

Physico-chemical Characterization of Gosainkunda Lake

Rosha Raut¹, Subodh Sharma¹, Roshan M. Bajracharya¹,
Chhatra Mani Sharma² and Smriti Gurung¹

¹Aquatic Ecology Centre, School of Science
Kathmandu University, Dhulikhel, Kavre

²Human and Natural Resources Studies Centre, School of Arts
Kathmandu University, Kathmandu
e-mail: rosha@ku.student.edu.np

Abstract

High altitude lakes are very sensitive to climate change due to their small catchment area, limited vegetation cover, surface water with low nutrients, and thin soil and low bedrock weathering rates. The present study was focused on high altitude Himalayan Lake Gosainkunda, situated at an elevation of 4300 m in the Langtang National Park, and carried out during the post- monsoon season (October) in 2010. The main aim of the study was to assess the water quality quantitatively considering the anthropogenic as well as natural impacts in the lake. The water samples were collected at six different sites to represent entirely the quality of the lake. The sampling sites were systematically designated as the inlet, outlet, human influence site, littoral zone, middle (central) and the deepest part of the lake. Some major cations (Ca^{++} , Mg^{++} , Na^+ & K^+) and anions (Cl^- , SO_4^- & HCO_3^-) were analyzed; the cation type is dominated by Ca^{++} (64%) while the anions are dominated by Cl^- (49%). Among the trace elements (Al, Fe, Mn, Zn, Cu, Cd, Cr, Ni, Pb & As), except for Al and Fe, all others were found below the detection limit.

Key words: Physical and chemical parameters, high altitude lakes, water quality

Introduction

High Elevation catchments are characterized by dilute surface waters, small terrestrial area, limited vegetative cover, thin soils and also bedrock weathering rate is very low (Psenner 1989, Drever & Zobrist 1992; Strang *et al.* 2010). The high altitude lakes are pristine habitats, undisturbed by direct anthropogenic activities due to their remoteness in location (Koinig *et al.* 1998). They are mostly oligotrophic as compared to lowland lakes. The lakes in these remote areas are particularly suitable for study, where the climate signals are maximized mainly due to the limited importance of human impact (Smol *et al.* 1991). Although, high altitude lakes in Nepalese Himalaya were considered as pristine (Aizaki *et al.* 1987), they are being affected by various environmental factors and climatic change due to acidification, eutrophication, global warming and UV radiation (Cantonati *et al.* 2001). Mountain lakes located at the high elevation are more susceptible to atmospheric inputs than lowland lakes due to factors such as climate, shallow soils, small watersheds and rapid flushing rates (Mosello *et al.* 1995,

Galassi *et al.* 1997, Lami *et al.* 1998).

In the context of Nepal, there are 79 large standing freshwater bodies in the mountain regions of Nepal (Gujja *et al.* 2007). Nepal has a total of 5358 lakes, of which, 2227 (42%) are situated above 3000 m elevation (Bhujju *et al.* 2010). Numerous limnological studies had been carried out in lowland and middle mountains compared to high altitude although Nepal has a large number of high altitude freshwater bodies. The first high altitude limnological study in Nepal was carried out by Löffler (1969), who provided the data on morphometry, temperature, chemistry and biology of 24 lakes at altitudes between 4500 and 5600 m in the Mount Everest region (Khumbu Valley). Although there have been several studies on high mountain lakes, very few studies focused on water chemistry (Löffler 1969, Aizaki *et al.* 1987, Tartari *et al.* 1998 a & b, Lacoul & Freedman 2005). Studies in other lakes include Okino and Satosh 1986, Aizaki *et al.* 1987, Liu & Sharma 1988, Tartari *et al.* 1998 a). Limnological studies in Sagarmatha National Park have been carried out in late 1990s. These studies are based on water

chemistry (Gosso *et al.* 1993, Tartari *et al.* 1997), and Lake Biota (Manca *et al.* 1994, Manca & Mura 1997). After several years Lacoul and Freedman (2005) made the contribution, especially in the physical and chemical limnology of lentic water bodies of Nepal in different altitudinal gradient ranging from tropical to lowland (77 m) and high altitude alpine region (up to 4980 m).

In fact, there is still a lack of information on high altitude

lakes although much research has been done in diverse fields. This is likely due to poor accessibility and harsh working conditions.

Methodology

Study area

Gosainkunda, the study area is a famous high Himalayan (alpine zone) lake situated above the tree line in the

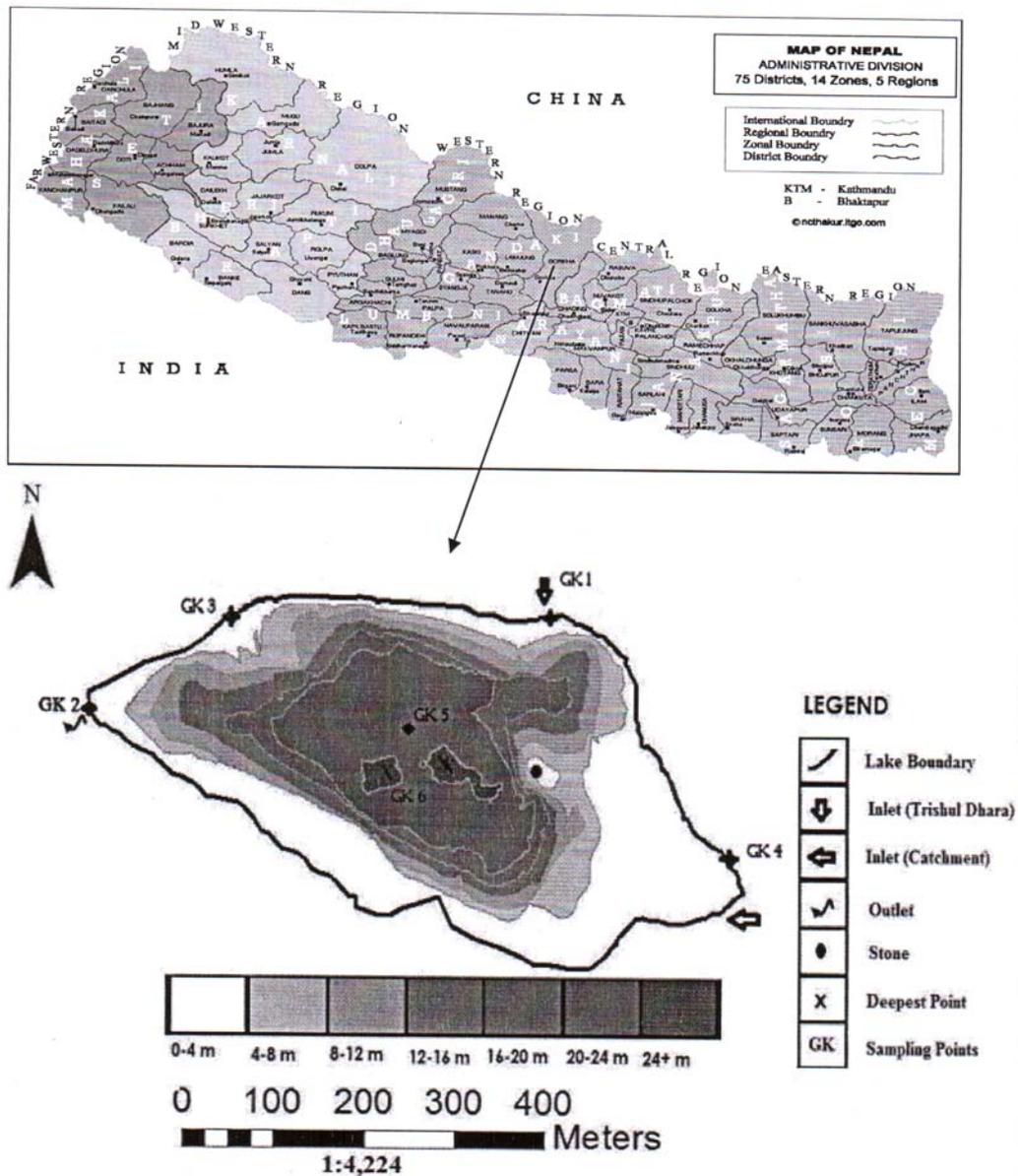


Fig.1. Map of Nepal indicating study location and lake Bathymetry showing sampling sites. Source: (Niraula, 2011). Location description of sampling sites GK1 to GK6 is presented in Table 2.

Langtang National Park in Rasuwa district of Nepal. It has high socio-cultural and religious importance. Every year, during the event of *Janaipurnima* (full moon festival in August) hundreds of Hindu and Buddhist pilgrims visit this lake. As a high altitude lake it has national and international importance for the people all over the world. Gosainkunda and associated lakes have been included as in the list of world Ramsar site no. 1693 on September 23, 2007 (Kafle & Savillo 2009). The lake remains frozen for six months in winter (October to June). It is formed by glacial or snow melt water in the eastern and central Himalayas (Lacoul & Fredman 2005). Some topographical characteristics of lake are given in Table 2.

Table 1. Topographical characteristics of lake Gosainkund (Source: (Niraula 2009))

Altitude (m asl)	4300
Longitude (East)	28° 05. 00'
Latitude (North)	85° 24. 96'
Lake surface area (ha)	13.8
Volume (m ³)	1464084.604
Maximum depth (m)	24.1

The lake can be reached in two days trekking from Dhunche, Rasuwa district through an adventurous 118 km mountain road from Kathmandu. In the surrounding area of Gosainkunda, there are 108 lakes of small to medium size. Mainly visible lakes in routes are commonly Sharaswatikund, Bhairabkunda and Gosainkunda.

Table 2. Sampling sites (locations) with longitude and latitude

Site Code	Longitude (East)	Latitude (North)	Sampling locations
GK1	85° 24. 811"	28° 04. 992"	Inlet (Trishul Dhara)
GK2	85° 24. 626"	28° 05. 041"	Outlet
GK3	85° 24. 710"	28° 05. 041"	Human influence area
GK4	85° 24. 001"	28° 04. 912"	Littoral zone
GK5	85° 24. 811"	28° 05. 041"	Middle (centre) of the lake
GK6	85° 24. 802"	28° 04. 982"	Deepest point of the lake

Field Sampling and laboratory analysis

The sampling of lake was started on a sunny day from noon and completed in the evening day of 25th October, 2010. Although middle surface water samples can be considered as the representative of the lakes (Göransson *et al.* 2003), the water samples were collected at six different sites of the lake to represent the water quality of the entire lake. The sampling sites were inlet, outlet, human influence sites, littoral zone, middle (central) and the deepest point of the lake, and coded as GK1, GK2, GK3, GK4, GK5 and GK6 respectively.

Physico – chemical parameters like pH, temperature, conductivity, and dissolved oxygen were measured by using multiparameter probe (Orion Star Series Multimeter set) in situ. Alkalinity was analyzed immediately after the collection of samples by trimetric method. For analysis of other chemical parameters, such as nitrate, nitrite, ammonia, total nitrogen and

phosphate, the samples were collected in a pre-washed 500 ml clean plastic container and preserved with conc. H₂SO₄ and also followed by same volume of samples in unpreserved condition for other chemical parameters like sodium, potassium, total silica, etc. However, for the trace metals like Fe, Mn, Cu, Zn, Cd, Cr, Ni, Pb and As, the samples were collected in pre acid washed plastic container and preserved with conc. HNO₃ and brought to the laboratory at Aquatic Ecology Center/Kathmandu University for further analyses. Fresh standard solutions were prepared from stock during analysis of each and every parameter and kept at least 4 different concentrations for calibration. All the sample collection techniques, quality control technique and analytical methods were followed by using Standard Methods for the Examination of Water and Wastewater (APHA, AWWA & WEF, 1998). The analyzed physico-chemical parameters and their brief test methods are mentioned in Table 3.

Table 3. List of analyzed physico- chemical parameters in water samples of Gosainkunda lake

Parameters	Units	Test methods
Water temperature	$^{\circ}\text{C}$	Thermometer
pH	-	Multi Parameter Probe
Electrical conductivity	$\mu\text{S}/\text{cm}$	Multi Parameter Probe
Turbidity	NTU	Nephelometric (Turbidity meter)
Total dissolved solids (TDS)	mgL^{-1}	Gravimetric
Total suspended solids (TSS)	mgL^{-1}	Gravimetric
Bicarbonate alkalinity (HCO_3^-)	mgL^{-1}	Titrimetric (H_2SO_4)
Chloride (Cl^-)	mgL^{-1}	Argentometric
Total hardness as CaCO_3	mgL^{-1}	EDTA Titration
Calcium (Ca^{++})	mgL^{-1}	EDTA Titration
Magnesium (Mg^{++})	mgL^{-1}	EDTA Titration
Dissolved oxygen (DO)	mgL^{-1}	Multi Parameter Probe
Sodium (Na^+)	mgL^{-1}	Atomic Absorption Spectrometer (AAS)
Potassium (K^+)	mgL^{-1}	Atomic Absorption Spectrometer (AAS)
Sulphate (SO_4^{--})	mgL^{-1}	Spectrophotometric
Total silica	mgL^{-1}	Molibdosilicate
Orthophosphorus	mgL^{-1}	Ammonium molybdate ascorbic acid red. ⁿ
Total phosphate (TP)	mgL^{-1}	Potassium persulphate digt ⁿ followed by Ammonium molybdate ascorbic acid reduction.
Organic nitrogen(ON)	mgL^{-1}	Kjeldhal digestion
Total nitrogen (TN)	mgL^{-1}	$\text{N}-\text{NO}_3+\text{N}-\text{NO}_2+\text{N}-\text{NH}_3+\text{Organic nitrogen}$
Aluminum (Al)	mgL^{-1}	Spectrophotometric (Erichrome Cyanine)
Iron, Manganese, Zinc, Copper , Cadmium , Chromium , Nickel & Lead	mgL^{-1}	Atomic Absorption Spectrometer (AAS)
Arsenic (As)	mgL^{-1}	Atomic Absorption Spectrometer (AAS) (Hydride Generation - vapour)

Data analysis

Descriptive statistics was performed using EXCEL worksheet, Pearson correlation between variables was estimated using the statistic software SPSS version 10.

Results and Discussion

The average value of pH was observed to be 7 indicating that the lake water is neutral. A low pH value was observed at the deepest point while highest was noted for the outlet of the lake, i.e. 5.7 and 8.9 respectively. The data on pH of water are given in table 4.

Table 4. Mean, maximum, minimum and standard deviation values of analyzed parameters

Parameters	Units	Mean (std)	Min. Value	Max. value
Temperature	°C	6.65 (±1.790)	2.7	7.9
pH	-	7.00 (±1.075)	5.70	8.90
Electrical Conductivity	µS/cm	11.66 (±5.249)	8.00	22.0
Turbidity	NTU	3.87 (±2.927)	<1	8.00
Total Dissolved Solids (TDS)	mgL ⁻¹	7.17 (±4.981)	2.00	14.0
Total Suspended Solids (TSS)	mgL ⁻¹	3.50 (±3.403)	1.00	11.0
Bicarbonate Alkalinity (HCO ₃ ⁻)	mgL ⁻¹	17.49 (±3.284)	12.2	19.52
Chloride (Cl ⁻)	mgL ⁻¹	20.50 (±13.781)	9.00	49.0
Total Hardness as CaCO ₃	mgL ⁻¹	14.0 (±6.904)	9.00	29.0
Calcium (Ca ⁺⁺)	mgL ⁻¹	3.47 (±2.055)	2.40	8.02
Magnesium (Mg ⁺⁺)	mgL ⁻¹	1.30 (±0.654)	0.24	2.19
Dissolved Oxygen (DO)	mgL ⁻¹	8.55 (±5.435)	3.60	17.5
Sodium (Na ⁺)	mgL ⁻¹	0.45 (±5.435)	0.33	0.82
Potassium (K ⁺)	mgL ⁻¹	0.28 (±0.071)	0.19	0.36
Sulphate (SO ₄ ⁻)	mgL ⁻¹	3.94 (±2.380)	2.31	9.06
Total Silica	mgL ⁻¹	1.64 (±0.353)	1.30	2.37
Total Phosphate	mgL ⁻¹	0.12 (±0.026)	0.11	0.16
Organic Nitrogen	mgL ⁻¹	1.08 (±0.715)	0.37	2.05
Total Nitrogen	mgL ⁻¹	1.53 (±0.774)	0.49	2.65
Aluminum (Al)	mgL ⁻¹	0.52 (±0.261)	0.30	1.03
Iron (Fe)	mgL ⁻¹	0.30 (±0.339)	ND (<0.05)	0.78

The average value of pH 7 was also reported by (Lacoul and Freedman 2005 & Shimkhada 2006). However, the alkaline pH has been reported in the Gokyo lake of Sagarmatha National Park by (Gurung *et al.* 2011, Lacoul & Freedman, 2005 and Tartari *et al.* 1998b).

The average value of conductivity was observed to be 11.7µS/cm. A slight increase in the conductivity value was observed for the deepest point of the lake i.e. 22µS/cm. Similar trend of conductivity was reported in a previous study of the Gosainkunda lake (Shimkhada, 2006). Lowest values were found in highly

transparent lakes in the Langtang region (Lacoul and Freedman, 2005). High altitude lakes generally possess low conductivity due to low weathering rates (Catalan *et al.*, 2006). Low conductivity indicates a low total concentration of dissolved ions (Stumm and Morgan, 1996).

The concentration of major cations in lake water was noted to follow the order of K⁺>Na⁺>Mg⁺⁺>Ca⁺⁺. Calcium was found to be the dominant cation (64%) in the lake (Figure 3). This was likely due to the presence of calcium bearing rocks and minerals in the area such as calcareous gneiss, calcite and limestone.

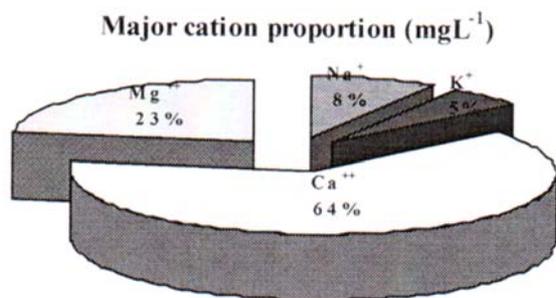


Fig. 2. Cations proportion in Gosainkunda lake

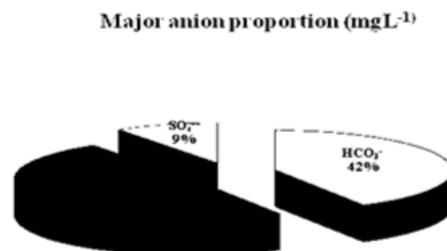


Fig. 3. Anions proportion in Gosainkunda lake

the order of $SO_4^{2-} > HCO_3^- > Cl^-$ with chloride being the dominant anion (49%) as shown in Figure 3. The concentrations of nutrients like nitrogen and phosphorus were found to be very low but in comparison, the concentration of nitrogen was considerably higher than phosphorus (Figure 4). This may be due to seepage of waste water (sewage) from the nearby lodges and hotels.

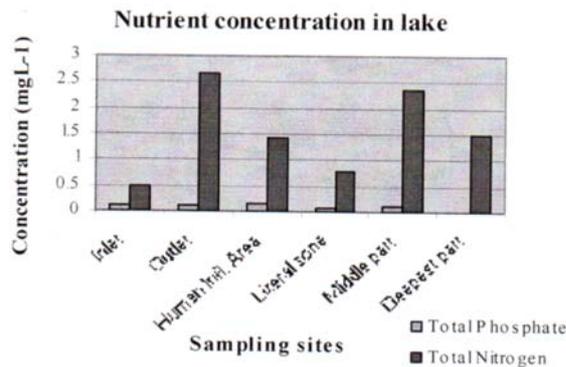


Fig. 4. Nutrient concentration in Gosainkunda lake

The Pearson correlation matrix between all the analyzed variables was determined as shown in Table 5. The pH of water was highly significantly positively correlated with total dissolved solids (TDS), total suspended solids (TSS) and total hardness (TH) reflecting the influence of minerals like calcium carbonate on pH. Likewise, the concentration of calcium ions in lake water was highly correlated positively with total hardness and chlorine concentration. Also, sodium ion concentration, sulphate ion concentration and silica were all highly positively correlated with each other. Water temperature was noted to be highly negatively correlated with sodium, sulphate and silica concentrations, suggesting lower dissolution rates as temperature increased in the range of water temperature measured. Likewise, total phosphate was highly negatively correlated with total suspended solids and aluminum concentration as was potassium concentration with organic nitrogen and total nitrogen concentrations (Table 5).

	Temp	pH	Cond	TDS	TSS	HCO ₃ ⁻	Cl ⁻	TH	Ca ⁺⁺	Mg ⁺⁺	OC	DO	Na ⁺	K ⁺	SO ₄ ⁻	SiO ₂	TP	ON	TN	Al	
Temp	1																				
pH	.30	1																			
Cond	-.37	-.68	1																		
TDS	.10	.83*	-.36	1																	
TSS	.12	-.46	.86*	-.17	1																
HCO ₃ ⁻	-.26	.19	-.34	.41	-.27	1															
Cl ⁻	.38	.53	.00	.43	.12	-.65	1														
TH	.17	.87*	-.38	.72	-.29	-.21	.83*	1													
Ca ⁺⁺	.35	.76	-.35	.57	-.25	-.44	.93**	.94**	1												
Mg ⁺⁺	-.24	.79	-.29	.77	-.27	.29	.36	.77	.52	1											
OC	-.19	-.53	.96**	-.14	.94**	-.21	.07	-.29	-.29	-.19	1										
DO	-.64	.35	-.06	.32	-.41	-.12	.36	.61	.48	.64	-.16	1									
Na ⁺	-.96**	-.16	.23	.12	-.15	.49	-.43	-.13	-.36	.35	.16	.59	1								
K ⁺	-.30	-.06	-.06	-.04	.00	.72	-.73	-.39	-.65	.23	-.01	-.22	.39	1							
SO ₄ ⁻	-.94**	-.19	.21	-.19	-.24	.11	-.29	-.05	-.23	.32	.03	.72	.84*	.31	1						
SiO ₂	-.89*	.09	.01	.24	-.41	.27	-.10	.22	.04	.49	-.09	.86*	.89*	.07	.84*	1					
TP	-.20	.56	-.76	.57	-.82*	.69	-.21	.28	.14	.46	-.71	.35	.39	.19	.16	.51	1				
ON	.54	.23	-.15	.17	-.07	-.60	.73	.44	.70	-.20	-.14	.05	-.58	-.95**	-.55	-.25	-.08	1			
TN	.67	.41	-.28	.38	-.08	-.41	.72	.51	.73	-.08	-.18	-.06	-.63	-.83*	-.71	-.35	.05	.95**	1		
Al	.33	-.63	.68	-.61	.82*	-.51	.01	-.49	-.33	-.61	.67	-.62	-.47	-.05	-.32	-.68	-.95**	-.00	-.08	1	

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Good positive correlations (at $P = 0.05$ level) were observed between water pH and calcium, magnesium, chlorine, and total phosphate concentrations reflecting that increased amounts of these ions lead to higher water pH values. Also, as expected, total dissolved solids was significantly positively correlated with calcium, magnesium, total phosphate and total hardness of water as were the latter parameters also positively correlated among each other (Table 5). Less well explained were correlations between temperature and ON and TN, Al and OC, potassium and bicarbonate ion concentrations, and dissolved oxygen and magnesium, sodium and sulphate concentrations.

Low concentration of iron was detected in site GK6. Whereas the average value of Al (0.52mgL^{-1}) was detected in all the sampling sites of lake ranging from 0.3mgL^{-1} to 1.03mgL^{-1} at sites GK1 to GK6 respectively. With increasing acidification, aluminum (Al) concentration commonly increases in surface water (Lydersen *et al.*, 2002). The maximum concentration of Al was observed where pH was low at site GK6, the deep part of the lake. High concentration of Al is toxic to aquatic biota (Baker & Schafield 1982; Hutchinsion *et al.* 1989) and can be expected to have an adverse effect on the biodiversity of the lake.

High altitude freshwater lakes are fragile and very sensitive ecosystem. All the aquatic life depends on the stability of water chemistry; thus, any significant changes in these lentic systems can lead to imbalance and adverse impacts on the organisms dwelling therein. Being located in remote area, alpine lakes are excellent indicators of long- range and other airborne pollutants. However, most of the high altitude lakes of Nepal have their own religious values as such they are also becoming impacted by cumulative effects of various anthropogenic. The lake Gosinkunda is in oligotrophic status, measuring low nutrient contents with neutral pH values as well as negligible concentration of trace metals. Calcium (Ca^{++}) and chloride (Cl^-) are the major cations and anions predominant in the lake water, respectively. The presence of chloride ions indicate some anthropogenic impact, which might be due to discharge of wastewater directly into the lake from the four lodges frequented by tourists. Therefore, it is recommended that a regular monitoring is required to assess the extent and severity of anthropogenic and natural impacts and compliance through legal enforcement conservation measures be

taken to conserve this highly precious high altitude lakes.

Acknowledgements

This research was initiated and supported technically as well as financially by Aquatic Ecology Centre (AEC), School of Science, Kathmandu University, Dhulikhel. Authors are thankful for assistance and cooperation to Sudip Niraula, Lekhendra Tripathi, Kolit Shakya and Saneer Lamichane during the field sampling.

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