{id})] \text{..........(2)}$$

Where V_i is the observed value of the ith parameter, S_i is the standard permissible value of the ith parameter and Vid is the ideal value of the i^{th} parameter in pure water. All the ideal values (Vid) are taken as zero for drinking water except pH and dissolved oxygen (Tripaty and Sahu, 2005). For pH, the ideal value is 7.0 (for natural/pure water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH is calculated from the following equation:

$$q_{pH=100}[V_{pH} \; -7.0)/(8.5-7.0)] \text{...........(3)}$$

Where V_{pH} = observed value of pH

For dissolved oxygen, the ideal value is 14.6 mg/L and the standard permissible value for drinking water is 5 mg/L. Therefore, its quality rating is calculated from the following equation:

$$q_{DO=}\ 100[(V_{DO} \; - 14.6)/(5.0 - 14.6)] \text{............(4)}$$

$V_{DO=}$ observed value of dissolved oxygen

RESULTS AND DISCUSSION

Water Quality Index depicts the composite influence of different water quality parameters and helps to communicate water quality information to the public and legislative decision-makers. Before the determination of Water Quality Index, the prerequisite is the determination of the physico-chemical properties of the sample.

Table 1: Water quality rating (Brown *et al.*, 1972; Chatterji and Raziuddin, 2002)

No.	WQI level	Water quality Status
A	0-25	Excellent
B	26-50	Good
C	51-75	Poor
D	76-100	Very Poor
E	Above 100	Unsuitable for drinking

Table 2: Observed values of physico-chemical parameters post monsoon (PMON).

Sl.No.	Parameters	L1	L2	L3	L4	L5	ICMR/BIS (Sn)
1	pH	6.84	6.11	6.11	6.05	6.03	6.5-8.5
2	Total Alkalinity (me/liter)	0.5	0.47	0.34	0.34	0.47	200
3	Electrical conductivity (μS/cm)	64.7	49.06	74.33	52.73	79.1	300
4	TDS (mg/l)	31.63	24.26	37.13	26.4	39.7	500
5	Sodium (mg/l)	4.6	1.82	5.78	2.97	4.91	200
6	Potassium (mg/l)	1.34	1.62	2.16	1.71	2.3	200
7	Chloride (mg/l)	47.93	35.5	47.33	59.1	59.1	250

Table 3: Observed values of Physico-chemical parameters during monsoon (MON).

Sl.No.	Parameters	L1	L2	L3	L4	L5	ICMR/BIS (Sn)
1	pH	6.59	6.29	6.11	6.04	6.09	6.5-8.5
2	Alkalinity (me/liter)	0.92	0.93	0.66	0.73	0.76	200
3	Electrical conductivity (μS/cm)	49.36	29.3	28.13	38.73	41.95	300
4	TDS (mg/l)	24.63	14.56	14.03	17.45	20.95	500
5	Sodium (mg/l)	6.6	3.82	7.56	4.32	7.52	200
6	Potassium (mg/l)	3.42	2.62	5.16	2.71	5.3	200
7	Chloride (mg/l)	81.65	45.5	81.65	87.5	106.5	250

Table 4: Calculation of Water Quality Index (WQI) of Ranikhola river Post Monsoon (PMON).

Parameter	(Wi)	(qi) 1	(qi) 2	(qi) 3	(qi) 4	(qi) 5	QiWi	QiWi	QiWi	QiWi	QiWi
Total alkalinity (me/liter)	0.03	0.25	0.24	0.17	0.17	0.24	0.01	0.01	0.01	0.02	0.01
pH	0.87	10.67	59.33	59.33	63.33	64.67	9.32	51.82	51.82	54.13	56.48
Electrical conductivity (μS/cm)	0.02	21.57	16.35	24.78	17.58	26.37	0.47	0.36	0.54	0.38	0.58
Total dissolved solids (mg/l)	0.01	6.33	4.85	7.43	5.28	7.94	0.08	0.06	0.1	0.07	0.1
Sodium (mg/l)	0.03	2.3	0.91	2.89	1.49	2.46	0.08	0.03	0.09	0.05	0.08
Chloride (mg/l)	0.03	19.17	14.2	18.93	23.64	23.64	0.5	0.37	0.5	0.61	0.62
					WQI		10.45	52.64	53.05	56.43	57.86
					AVG		46.08				
					Grading		A	C	C	C	C

Table 5: Calculation of Water Quality Index (WQI) of Ranikhola river in Monsoon (MON).

Parameter	Wi)	(qi) 1	(qi) 2	(qi) 3	(qi) 4	(qi) 5	QiWi	QiWi	QiWi	QiWi	QiWi
Total Alkalinity (me/liter)	0.03	0.46	0.47	0.33	0.37	0.38	0.02	0.02	0.01	0.01	0.01
PH	0.87	27.33	47.33	59.33	64	60.67	23.87	41.34	51.82	55.9	52.98
Electrical conductivity (μS/cm)	0.02	16.45	9.77	9.38	12.91	13.98	0.36	0.21	0.2	0.28	0.31
Total dissolved solids (mg/l)	0.01	4.93	2.91	2.81	3.49	4.19	0.06	0.04	0.04	0.05	0.05
Sodium (mg/l)	0.03	3.3	1.91	3.78	2.16	3.76	0.11	0.06	0.12	0.07	0.12
Chloride (mg/l)	0.03	32.66	18.2	32.66	35	42.6	0.86	0.48	0.86	0.92	1.12
					WQI		25.27	42.15	53.05	57.22	54.6
					Avg		46.45				
					Grading		B	B	C	C	C

Physicochemical Analysis of Water Samples

The following observations as represented in Table 2 and 3 are made concerning to various parameters for the two seasons based on experimental analysis.

The pH value gives a measure of the acidic or alkaline condition of the water sample. The range of pH values for post monsoon and monsoon season observation varies from 6.03 to 6.84 and 6.04 to 6.59 respectively. The observed values of pH indicate no marked difference for the Post monsoon and monsoon season. A slightly acidic pH was recorded for both the season which were also in conformity to the results observed by Gupta *et al*. (1992) and Mukhopadhyay, (1996) as a feature of the high altitude region prevalent in North-

Figure 1: Sampling point locations along the Ranikhola Stretch (L1, L2, L3, L4 and L5)

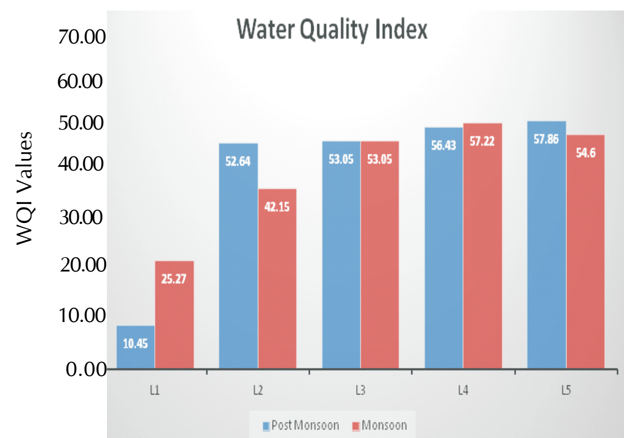

Fig ure 2: Water Quality Index of Ranikhola river in Post Monsoon and Monsoon season

Eastern part of India. The pH value for this study falls within 6-8 which is the common range of values for natural water (Thakre *et al.*, 2010).

Electrical conductivity (EC) is an indirect measure of total dissolved salts. Observed minimum and maximum values for EC for different sampling stations in the PMON was found to be in the range of 49.06 μS/cm to 79.1 μS/cm while the minimum and maximum EC values for MON was found to be in the range of 28.13 μS/cm to 49.36 μS/cm. The EC values were observed to be higher for the Post Monsoon season for all the sampling stations. This higher values may be attributed to the presence of high ionic constituents like sodium, potassium, calcium, magnesium *etc.* during the PMON season. Similar observations were also noted by Yogendra and Puttaiah, 2008).

Total Dissolved Solids (TDS) is determined for measuring the amount of solid materials dissolved in the water and indicate the general nature of water quality or salinity. Higher TDS value was recorded for PMON samples ranging from 24.26 μS/cm to 39.7 μS/cm for the different stations whereas slightly lower TDS value was recorded for MON season samples in the range of 14.03μS/cm to 24.63 μS/cm. The values observed were all found to be under the desirable limit as prescribed by ICMR (Indian Council of Medical Research) and BIS (Bureau of Indian Standards).

Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), added through industrial effluents, sewage, *etc.* The concentration of chloride was found to be within the permissible range of 250 mg/l (ICMR/BIS) for both the seasons. A higher concentration of chloride was recorded in the MON season with a value from 45.5 mg/l to 106.5 mg/l, whereas a lesser concentration was recorded with a value of 35.5 mg/l to 59.1 mg/l for the PMON season.

The concentration of sodium was found to be in the range of 1.82 mg/l and 5.78 mg/l for the PMON season while the recorded values for MON season was found to be in the range of 3.82 mg/l to 7.56 mg/l. A lower concentration of sodium as observed for the PMON season which may be due to the dilution caused by the monsoon spell and recharge of fresh water from the hilly springs. Likewise, the concentration of potassium was found to be in the range of 1.62 mg/l and 2.16 mg/l for the PMON season while the recorded values for MON season was found to be in the range of 2.62 mg/l to 5.30 mg/l. According to ICMR/BIS standards, the concentration of sodium in drinking water should be within 200 mg/l. In the present study, the values fall well below the prescribed limits.

Alkalinity is a measure of the ability of water to neutralize the acid. It may be due to the presence of salts of carbonates, bicarbonates, borates, silicates and phosphates along with the hydroxyl ions in the free state. The main contributors to alkalinity are the hydroxides, carbonates and bicarbonates (Pandey *et al.*, 2014). The alkalinity of the water samples ranges between 0.34 me/litre to 0.5 me/litre and 0.66 mg/l to 0.93 mg/l for the PMON and MON season respectively. The values of alkalinity show no major difference for both the seasons. Under normal conditions, the bicarbonate concentrations in rainwater are commonly less than 10 mg/l.

Water Quality Index (WQI) calculation

The calculation of WQI was done using Weighted Arithmetic Index Method which involves the estimation of 'unit weight' assigned to each physicochemical parameter selected. The weightage assigned to each of the physico-chemical parameters depends on the permissible limit in drinking water established by National and International Agencies (WHO, IS-10500 *etc*). Weightage of the parameter is inversely proportional to its permissible limits, *i.e.*, weightage of parameter I = 1/Si, where Si = maximum permissible limits of the parameter. The calculated values and the pictorial representation of the water quality index of all the samples for the two different seasons are presented in Table 4, Table 5 and Fig. 2 respectively.

Table 4 and 5 represents the calculated values of the Water Quality Index from the five sampling stations for two different seasons. pH was found to be the most dominating parameters followed by chloride and electrical conductivity (EC). The average value of WQI values for all the stations was observed to be 46.08 and 46.45 for PMON and MON season respectively.

From the tables and figure it was observed that the WQI values recorded a more degraded value of 25.27 for the L1 stations and the remaining stations recorded value of 42.15, 53.05, 57.22 and 54.60 for L2 to L5 stations respectively in the monsoon season. The inflow volume of runoff and sewage discharge is much more pronounced in the monsoon season which may have cause the degraded value of WQI. The post monsoon observation shows a lesser degraded value of the L1 stations as 10.45 whereas the remaining sampling stations show a relatively similar value of WQI values as 52.64, 53.05, 56.43 and 57.86 for L2 to L5 stations respectively. The sampling stations from L2 onwards traverses through the urbanized town area of Ranipool. The sewage, urban runoff discharge from this part of town area may have attributed to the degradation of the WQI values at these sections. The presence of some residential homes in the adjoining areas of station L2 to L5 and some sand mining activities has contributed in a major way to the physicochemical parameters of the river water A similar finding has also been reported by researchers Singh and Kamal (2014) and Bora and Goswami (2017) in their studies in the assessment of surface water quality status of Kolong River, Assam. The WQI values fall in the poor category from L2 to L5 except for the L1 sampling stations for the PMON season, whereas for the WQI values for MON season recorded a poor category for the sampling stations from L3 to L5. The overall WQI value degraded as the river traverses from the upstream section (L1) towards the downstream section (L5) indicating that water quality deteriorates as the river flows from upper reaches to urbanized/ downstream area. The main cause of deterioration in water quality at these five sampling stations is due to the high anthropogenic activities, untreated or inadequately treated sewage, lack of proper sanitation, and urban runoffs.

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