CHARACTERIZATIONS OF WATER QUALITY IN WEST-SETI AND TAMOR RIVER BASINS, NEPAL

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Abstract: This study presents the geochemical composition and water quality of waters in the West-Seti and Tamor River basins in Nepal Himalaya with the aim to reveal their hydrochemical characteristics and to evaluate the water quality. Water samples were collected from 18 sites of the rivers in the pre-monsoon season and analysed the physicochemical parameters to characterize their quality. The parameters- temperature, pH, conductivity, and total dissolved solids were measured in the field, while the major ions (Na^+, Ca^{2+}, Mg^{2+}, Si^{4+}, SO_4^{2-}, NO_3^-, HCO_3^-, Cl^-, and F^-) were analyzed in the laboratory. Overall results of physicochemical parameters revealed that the ionic strength is much distinct; however, the waters are chemically pure in both the river basins with very less electrical conductivity (<250 µS/cm) and total dissolved solids (<120 mg/L). Bicarbonate (HCO_3^-) has a significant correlation with Ca^{2+} and Mg^{2+} suggesting carbonate rock weathering as the dominant geochemical process in both of the basins. The concentrations of Ca^{2+}, Mg^{2+}, and HCO_3^- in the water of the West-Seti is relatively higher than the waters in the Tamor River basin. Mostly, the geochemical facies of both the rivers are characterized by the Ca-Mg-HCO_3- type (88.9%), with dominant carbonate dominated lithology. However, hydrochemical facies clearly suggested spatial discrimination between two basins with dominant geogenic signatures as Ca-SO_4-Cl type water facies are also reported from the Tamor River basin. The results exhibited that the concentrations of measured parameters were relatively very low and within the WHO guideline values and currently under a safe level of the water quality for drinking and ecosystem health perspectives; however, further in-depth research is recommended in the periodic basis to assess traces of climate change imprints, and anthropogenic interferences for more consistent and reliable dataset. The findings of this study could be useful for the water quality management in the glacier-fed Himalayan River basins.

Keywords: Water quality; Geochemical composition; Hydrochemical facies; Glacier-fed basins.

INTRODUCTION

The Himalaya is considered to be the water towers on the earth and its surface for supporting livelihood to millions of people and ecological services[1]. The Himalayan and its surroundings-Hindu-Kush Mountains and the Tibetan Plateau -host the highest quantity of glaciers mass outside the polar regions[2]. Melt waters from mountain glaciers of the Himalaya are one of the major water sources, particularly during dry season, along with rainfall and ground water on which a large group of population depends for drinking and sanitation, irrigation, and hydropower gener ation[3]. Hydrochemistry illustrates the health of the river basin[4], including the current status and potential sources of the chemicals A recent study in the Himalaya has indicated an annual increase in the nitrogen and phosphorous concentration in the high-altitude river water[5]. Moreover, the growing demand for freshwater in downstream stretches and the geological setting has made the hydrochemical

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study of Himalayan glaciers highly imperative to sustain the livelihoods of people and maintain the ecological health[6,3].

Geologically, catchments differ in both the release rates of chemical species to streams and lakes, and the relative proportion that are released. Yet, for the major ions at least, the relative proportion does not greatly differ in well-watered portion of the temperate, arctic, and sub-tropical regions. In majority of the Himalayan River basins reported that the most common ion sequences as equivalent weight is Ca^{2+}> Mg^{2+}> Na^{+}> K^{+} for the cations and HCO_3^{-}> SO_4^{2-}>Cl^{-} for the anions[7]. There are various natural and anthropogenic factors responsible for the elevated concentrations of these hydrochemical variables and global climate change has further aggregated the problems. Therefore, chemical characterization of waters in the glacierized basin is extremely important to find out the weathering reactions, anthropogenic, and climate change implications on the water resources. The in-depth study will give the new insights under the changing context of the global environment and can contribute in entire river basin management[8,9]. Thus, the objective of this study is to characterize the geochemical compositions and water quality of the glacierized river basins of Nepal Himalaya.

STUDY SITE

The study was conducted in the two glacierized basins (Figure 1) in the eastern and western parts of Nepal: Tamor (Area: 5,875 km^2) and West–Seti River basins (area: 7,449 km^2), respectively (Table 1).

These basins were studied due to their location in two different geographic settings with distinct climatic characteristic. The Tamor River, lying in the eastern part of Nepal, is one of the major tributaries of the Koshi River. The River originates from Mount Kanchanjunga. It extends from 228 to 8,586 m within around 100 km of latitudinal distance, with an average elevation of 2,862 m asl. The second basin, i.e., the West–Seti River basin, is one of the major tributaries of the Karnali river (the longest river in Nepal). The river originates from the snowfields and glaciers around the twin peaks of Api and Nampa in the south facing slopes of the Himalaya. The average elevation of the basin is 2,509 m, but it varies from 314 m at basin outlet to 7,045 m of Api and Nampa high mountain ranges.

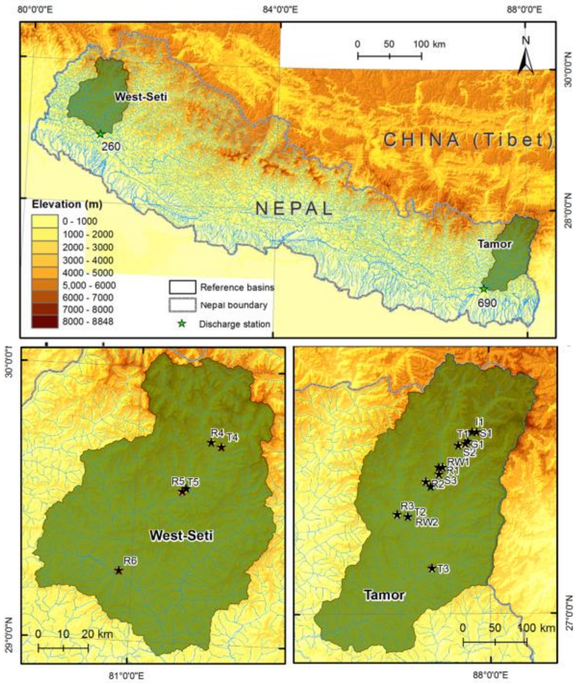

Figure 1: Locations of study basins, indicating the sample sites

Table 1. Basin characteristics of the study area

Description	Tamor basin	West-Seti basin
Origination	Kanchenjunga Mountain	Api and Nampa mountain
Major River	Koshi	Karnali
Basin area (km^2)	5875	7449
Min. elevation (m)	228	314
Max. elevation(m)	8586	7045
Mean elevation (m)	2862	2509
Slope (°)	27.8	29.7

MATERIALS AND METHOD

Water Sampling

Water samples for the analysis of major cations (Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}), major anions (SO_4^{2-}, NO_3^{-}, HCO_3^{-}, Cl^{-}, F^{-}) and total Silica (Si) were samples from the Tamor and West-Seti River basins on the southern side of the Nepalese Himalaya during Pre-monsoon season at 13 sites in the-Tamor and 5 sites in the West-Seti River basins. The samples were collected, preserved, and analyzed following the standard procedures[10]. The sampling sites of two river basins are given in Table 2.

Table 2. Description of the sampling sites in the Tamor and West-Seti River basins.

River Basin	Sample Code	Site	Latitude	Longitude	Elevation (m)
Tamor	I1	Ghunsa	27.66	87.95	3470
	G1	Phole	27.62	87.9	3135
	R1	Hellok	27.53	87.8	1550
	R2	Chiruwa	27.48	87.74	1159
	R3	Dhobhan	27.36	87.62	641
	RW1	Sekathum	27.54	87.81	1572
	RW2	Taplejung	27.36	87.66	735
	S1	Ghunsa	27.66	87.94	3464
	S2	Gyabla	27.61	87.87	2719
	S3	Phembu	27.51	87.79	1537
	T1	Phole	27.62	87.91	2930
	T2	Dhobhan	27.36	87.62	641
	T3	Hewa	27.17	87.76	476
West-Seti	R4	Kanda	29.74	81.31	1925
	R5	Chainpur	29.55	81.20	1317
	R6	Dipayal	29.25	80.95	503
	S4	GhatKhola	29.72	81.35	2036
	T4	BhateKhola	29.55	81.19	1252

Sample Analysis

A total of 18 water samples were collected from the West–Seti and Tamor River basins (Figure 1). The water samples were collected in sterilized bottles and were stored at 4 °C till further research. Standard chemicals were used for analytical reagent grade only. Analysis was carried out for various physicochemical parameters such as temperature, pH, electrical conductivity (EC), calcium, magnesium, nitrate, sulphate, silica, sodium, fluoride, chloride and alkalinity, as per standard procedures[10], at Water Engineering and Training Center (WETC) laboratory, Kathmandu Nepal. The water samples have been assessed by comparing each parameter with the standard limit of that parameter were collected, preserved, and analyzed following the with World Health Organization (WHO) Standard. The physical parameters- pH and temperature were measured in the field (HANNA). The concentration of nitrate, silica and fluoride is estimated by UV spectrophotometer (SSI UV 2101) at different wavelengths. The calcium, magnesium and sodium ions were estimated by Atomic Absorption Spectrophotometer (AAS) method by using Microprocessor Flame Photometer ESICO MODEL 1382. Sulphate was measured by Barium chloride titration method whereas chloride by titration with silver nitrates solution and bicarbonate alkalinity by sulphuric acid titration. The TDS was calculated from the EC. All the parameters were estimated by using the standards as described in Table 3.

Table 3. Physicochemical parameters of water (standards)

Parameters	Units	WHO		Method used
Conductivity	µS/cm	1000		2510 B, APHA 21st edition
pH	-	6.5 – 8.5		4500-H+ B, APHA 21st edition
Nitrate	mg/L as NO_3	50		4500-NO3 B, APHA 21st edition
Bicarbonate as alkalinity	mg/L as $CaCO_3$	600		2320 B, APHA 21st edition
Calcium	mg/L	100		3500-Ca B, APHA 21st edition,
Magnesium	mg/L	50		3500-Mg B, APHA 21st edition,
Sulphate	mg/L	250		4500-SO4, APHA 21st edition
Silica	mg/L	-		4500- SiO2 D, APHA 21st edition
Sodium	mg/L	200		3111 B, APHA 21st edition
Chloride	mg/L	250		500 Cl- B, APHA 21st edition
Fluoride	mg/L	1.5		4500 F- D, APHA 21st edition

RESULTS AND DISCUSSION

Physicochemical Parameters

The physicochemical properties of various water samples of Tamor and West-Seti River basin are presented in Table 4. Relatively low concentrations of the measured variables (within the WHO) indicating that the waters in both basins are currently a safe level for maintenance of human and the ecosystem health. The Hydrogen ion concentration (pH) of majority sample waters of Tamor and West-Seti River basins was found to be slightly alkaline in nature and ranged between 6.8 and 7.9. As per WHO, the pH limits from 6.5 -8.5. The pH of Tamor is slightly below the range whereas West-Seti are within desirable and suitable range[11,12].

The concentration of EC ranges from 16-64 µS/cm for water samples in the Tamor river basin. The concentration ranges from 27-215 µS/cm for water sample of West-Seti River basin. This shows the variation on the mineral concentration as EC measures the mineral concentration of the water sources. The variation in the conductivity and most of the major ions showed higher values in the lower elevation sites may be due to rapid dissolution, higher temperature, high erosion, mixing of tributaries and enhanced weathering along the distance downstream. The calcium carbonate weathering is the major source of dissolved ions in the region. Correlations among the divalent cations and HCO_3^- probably reflect common geologic sources of these ions [13]. These results are consistent with the previous studies conducted from the rivers of Nepal including freshwater lakes and, Seti, Bagmati and Karmanasha Rivers[20,21,22,23].

Only one sample (RW-1) has nitrate concentration 3 mg/L and all other points have its concentrations below 2 mg/L in both the basins. This indicates that the anthropogenic interferences in both the river basin is minimum till date. However, relatively higher value of nitrate in some of the sampling points could be attributed from the anthropogenic activities such as cremation sites, religious activities and farmland along the river banks. Such interpretation is pretty agreed with the previous studies from the regions[20, 24]. Moreover, the mean concentrations of nitrate was found within the WHO guideline values (Table 3). The concentrations of sulphate and chloride were found to be in negligible amount i.e., < 5.0 mg/Land <1.0 mg/l, respectively in both the basins except R-4 (for chloride value: 2 mg/l). As per WHO guideline, the concentration for both sulphate and chloride are 250 mg/l. Thus, the water is in suitable and desirable condition in both the river basins. The fluoride content in the water samples of Tamor and West-Seti River basin ranges from 0.04-0.4 mg/l, which is below the WHO maximum permissible, limit i.e., 0.5-1.5 mg/l. The silica concentration was found in the range between 2.8 - 30.4 mg/L for the various water samples of two river basins (Tamor and West–Seti River).

The concentration of silica is between 3.3 and 30.4 mg/L which lies in the average standard for the natural water which ranges from 1.0 to 30.0 mg/l. The Ca-HCO_3 dominance indicate the fresh water recharge and is predominant due to ion exchanges. Due to the presence of silica in water. Weathering of silica in different forms leads the higher concentration of HCO_3^-. Weathering of rocks is the dominant mechanism controlling the hydrochemistry of drainage basins which occur when water flows at the ice-rock interface [14,15]. The potential factors that may have contributed to the increase of solute concentrations in the river basins, with special attention towards SO_4^{2-} and HCO_3^- ions: atmospheric deposition, weathering, precipitation, glaciation, and snow cover duration. SO_4^{2-} concentrations are directly related to glacier coverage ($r = 0.72$, $p < 0.001$) i.e., higher solute concentrations are found for basins with more glacial coverage. No relationship can be observed with the other selected variables and in particular with the snow cover duration. Furthermore, we note that the HCO_3^- concentrations do not have significant relationship with the land cover and the snow cover duration [8].

The total hardness as bicarbonate alkalinity was found to be higher in West-Seti than in Tamor basin. The concentration ranges from 12-24 mg/L and 16-96 mg/L in the Tamor and West-Seti, respectively. The concentration of calcium is below the guideline and ranged from 1.25–33.16 mg/l. The sodium was in the range of 0.65 - 1.77 mg/L of the various water samples of Tamor and West-Seti River basin. Similarly, magnesium concentration is less as compared to calcium concentration and is ranged within 0.3 to 11.25 mg/l. The concentration of the major cations in the Tamor River and its tributaries were found in the order of Ca^{2+}>Na^+> Mg^{2+} which is similar with the study for Langtang River[16] but it is slightely different from the overall cationic dominace order in the Gandaki and Seti rivers [20, 21].

The sample water indicated Ca^{2+} dominance over Na^+ and weak acids (HCO_3^- and CO_3^-) dominance over strong acids (SO_4^- and Cl^-). Cation and anion analysis also showed that Ca^{2+} and HCO_3^- are indeed the most dominant. The sources of runoff water can be distinguished by chemical tracers because each pathway results in characteristic chemical properties. The concentrations of ions reflect chemical water- rock interactions in water pathways. It concluded that the solute concentrations are appropriate tracers because different components of the water cycle tend to be dominated by different ions. For example, precipitation tends to have high proportional concentrations of Cl^-, since atmospheric vapor evaporated from salty oceans will contain this ion, but low proportional concentrations of ions such as Ca^{2+} and Mg^{2+} as these are largely derived from bedrock [17]. Moreover, anthropogenic activities have less impact in the both the basins, and thus the ionic chemistry and hydrochemical characteristics of the rivers are mostly controlled by natural processes.

Table 4. Physicochemical characteristics of water in Tamor and West-Seti River basins, Nepal

Basin	Sample ID	NO_3^-	HCO_3^-	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Si	Na^+	Cl^-	F^-	EC	TDS	pH
Tamor River	Ghunsa (I-1)	0.95	12	2.42	0.45	<5.0	4.1	0.65	<1.0	0.27	16	9	75
	Pole (G-1)	0.78	12	2.42	0.77	<5.0	9.4	1.30	<1.0	0.16	20	11	73
	Hellok (R-1)	0.52	12	2.42	1.37	<5.0	5.6	1.58	<1.0	0.18	46	25	73
	Chiruwa (R-2)	0.74	16	4.04	1.26	<5.0	6.6	1.77	<1.0	0.4	51	28	74
	Dhobhan (R-3)	0.87	16	4.04	1.3	<5.0	11.2	1.88	<1.0	0.34	40	22	7.3

	Sekathum (RW-1)	3.00	12	1.25	0.48	<5.0	3.3	1.64	<1.0	0.08	35	19	6.9
	Taplejung (RW-2)	1.01	12	1.26	0.30	<5.0	2.8	0.71	<1.0	0.04	16	9	6.8
	Ghunsa (S-1)	0.02	16	4.04	0.67	<5.0	4.8	1.29	<1.0	0.19	51	28	7.0
	Gyabla (S-2)	0.55	12	2.42	0.48	<5.0	6.1	0.82	<1.0	0.15	12	6	7.0
	Phembu (S-3)	0.40	16	5.67	1.28	<5.0	15.8	1.16	<1.0	0.13	51	28	7.2
	Pole (T-1)	0.54	20	6.47	1.21	<5.0	6.4	1.71	<1.0	0.57	64	35	7.3
	Dhobhan (T-2)	1.20	20	8.90	1.54	<5.0	16.7	1.66	<1.0	0.13	41	22	7.3
	Hewa (T-3)	1.50	24	4.85	1.67	<5.0	9.9	1.19	<1.0	0.28	56	30	7.4
West-Seti River	Kanda (R-4)	1.50	96	33.16	11.25	<5.0	4.8	1.52	2	0.1	215	116	7.5
	Chainpur (R-5)	0.88	52	12.13	5.66	<5.0	6.9	1.64	<1.0	0.25	105	57	7.5
	Dipayal (R-6)	1.30	60	17.86	9.79	<5.0	3.3	1.19	<1.0	0.15	159	86	7.9
	GhatKhola (S-4)	0.02	16	5.68	1.15	<5.0	2.45	1.15	<1.0	0.05	27	15	7.4
	BhateKhola (T-4)	1.50	56	20.20	3.28	<5.0	3.04	1.01	<1.0	0.08	117	63	7.6

Characterizations of hydrochemical facies

Major cations and anions (milli-equivalent %) are plotted in a Piper diagram (Figure 2a and 2b), in which the cations and anions are illustrated in the bottom left and right triangles, respectively. The results are further projected into the central diamond field to evaluate geochemical facies[1] to present the clear picture of the hydrochemical facies. In the cation triangle, most of the samples lie in the left corner where Ca^{2+} values are higher (> 50%), revealing the dominance of calcium. Just two samples from the Tamor River lie towards the right corner of the cation plot, displaying an increased concentration of sodium and potassium ions, which indicates the influence of local sources of Na^{+} and K^{+} [18], with increasing concentrations of dissolved silica, similar results are also reported from the neighbouring Teesta River Basin[25] .

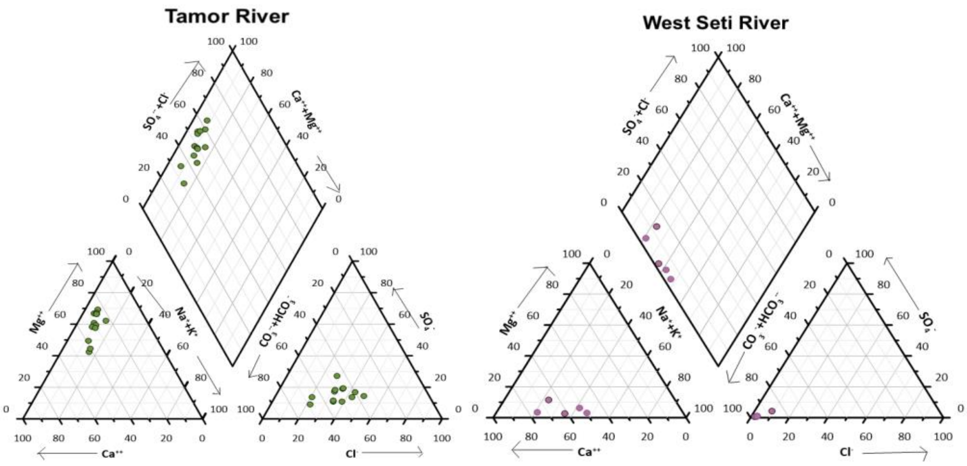

Figure 2: Piper diagram showing the geochemical facies of water quality in a) Tamor River and b) West Seti River, Nepal.

In the anion triangle, most of the samples lie on the left side of the triangle, showing a dominance of HCO_3^- over Cl^- and SO_4^{2-}; however, all the samples from the West- Seti are dominated by Ca-HCO_3. There are six subfields in the diamond-shaped Piper diagram (Figure 2a and 2b): (1) Ca-Mg-HCO_3, (2) Na- Cl, (3) mixed Ca- Mg- Cl, (4) mixed Ca-Na- HCO_3, (5) Ca-SO_4-Cl, and (6) Na HCO_3 [9]. Mostly, the geochemical facies of the rivers are characterized by the Ca-Mg-HCO_3- type (88.9%). Apart from this, two samples from the Tamor River, lies in the Ca-SO_4-Cl type. The hydrochemical facies clearly suggested spatial discrimination between different two glacier-fed river basins with dominant geogenic signatures. There carbonate dominated under lying lithology is clearly visible in the West Seti River whereas in the Tamor River mix type of lithological signature can be anticipated from the aforementioned hydrochemical facies. These results are consistent from the previous studies conducted in the glacier-fed Himalayan regions[26].

Correlation analysis

The concentrations of Ca^{2+}, Mg^{2+}, HCO_3^- in the water of the West-Seti is strongly higher than the waters in the Tamor basin (Figure 3).

The results suggest that bicarbonate (HCO_3^-) has a significant correlation with Ca^{2+} and Mg^{2+} suggesting carbonate rock weathering as the dominant geochemical process in the region (Figure 4).

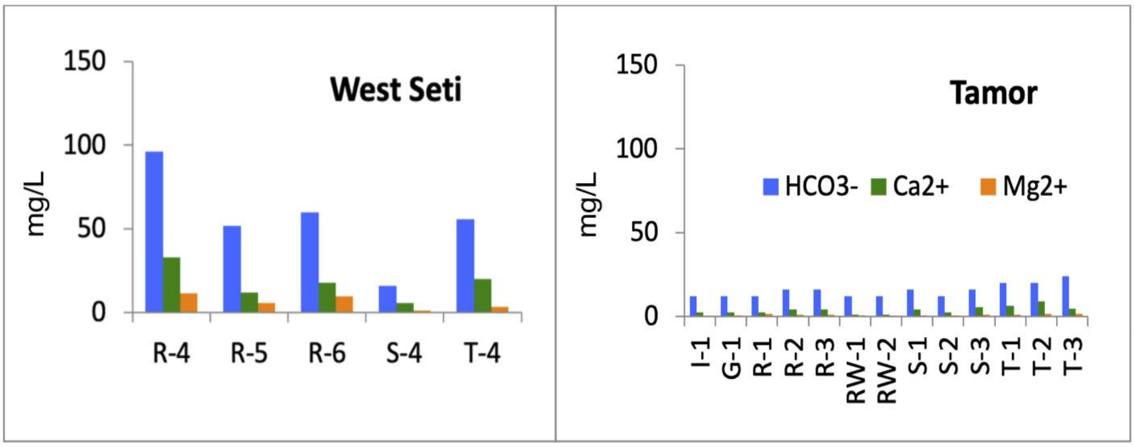

Figure 3: Graph showing the concentration of calcium, magnesium and bicarbonate.

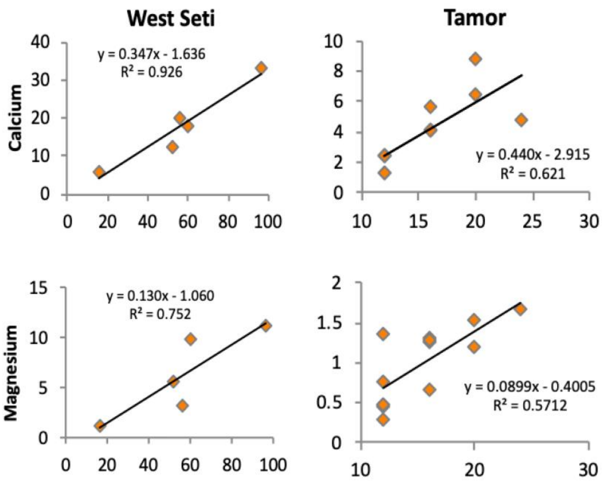

Figure 4: Graph representing correlation Ca^{2+} and Mg^{2+} with HCO_3^-.

The study shows that the chemical weathering is higher in the west-Seti River than in the Tamor basin. The results showed the good agreement with the previous studies conducted in the Nepal Himalaya and other Himalayan river basins[20, 27].

CONCLUSIONS

The hydrochemistry of the West-Seti and the Tamor Rivers were assessed to characterize and evaluate the water quality. The results revealed that ionic strength is much distinct, for instance EC and TDS are markedly higher (>3.2 times) in the West-Seti compared to Tamor River. Similarly, the cation and anion ratios reflect the spatial variability as the concentration of chemical parameters are markedly higher in West-Seti in comparison with Tamor River basin. The results exhibited that the under lying rocks are relatively more resistant to weathering condition in the Tamor in comparison to the West-Seti River basin. These findings are clearly demonstrated through the Ca-HCO_3 and Ca-SO_4-Cl types of water facies in the West-Seti and Tamor River, respectively. Further, the results indicated that bicarbonate (HCO_3^-) has a significant correlation with Ca^{2+} and Mg^{2+} suggesting carbonate rock weathering as the dominant geochemical process in both of the basins.

Increased value of Ca^{2+} and HCO_3^- in the West-Seti River as compared to the Tamor River is probably due to carbonate domination under-lying lithology. Hydrochemistry also suggested that the waters in both the river basins have minimal influence by the anthropogenic activities.

The study clearly demonstrates that all the measured physicochemical parameters of both the glacier-fed river basins are within the WHO guideline values and currently under a safe level of the water quality for drinking and ecosystem health perspectives. However, further in-depth research is recommended in the periodic basis to assess traces of climate change imprints and anthropogenic signatures for more consistent and reliable dataset from the glacier-fed Himalayan river basins. The findings of the present study could be useful for the sustainable water quality management in the glacier-fed Himalayan River basins.

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