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Assessment of the surface water quality in high-altitude springs in the Sagarmatha (Everest) National Park, Nepal

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Abstract

This study's goal was to examine how the physico-chemical properties of high-altitude springs in eastern Nepal's Sagarmatha National Park and buffer zone changed annually over a period of three years (2008-2010). The majority of the sampling locations were chosen along the treks from Lukla to Everest Base Camp, Gokyo, and Imja valley. Chemical parameters, such as total nitrogen and total phosphorous, were studied in the ecology laboratory of Central Department of Botany, Tribhuvan University, while physical characteristics such as pH, temperature, total dissolved solids (TDS), and conductivity were assessed on the spot by water analyzer kit Although water quality standards still meets the WHO's and Nepal's standards for drinking water, the quality of the spring water is starting to deteriorate. On the main tourist treks, Changes in water quality metrics in water bodies have been observed. Each year, the values of total nitrogen (TN-NO_3), total phosphorous (TP-PO_4), and pH change, indicating a decline in the quality of the springs water bodies in the Sagarmatha National Park and Buffer Zone (SNPBZ). The values of TN-NO_3 and TP-PO_4 had significantly increased, indicating that human impact had also increased. Although the amount of total nitrogen in water samples was lower than the WHO limit, there has been an increase in nitrate-nitrogen as compared to past findings. Similar to this, it was discovered that the total phosphorus value increased both annually and in earlier reports. Therefore, sufficient care should be taken to stop future deterioration. The research produced a database for the current state of Nepal's highland springs, which may be used to manage the springs and research how human activity affects water quality.

Keywords: Degradation, Human impacts, Physico-Chemical Characteristics; Springs, Water quality

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Introduction

The Sagarmatha National Park (SNP) in Nepal's Solukhumbu District is home to many peaks exceeding 7000 meters, including Mount Everest, the highest peak in the world. It was founded in 1976 AD and recognized as a World Heritage Site in 1979 AD, making it a well-liked ecotourism destination for visitors from around the world. Over 500,000 domestic and foreign hikers have visited the National park since the first ascent of Everest in 1953. Twenty tourists visited the Everest region in 1964; this number increased to 32,084 in 2010, and has been steadily rising since. Many individuals travel to the park to work as guides and porters in addition to international trekkers. On the one hand, the Everest region's tourism industry generates financial gains, and on the other it has raised some environmental concerns (Caravello *et al* 2007).

Several studies have been conducted on spring water, providing valuable insights into morphometry, physico-chemical and biological features, primary productivity, and trophic status (Reda 2015, Awol 2018, Yousefi and Sahebian 2017, Mihale 2015, Gurung *et al*. 2019). Similarly, numerous studies have explored the interrelationships among various water quality parameters (Kale 2016).

Limnological studies in the Himalayans have been carried out since the beginning of the century (Sars, 1903; Hutchinson, 1937). Similarly, Loffer (1969), Aizaki *et al* (1987) added useful contribution to morphometry, physico-chemical and biological features, primary productivity and trophic status in the eastern Nepalese Himalayas. Nowadays, several studies have focused on the water chemistry of the high land (Aizaki *et al* 1987, Tartari *et al* 1998, Lacoul and Freedman 2005, Ghimire *et al* 2013). They provided the data on morphometry, bathymetry, and pollution levels for the management and protection of the high-altitude wetlands of Nepal. Therefore, we hypothesized thatthe quality of the water measured in terms of physico - chemical properties has altered by different activities related to water bodies. So, the main objective of the study was to analyze the physico-chemical characteristics of the springs located inside the Sagarmatha National park Buffer Zone (SNPBZ). To understand the ecological status and annual changes in the aquatic ecosystem of spring water in SNPBZ, temperature, pH, conductivity, TDS, nitrogen and phosphorous were measured during the years (2008-2010).

Materials and methods

Study site

The terrain of Sargarmatha National Park, which is characterized by harsh topography, stretches from 86°30'53" to 86°99'08" E longitude to 27°30'19" to 27°06'45" N latitude (Figure 1). The park's elevation varies from 2,845 m in Jorsella to 8,848 m at the summit of Mount Everest. It includes the significant settlements of Namche, Khumjung, and Chaurikharka. The park, which has a land size of 1,148 sq km, is situated on the southern slope of Sagarmatha (Mt. Everest). The distance between this park and Kathmandu is 140 kilometers. Geologically young, the mountains of Sagarmatha National Park are surrounded by glacial valleys and deep gorges. People in the Khumbu region primarily make their living from tourism. Many of the locals still rely on agricultural and pastoral activities, nevertheless. The region is inhabited mainly by Sherpa, followed by Tamang, Rai ethnic groups.

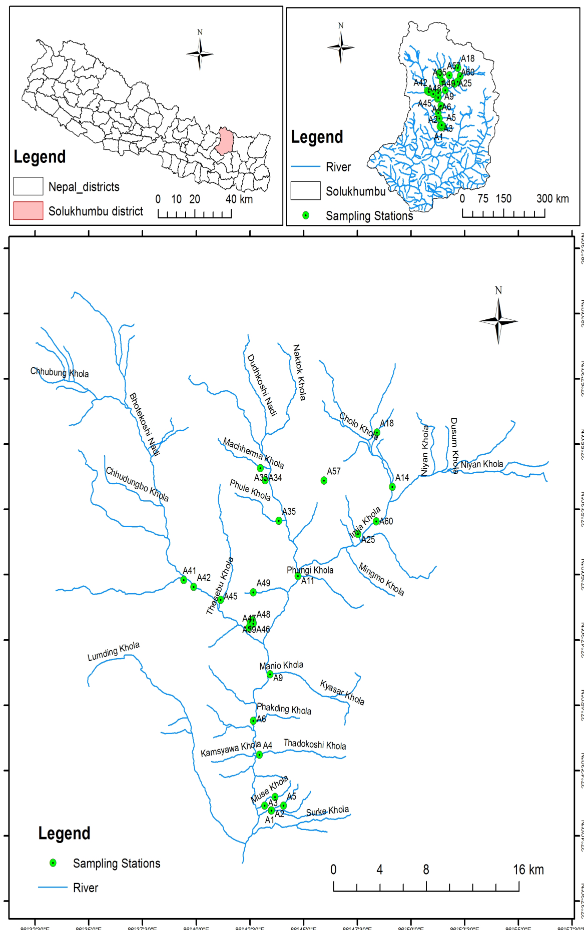

Figure 1: Study area showing sampling points of Sagarmatha National Park and Buffer zone.

Sample collection sites

Twenty seven water samples were collected and analyzed for three consecutive years from 2008 to 2010 form the springs (one composite sample from each spring). The criteria for the selection of sampling points were based on the vicinity of tourist trails located on the banks of spring water bodies and sources of major spring systems, and springs near by the settlement (Table 1)

Table 1: Description of the sample collection sites in SNPBZ.

S. N	Name of Site	Lat.	Long.	Alt.(m)
A1	Ghatte khola	27.68272	86.72495	2850
A2	Hadi Khola	27.68262	86.72503	2593
A3	Muse Khola	27.68577	86.71978	2767
A4	Thado Koshi	27.7183	86.71577	3289
A5	Ghatta Khola	27.68585	86.73437	4279
A6	Thado Khola Phakding	27.73988	86.71093	4610
A9	Monju Khola	27.76977	86.72398	4020
A11	Phunki Tenga Spring	27.83253	86.74562	3929
A14	Pheriche Spring	27.8893	86.8188	4325
A18	Lobuche Khola	27.92405	86.8069	4015
A25	Panboche Spring	27.85933	86.79223	3353
A33	Machhermo Khola	27.90133	86.7165	3440
A34	Luza Khola	27.8935	86.72013	3414
A35	Dole River	27.86775	86.73077	3708
A37	Namche Spring	27.80268	86.70852	3692
A38	mid of Namche Spring	27.804183	86.710283	3405
A39	Mouth of Namche Spring	27.80415	86.71032	3389
A41	Thame Khola (Spring)	27.82995	86.65692	3112
A42	Thame Khola(KBC)	27.82548	86.66473	3440
A45	Theso Khola	27.81728	86.68557	2661
A46	Mislung	27.80248	86.7109	4977
A47	Namche Spring	27.79935	86.7074	4110
A48	Mislung Spring	27.802017	86.71095	2860
A49	Tok-tok Khola	27.822	86.71095	2850
A57	Amphulapchacho	27.8933	86.76578	2593
A60	Somera	27.86728	86.80635	2767
A61	Lukla Tamang Spring	27.69125	86.72777	3289

Sampling was done in the months of May-June. Physical parameters (temperature, pH, conductivity, TDS) were measured on the spot by using a water analyzer kit (Deluxe water and Soil analysis kit, model 191), and chemical parameters (nitrogen and phosphorous) were analyzed to record the physical and chemical characters of springs to understand the status and annual changes in the aquatic ecosystem of a springs water system.

Sample preservation and lab analysis

Acid-rinsed polythene bottles (125 ml) were used to collect water samples. The pH of the samples was reduced below 2 (acidic medium) using three drops of strong nitric acid. The samples were brought to Kathmandu, where they were examined in the Ecology laboratory of Central Department of Botany Tribhuvan University. In accordance with Trivedy and Goel's standard curve approach (1986), the nitrogen and phosphorous levels of spring water samples were determined by colorimetry.

Statistical analysis

Stastistical analysis was done using one way analysis of the variance (ANOVA) for compare mean by using SPSS 16.0 version

Results and Discussion

Physical parameters

Twenty-seven springs were studied in SNPBZ in 2008-10. Among them, the average value of water temperature varied from 9 $^{\circ}$C 9 to 15 $^{\circ}$C (Table 3, Figure 2). The highest values were noted in Mislung tap spring (14.67°C) and Thadokhola near Phakding (13.83 °C). Somare spring, Phunki Tenga spring, and Lobuche showed the lowest temperature (Table 2). Sharma *et al* (2010) also record the temperature of surface water was 8°C and 7°C for the surface water in upper Khumbu valley. Glacier retreat in the Everest region was found very rapidly (5.5-8.7 m / annum) which accelerated (5.56-9.1 m/annum) from1997-2001 (Ren *et al,* 2004) probably due to climate change (Ives 2005).

Average pH value of the spring's water bodies was noted ranging from 6.0 to 8.0, which indicated neither acidic nor basic status (Table 3, Figure 3). Some springs exceptionally showed higher pH values than the normal range; Somare spring (8.5) and 8.2 in 2008 and 2010 respectively. Similarly, Lukla Tamang spring showed 9.0 in 2008, whereas 5.7 were recorded in 2010 due to anthropogenic activities in the vicinity of the springs. Similarly, Ghattekhola, Hadikhola springs showed a significant decrease in pH value (2008>2009>2010) (Table 2). In all cases, garbage pits were found close to the spring water courses which ultimately affected the pH value of springs. Different streams showed the same range as the previous report, Lobuche Khola at Pheriche; 7.5 (Tartari *et al* 1998) whereas the present study it was recorded 7.2. Renold et al (1998) found 6.5 to 8.7 in the surface water of upper Khumbu region. So, pH values were found in the decreasing trend. Although, all the present data were found below the WHO standards and National Water quality standards for drinking purposes.

Average TDS value of different samplings points of water bodies of springs ranged between 0.003 to 0.043 mg/l. The minimum average TDS value was recorded in Luza Khola, Machharmo

Table 2. Physical and chemical characteristics of water in different springs in SNPBZ.

SN	Temp.			pH			TDS (MG/L)			Conductivity			TN-NO_3			TP-PO_4		
	2008	2009	2010	08	09	10	08	09	10	08	09	10	08	09	10	08	09	10
A1	14	11.5	10.5	7.4	7.4	7.2	0.01	0	0.01	0.02	0.02	0.02	0.93	0.24	0.93	0.15	0.2	1.99
A2	13.9	12	11	7.4	7.1	6.5	0.01	0	0	0.02	0.01	0.01	0.18	0.93	0.85	0.12	0.04	0.37
A3	14.7	12.5	11	7.4	7.1	7.3	0.01	0.01	0.01	0.02	0.02	0.02	0.17	0.76	0.77	0.12	0.23	1.49
A4	14.7	11.2	10.5	7.1	7.2	7.5	0.01	0	0.01	0.02	0	0.02	0.19	1.74	2.39	0.12	0.08	0.5
A5	14.3	11.3	10	7.3	7.3	6.8	0.01	0.01	0	0.01	0	0.01	0.5	0.32	1.3	0.06	0.15	0.48
A6	15.5	13	13	6.8	7.2	7.2	0.01	0.04	0.04	0.02	0.06	0.07	0.71	1.39	3.02	0.15	0.12	2.7
A9	10.5	12	12.4	7.2	7.6	6.5	0.01	0	0.01	0.02	0	0.02	0.47	0.46	1.03	0.05	0.82	0.32
A11	8.6	10.5	10.6	7.5	7	7.4	0.01	0.01	0.02	0.02	0.03	0.04	0.65	0.31	1.23	0.12	0.28	3.73
A14	11.2	10.4	9.5	7.5	6.7	6.8	0.02	0.02	0.02	0.03	0.03	0.03	0.61	0.74	2.6	0.14	0.24	1.08

Contd…

A18	9.5	10.5	7.1	7.1	6.7	5.1	0.02	0.02	0.04	0.03	0.04	0.03	0.9	0.84	1.3	0.46	0.46	0.65
A25	11.2	10.5	10.3	7.4	6.6	7.3	0.02	0.01	0.03	0.03	0.02	0.04	0.56	1.87	2.8	0.07	0.28	1.09
A33	13	10.5	9.5	7.1	6.9	6.5	0.01	0	0	0.02	0.01	0.01	0.27	0.42	1.5	0.07	0.08	0.32
A34	12.5	10.5	10.6	7.5	6.6	6.5	0	0	0.01	0.01	0	0.01	0.54	1.02	2.13	0.19	0.28	0.29
A35	12	10.3	10.2	7.6	7	5.6	0.01	0	0	0.01	0.01	0	0.61	1.39	1.58	0.02	0.08	0.25
A37	9.5	13	12	6.8	6.6	6.7	0.04	0.01	0.01	0.06	0.02	0.02	0.77	1.75	1.01	0.02	0.14	3.01
A38	13.2	12.5	13	7.3	5.2	7.3	0.02	0.01	0	0.04	0.03	0.01	1.44	1.44	2.36	0.48	0.34	1.06
A39	12.4	12	11.5	7.5	6.5	5.9	0.02	0.02	0.02	0.03	0.03	0.03	0.54	0.79	2.51	0.14	0.2	0.36
A41	14.2	11.5	12	7	6.7	7.3	0.01	0.01	0	0.02	0.02	0.01	0.63	0.32	0.99	0.12	0.56	0.27
A42	12.9	10	14	7.2	6.4	6.4	0.01	0.01	0.01	0.02	0.02	0.02	0.77	0.67	0.43	0.28	0.23	0.24
A45	14.7	8.2	11	7.4	6.5	6.2	0.02	0	0	0.02	0.02	0.02	0.51	0.35	2.05	0.11	0.03	0.28
A46	15	14	15	7.5	6.6	6.6	0.02	0.01	0.01	0.03	0.02	0.02	1.94	2.22	0.78	0.29	0.09	0.62
A47	13.5	12	13.2	7.7	7.9	6.2	0.02	0.04	0.01	0.04	0.05	0.02	0.97	1.93	0.76	0.25	0.02	1.03
A48	14.4	14	12.5	7.5	7.1	6.4	0.03	0.01	0.01	0.04	0.02	0.03	0.63	1.77	1.54	0.12	0.12	0.62
A49	13.5	13	13	7	7.4	5.5	0.01	0.01	0	0.01	0.01	0	0.94	1.2	1.87	0.12	0.16	0.23
A57	4.1	4.1	12	7.3	7.3	7.3	0.01	0.01	0.01	0.02	0.02	0.02	0.86	0.86	0.86	0.32	0.32	0.32
A60	8	10.5	9.5	8.5	6.6	8.2	0.02	0.01	0.01	0.03	0.02	0.02	0.93	2.14	2.2	0.69	0.36	0.82
A61	7.7	11	11	–	6.6	5.7	0.04	0.04	0.05	0.06	0.07	0.08	1.18	0.51	2.6	0.38	2	3.9

Table 3: Average annual mean comparison between 2008, 2009 and 2010.

Parameters	2008	2009	2010
Temp(°C)	12.174 ±2.763	11.204±1.93	11.330±1.656
pH	7.407 ±0.455	6.899±0.503	6.660±0.718
Conductivity (mS)	0.026 ±0.013	0.021±0.018	0.023±0.018
TDS (mg/l)	0.016±0.009	0.011±0.012	0.013±0.013

Khola, Dole Khola etc whereas the highest value was recorded by Tamang springs Lukla (0.043), which showed annual higher value than other spring, 0.04 in 2008, 0.04 in 2009 and 0.05 in 2010 (Table 2). It is due to low volume of water and direct discharge of human excreta, and other waste into springs that can be observed directly.

The average values of conductivity were recorded between 0.01 to 0.07 (Table 3, Figure 4). Tamang tole spring, which showed the highest conductivity value across the entire study period which indicates the high discharged from near settlement directly into the spring. In 2008, the value was noted 0.06, 0.07 in 2009 and 0.08 in 2010 (Table 2). Annually increasing value indicates increasing anthropogenic pressure. Minimum conductivity was recorded in Tok-Tok, Dole river, Luza, Ghatte khola with similar values of 0.007 (Table 2). These points also showed the minimum TDS values. Similar result was reported in earlier research (0.008-0.067 s/cm by Lami *et al* (2007) for high altitude water of Khumbu valley, 0.011 to 0.51 s/cm by Antoninetti *et al* (1998) for Khumbu water. 0.019 to 0.057 s/cm in the streams of upper Khumbu valley by Renold *et al* (1998).From the conductivity and TDS data, the water quality of the spring is still better.

Chemical Parameters (Total nitrogen and Total phosphorous)

The average values of total nitrogen were recorded from 0.52- 1.76 mg/l in different springs (Table 4, Figure 6) . The higher value was found in different springs in the 1st, 2nd, and 3rd year: Thadokoshi Phakdings (1.44 mg/l), Panboche spring (1.74 mg/l), Thadokhola Phakding (1.71 mg/l),

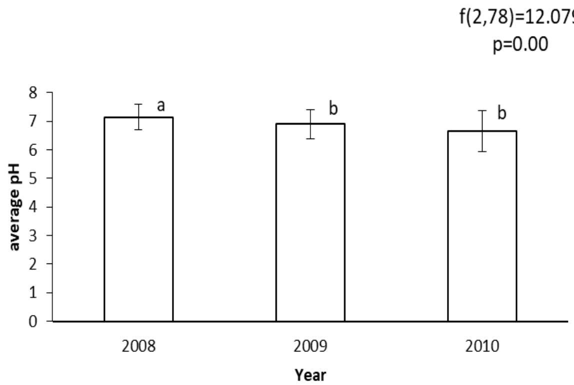

Figure 2: Average Temperature of springs water in 2008, 2009 and 2010. *F = (degree of freedom between the group, within the group) (p=level of significance, a, b, c represent the annual variation).

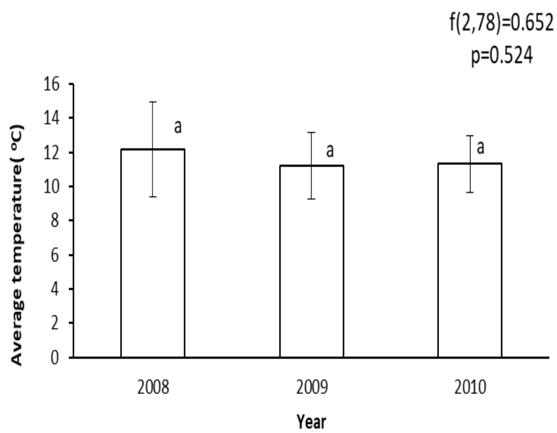

Figure.3: Average pH of springs water in 2008, 2009 and 2010. *F = (degree of freedom between the group, within the group) (p=level of significance, a, b, c represent the annual variation).

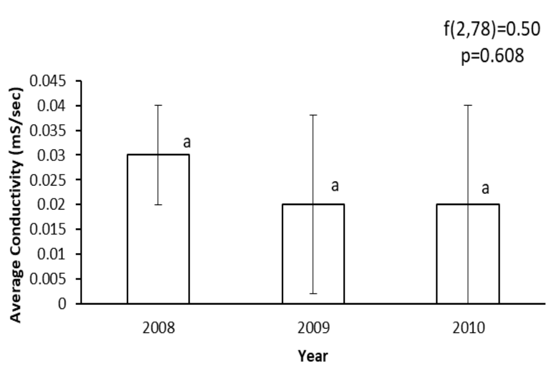

Figure.4: Average conductivity of springs water in 2008, 2009 and 2010. *F = (degree of freedom between the group, within the group) (p=level of significance, a, b, c represent the annual variation).

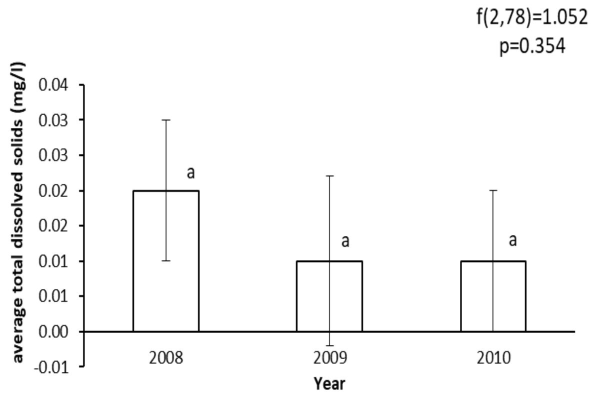

Figure.5: Average total dissolved solids in spring water in 2008, 2009 and 2010. *F = (degree of freedom between the group, within the group) (p=level of significance, a, b, c represent the annual variation).

Namche spring Namche spring (mid of Namche) 1.43 mg/l, Mislung springs flowing from the Mislung tap (1.65mg/l), Somare spring (1.76 mg/l) but occasionally some points in 2010 the point of sources of spring of Namche (2.5 mg/l), Theso Khola 2.05 mg/l, Tamang spring Lukla (2.60 mg/l) were recorded (Table 2). Generally, all springs flow near by the settlements. Many hotels and tea shops don't have toilets as well as septic tank for the toilet (Ghimire et al, 2010). They directly discharge the human waste into the springs. In most cases, the distance between settlement, toilet, garbage pit, and spring was as less as 5 m (e.g: Panboche, Lobuche etc.) (Manfredi et al, 2010).

Ngozumpa glacier previously had 0.37 mg/l total nitrogen whereas the present average TN measured as nitrate was 1.05 mg/l (0.71 mg/l in 2008, 2.17 mg/l in 2010) (Table 2). Both Lobuche Khola and Pheriche showed much higher values than the prior ones. The previous record was 0.17 to 0.237 mg/l, whereas 1.41 mg/l in Lobuche Khola in Pheriche and 0.75 mg/l in Lobuche were 4-5 times higher. The rate of atmospheric nitrogen deposition was also reported by some earlier investigations as having a considerable impact on the TN-NO_3 value in the water bodies (0.3 kg/ha/year by Tartari et al 1988, Reynolds et al 1998). Springs were discovered nearby, passing through a town, a rubbish pit, a septic tank (toilet), and agricultural area (i.e. Phakding, Lobuche, Pheriche, Tamang spring Lukla, Namche spring etc).

Table 4: Average annual mean comparison of nitrogen and phosphorous.

Parameters	2008	2009	2010
$TN\text{-}NO_3$(mg/lit)	0.719±0.384	1.051±0.626	1.607±0.754
$TP\text{-}PO_4$(mg/lit)	0.191±0.159	0.293±0.384	1.038±1.082

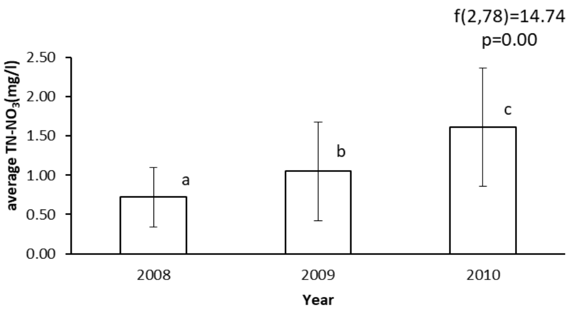

Figure.6: Average TN-NO3 of springs water in 2008, 2009 and 2010. *F = (degree of freedom between the group, within the group) (p=level of significance, a, b, c represent the annual variation).

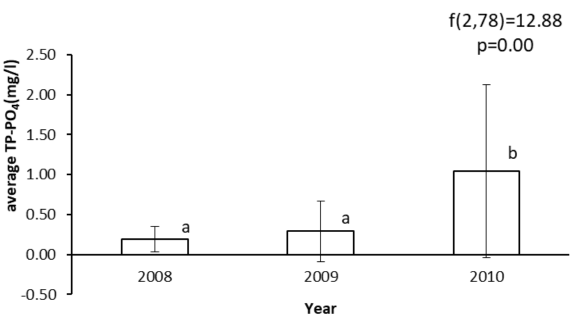

Figure.7: Average $TP\text{-}PO_4$ of springs water in 2008, 2009 and 2010. *F = (degree of freedom between the group, within the group) (p=level of significance, a, b, c represent the annual variation).

According to Renold et al. (1998), the Khumbu region's NO_3-N concentration ranged from 0.01 to 0.69 mg/l for surface water to 0.15 to 0.17 mg/l for spring water, 0.03 to 0.21 mg/l for glacier melt water, and 0.04 to 0.29 mg/l for an Upper Khumbu valley stream. So, all these anthropogenic activities enhanced TN in springs. $TN\text{-}NO_3$ significantly increased from 2008 to 2009, and to 2010. (Figure 6).

The amount of phosphorous was recorded between 0.12-2.09 mg/l (Table 2). The minimum value was recorded in Dole River (0.12 mg/l) whereas the maximum in Lukla Tamang spring (2.09 mg/l). Other higher values were: 1.38 mg/l in Phunki Tenga spring, Ghatte Khola (0.23 mg/l), Muse Khola (0.61 mg/l), Lobuche spring (0.52 mg/l), Namche spring (1.06 mg/l), Somare spring (0.62 mg/l), Namche spring (from the mid of Namche) was 0.63 mg/l.In 2008, the value was recorded between the range 0.08-2 mg/l. but in 2009 the range was 0.23-3.9 mg/l. Namche spring showed 3.01 mg/l in 2010 due to high human activity during this time like washing, bathing etc. Tamang Tole spring also showed the highest value i.e., 3.9 mg/l in 2010 (Figure 7). This point showed a higher rank in all values like TDS, conductivity, $TN\text{-}NO_3$, and Phosphorous also. A similar trend was observed in the final year (2010), the value ranged between 0.23 and3.9 mg/l (Table 2).

Lami *et al* (2007) analyzed the water chemistry and concluded that phosphorous contained lower than 0.005mg/l in more than 50% of samples whereas the present average phosphorous as phosphate value was found 0.345 mg/l (Figure 7). So, comparatively, there is a trend of increasing value of phosphorous in water bodies. The annual variation also showed that there was an increasing trend from year to year. But all the values were found between the standard limits by WHO, National Drinking water standards drinking as well as other purposes, but values were recorded more than 5-6 times from the previous record.

Conclusion

The current research shows that the concentration of chemicals (TN and TP) in the water bodies of the Khumbu region is rising, even though it is still below WHO guidelines. While the quality of the spring water generally continues to meet WHO and Nepalese drinking water standards, the process of pollution has already begun. Since most of the restrooms in the Khumbu region have excreta leaks, the situation is not suitable. The state of the toilets can be improved to stop pollution from entering water sources.

Each year, the values of $TN\text{-}NO_3$, $TP\text{-}PO_4$, and pH change, indicating a decline in the quality of the springs' water bodies in the SNPBZ. While nitrogen and phosphorous arriving from the agricultural field is also due to increased tourist flow as well as anthropogenic activities towards water bodies, a significant increase in the value of $TN\text{-}NO_3$ and $TP\text{-}PO_4$ suggested that anthropogenic influence was also growing. The amount of total nitrogen in water samples was lower than the WHO norm, although there was a rise in nitrate-nitrogen between 2008 and 2010, as well as compared to earlier findings.

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