WATER QUALITY OF MARSHYANGDI RIVER, NEPAL: AN ASSESSMENT USING WATER QUALITY INDEX (WQI)

Reeta Singh[1,*], Sadhana Pradhanang Kayastha[1], Vishnu Prasad Pandey[2]

[1]*Central Department of Environmental Science (CDES), Tribhuvan University, Nepal*
[2] *Department of Civil Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal*
*Corresponding author: rsingh@cdes.edu.np, reetasingh80@gmail.com

ABSTRACT

Water quality index (WQI) is a valuable arithmetic tool that depicts the overall status of water quality in a single number to prioritize for management interventions**.** This study aims to assess water quality based on the WQI to provide insights into the status of the aquatic ecosystems in the Marshyangdi River basin, a tributary of the Narayani River, originating from the Himalaya. Water samples were collected from twenty-one sampling locations in the Marshyangdi River covering four districts from upstream (Kangsar) to the downstream region (Mugling) during pre-monsoon season (May) 2019. Eight selected physico-chemical parameters (TDS, pH, EC, DO, Cl^-, NH_3, PO_4^{3-}, NO_3^-) were analyzed and aggregated in the form of WQI. Results showed that WQI ranges from 32.5 to 46.9, indicating the excellent water quality suitable for the sustenance of the aquatic ecosystem at all the sampling locations. These study results are expected to provide the baseline information on the present status of water quality along the longitudinal section of the Marshyangdi River, which could be helpful for the concerned authorities to manage water quality for the sustenance of the aquatic ecosystem.

Keywords: Aquatic life, freshwater, Marshyangdi, Water Quality Index

INTRODUCTION

Freshwater ecosystems are home for diverse macro-organisms, which play a significant role in maintaining ecological functions and services (Rinzin *et al.*, 2009). It is, therefore, important to protect freshwater sustainably. However, freshwater ecosystems have been seriously threatened worldwide due to its unsustainable use and inadequate management because of pollution, climate change impacts, over-exploitation, and other stresses (IPCC, 2007; Gleeson *et al.*, 2012; Gyawali *et al.*, 2015). Such unsustained use of freshwater has threatened its availability in many parts of the world, affecting adversely the public and river health, agricultural production, and livestock populations in the entire Himalayan region (Kannel *et al.*, 2007b; ICIMOD, 2015).

Monitoring of water quality has become a necessity to safeguard public health and protect valuable freshwater resources (Kannel *et al.*, 2007b). Water quality can be assessed based on Water Quality Index (WQI) computed by aggregating together physical, chemical and biological parameters. The WQI, therefore, helps to transform large number of parameters into a single dimensionless number which depicts the overall water quality status at a certain location over time (Espejo *et al.*, 2012). The WQI has become one of the popular and effective tools for assessing the health status of river water quality (Chapman,1992; Bordalo *et al.*, 2001; Lumb *et al.*, 2011;

Espejo *et al.*, 2012) by providing the information in an understandable and useable form for the public (Darapu *et al.*, 2011; Ruhayu *et al.*, 2015). It is because, the final information is in the form of values and transformation table so that layman can understand simply looking at it.

WQI was first proposed by Horton (1965) and since then many different frameworks for WQI assessment have been developed. Some of them, as reported in Said *et al.* (2004), are the US National Sanitation Foundation Water Quality Index (NSFWQI; Brown *et al.*, 1970), Canadian Water Quality Index (CCME, 2001), British Columbia Water Quality Index, (BCWQI; Zandbergen & Hall, 1998), Oregon Water Quality Index, (OWQI; Cude, 2001). However, there is no "rule of thumb" on selecting input or important variables, one can select parameters based on water quality measurements relevant to the study site (CCME, 2006). But, in all approaches of WQI calculation, four common steps are used (Abassi & Abassi, 2012): (i) selection of variables, (ii) transformation, following a common scale, of these variables that have initially of different dimensions, (iii) creation of sub-indices by assignment of a weighting factor to each transformed variable, and (iv) computation of a final index score using the aggregation of sub-indices. Then the computed WQI values are categorized into qualitative classes such as "excellent" "good", "poor", "very poor"

and unsuitable for the intended purpose based on the WQI score.

In the Nepalese context, the studies related to water quality based on WQI are quite limited (Kayastha, 2015). Furthermore, most of the studies have been conducted in the Bagmati River, and only a few others have focused their studies on the watersheds of Western Nepal (Gurung *et al.*, 2019; Thapa *et al.*, 2020). Most of the water quality studies have compared its suitability with the drinking water quality standard of the respective country and with the World Health Organization Guidelines (WHO, 2006; WHO, 2017). For example, Regmi *et al.* (2017) investigated the water quality aspect of the major rivers in the Kathmandu Valley for the aquatic ecosystems and recreation using the Canadian Council of Ministers of the Environment water quality index (CCME WQI). Kannel *et al.* (2007b) used WQI to evaluate spatial and temporal changes of the water quality in the Bagmati river basin (Nepal) during 1999–2003 and classified the water quality into three groups, namely, good, medium, and bad. Similarly, Thapa *et al.* (2020), based on WQI scores, revealed that the water from the springs of the Jhimruk watershed is excellent in the post-monsoon, while in the pre-monsoon season, it ranges from excellent to good condition thus, indicating no threat to consumer's health. Protection of the aquatic environment is eminent to the world water resources. Maintaining a healthy aquatic environment in Nepal is important for the aquatic economic resources and promoting tourism (Smakthin & Shilkapar, 2005). To date, none of the study was conducted to assess the water quality based on WQI in the Himalayan watersheds which hosts many hydropower projects with the potentiality of affecting river health. Hence to fill that knowledge gap this study was conducted in Himalayan snow-fed Marshyangdi River at different locations, including its tributaries, to assess the status of water quality for the sustenance of aquatic organisms.

MATERIALS AND METHODS
Study area
The Marshyangdi river is a perennial snow-fed river with a length of approximately 150 km and located within 27°50'42" to 28°54'11" N Latitudes and 83°47'24" to 84°48'04" E Longitudes covering a watershed area of 4,748 sq. km as shown in Fig. 1. The Marshyangdi River begins at the confluence of two mountain rivers, the Khangsar and the Jharsang, in northwest of the Annapurna massif at an altitude of 3600 above mean sea level (masl) then it flows eastward through Manang district and southward through the Lamjung district covering other districts, Gorkha and Tanahu, and finally, it joins the Trishuli River at Mugling. The major sources of the Marshyangdi are the glaciers of the Annapurna Himalaya range, Manaslu Himalaya range and Larkya Himalayan sub-range, besides seasonal springs and monsoon rains. The elevation of this watershed varies between 274 to 8,042 meters masl, representing the bioclimatic zones from subtropical (1,000-2,000 m) to alpine zone (4000-5000) (Shrestha, 2008). The climate varies from Tropical Savannah in the lower belt to Polar frost type in the higher altitudes (Karki *et al.*, 2016). The watershed is predominated by the grassland (17.4%), followed by barren land (11.7%), agricultural land (11.28%) and the remaining occupied by other land cover types such as, shrubland, forest, water bodies, snow and glaciers, and built-up area (ICIMOD, 2010).

Presently three hydropower projects Marshyangdi [(69MW), Middle Marshyangdi (70MW), and Upper Marshyangdi (50MW)] are in operation in the Marshyangdi basin, and 47 additional hydropower projects of various sizes (2MW- 600 MW) are in different stages of construction (DOED, 2020) in the main river and in its tributaries. Water abstraction for hydropower may alter hydrology downstream and affects river health. Furthermore, river is disturbed at various locations due to intensive sand mining activities. These activities in the watershed may affect river health, thus necessitating the need to assess water quality at different locations.

Sampling locations
This study was conducted during pre-monsoon (May) 2019. Twenty-one sampling locations from downstream (before mixing with Trisuli river) to upstream (non-impact area) were selected for the physicochemical analysis of the water. The site selection was based on the presence of major tributaries, anthropogenic influences such as tourism, hydropower and accessibility of the sampling locations. Among the total 21 locations; 15 were in the mainstream and six in the tributaries. The detailed characteristics of the sampling locations are provided in Fig. 1 and Table 1.

Water Sample collection and analysis
A composite sampling technique was employed to collect the water samples from the surface of the river for the analysis of physico-chemical parameters. The surface water samples with three replicates were collected and then composited and stored in a clean 500-milliliter polyethylene bottle. Water samples were then kept in a cool box at 4° C to minimize microbial activity and brought to the laboratory for chemical analysis, following standard procedures (APHA, 2005). The physico-chemical parameters such as hydrogen ion concentration (pH), total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), were measured in situ using HANNAHI98129 probe. Chloride was determined by silver nitrate titration method while nitrate (NO_3^-), ammonia (NH_3) and phosphate (PO_4^{3-}) were determined in the laboratory following APHA (2005).
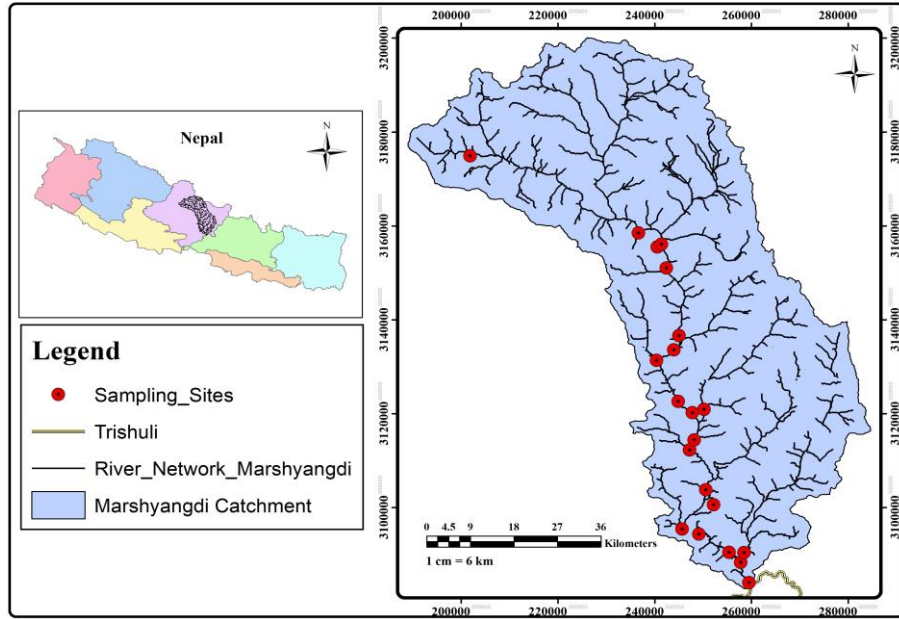
Figure 1. Study area and sampling locations along the Marshyangdi River

Table 1. Description of sampling locations in the Marshyangdi River and its tributaries.

Site name	Site Code	Altitude (m)	Latitude	Longitude	Site description
Mugling	M01	216	84° 33'22.21	27º 51' 26.67"	Downstream of the river, before mixing with Trisuli River
Abukhaireni	M02	227	84⁰ 32'25.58"	27º 53' 20.80"	Below the confluence point after mixing of Daraudi River with Marshyangdi
Daraudi River	M03	271	84° 33'06.11"	27° 54' 54.68"	Tributary
Marshyangdi D/S	M04	286	84° 30'53.17"	27º 54' 55.25"	Downstream from Marshyangdi HP
Marshyangdi U/S	M05	335	84° 27'59.37"	27º 56' 59.13"	Upstream of Marshyangdi HP
Chudi River	M06	378	84° 24'53.67"	27º 57' 33.00"	Tributary river, dominated by human activities (washing, bathing)
Turture	M07	368	84° 27'47.59"	28º 02' 06.57"	Downstream to the confluence of Tributary River Chepe to Marshyangdi
Chepe River	M08	490	84° 28'48.69"	28º 03' 23.90"	Tributary
Paudi River	M09	477	84° 25'40.28"	28º 06'42.16"	Tributary
Bhoteodar	M10	492	84° 26'14.88"	28º 07' 49.52"	Upstream of Paudi
Dordi River	M11	640	84° 27'24.89"	28º 11' 22.33"	Tributary
Middle Marshyangdi D/S HP	M12	582	84° 25'58.00"	28º 10'59.70 "	Downstream to Middle Marshyangdi HP
Middle Marshyangdi U/S HP	M13	610	84° 24'05.40"	28º 12' 13.11"	Upstream to Middle Marshyangdi HP
Khudi River	M14	798	84° 21"15.90"	28º 16' 58.55'	Tributary
Upper Marshyangdi D/S HP	M15	851	84° 23'18.67"	28º 18' 12.39"	Downstream to Upper Marshyangdi HP
Upper Marshyangdi U/S HP	M16	861	84°23'58.86"	28º 19' 52.52"	Upstream to Upper Marshyangdi HP
Tal Bazzar	M17	1675	84°22'24.57"	28º 27' 56.54"	Settlement; tourism area
Dharapani	M18	1813	84°21'31.08"	28º 30' 25.20"	Cross-sectional point, the site after mixing with Dudh Khola
Chame	M19	2604	84°15'30.61"	28º 33' 11.53"	Below Chame Bazzar and Hotspring
Dhukurpokhari	M20	3156	84° 09'36.53"	28º 36' 29.33"	Minimum human activities: Undisturbed site
Khangsar	M21	3714	83° 56'55.12"	28º 40' 28. 23"	Minimum human activities: Undisturbed site

Note: M: Marshyangdi; HP: Hydropower; U/S: Upstream; D/S: Downstream

Calculating Water Quality Index (WQI)
In this study the mean of physicochemical parameters, namely TDS, pH, EC, DO, Cl-. NH3, PO4³, NO3⁻ were used to determine the suitability of water for sustenance of the aquatic ecosystem. These eight parameters were chosen based on a literature review (Pesce & Wunderlin, 2000; Said *et al.*, 2004; Kannel *et al.*, 2007a, b; Regmi *et al.*, 2017). Then weight to each parameter (w_i) was assigned according to its relative importance (Sanchez *et al.*, 2007) in the overall quality of water for the protection of the aquatic ecosystem based on percent compliance with the objective value. Weights of 5, 4, 3, 2, 1 were assigned to the quality parameters when range of 0-20, 21-40, 41-60, 61-80 and 81-100 % of samples are within the permissible limit respectively (Raychaudhuri *et al.*, 2014). Second, the relative weight (W_i) was calculated for each parameter based on equation (1).

$$W_i = \frac{wi}{\sum_{i=1}^{n} wi} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where, Wi is the relative weighting; wi is the weighting of each parameter and $\sum wi$ is the sum of all parameters and n is the number of parameters.

In the next step, quality rating for each parameter was assigned by dividing the concentration in each water sample by respective standard according to the guidelines, and the result was multiplied by 100 as per equation (2)

$$qi = C_i/S_i*100 \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

where, q_i= is the quality rating; C_i= is the concentration of each chemical parameter in each water sample in milligrams per litre; S_i = is the standard for each chemical parameter in milligrams per litre.

Finally, the water quality index was calculated by adding the sub-index of water quality (SIi) for each parameter using equation (3), which was then summed up to find out the final WQI using equation (4).

$$SI_i = W_i. q_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$
$$WQl = \sum_{i=1}^{n} SIi \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

Where, SI_i is the sub-index of water quality, W_i is the relative weighting, q_i is the quality rating scale, and WQI is the water quality index.

At last, the water quality of the river is categorized into five classes Excellent, Good, Poor, Very Poor, Unfit for Drinking based on the WQI value range (Table 2).

Table 2. Classification of computed Water Quality Index (WQI) values (Raychaudhari *et al.*, 2014)

WQI Range	Type of water
< 50	Excellent water
50.1 – 100	Good water
100.1 – 200	Poor water
200.1– 300	Very poor water
>300.1	Unfit for drinking

RESULTS AND DISCUSSION
Physico-chemical characteristics of river water
The mean of the selected eight physico-chemical parameters across the sampling sites are presented in this section (Table 3; Fig. 2a, b & c). The results of study do not reveal spatial variation across the studied sites within the studied physico-chemical parameters.

pH is an important physico-chemical parameter of river water which influences the biotic composition of the system. It plays a vital role in an aquatic ecosystem since all the biochemical functions and retention of physicochemical attributes of the water is greatly dependent on pH (Tadesse *et al.*, 2018). However, it can be toxic when it is more than the desirable limit and affect aquatic life due to its influence on ammonia, hydrogen sulfide and heavy metals (Klontz, 1993; Tadesse *et al.*, 2018). In the present study pH ranges from 8.3 (M11, Dordi River) to 9.0 (M06, Paudi River) (Table 3), showing not much variation and within the permissible limit. The

observed values of pH indicate the alkaline nature of water, agreeing with one of the studies done at the Marshyangdi River (Ghezzi *et al.*, 2019). The authors have mentioned that the water samples were slightly alkaline in the river due to sufficient carbonates across different geological and tectonic stratigraphic units in Tethyan Himalayan Sequence (THS) and Greater Himalayan Sequence (GHS).

Dissolved oxygen (DO) is a common indicator of the health of an aquatic ecosystem. The saturation concentration of DO (oxygen in water) is a function of the water temperature and salinity (Loucks & Beek, 2017). High amount of DO indicates that the water quality is good (high quality) due to the self-purification capacity of the water. The dissolved oxygen (DO) values at the studied locations range from 5.1 mg/L (M17; Tal Bazzar) to 7.4 mg/L (Turture; M07) (Table 3), indicating presence of optimum value for the sustenance of aquatic life.

Table 3. Physicochemical parameters of Marshyangdi River during pre-monsoon 2019 (n=3)

Site Code	pH	DO (mg/L)	TDS (mg/L)	EC µS/cm	Cl⁻ (mg/L)	NH₃ (mg/L)	NO₃⁻ (mg/L)	PO₄³⁻ (mg/L)
M01	8.8	6.1	144.0	286.5	32.66	0.04	1.07	0.03
M02	8.7	7.1	121.5	251.5	84.85	0.07	0.74	0.06
M03	8.9	6.4	113.5	226.0	12.07	0.04	0.03	0.02
M04	8.9	6.6	158.5	316.5	19.53	0.10	0.92	0.01
M05	8.8	6.9	152.5	308.0	18.82	0.18	1.00	0.01
M06	9.0	5.2	94.0	186.5	8.52	0.06	0.85	0.01
M07	8.7	7.4	97.0	297.5	15.62	0.05	1.11	0.01
M08	8.5	6.4	51.5	106.0	7.10	0.05	0.59	0.01
M09	9.0	5.7	61.0	123.0	11.72	0.07	0.26	0.02
M10	8.5	7.2	145.0	279.5	19.88	0.03	1.03	0.01
M11	8.3	7.1	39.9	148.0	11.36	0.03	1.11	0.01
M12	8.5	7.3	148.5	295.0	19.17	0.11	0.59	0.01
M13	8.8	6.8	122.5	248.5	35.86	0.03	1.22	0.02
M14	8.5	6.5	49.5	100.0	9.94	0.03	1.40	0.10
M15	8.4	6.7	175.0	351.5	25.21	0.03	1.11	0.05
M16	8.8	5.9	175.5	360.0	22.72	0.03	0.67	0.02
M17	8.9	5.1	165.0	328.5	18.11	0.03	1.25	0.04
M18	8.9	5.6	153.0	312.0	12.03	0.03	1.37	0.04
M19	8.9	6.7	105.0	299.5	11.36	0.03	1.41	0.04
M20	8.9	5.9	127.5	249.0	13.49	0.03	1.15	0.04
M21	8.7	6.5	168.0	357.5	12.78	0.03	0.78	0.04

Total dissolved solids (TDS) are one of the most important parameters to consider for the sustenance of aquatic life and it is linearly correlated with Electrical conductivity (EC) Fig. 2a. TDS values ranges from 39.9 mg/L at M11 (Dordi River) to 168 mg/L at M21 (Khangsar; Marshyangdi River), which is quite below the prescribed standard (Table 4), indicating no effect on the aquatic ecosystem. However, if its content exceeds the limit, it may affect the osmoregulation of freshwater in organisms, reduces the solubility of gases (like oxygen) as well as limit the utility of water for various purposes (drinking, irrigation and industrial) (Tadesse *et al.*, 2018). A high concentration of TDS also reduces water clarity, decreasing photosynthesis, increasing the water temperature after combining with toxic compounds and heavy metals ultimately affecting the aesthetic value and physicochemical properties of water (Tadesse *et al.*, 2018; Gurung *et al.*, 2019).

The electrical conductivity (EC) is a measure of the ions or salinity, which gives an estimate of the presence of certain ions reflecting the presence of high dissolved solids (Orebiyi *et al.*, 2010; Kayastha, 2015). EC ranges from 100 µS/cm (M14; Khudi) to 357.5 µS/cm (M21; Kangsar) (Table 3), which are within the permissible levels (Table 4), but it may induce corrosive nature in water if exceeded its limit (Tadesse *et al.*, 2018).v Chloride occurs naturally in all types of freshwaters, usually in low concentration. The value of chloride in the river ranges from 7.1 mg/L (M08; Chepe River) to 84.8 mg/L (M02; below the confluence with Daraudi River), which is quite low in comparison to the permissible level for aquatic organisms (500 mg/L) (Table 4).

Dissolved inorganic phosphorus, inorganic nitrogen is generally regarded as critical nutrients to the aquatic ecosystem functioning (Dodds, 2002; Allan & Castillo, 2007; Hamid *et al.*, 2020). These nutrients (nitrates, phosphate) may be attributed due to the processes of organic mineralization derived principally from the surface runoff (Tadesse *et al.*, 2018). In the present study nutrients like phosphate (PO_4^{3-}) and nitrate (NO_3^-) are within the prescribed limit (Table 4), indicating no threat of eutrophication which might occur due to the nutrient enrichment in water systems (Loucks & Beek 2017).

WQI across the sampling locations
The WQI of the Marshyangdi River is calculated and presented in Table 5.WQI values range from 32.5 to 46.9 indicating the water quality falls in the excellent category at all the locations (Table 2), thus ensuring the protection of aquatic life in the Marshyangdi River. Table 4 presents the prescribed values for water quality used in the computation of WQI, which reveals that most of the parameters were within acceptable limits. The previous study in Jhimruk River watershed also indicated the excellent water quality during the pre-monsoon season based on the water quality index (Thapa *et al.*, 2020). In addition, Rana and Chettri (2015) also reported that the stream possesses good water quality based on WQI in Bhalu Khola, a tributary of the Budhigandaki River. Similarly, Gurung *et al.* (2019) revealed that the water quality ranges from being poor to good conditions in the spring sources located in the rural watershed of Western Nepal based on the water quality index suggesting using the water for domestic purposes after suitable treatment.
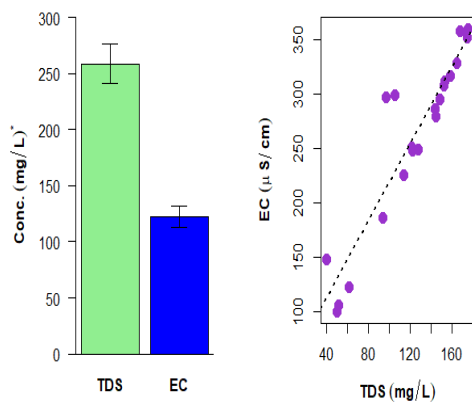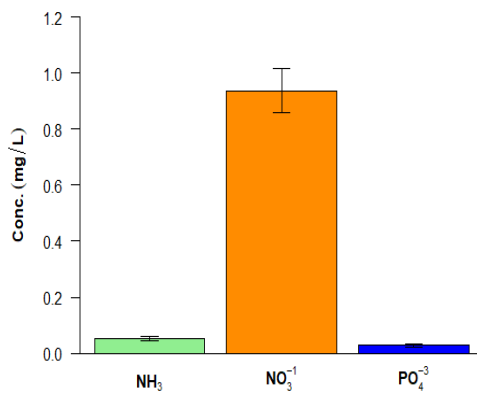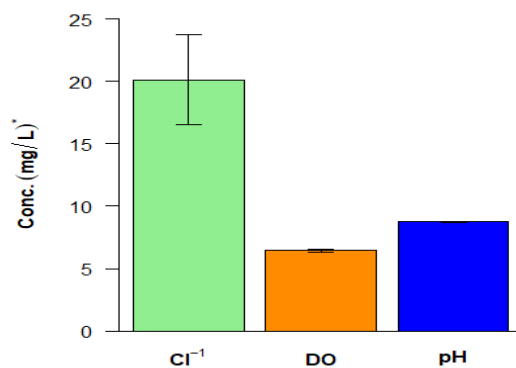
Fig. 2a

Fig. 2b

Fig. 2c

Figure 2. Selected physico-chemical parameters of Marshyangdi River; a) TDS and EC; b) NH$_3$, NO$_3$$^{-1}$ and PO$_4$$^{-3}$; and c) Cl$^-$, DO and pH (*represent unit for pH, as pH units).

Table 4. Water quality standards, weight (wi) and calculated relative weight (Wi) for each parameter.

Category	Parameters	Prescribed values	Percent compliance	Weight (wi)	Relative weight (Wi)	References
Physical	EC	1000	100	1	0.13	BBWMSIP (1994) in Regmi *et al.* (2017); BIS (2012)
	TDS	1000	100	1	0.13	BBWMSIP (1994) in Regmi *et al.* (2017)
	pH	6.5-9	100	1	0.13	CBS (2019); CCME (2001)
Chemical	NH$_3$	1.2	100	1	0.13	CPCB (979) in Singh and Kaushik (2018)
	Cl$^-$	500	100	1	0.13	BBWMSIP (1994) in Regmi *et al.* (2017)
	NO$_3$$^-$	45	100	1	0.13	CCME (2001)
	PO$_4$$^{3-}$	0.1	100	1	0.13	BBWMSIP (1994) in Regmi *et al.* (2017)
	DO	5	100	1	0.13	CBS (2019); CCME (2001)
				$\sum$**wi =8**		

Table 5. Subindex of each chemical parameter (Sli), WQI and water classification of each water sample of Marshyangdi watershed for pre-monsoon.

				Sl_i					Total Sl_i=WQI	Water classification
Sites	TDS	pH	DO	EC	NH$_3$	NO$_3^-$	PO$_4^{2-}$	Cl$^-$		
MA01	1.87	12.71	15.86	3.72	0.41	0.31	3.85	0.85	39.58	Excellent
MA02	1.58	12.57	18.36	3.27	0.73	0.21	8.05	2.21	46.97	Excellent
MA03	1.48	12.86	16.58	2.94	0.46	0.01	2.45	0.31	37.08	Excellent
MA04	2.06	12.92	17.23	4.11	1.11	0.27	0.70	0.51	38.90	Excellent
MA05	1.98	12.73	17.97	4.00	1.95	0.29	1.05	0.49	40.46	Excellent
MA06	1.22	12.95	13.47	2.42	0.65	0.25	1.40	0.22	32.58	Excellent
MA07	1.26	12.51	19.21	3.87	0.51	0.32	0.70	0.41	38.79	Excellent
MA08	0.67	12.22	16.65	1.38	0.51	0.17	1.40	0.18	33.19	Excellent
MA09	0.79	13.00	14.69	1.60	0.76	0.08	2.10	0.30	33.32	Excellent
MA10	1.89	12.32	18.73	3.63	0.27	0.30	0.70	0.52	38.36	Excellent
MA11	0.52	12.05	18.33	1.92	0.27	0.32	0.70	0.30	34.40	Excellent
MA12	1.93	12.29	18.85	3.84	1.22	0.17	1.05	0.50	39.84	Excellent
MA13	1.59	12.72	17.73	3.23	0.27	0.35	2.80	0.93	39.63	Excellent
MA14	0.64	12.32	17.00	1.30	0.27	0.40	14.00	0.26	46.20	Excellent
MA15	2.28	12.09	17.29	4.57	0.27	0.32	7.00	0.66	44.47	Excellent
MA16	2.28	12.74	15.34	4.68	0.27	0.19	3.15	0.59	39.25	Excellent
MA17	2.15	12.81	13.22	4.27	0.27	0.36	5.60	0.47	39.15	Excellent
MA18	1.99	12.91	11.91	4.06	0.27	0.39	5.60	0.31	37.44	Excellent
MA19	1.37	12.88	17.42	3.89	0.27	0.41	5.60	0.30	42.13	Excellent
MA20	1.66	12.91	15.34	3.24	0.27	0.33	5.60	0.35	39.69	Excellent
MA21	2.18	12.60	16.77	4.65	0.27	0.22	5.60	0.33	42.62	Excellent

The water flow is one of the important variables which significantly impact water quality due to its natural capacity of diluting the pollutants (Darapu *et al.*, 2011; Iticescu *et al.*,2019). Thus, the excellent water quality in the Marshyangdi River may be due to the high flow, which helps in diluting the pollutants. During field visits, while observing the site conditions at each of the locations we don't observe dumping of waste except at the site (Turture; M07) which falls outside the Annapurna conservation area. Further due to the absence of any industrial activities, intensive agriculture runoff in and around the river may help to possess the present water quality status of the Marshyangdi River.

CONCLUSIONS

This study presents an assessment of water quality based on the water quality index (WQI) in one of the least studied rivers, Marshyangdi, where many hydropower projects are planned, and three of them are already in operation. The concentrations of all the studied physico-chemical parameters such as pH, EC, TDS, DO, NO$_3^-$, PO$_4^{3-}$, NH$_3$, and Cl$^-$ were within the prescribed limit and in compliance with national and international standards. Based on WQI, we can conclude that river water is favorable for aquatic biota, with respect to parameters chosen, thus indicating the healthy state of river at all the studied locations during pre-monsoon season of 2019. The excellent water quality in the Marshyangdi River is likely due to the high flow that helps in diluting the water. Further spatial and altitudinal variation has not been observed in the present study, justified by the same water quality class across all the stations.

AUTHOR CONTRIBUTIONS
RS conceptualized, performed fieldwork, analyzed the data and wrote the first draft of the manuscript. SPK contributed to research conceptualization, data curation, review and editing. VP contributed to conceptualization, review and editing the manuscript.

CONFLICT OF INTEREST
The authors declare no competing interests.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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