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Assessment of Physico-Chemical Parameters of Meltwater of Ponkar Glacier, Manang, Nepal

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Abstract

A study of the melt water draining from Ponkar glacier, Bhimthang Valley, Nepal was performed to determine various physico-chemical parameters prevailing along 16 sampling sites consisting of moraine dammed, Ponkar Lake at 4100 metres to downstream glaciated stream at 1930 metre. Temperature, pH and Electrical conductivity were recorded on site and the melt water samples were brought in laboratory and different parameters were analyzed following APHA, AWWA, WEF (2012). The glacier melt water was alkaline in nature with pH 7.876 (± 0.340) and electrical conductivity was 70.187 (± 28.33) µS/cm. The concentration of cations were in the order of $Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$. Similarly, the order of major anions was $HCO_3^{-}>Cl^{-}>SO_4^{2-}>NO_3^{-}$ respectively. Calcium and magnesium were the dominant cations, while bicarbonate and chloride were the dominant anions. Piper plot showed calcium-sulphate weathering as the major source of dissolved ions resulting Gypsum as dominant rock type. The trace metals were found in order Fe>Al>Zn>Mn. The study provides the baseline data on physical- chemical characteristics of glacial melt water in Ponkar glacier, Nepal.

Keywords: Glacial melt water; Manang; Physico-chemical; Ponkar glacier

Introduction

The Hindu Kush Himalayan region (HKH) covers more than 4 million square kilometres (km^2) of mountains spreading across Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Pakistan and Nepal [1,2]. The HKH region is the origin of most of the important river system in Asia including Nepal which supports densely populated region by providing several ecosystem services [3] and glacier shrinkages will have important implications in several ecosystem services to the regions that glacier-fed rivers are present [4].

Melt waters from mountain glaciers of the Himalayas are one of the dominant water resources for Nepal [5] on which the country depend for drinking water, irrigation and hydropower [6]. However, rapid glacial retreats as a result of global climate change can have significant impacts on hydrological regimes resulting in decrease in water resources [7,8], quality and quantity. Chemical composition of precipitation, snow and glacier melt and discharge in a glaciated river basin is important in understanding climate change impacts [9,10]. Investigation on melt water hydrochemistry of glaciers is important not only for water resource management in Himalaya and to understand the complex weathering dynamics operating in the glaciated river catchments but also to study the impacts of global climate change on these glaciers. Moreover, the growing demand for freshwater in downstream stretches for drinking, agricultural and hydropower purposes as well as the ecological setting has made the hydro chemical study of Himalayan glaciers highly imperative [11]. The main objective of the study is to determine the physico-chemical characteristics of melt water draining from Ponkar Glacier and establish link of physical-chemical parameters of melt water and geological features in Ponkar glacier area.

Materials and Methods

Study area

Ponkar Glacier is located in Bhimthang Valley, Manang district, Gandaki Zone, Western Development Region of Nepal. Ponkar Glacier (84˚28'14" E, 28˚37'49"N) is a debris cover glacier which lies in the headwaters of DudhKhola, located in Marsyangdi Sub-basin of Gandaki River basin (Figure 1). It has an area of 28.509 km^2 with mean elevation of 5679 m.a.s.l. The estimated average thickness of the glacier is 134.05 m [12].

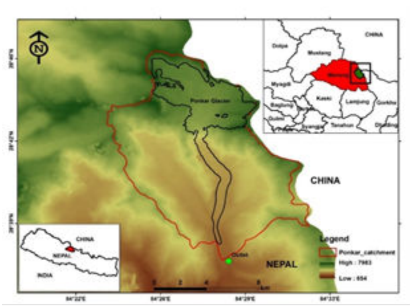

Figure 1: Study area map.

Sampling and analysis

Ponkar Pond is located along the Ponkar Glacier and Dudh Koshi river start from the terminus of Ponkar Glacier. Dudh Koshi river is Ponkar Glacial fed river which finally feds in Marsyandhi river basin at downstream. So, total of 16 water stations starting from Ponkar glacier (PG 01: Altitude 4100 m) following glacier terminus (PG 07: Altitude 3650 m) to downstream glacier fed river (PG 16: Altitude 1930 m) was taken for glacier melt water sampling (Figure 2).

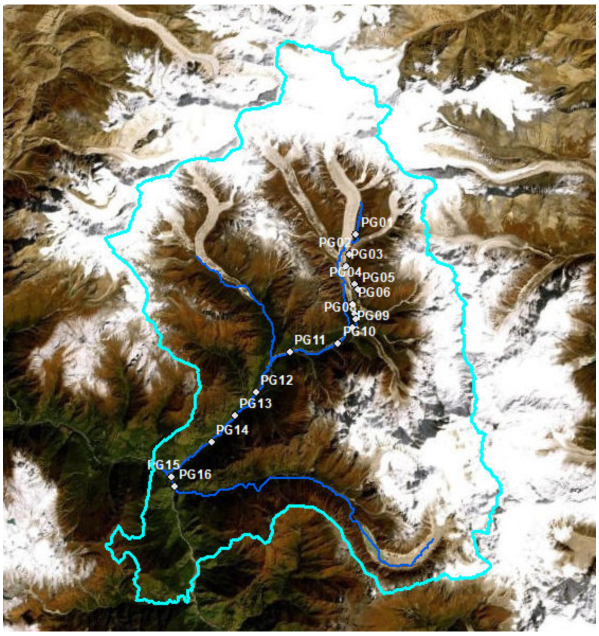

Figure 2: Map of the location of water sampling stations.

The water samples were collected from each of these stations in pre monsoon season (2017 and 2018). The sampling was carried out keeping in view the site accessibility and proper geo-morphological variation among the sampling sites. The sampling sites were chosen to establish the quality of the river at each point it comes in contact with the different geological factors. Parameters with extremely low stability such as Temperature, Conductivity and pH were determined on the field using calibrated field probes (Multiprobe HI 98194), Turbidity by Turbidity meter (Model no HI 98713) and Total dissolved solids by Gravimetric method. The water samples were collected in 500ml polyethylene glass, brought in ice box and store in freezer in laboratory. The samples was analysed within 2 weeks in Environmental pollution laboratory, Kathmandu University, Nepal. For trace metals 2ml of con HNO_3 was added in water sample bottles.

The anions, cations and heavy metals were analyzed in UV-spectrophotometer and Atomic absorption spectrophotometer following methods: (Calcium- 2500 Ca B, Magnesium- 3500 Mg B; Iron-3111B; Maganese-3111B;Sodium-3500 NaB; Potassium - 3500 KB; Zinc-3111B; Aluminium-3500-Al B) from APHA, AWWA, WEF (2012). ArcMap 10.x version was used for all the spatial works. The relationship between water composition and rock type was evaluated by plotting the concentration of major cations and anions in Piper 1994 Tri-linear diagram [13]. Grapher 13 software was used to plot the piper diagram. Further, SPSS and R software were used for statistical analysis like normal distribution, correlation and Principal Component Analysis (PCA) [14].

Result and Discussion

The results of *in situ* measurement of melt water for different physical parameters are given in Table 1.

Sampling sites	Altitude (ma.s.l.)	pH	EC (μScm^{-1})	Turbidity (NTU)	TDS (mg/L)
1	4100	8.7	78	10.4	42.44
2	4058	8.1	74	15.4	122.42
3	3910	7.2	43	41.8	51.68
4	3780	7.3	93	2.16	82.5
5	3650	7.7	112	17.3	98.24
6	3594	7.9	67	33.6	74.56
7	3590	8.1	32	1.74	60.34
8	3583	7.6	31	119.33	20
9	2994	7.7	53	55.86	32
10	2841	7.9	76	67.83	36
11	2730	7.9	92	51.6	41
12	2467	8	110	60.23	55
13	2323	7.9	91	39.3	45
14	2248	8	98	99	48
15	1948	7.9	30	44.57	14
16	1930	7.7	43	77.63	26

Table 1: Field parameters of melt water samples of Ponkar glacier.

PG1- PG7 sampling sites are considered as upstream where water samples are collected from Ponkar glacier to glacier terminus. From PG 8 sampling site onwards, the glacier melt water mixed into Dudh Koshi River and we collected water samples till PG 16, where this river finally mixed into big Marsyandi River and these sites could be considered as downstream glacier fed sites.

The average pH indicates the alkaline nature of melt water of Ponkar Glacier. The glacier waters are normally found to be slightly alkaline [15]. The average conductivity was found be in the range of $70.187 \pm 28.33\ \mu Scm^{-1}$. Along with suspended impurities, temperature is also an important factor contributing towards electrical conductivity. The temperature tends to increase the rapid dissolution of the minerals thereby increasing the conductivity of water bodies.

The average total dissolved solid in the region was recorded as 30.510 ± 12.892 ppm. During pre-monsoon season, the amount of solutes could be high due to decrease in water volume. This record is also compared to be of similar concentration in the study of Langtang Valley [16]. The average turbidity of the water in that region was found out to be 46.109 ± 33.784 NTU which is of the normal range in the alpine region [17]. Lakes and river originating from glacier frequently receive inputs of finely ground rock particles of glacial origin; thus, often has a grey or whitish appearance making it highly turbid [18].

The turbidity was recorded to be highest in PG 8 which could be due to the sediments carried by the stream from the debris glacier (Figure 3).

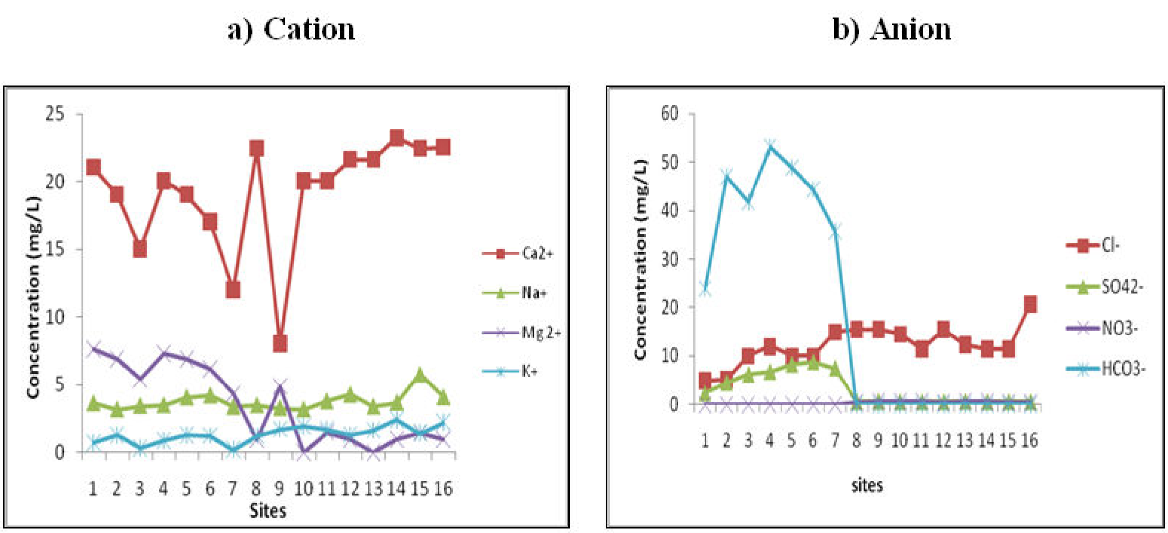

Figure 3: Concerntration of cation and anion in different sampling sites of Ponkar glacier.

The concentration of cations is in the order of Ca^{2+}> Mg^{2+}>Na^{+} >K^{+}. Calcium is the dominant cation with average concentration of 19.048 ± 4.19 mgL^{-1}. The average concentrations of other cations, i.e., Mg^{2+}, Na^{+} and K^{+} are 4.047 ± 2.737 mgL^{-1}, 3.788 ± 0.645 $mgL^{-1}$and 1.324 ± 0.612 mgL^{-1}. Due to the hardness in water seen in the site, which is primarily due to calcium and magnesium, it is quite justifiable to say that calcium is the dominant cation.

The dominance of the major anions is in the order of HCO_3^- > Cl^- >SO_4^{2-}> NO_3^{-1}. HCO_3^- is the dominant anion for PG 1- PG 7 and we could not perform laboratory analysis for HCO3- from PG 8- PG 16. The average concentration of anions, Cl^- and SO_4^{2-} are12.26 ± 3.97 mgL^{-1}. NO_3^- was not detected in seven sites (PG 1 to PG 7). The reason behind this could be the unsteady stream flow and Dissolved Organic Carbon (DOC) availability create the hotspots and hot moments that dominate NO^{3-} reactivity and its removal in high altitude glaciers [19].

The relationship between water composition and rock type are evaluated by plotting the concentration of major cations and anions in the Tri-Linear diagram [13] (Figure 4).

The Piper plot showed that percentage value of (Ca+Mg) was considerably higher than the alkali metals (Na+K), whereas on the other hand percentage value of strong acids (SO_4+Cl) was significantly higher than the weak acids (HCO_3) (Figure 4). It can be vividly seen that calcium is significantly higher than other cations (Mg, Na and K). On the other hand, strong acids (SO_4 and Cl) are dominant over weak acids (HCO_3 and CO_3). This confirms that the calcium sulphate weathering is the major source of dissolved ions in the region due to calcareous bedrock geology of the study area. Similar results were in recorded in meltwater of Chaturangi Glacier, Garhwal Himalaya, India; Urunmqi Glacier no 1, China and Teesta river, Sikkim, India [20-22].

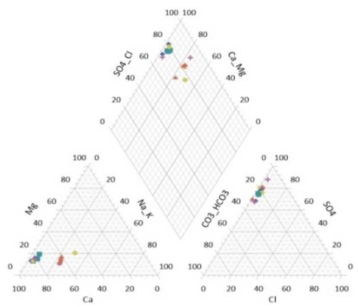

Figure 4: Piper plot diagram of the meltwater draining from Ponkar glacier.

The dominance of the trace metals found in the Ponkar glacier melt water is in the order of Fe>Al>Zn>Mn. The study area comprised of the dominance of Gneiss which generally contain Magnesium and Iron in the minerals Amphibole and biotitic mica [23]. We recorded Piles of Gneiss so Iron was recorded in highest concentration in glacier melt water (Figure 5).

Out of eighteen parameters, only two parameters – Turbidity and Total Dissolved Solids were found to be normally distributed at 5% level of significance from Shapiro-Wilk test so Spearman Correlation was performed. Correlation analysis was done to study the nature and significance of the correlation among the parameters assessed and a correlation matrix with correlation coefficients (R) for all pairs of variables was obtained at 5% level of significance. Water temperature showed a good correlation with Turbidity (γ=0.6529) as well as Chloride (γ=0.7686). Water Temperature tends to increase with the increasing turbidity and warm temperatures are desired to increase the capabilities of chlorine. pH showed good correlation with Total

Dissolved Solids (γ=0.549). The carbonate and bicarbonate concentration can result to this correlation. Electrical Conductivity displayed good correlation with Total Dissolved Solid γ =0.543) indicating that as concentration of dissolved constituents rises electrical conductivity also rises. A good correlation of Turbidity was also observed with respect to Calcium (γ=0.6519), Potassium (γ=0.7158) and Chloride (γ=0.6219) resulting that the high concentration of these ions can impact to the clarity of water. Calcium (Ca^{2+}) revealed a negative correlation with Magnesium (Mg^{2+}) (γ= -0.525) as well as Sulphate ($SO4^{2-}$) (γ=-0.510) resulting an inverse relationship between the variables. Magnesium seems to have an inverse correlation with Potassium (K) (γ=-0.621) resembling the decrease of value with the increasing concentration of potassium. Similarly, Iron (Fe) seemed to have a good correlation amongst Potassium (K) (γ=0.538) and Chloride (Cl) (γ =0.531). The good correlation between iron and chloride might lead to a good of iron with Total Dissolved Solids (γ=0.521) correlation. Likewise, a good correlation between Zinc and Aluminium (γ=0.511) is also seen from the Spearman Correlation resulting in the possibility of Zinc-Aluminium alloys.

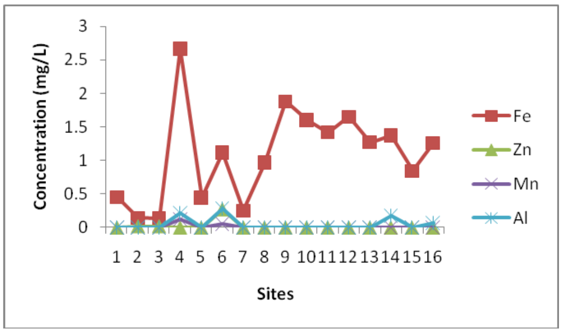

Figure 5: Concentration of trace metals at different sampling sites.

We performed Principal component analysis for identification of patterns in the data set, and describing the data to emphasize their similarities and differences. Five factors were recognized as Eigen values more than one in factor analysis of melt water samples illustrating about 81.34% of the total variability in the data set. From the performed PCA, Factor 1 represented 26.04% variance showing a strong loading of Turbidity, K and Ca resulting in the clarity of the melt water. Similarly, Factor 2 represented 20.40% variance displaying a potential loading of HCO_3 and SO_4 describing contribution from carbonate weathering, sulphate minerals dissolution as well as pyrite oxidation. Mn and Al were also prominent loading in this factor. Likewise, Electrical conductivity and Total dissolved solids showed a potential loading in Factor 3 with 16.18% variance. Factor 4 represented 10.53% variance with a potential loading of Zn. Finally, Factor 5 represented 8.19% variance with a potential loading Ca and Na. This factor describes contribution from weathering of silicate minerals.

Conclusion

The study uncovered the analysis of the physico-chemical parameters present in the meltwater draining from the Ponkar Glacier, Manang, Nepal. The alkaline nature of pH and variable Total dissolved solids were observed in all of the 16 sampling sites. Calcium and bicarbonate ions were the dominant cation and anion respectively. The concentration of cations and anions are in the order of Ca^{2+}>Mg^{2+}>Na^{+}>K^{+} and HCO_3^{-}>Cl^{-}>SO_4^{2-}>NO_3 respectively. The trace metals were found in the order Fe>Al>Zn>Mn. Calcium sulphate weathering was found to be the major source of dissolved ions in the regions. There have been detailed field measurements in only 12 out of 54,000 glaciers of the Himalayas and shrinking of glaciers and temperature rise is found to be the highest than any other place in the planet so we hope to conduct more scientific studies in glacial melt water chemistry in Nepal's glaciers.

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Conflicts of Interest

The authors declare no conflict of interest.

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