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An Evaluation of Physicochemical Analysis and Water Quality Index of Ratuwa River of Damak, Jhapa, Nepal

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Abstract **- Water quality is the index of good health and well-being of society. So it is one of the great concerns all over the world. In the present study, we have measured some physicochemical parameters to understand the pollution status of Ratuwa river and to create the awareness in the local people. Standard procedures APHA methods had been used to analyze the parameters and the result shows that all the measured parameters such as color, pH, EC, TSS, TDS, DO, sulphate, chloride, total hardness, total phosphorus, calcium, magnesium etc are in permissible ranges, but turbidity and BOD are relatively higher than that of the standard value prescribed by Nepal Drinking Water Quality Standard (NDWQS) and Indian Council of Medical Research (ICMR). These two parameters are responsible to increase the Water Quality Index (WQI) of Ratuwa River making it unfit for any purposes.**

Keywords **- Water quality index (WQI), Physico-chemical parameters, Dissolved Oxygen**

I. INTRODUCTION

Water is essential for the survival of all forms of life [1-2] and is used in various applications such as irrigation, domestic and sanitation purposes. Rivers are important sources to provide the daily needs of water both for animals and plants and are the most exploited in nature due to the changing lifestyle of the people, increasing urbanization and overpopulation [3]. Such resources are becoming the dumping sites of domestic, municipal and industrial wastes [4] due to highly soluble nature of dissolved matters. The contaminated river water is not a good sign for the human health and other aquatic organisms as it creates the numerous health hazards. So good quality of water is essential for all form of life and can be checked by examining its various physic-chemical and microbial parameters. Any alteration beyond the permissible range in these parameters makes the water polluted [5] and may be unfit for any purpose for which it is intended to use. So, regular monitoring and analyzing of the water is essential to evaluate its quality and degree of pollution which is caused by the natural calamities or anthropogenic activities. Damak is a small city in the eastern Nepal where there is no practice for the management of river water. Dumping site of the municipality is also established at the bank of the Ratuwa river from where the chances of mixing of contaminants are highly probable.

In our study, Eighteen physicochemical parameters such as color, turbidity, pH, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), sulphate, chloride, nitrate, total phosphorus (TP), total hardness, total alkalinity, calcium, magnesium, silica, dissolved oxygen (DO) and biological oxygen demand (BOD) of samples are analyzed and interpreted to understand the pollution level of Ratuwa river. Their average values are compared with NDWQS, WHO, and ICMR [6-12] standards and also used to evaluate WQI. Such type of work is vital to inform and create awareness among the people and authorities of municipality about the pollution status of river and direct consequences on their health and recreational works. The monitoring of these parameters can support the conservation and management system of Ratuwa river.

II. WATER QUALITY INDEX COMPUTATION

WQI is the effective tool that represents the overall water quality at a certain place and time based on physicochemical and microbial parameters [13-15].

Horton (1965) has first used the concept of WQI then developed by Brown *et.al*. (1970) and improved by Deininger (Scottish development department, 1975).
Calculation of WQI using this method is given in Equation (1).

$$\mathrm{WQI} = \frac{\sum q_n W_n}{\sum W_n} \qquad \ldots\ldots\ldots(1)$$

Where, q_n and W_n be the Quality rating and Unit weight of nth water quality parameter. The quality rating (q_n) is calculated using the relation given in Equation (2)

$$q_n = \left[\frac{(V_n - V_{io})}{(S_n - V_{io})}\right] \times 100 \ldots\ldots\ldots(2)$$

Where, V_n, V_{io} and S_n be the estimated value, ideal value and standard permissible value of the nth parameter. For all parameters ideal values (V_{io}) were taken as zero for drinking water except for pH=7.0 and DO =14.6 mg/l.
The unit weight (W_n) is calculated using the relation given in Equation (3).

$$W_n = \frac{K}{S_n} \qquad \ldots\ldots\ldots(3)$$

Where, K= proportional constant and it is calculated by using the relation given in Equation (4).

$$K = \frac{1}{\Sigma\left(1/S_{n=1,2,3\ldots}\right)} \qquad \ldots\ldots\ldots(4)$$

III. MATERIALS AND METHODS

Ratuwa is a small perennial river and serves as the border of eastern Damak. It originates from Siwalik hill and mixes to the Kankai river in Bihar before merging to Ganga river. The water sample was collected in a one-liter plastic bottle just a few hundred meter away from the Ratuwa bridge during the pre-monsoon and post-monsoon period dated 11th May 2017 and 8th September 2017 respectively. The bottles were rinsed before filling sample, sealed tightly and labeled in the field. The samples were taken by pumping to avoid contamination from the surface of the river basin and brought to Nepal Batawaraniya Sewa Kendra, Biratnagar for the laboratory test. Standard procedures for the measurement and their average values with standard deviation are shown in Table I. WQI is an important parameter to check the quality of water, and its calculation was carried out by using relations given in the water quality index computation.

IV. RESULTS AND DISCUSSION

The result of physicochemical analysis is presented in Table I with mean and standard deviation taken during the pre-monsoon and post-monsoon period and discussion of each parameter is made separately. The result is also displayed in bar diagram in Fig. 1.

Color : The water of zero Hazen is colorless and colored water results due to the presence of dissolved organic matters which originate from soil and decaying vegetables. It is strongly affected by the presence of iron and other metals [16]. Ratuwa river consists of 0.72 and 9.5 Hazen in the pre-monsoon and post-monsoon season so that its average value is 5.14 with standard deviation 6.17 and it is around the permissible range of Nepal Standard for drinking (5 Hazen). A major contribution to increasing the color in post-monsoon period may be due to the total dissolved solids.

Table I
Standard procedures for the measurement of physic- chemical parameters with measured value

SN	Parameter	Unit	Result (pre monsoon	Result (Post monsoon)	Mean Value	Standard deviation	Method
1	Color	Hazen	0.78	9.5	5.14	6.17	APHA-2120C
2	Turbidity	NTU	70	60	65	7.07	APHA-2130B
3	pH	-	6.70	7.1	6.9	0.28	APHA-4500 H+
4	Electrical Conductivity	µS/cm	134.60	154.5	144.55	14.07	APHA-2510
5	Temperature	ºC	29.50	31.8	30.65	1.63	Electrometric
6	TDS	mg/l	67.30	77.25	72.275	7.04	APHA-2540 C
7	TSS	mg/l	20	56	38	25.46	APHA-2540 D
8	Chloride	mg/l	7	2	4.5	3.54	APHA-2500 B
9	Sulphate	mg/l	129	25	77	73.54	APHA-4500 SO_4^{2-} C
10	Silica as (SiO_2)	mg/l	450.51	127.62	289.065	228.32	APHA-4500
11	Nitrate Nitrogen	mg/l	<0.05	<0.05	--	--	APHA-4500
12	Total Phosphorus	mg/l	0.28	<0.05	0.28	--	APHA-4500
13	Total Hardness	mg/l	65	54.71	59.855	7.28	APHA-2340
14	Total Alkalinity	mg/l	136	59.50	97.75	54.09	APHA-2320
15	Calcium	mg/l	25.14	19.24	22.19	4.17	APHA-3500
16	Magnesium	mg/l	1.94	12.15	7.045	7.22	APHA-3500
17	BOD	mg/l	54.70	39.62	47.16	10.66	APHA-5210
18	DO	mg/l	6.67	3.67	5.17	2.12	APHA-4500

Turbidity: It is the amount of cloudiness, due to which it's impossible to see throughout the water and is caused by suspended particles or colloidal matter and chemical precipitations [17]. The maximum limit of Nepal for standard drinking water is 10 NTU but in our sample, it was 70 and 60 NTU during the pre-monsoon and post-monsoon season respectively. It is far beyond NDWQS for drinking water. A Few days ago of sample collection during pre-monsoon and post-monsoon period, there was rainfall in the Siwalik hill so that water was somewhat turbid due to the excessive presence of silt, sand, and mud. Overall, soil erosion and runoff from the catchments are the major sources of high turbidity in the river water. A higher value of turbidity reduces the aquatic vegetation and subsequently reduces the food sources for many aquatic animals [18]. Similarly, its higher value can also interfere with disinfection and provides a medium for microbial growth that causes symptoms such as nausea, cramps, diarrhea, and associated headaches [19]

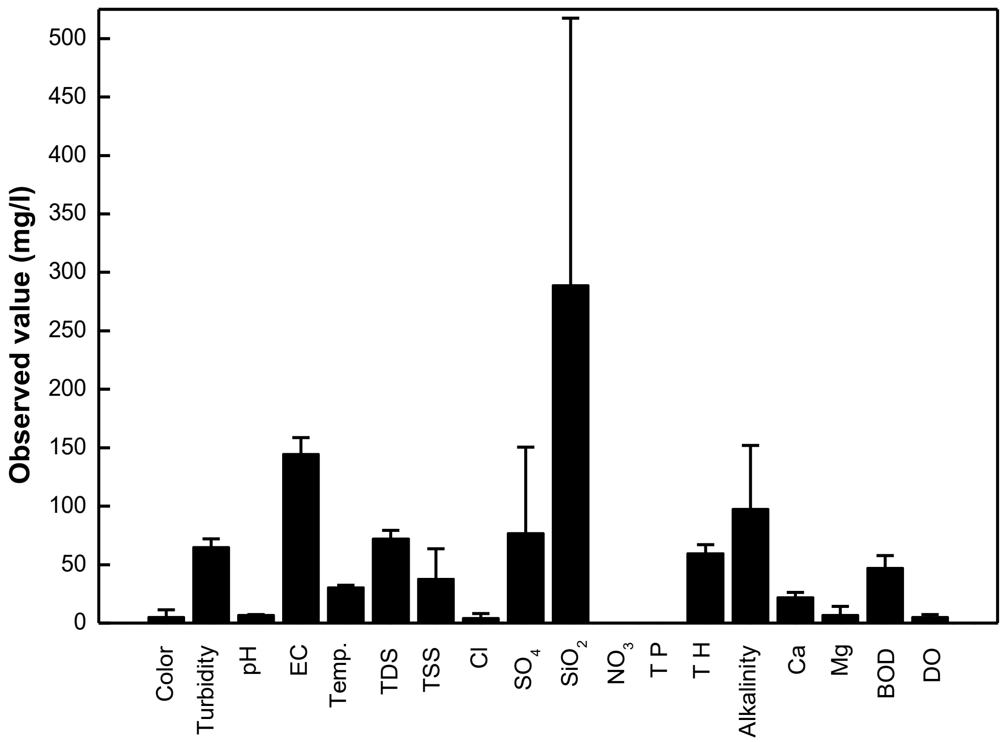

Fig. 1 Bar diagram of average value of physico-chemical parameters with error bar

pH: It is the most important analysis in water testing and indicates the acidic or alkaline nature of water. The standard for any purpose in-terms of pH is 6.5-8.5. Ratuwa river was slightly acidic in pre-monsoon (6.7) and slightly basic in post-monsoon (7.1). Slightly acidic nature of water may be due to acid rain and low temperature in pre-monsoon [20]. The presence of an excess of CO_2 and SO_2 in the atmosphere during the pre-monsoon period partially dissolved in water and formed carbolic acid and sulfuric acid. The river being the runoff nature adds those acids to the water, making a more acidic condition.

Electrical conductivity: It measures the ionic condition of water which is greatly affected by temperature, concentration of impurities, and mobility of ions [21].It helps to figure out the dissolved solid contents. The result showed that water in the post-monsoon period was conducting more (154.5µS/cm) than in pre-monsoon period (134.6µS/cm). The average value of the measured EC is 144.55µS/cm and it is in the range of WHO standard 300µS/cm. The increase in electrical conductivity in post monsoon period was due to the presence of an excess of TDS.

TSS and TDS: TSS is the part of total solids retained by a filter, whereas TDS is the remaining part that passes through the filter.Suspended solids or particles are the natural pollutants that cause the turbidity in water [22] whereas the TDS increases the conductivity and color of the water. In the sample, the TDS and TSS are 67.30 and 20 mg/l in pre-monsoon and 77.25 and 56 mg/l in post monsoon respectively. The most desirable limit of TDS and TSS both are 500 mg/l according to WHO standards. High values of TDS in drinking water are generally not harmful to human beings but may affect persons, who are victims of kidney and heart diseases [23].

Chloride: It is a dominant anion in water and is essential for life. Its excessive amount can constitute a health hazard [24]. In our study, the chloride content in Ratuwa river is 7mg/l and 2ng/l in the pre-monsoon and post-monsoon. These values are relatively very low as compared to the NDWQS (250 mg/l) and it confirms that water is less contamination of the chloride.

Sulphate: It is the least toxic anion of which WHO standards for drinking is 200 mg/l, but its value should not exceed 500 mg/l [25]. The amount of sulphate determined in our study was 129 mg/l and 25mg/l respectively. So that its average value is 77 with standard deviation 73.54 respectively.

Silica: It is the mineral that is abundantly found in the Earth's crust and can exist in both particulate and soluble form in water. It comes in water by the gradual degradation of silica-containing minerals. The silica content in river water is generally in the range of 5 to 25 mg/l but in some region, its concentration is above 100 mg/l [26]. In our sample, its average concentration was 289.065mg/l with standard deviation 228.32 mg/l.

Nitrate: It is generally present in water by the aerobic decay of organic nitrogenous compounds. In our samples, the nitrate was below the certain limit (<0.05mg/l) so that instrument could not detect it. The result shows that presence of sources of nitrate such as chemical fertilizer, plant decays, and animal debris is extremely low.

Total Phosphorus: It is the prime nutrient for growth and development of algae an aquatic plants and is normally very low (< 1 mg/l) in clean potable water. However, the presence of excessive phosphorous supports the growth of algae and aquatic plants consuming oxygen sufficiently. In this study, total phosphorus was below the detection level in the post-monsoon period but it was 0.28 mg/l in the pre-monsoon period. The low value of phosphorus indicates the absence of the domestic and industrial wastes in Ratuwa river [27]. There is no standard and permissible value prescribed for drinking water.

Total Hardness: It is the total sum of calcium and magnesium hardness in water, expressed as calcium carbonate equivalents in milligrams per liter. Its higher value is not desirable forever for washing, bathing, and laundering, however, its lower value is beneficial in reducing the corrosion in pipes [28]. The minimum value of TH was recorded in the post-monsoon period (54.71mg/l) and maximum value in pre-monsoon period (65mg/l) and it was concluded that Ratuwa river had soft water in the post-monsoon period (<60mg/l) and moderately hard in pre-monsoon period (>60 mg/l). The hardness of Ratuwa river may be due to the accumulation of the natural salts from soils and rocks [29].

Total alkalinity: It is the capacity of water to neutralize acids and provides an idea of natural salts present in water. Hydroxide, carbonates, and bicarbonates are the dominant source of total alkalinity. Reactions of carbon dioxide with calcium or magnesium carbonate in the soil or water create considerable amounts of bicarbonate that increases alkalinity. Highly alkaline water is unpalatable and can create gastrointestinal discomfort. The standard desirable limit of alkalinity in potable water is 200 mg/l prescribed by WHO but in our sample, its average value is 97.75 with standard deviation 54.09.

Calcium and Magnesium: These minerals are very common in river water and also essential to all organisms for proper bone growth, bone structure, muscle contraction and blood clotting. Calcium concentrations were 25.14 and 19.24 mg/l and magnesium concentration were 1.94 and 12.15 mg/l during pre-monsoon and post monsoon season. The desirable limits of the calcium and magnesium for drinking water as per the WHO standards are 75 and 50 mg/l respectively. Overall ionic dominance pattern $Ca > Mg$ and $SO_4 > Cl$represents the freshwater [30] and it isin favor of the ionic dominance presence in our sample. But if the dominance of chloride over sulphate was found in the Ratuwa river, there might be an excess of domestic wastes. So we conclude that there is an absence of the domestic wastes in Ratuwa river and the same conclusion has also been drawn from the low value of phosphorus.

DO and BOD: Dissolved oxygen supports the aquatic animals by providing the necessary oxygen for breathing. The amount of DO is controlled by water temperature and organic dissolved matters. Dissolved oxygen if less than 3 mg/l can interfere the growth rate of the fish population whereas above 4 mg/l can support aquatic lifebut for drinking purpose, its value should be greater than6 mg/l and can impart good aesthetic taste [31].DO values 6.67 and 3.67 mg/l in pre-monsoon and post-monsoon indicate that post-monsoon period is unsupportive for the fish production and the low value of the DO in the post-monsoon season is due to the increase of TDS in the water.

Table II

Calculation of WQI of Ratuwa river with an average value of each parameter

SN	Parameters	Observed Average Value (V_n)	Standard Values (S_n)	Recommended Agencies	Unit Weight (W_n)	Quality rating (q_n)	$q_n W_n$
1	Color	5.14	5	NDWQS	0.212	102.8	21.7936
2	Turbidity	65	5	NDWQS	0.212	1300	275.6
3	pH	6.9	6.5-8.5	NDWQS	0.125	-6.67	-0.83375
4	EC	144.55	300	WHO	0.0035	48.18	0.16863
5	Temp	30.65	-	-	-	-	-
6	TDS	72.275	500	WHO	0.0021	14.46	0.03037
7	TSS	38	500	WHO	0.0021	7.6	0.01596
8	Chloride	4.5	250	NDWQS	0.0042	1.8	0.00756
9	Sulphate	77	200	WHO	0.0053	38.5	0.20405
10	Silica	289.065	No limit listed	-	-	-	-
11	Nitrate	BDL	45	WHO	-	-	-
12	Total Phosphorus	0.28	No limit listed		-	-	-
13	Total Hardness	59.855	300	WHO	0.0035	19.95	0.06982
14	Total Alkalinity	97.75	200	WHO	0.0053	48.88	0.25906
15	Calcium	22.19	75	WHO	0.014	29.59	0.41426
16	Magnesium	7.045	50	WHO	0.021	14.09	0.29589
17	BOD	47.16	5	ICMR	0.212	943.2	199.9584
18	DO	5.17	6	WHO	0.177	109.65	19.40805
					$\sum W_n = 0.999$	$\sum q_n = 2672.03$	$\sum q_n W_n = 517.39$
WQI =517.90							

NDWQS stands for Nepal Drinking Water Quality Standards
WHO stands for World Health Organization
ICMR stands for Indian Council of Medical Research
BDL stands for Below detection limit

Table III

WQI and corresponding water quality status with their possible usages

SN	WQI	Status	Possible Usages
1	0-25	Excellent	Drinking, Irrigation and Industrial
2	26-50	Good	Drinking, Irrigation and Industrial
3	51-75	Fair	Irrigation and Industrial
4	76-100	Poor	Irrigation
5	101-150	Very Poor	Restricted use for Irrigation
6	Above 150	Unfit for drinking	Proper treatment required before use

Biological Oxygen Demand: BOD is related to the slow biological oxidation process in which organic matters are decomposed by certain microorganism into carbon dioxide and water in aerobic conditions using dissolve oxygen. It measures the strength to stabilize organic matters in terms of oxygen required [32]. During both pre and post-monsoon period, BOD was extremely high (54.70 and 39.62 mg/l) relative to the standard value 5 mg/l indicating the poor water quality. The main contributors to increasing the BOD level in Ratuwa river should have organic material from decaying plants and animal wastes that are runoff by the river water from the catchment area.

Water Quality Index: WQI of Ratuwa river was computed from the average values of physicochemical parameters taken during pre-monsoon and post-monsoon. The calculation of the WQI on the basis of these parameters is also shown in Table II and corresponding water quality status is also shown in Table III. The water quality index of Ratuwa river is 517.90. The rating of water quality status shown in the Table III indicates that the river water is not appropriated for any purpose like drinking, irrigation and industrial. The WQI of our result is compared to Bhagirathi river of Uttarakhand, India carried out by Pathak et.al (2015) [2] at different seasons and found that WQI of Ratuwa river is extremely high but it is comparable to that of Vishwamitri river [14]conducted by Magadum et al (2017) by the same method. It is also found that higher value of turbidity and BOD are responsible for the degradation of the quality of Ratuwa river.

V. CONCLUSION

Physicochemical analysis of Ratuwa river was performed with the measurement of the eighteen different parameters and the result shows that all the measured parameters are in the acceptable limit except the turbidity and BOD value that are far beyond the acceptable limit and are responsible to increase the WQI. The WQI of the Ratuwa illustrates that water is unfit for any purpose like domestic, drinking, irrigation and industrial due to its higher value of turbidity and BOD. So, proper treatment is highly needed for low risk of immediate or long-term harm. On the basis of fluctuated data, we can suggest that intense focus for monitoring the physicochemical properties and water quality index is essential in Ratuwa river. This work also helps to create and develop awareness among the people to maintain the quality of the river water. In a nutshell, it is advised not to consume water without proper treatment.

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