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Spatial variation of the soil and water qualities in the Mountain lakes at different altitude of Arunachal Pradesh, India

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ABSTRACT

A rapid assessment of certain water and soil quality parameters were undertaken in different lakes covering 4 districts of Arunachal Pradesh from the month of May, 2019 to March, 2020. The sampling and analysis were performed following the standard methods and recommended protocols for each of the parameters. The results indicate maximum pH value of 7.9 in the high altitude Kyalem Lake in Tawang and minimum of 7.0 in the low altitude Bone Lake in Upper Siang. The value of highest dissolved oxygen (11.55 mg/L) was found in Hireng Lake of Upper Siang and lowest (1.15 mg/L) in PTsho Lake of Tawang whereas the highest value of free carbon dioxide (1.3 mg/L) was recorded in Nagula Lake of Tawang and lowest (0.2mg/L) in Pegu Lake of Upper Siang. The highest alkalinity (7.8 mg/L) was found in Bone and lowest (1.4 mg/L) in Kyalem; the highest hardness (19 mg/L) was found in Pegu and lowest (3.5 mg/L) in Mehao. Among the soil parameters, the highest moisture of 69% was recorded in Pegu and the lowest of 61% in Shungatser (Tawang); the highest water retention capacity (0.92 mg/L) was found in Ganga and the lowest (0.8 mg/L) in Mehao and the higher soil pH around 6.9 was recorded in lakes of Sela, Nagula and Shungaster (Tawang) while the lowest value of 5.0 was found in Kyalem. The values for available soil nitrogen, phosphorus, potassium and organic carbon showed fluctuations in accordance with the altitudinal variations of lakes. Further, the soil texture was also observed to be mostly sandy loam and clay loam in majority of the lakes. The results obtained from the water quality and soils of studied lakes revealed that there was distinct slight variation among the lakes due to the altitudinal variation.

Key words: *Water Quality, Soil, Altitude, Lake, Arunachal Pradesh.*

Introduction

Lakes are dynamic lentic ecosystems and significant resources of inland water to meet the increasing water demand. However, the quality of water determines the functional patterns of utilization based on its physical, chemical and biological variables (Yu *et al*., 2010). Further, the diversified functional roles viz. hydrological and chemical cycles, holding of biological diversity and food web have made the lakes as the "kidneys of the landscape" (Barbier *et al*., 1997). High altitude lakes play a crucial role in biodiversity conservation, maintenance of wildlife habitat, formation of grazing areas for livestock and ultimately provide socio-economic sources and commodities for inhabitants in and around. The

Space Applications Centre (SAC), one of the major centers of the Indian Space Research Organization (ISRO) has reported numbers of high altitude lakes at more than 3,000 metres above mean sea level (msl), often fed by glaciers or snow from the surrounding mountains. The healthy ecosystems thus depend on the physico-chemical qualities of the water, soil and available life forms which in turn determines the trophic status of the water bodies. The notable works on lakes of northern and north-east India are Bhambri *et al*. (2015) on inventory of glacier lakes of Uttarakhand; Pant *et al*. (2017) on physico-chemical properties of a Himalayan lake of Uttarakhand; Sharma and Tiwari (2018) on physico-chemical characterization of water of sacred lake Nachiketa Tal in Garhwal Himalayas; Nath and Deka (2012) on fish diversity and conservation status of Chandubi tectonic lake, Assam; Raj *et al*. (2013) on glacial lakes of Sikkim; Kangabam *et al*. (2015) on ecology of Loktak lake, Manipur; Devi *et al*. (2016) on Phytoplankton community of Lake Baskandi anua, Cachar District, Assam; Hazarika and Kalita (2020) on limnological investigation in relation to plankton and fishes of Tasek Lake of East Garo Hills, Meghalaya. However, there exists extensive information gap so far on lake soil and water qualities of glacier-fed, spring-fed and rain-fed lakes in Arunachal Pradesh, India. Therefore, this paper intends to unfold the vital ecosystem parameters which may be of immense use in framing utilization and conservation strategies of mountain lakes in Arunachal Himalayas.

Materials and Methods

A preliminary survey was carried out in lakes situated at different altitudes of Arunachal Pradesh. The lakes have been selected on the basis of low, mid and high altitude. The low altitude lakes were Ganga (*Papum Pare*), Pegu, Hireng and Bone (Upper Siang) with altitudinal range of 274 to 445 m (msl). Mehao (Lower Dibang Valley) located at altitudinal range of 1661 to 1738 m (msl) was selected as mid altitude lake. The Kyalem, Nagula, PTsho, Sela and Shungatser lakes of Tawang situated at altitudinal range of 3705 to 4230 m (msl) were selected as high altitude lakes (Figure 1 & 2). In the low and high altitude lakes only one sampling site was selected for the investigation while in mid altitude lake of Mehao, 4 sampling sites were selected for the study. Mehao with about 400 hectares of surface area is the largest lake in the state which is situated 14 km away from the Roing town. The lakes of Tawang district are about 5 to 14 hectares in water area and

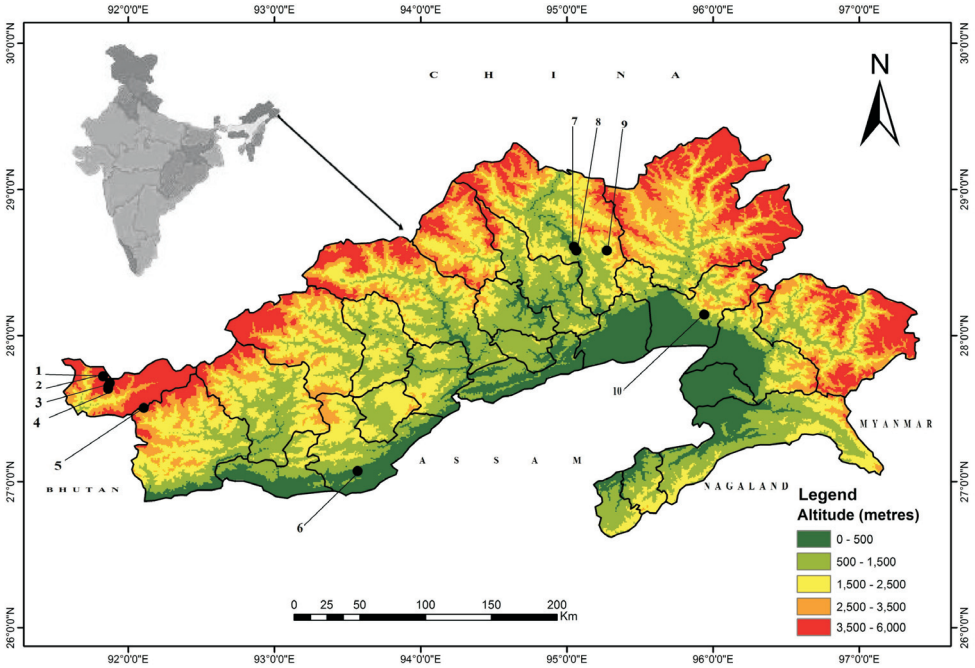

Fig. 1. Location of study area in Arunachal Arunachal Pradesh (India).
(Legends: 1- Shungaster; 2- Kyalem; 3- Nagula; 4- PTsho; 5- Sela; 6- Ganga; 7- Hireng; 8- Bone; 9- Pegu; 10- Mehao)

A view of PTsho Lake in Tawang

Collection of samples at Shungatser Lake, Tawang

Project personnels at Mehao Lake, Lower Dibang Valley

A view of Ganga Lake, Papum Pare

A view of Hireng Lake, Upper Siang

mostly located within a radius of 12-25 km from the Tawang town. Ganga is a medium-sized lake which is situated 6 km away from the Itanagar, the capital of Arunachal Pradesh and the water body is surrounded by primeval vegetation. Pegu, Hireng and Bone lakes are comparatively smaller lakes located in a radius of 6-12 km from the Yingkiong town. The water parameters like pH, dissolved oxygen, free carbon dioxide and hardness were estimated by following the scheme of APHA (1998). The soil physico-chemical properties were estimated by following appropriate procedures like moisture (Oven drying method), texture (Hydrometer analysis), water retention capacity (Klute, 1986), pH (pH meter), organic carbon (Walkley and Black, 1934), available K (Metson, 1956), available P using Olsen's method (Olsen *et al*., 1954) and total nitrogen using Kjeldahl method (Jackson, 1967).

Results and Discussion

The results of the water quality parameters are presented in Table 1 along with name of lakes, its location, and altitude. A marked fluctuation in the physico-chemical variables was observed in the lakes. Among the lakes, the pH was alkaline and was found to be lowest (7.0) in Bone lake while it is highest (7.9) in Kyalem lake; dissolved oxygen (DO) was found to be highest (11.55 mg/L) in Hireng lake while it is lowest (1.15 mg/L) in PTsho lake; the highest (1.3 mg/L) free carbon dioxide (FCO_2) was observed in Nagula lake while it is lowest (0.2 mg/

L) in Pegu, Ganga and Mehao lakes; the highest alkalinity (7.8 mg/L) was found in Bone lake while it is lowest (1.4 mg/L) in Kyalem lake; the highest hardness (19 mg/L) was found in Pegu lake while it is lowest (3.5 mg/L) in Mehao lake.

The study recorded highest pH in high altitude lakes followed by mid altitude and low altitude lakes. The pH is a key factor that decides the suitability of water for various purposes. The observed values of pH from the studied lakes lie within the range of 6.5–8.5 as per World Health Organization (WHO) standards of drinking water. It indicates that the water is almost neutral in nature. The findings are in relative agreement with the findings in Satopanth Lake of Garhwal Himalaya (Sharma and Kumar, 2017). The highest value of dissolved oxygen (DO) was observed in low altitude lakes followed by mid altitude and high altitude lakes. Dissolved oxygen is vital parameter for the survival of all aquatic life; in addition it is the most reliable criterion for assessing the trophic status i.e. eutrophication (Edmondson, 1966). The mean values of dissolved oxygen of all the studied lakes (except high altitude lakes in Tawang district) do not reach the critical values of 5.0 mg/L as given in WHO standards for drinking water. Similar results were recorded by Saini *et al*. (2008) and Sharma and Kumar (2017) in different lakes of the Himalayan region. The causes of low dissolved oxygen content in the high altitude lakes are probably due to the location of the lakes in the higher altitude Himalayan regions.

The highest value of FCO_2 was recorded in high altitude lakes followed by low altitude and mid altitude lakes. The mean values of free CO_2 were found very less (less than the prescribed limit of 250 mg/L for drinking water given by WHO). Overall, the highest value of alkalinity was found in low altitude lakes followed by mid altitude and high altitude lakes. Alkalinity is a total measure of the substances in water that have "acid-neutralizing" ability. The mean value of alkalinity of studied lakes was less than the permissible level of 200mg/L^{-1} recommended by the WHO for drinking water. The

Table 1. Water quality of the selected lakes

District	Name of Lakes	Location (Lat/long)	Altitude (m)	pH	DO (mg/L)	FCO_2 (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)
Upper Siang	Pegu	28° 34' 57" N 95° 03' 50" E	274	7.2±0.2	10.1± 0.4	0.2± 0.11	7.2± 1.42	19± 3.12
	Hireng	28° 34' 57" N 95° 16' 23" E	383	7.1±0.3	11.55±0.32	0.3± 0.12	5.2± 1.1	5.6± 1.02
	Bone	28° 36' 28" N 95° 02' 52" E	445	7.0±0.1	10.6± 0.52	0.4± 0.15	7.8± 1.24	7.0± 1.88
Papum pare	Ganga	27° 04' 26" N 93° 34' 05" E	341	7.4±0.3	8.5± 0.31	0.2± 0.1	3.2± 0.82	6.4± 2.04
Tawang	Sela	27° 30' 22" N 92° 06' 22" E	4164	7.8±0.2	2.01± 0.2	0.5± 0.32	4.5± 1.22	6.2± 1.4
	Kyalem	27° 40' 34" N 91° 52' 26" E	4230	7.9±0.3	2.72± 0.43	0.7± 0.25	1.4± 0.62	10.3± 2.46
	Nagula	27° 39' 16" N 91° 51' 48" E	4122	7.8±0.2	1.61± 0.42	1.3± 0.26	2.6± 1.02	10.2± 2.17
	Shungatser	27° 43' 20" N 91° 49' 37" E	3705	7.5±0.3	3.02±0.45	0.5± 0.11	2.5± 1.08	4.7± 1.52
	PTsho	27° 38' 13" N 91° 51' 23" E	3904	7.6±0.3	1.15±0.23	0.5± 0.14	3.9± 1.03	8.2± 2.72
Lower Dibang Valley	Mehao (Site-1)	28° 08' 41" N 95° 56' 22" E	1671	7.5±0.2	5.54±0.54	0.3±0.1	4.7±1.12	3.8±1.02
	Mehao (Site-2)	28° 08' 33" N 95° 56' 33" E	1738	7.6±0.1	6.35±0.82	0.2±0.1	4.8±1.55	5.2±1.65
	Mehao (Site-3)	28° 09' 12" N 95° 56' 38" E	1680	7.6±0.2	5.42±0.21	0.2±0.1	2.9±0.98	3.5±1.0
	Mehao (Site-4)	28° 08' 59" N 95° 56' 22" E	1661	7.5±0.1	5.84±0. 35	0.2±0.1	3.1±1.01	3.5±1.0

total hardness which is also vital parameter of water quality for use in domestic, industrial and agricultural purposes was found to be more or less similar in high altitude and low altitude while comparatively low in mid altitude lakes. The mean value of total hardness was also found to be less than the WHO standards for drinking water (200 mg/L). The main reasons for less amount of total hardness is due to the fewer amounts of cations dissolved in water. Similar results were recorded by Saini *et al*. (2008) and Sharma and Kumar (2017) in different Himalayan lakes. The dissolved oxygen, free CO2, alkalinity, hardness and pH affects the distribution of phytoplankton in lakes.

The results of soil parameters are given in Table 2. The results show highest moisture content of 69% in Pegu Lake and lowest of 61% in Shungatser Lake. Ganga Lake shows highest water retention capacity (0.92 mg/L) while Mehao Lake the lowest (0.8 mg/L). Three lakes of Tawang namely Sela, Nagula and Shungatser recorded the highest soil pH (6.9) and Kyalem Lake the lowest with 5.0. The soil texture was mostly sandy loam and clay loam in all the lakes. In terms of the available nitrogen (ammonium & nitrate) a fluctuation between high and low in all the lakes was found. The phosphorus and potassium in the soil were observed to be fluctuating between low and high in all the lakes. Organic carbon content was found to be high in higher altitude lakes (except one lake) and medium in mid and low altitude lakes.

The highest percentage of moisture content was recorded in low altitude lakes followed by mid and low altitude lakes. The soil moisture content was comparatively high in comparison to the adjoining area which indicates that the soil particles are small and finely structured. A similar finding was also reported by Das and Bindi (2014) in the soils of Jaisamand lake area. Soil moisture influences the physical, chemical and biological properties of soil like texture, quality and quantity of organic and inorganic matter and the nature and volume of pore size (Das and Bindi, 2014). The water retention capacity on average was found to be high in mid and high altitude lakes but comparatively lower in low altitude lakes. Water retention capacity of soil is determined by its texture, structure and the content of organic matter. The findings of lower water retention capacity in low altitude soils were in contrast to the observations of Deb *et al*. (2013). The average soil pH was found to be slightly acidic (6.23) in most of the lakes probably due to high rainfall as rainwater is known to be slightly acidic. However, the present findings are in contrast to the observations of Das and Bindi (2014) in the soils of Jaisamand lake area and Deb *et al*. (2013) in South Sikkim. The soil texture varied from sandy loam to clay loam. Most of the low altitude samples show finer texture and reverse in higher altitude. The present finding is similar with the observation of Deb *et al*. (2013).

Nitrogen, phosphorous and potassium are the main soil nutrients for normal germination, growth and maturity of plants. The availability of nitrogen depends on the varying degree of soil microbial decomposition (Gairola and Soni, 2010). The study found fluctuations in the available nitrogen, phosphorus, potassium and organic carbon content in the lakes of different altitude. The nitrogen and phosphorus content in the soil was found to be insufficient in the lakes. Phosphorous act as a limiting or co-limiting factor of ecosystem productivity

Table 2. Soil properties of different lakes

Lake	Moisture (%)	Water Retention Capacity (ml/gm)	Soil pH	Available Nitrogen		Phosphorus	Potassium	Organic carbon	Soil Texture
				Ammonium (NH_4+)	Nitrate (NO_3-)				
Kyalem	62	0.48	5.0	Low	Medium	Low	Very high	High	Sandy loam
Sela	63	0.72	6.9	Very low	Low	Low	Very high	High	Sandy clay loam
Nagula	62	0.8	6.9	Low	Medium	Medium	Medium	High	Sandy loam
PTsho	62	0.8	6.7	Very low	Low	Medium high	High	High	Sandy clay loam
Shungatser	61	0.84	6.9	Very low	Low	Medium high	Very high	low	Sandy clay loam
Mehao	68	0.8	5.1	Very low	Medium	Medium high	Very high	High	Sandy clay loam
Ganga	67	0.92	6.5	Very low	Medium	Low	Very high	Medium	Sandy clay loam
Pegu	69	0.48	6.4	Low	Low	Low	High	Medium	Loamy sand
Hireng	66	0.64	6.2	Medium	Low	Medium	High	High	Loamy sand
Bone	67	0.64	5.7	Low	Medium	Medium	Very high	Medium	Sandy loam

(Elser *et al*., 2007; Harpole *et al*., 2011) and low P availability can constrain N_2 fixation (Wang *et al*., 2007; Vitousek *et al*., 2010). Medium to very high Potassium was observed in all the lakes which may be attributed to the leaching of potassium from the adjacent areas. The organic soil matter includes plant and other debris which varies depending on the rate of decomposition. The organic carbon content was medium to high in all the lakes except Shungatser Lake which is dissimilar to the observations of Das and Bindi (2014).

Conclusion

The findings show variations in the water quality and soil properties among the lakes of different altitude. Overall, the water quality of the lakes was good as per the standards of WHO and Bureau of Indian Standards (BIS). The water quality values of the lakes except Sela, Nagula and PTsho was found within the permissible limit of BIS (2012). The soil pH of most of the lakes except Kyalem and Mehao was recorded close to neutral (pH 5.7 to 6.9). The evaluation of general water quality and soil properties of the lakes reveals no pollution load and significant impact of anthropogenic activities. The aquatic organisms in the lakes were found to vary due to the altitudinal variation. The water samples of the lakes were found to be free from harmful pathogens with no psychrophillic bacterial population including (lichens and fungi). The present baseline findings can be a reference for further studies in managing the lakes of the Himalayan region for sustainable development.

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