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Physico-Chemical characteristics of Lakes of Chitwan National Park, Central Nepal

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ABSTRACT: Wetlands are the areas where water is the primary factor controlling the environment, associated plant and animal life. Present study had been conducted to investigate the physico-chemical characteristics of water. Five lakes, i.e. Tamor, Beeshazar, Kingfisher, Athaieshazar and Chepang of Chitwan National Park were studied during post-monsoon season. Four different sites were studied for each lake. Twelve replica of water samples were collected from each site of the lakes and physico-chemical parameters, i.e. pH, Temperature, DO, Total Alkalinity, Conductivity, Total Hardness, Nitrate, Inorganic phosphorus, Total Solid Matter and Free CO_2 were analyzed by using standard method of APHA, 2012. Data obtained from water analysis were analyzed by SPSS statistics 20. Higher value of nitrate was found in Beeshazar Lake i.e. 4.41±0.52 mg/L and higher value of inorganic phosphorus was found in Tamor Lake i.e. 2.93±0.29 mg/L. All the studied lakes showed hyper-eutrophic category on the basis of nitrate and phosphorus concentration. Runoff of polluted water with agricultural fertilizers, pesticides and untreated industrial discharge as well as domestic wastes from Khageri canal and excessive growth of invasive macrophytes are major threats of studied lakes.

Keywords: Hyper-eutrophic, Invasive, Macrophytes, Physico-chemical Characteristics.

INTRODUCTION

Wet lands have been described as "*the kidneys of the landscape*" and as "*biological super markets*" and thus are known as one of the world's most productive environments (Barbier *et al*., 1997). They help in flood protection; improve water quality by buffering sediments, nutrients and contaminants coming from inflowing waters; support local and migratory animals and provide a wide variety of foods (Groom *et al*., 2006).

Mostly the quality of an aquatic ecosystem is dependent on the physical and chemical qualities of water (Kunwar and Devkota, 2012). Temperature is basically important for its effect on the chemistry and biological reactions in the organisms in water and important in the determination of various other parameters such as pH, conductivity and various forms of alkalinity (Trivedy and Goel, 1986).

Both nitrogen and phosphorus are of greater concern because they limit the amount of plant growth in lake (Gupta, 2000). Phosphate is considered to be the most significant among the nutrients responsible for eutrophication of the rivers (Suma and Rajeshwari, 2013). Trophic state of a lake can be considered on the basis of nutrient concentration in the lake water (Table 1).

Alkalinity is mostly caused by the presence of carbonates, bicarbonates and hydroxides produced by rock (Fisheries Research Center, 1994). Hardness is a measure of calcium and magnesium ions.

Table 1: Trophic status of lakes according to Forsberg and Ryding (1980).

Total Nitrogen (µg/L)	Total Phosphorus (µg/L)	Trophic status
<400	<15	Oligotrophic
400 – 600	15 – 25	Mesotrophic
600 – 1500	25 – 100	Eutrophic
>1500	>100	Hypereutrophic

Hardness is expressed as calcium carbonate (mg/L), with soft water ranging from 0-75 mg/L and hard water from 150-300 mg/L (Fisheries Research Center, 1994). Free CO_2 dissolved in water is the only source of carbon that can be used in photosynthetic activity of aquatic autotrophs (Gupta, 2000). The sufficient supply of dissolved oxygen (DO) is one of the most important components necessary for a normal aquatic community and it is a single limnological parameter that speaks about health of tropic status and productivity of a biotic system (Awasthi and Tamot, 2010; Saleem *et al.* 2013).

Nepal's wetlands are facing degradation primarily due to eutrophication and land reclamation. These are critically threatened by the effects of anthropogenic activities such as deforestation, unregulated hunting, dam construction, and increased pollution due to discharges of untreated effluents and runoff from agricultural fields (Joshi *et al.*, 2001). Monitoring water quality parameters is very important to determine the actual limnological status of wetlands (Pradhan, 1998).

The wide spread growth of alien invasive species has almost covered the wetland area causing habitat modifications that might have affected water quality and might have altered structure and functions of aquatic system that support rare and endangered plants and animals species. Lakes with the highest rate of overgrowth were characterized by a high content of nitrogen as well as with high concentration of potassium (Lawniczak-Malinskaand Achtenberg, 2018). Numerous researches had been conducted to study the ecology of Beeshazar Lake but other lakes have not been much explored ecologically. The findings created a database for current pollution status and water quality of five different lakes of Chitwan National Park, which can be used for the management of these lakes as well as to study the impact on water quality.

MATERIALS AND METHODS

A. Study Area

Chitwan National Park (Latitude 27˚37'0"N and Longitude 84˚25'59"E) lies in the Central Nepal with core area of 932 km² and a Buffer zone of 750 km². Its elevation ranges from 150 m to 815 m above mean sea level and represents an inner Doon Valley. The park is about 160 km from capital city (Kathmandu). Kasara and Sauraha (main entry point) are 24 km and 18 km far from Bharatpur airport respectively. The studied lakes fall in the tropical climate region and are dominated by a summer monsoon climate. The monsoon begins in late June and continues until early October and brings nearly 80% of the rainfall. The average annual rainfall is 2600 mm and maximum rainfall is 452 mm and the average annual atmospheric temperature varies 23.98˚C (Fig. 1). It has typical sub-tropical vegetation. The main surrounding forest is dominated by *Shorea robusta* and prominent associated invasive vegetation include *Eichornia crassipes*, *Pistia stratiotes*, *Leersia hexandra*, *Alternanthera sessilis*, *Ageratum conyzoides*, *Chromolaena odorata*, *Ipomoea carnea* ssp. *Fistulosa* (Management Plan CNP, 2015).

Among five studied lakes, Tamor Lake lies South of Kasara Headquarter (within the core area of national park) and far away from the human settlement areas. Beeshazar, Kingfisher, Athaieshazar and Chepang Lakes are situated within Barandabhar forest. These Lakes are located in an area of high urban density and near the human trail area and are an integral part of the Khageri Canal. Location of the all studied lakes can be seen in Fig. 2.

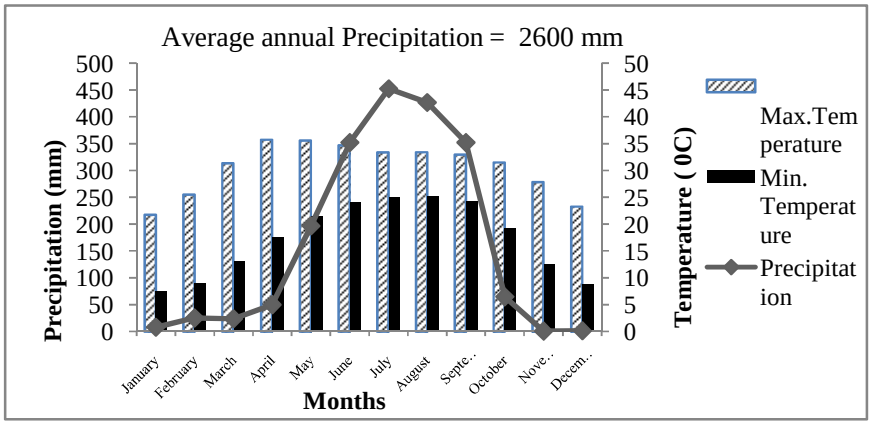


Fig. 1. Temperature and Precipitation of Rampur Meteorological Station, 2007-2016.

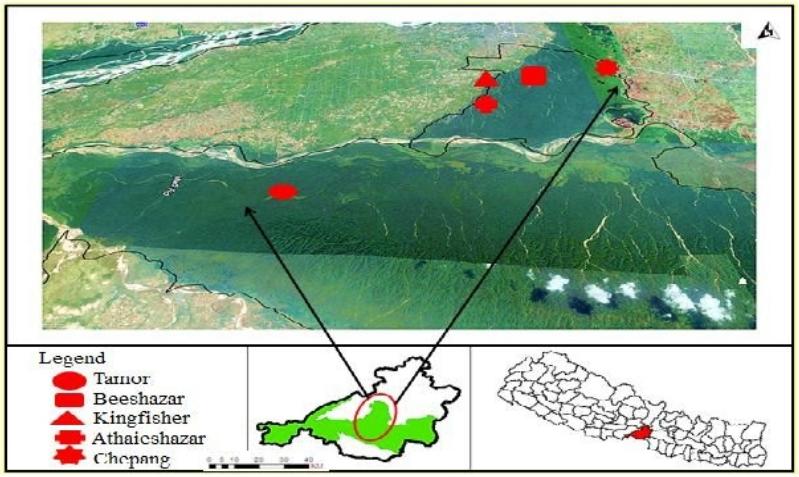


Fig. 2. Location Map of Studied Lakes.

B. Sampling

Water samples at the depth of 0.5 m were collected into twelve sampling bottles from each study site. Altogether, 48 water samples were collected from each lake. Water temperature with the help of mercury thermometer of -10 to 50°C with 0.2°C least count and pH with the help of Pocket- sized pH meter (Model- "pH 009" with accuracy of ± 1) were measured on the spot. Water samples for dissolved oxygen were fixed by adding 2 ml manganous sulphate and 2 ml alkakine iodide (APHA, 2012). Water sample was brought to the laboratory by keeping in an ice box and free carbon dioxide, total hardness, total alkalinity, dissolved oxygen, nitrate as total nitrogen, inorganic phosphorus, total solid matter and conductivity were determined immediately following APHA (2012) in ecology laboratory of Central Department of Botany. Table 2 shows the methods and instruments used for determination of physio-chemical parameters.

Table 2: Methods (APHA, 2012) and Instruments used for determination of physico-chemical parameters.

Parameters	Methods	Instruments
Temperature	—	Mercury Thermometer
pH	—	pH-Meter (model-pH 009)
DO	Winkler's Iodometric Method	—
Free CO_2	Phenolphthalein-Titration	
Total Hardness	EDTA Method	—
Total Alkalinity	Acid-Base Titration	—
Total Solid Matter	Complete Evaporation Method	—
Conductivity	-	Conductivity meter (model 191)
Nitrate	Phenol Disulphonic acid method	Spectrophoto-meter (spectronic 21, Milton Roy Company)
Inorganic Phosphate	Ammonium Molybdate Solution Method	Spectrophoto-meter (spectronic 21, Milton Roy Company)

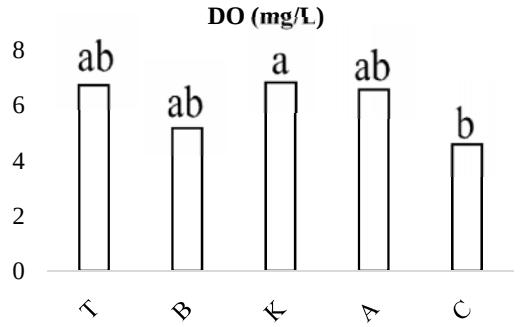
RESULTS

The results of the physico-chemical parameters of studied lakes explained the different values recorded for different parameters during the study period. The overall mean (±standard deviation) value for DO (5.95±0.27 mg/L), inorganic phosphorus (2.46±0.08 mg/L), total hardness (77.3 ± 4.43 mg/L), free CO_2 (89.73 ± 4.15 mg/L), total alkalinity (79.17±5.02 mg/L), nitrate (3.41±0.26 mg/L), total solid matter (340.00±22.45 mg/L), conductivity (66.07±6.07 µS/cm), pH (7.34±0.09) and temperature (28.55±0.31˚C) were found significantly different (p<0.05) among the studied five lakes except for the mean value of total solid matters (p=0.092) (Table 3).

Table 3: Mean (± SD) value of physico-chemical parameters of water of lakes. Bold letters indicates highest value) (Chi-square value (χ2) and significance value (p) were obtained by Kruskal Wallis test).

Parameters/Lakes	Tamor	Beeshazar	Kingfisher	Athaieshazar	Chepang	Average	χ^2	d f	*P*
DO (mg/L)	6.71±0.30	5.16±0.78	**6.79±0.48**	6.54±0.42	4.56±0.63	5.95±0.27	12.47	4	0.014
Inorganic phosphorous (mg/L)	**2.93±0.29**	2.50±0.15	2.15±0.08	2.65±0.08	2.07±0.14	2.46±0.08	12.62	4	0.013
Total Hardness (mg/L)	60.5±3.03	53.5±3.43	81.33±7.93	**133.5±2.48**	57.66±5.90	77.3±4.43	35.40	4	0.001
Free CO_2 (mg/L)	69.75±4.78	70.92±4.95	86.73±4.01	**142.00±7.18**	79.24±4.36	89.73±4.15	32.98	4	0.001
Total Alkalinity (mg/L)	74.17±5.96	62.50±2.18	53.33±5.12	**147.50±6.76**	58.33±3.22	79.17±5.02	34.10	4	0.001
Nitrate (mg/L)	3.84±0.60	**4.41±0.52**	1.91±0.08	2.74±0.10	4.16±0.84	3.41±0.26	12.21	4	0.016
Tota Solid Matter (mg/L)	233.33±22.47	350.0±55.73	**433.33±59.46**	350.00±43.5	333.33±51.25	340.0±22.45	8.00	4	0.092
Conductivity (µS/cm)	57.05±7.05	48.49±8.49	49.58±9.58	**129.72±45.5**	45.50±5.90	66.07±6.07	42.30	4	0.001
pH	**8.48±0.15**	7.38±0.15	6.80±0.03	7.23±0.04	6.80±0.04	7.34±0.09	45.83	4	0.001
Temperature (˚C)	29.25±0.13	**30.25±1.03**	27.00±0.37	29.00±0.74	27.25±0.25	28.55±0.31	24.99	4	0.001

The highest and lowest value for DO was found in Kingfisher (6.79±0.48 mg/L) and Chepang (4.56±0.63) respectively (Fig. 3) and the highest values for total hardness was found in Athaieshazar (133.5±2.48 mg/L) and lowest values was in Beeshazar (53.5±3.43 mg/L) (Fig. 4).



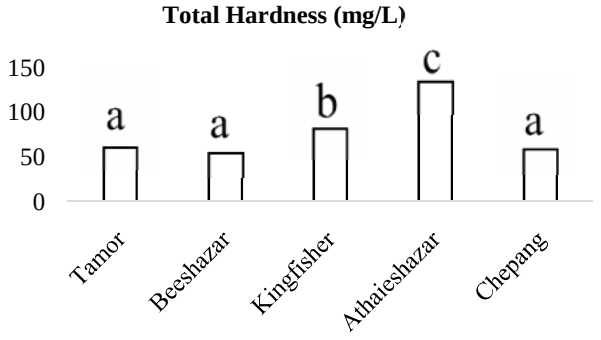
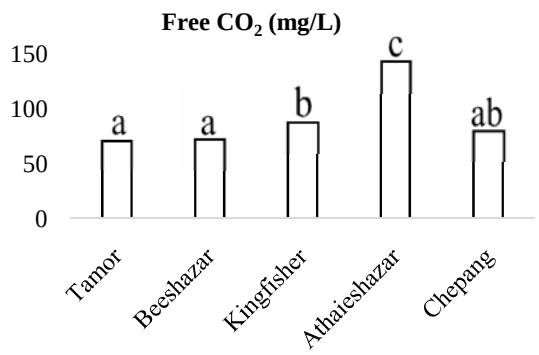


Fig. 3. DO values for studied lakes.

Fig. 4. Total Hardness values for studied lakes.



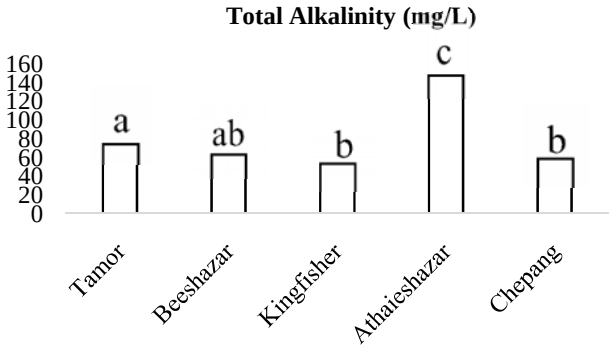
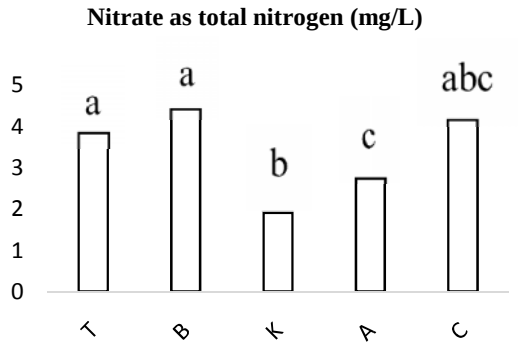


Fig. 5. Free CO_2 values for studied lakes.

Fig. 6. Total Alkalinity values for studied lakes.

The highest value of free CO_2 and total alkalinity were found in Athaieshazar (142.00±7.18 mg/L and 147.50±6.76 mg/L) and lowest values for these were found in Tamor (69.75±4.78 mg/L) and Kingfisher (53.33±5.12 mg/L) respectively (Fig. 5 and 6).

The highest and lowest value for nitrate was found in Beeshazar (4.41±0.52 mg/L) and Kingfisher (1.91±0.08 mg/L) and the highest and lowest value for inorganic phosphorus was found in Tamor (2.93±0.29 mg/L) and Chepang (2.07±0.14 mg/L) (Fig. 7 and 8).



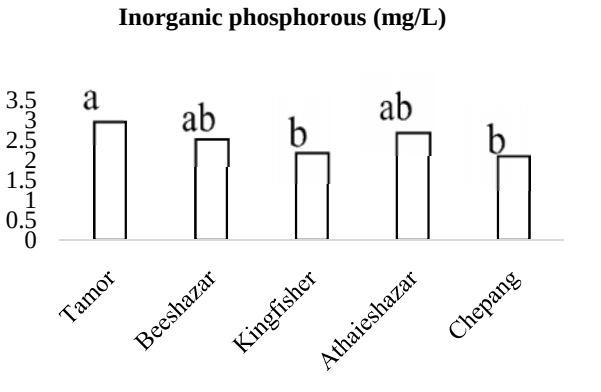


Fig. 7. Nitrate values for studied lakes.

Fig 8. Inorganic phosphorus values for studied Lakes.

The highest values for total solid matter, conductivity, pH and temperature were found in Kingfisher (433.33±59.46 mg/L), Athaieshazar (129.72±45.50 µS/cm), Tamor (8.48±0.15) and Beeshazar (30.25±1.03˚C) respectively and the lowest values for these parameters were found in Tamor (233.33±22.47 mg/L), Chepang (45.50±5.90 µS/cm), Kingfisher (6.80±0.03) and Kingfisher (27.00±0.37˚C) (Fig. 9-12).

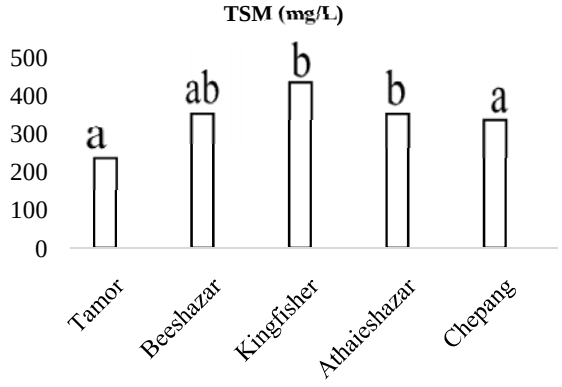


Fig. 9. TSM values for studied lakes.

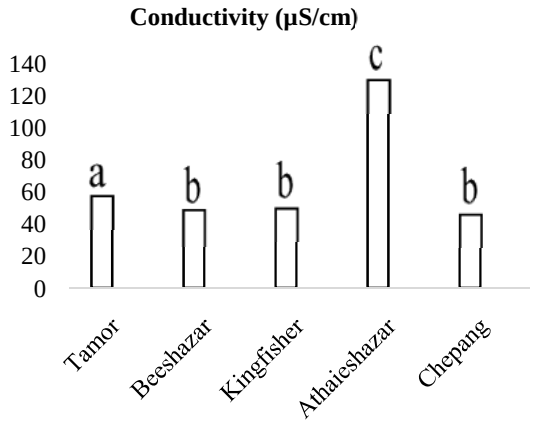


Fig. 10. Conductivity values for studied lakes.

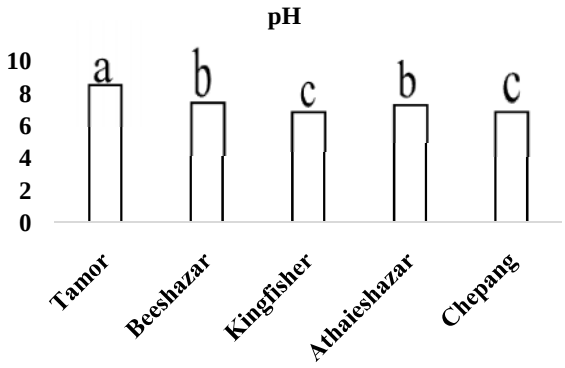


Fig. 11. pH values for studied lakes.

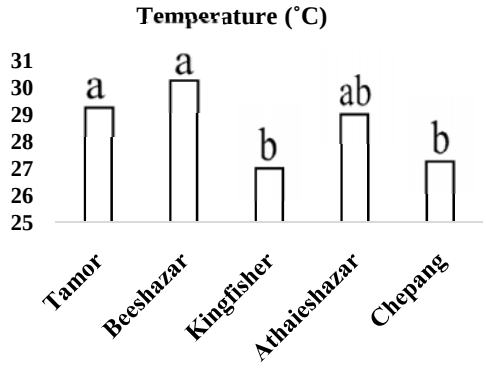


Fig. 12. Temperature values for studied lakes.

(**Note**: for each parameters significant differences between lakes are indicated by different superscript letter).

Table 4: Spearman correlation coefficient values between Physico-chemical Parameters.

	DO	Totl_Hrdn	Free_CO_2	Totl_alka	Nitrate	Pi	TSM	Cond	pH	Temp
DO	1.000									
Totl_Hrdn	0.473**	1.000								
Free_CO_2	0.037	0.499**	1.000							
Totl_alka	0.254*	**0.554****	0.414**	1.000						
Nitrate	-0.082	**-0.110**	**-0.244**	0.246	1.000					
Pi	0	0.401**	-0.018	0.326*	0.445**	1.000				
TSM	0.304*	0.446**	0.108	0.143	-0.062	0.070	1.000			
Cond	0.393**	**0.683****	0.385**	**0.730****	0.141	0.415**	0.109	1.000		
pH	0.145	0.114	-0.199	0.468**	0.341**	0.412**	**-0.134**	0.449**	1.000	
Temp	0.152	-0.030	-0.156	0.150	0.057	0.326*	-0.011	0.233	**0.572****	1.000

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

(DO= Dissolved Oxygen, Totl_Hrdn= Total Hardness, Totl_alka= Total Alkalinity, Pi= Inorganic phosphorus, TSM= Total Solid Matter, Cond= Conductivity, Temp= Temperature)

Total hardness showed strong positive correlation with total alkalinity and conductivity. Total alkalinity showed positive correlation with conductivity and pH showed positive correlation with temperature. Strong negative correlation of total hardness and free CO_2 with nitrate and total solid matter with pH (Table 4).

DISCUSSION

All the studied lakes showed hyper-eutrophic category for nitrate and phosphorus concentration on the basis of trophic level proposed by Forsberg and Ryding (1980). There was significant difference (p=0.014) in DO value among studied lakes. Highest mean DO value of Kingfisher Lake may be due to low temperature with high aeration rate (Burlakoti, 2003; Bashir *et al.* 2018). Similar observation for DO value was also made by Mustapha (2008) in water of Oyun Reservoir, Nigeria. Lower DO value in Chepang revealed the increase in organic pollution and die-off and decomposition of submerged plants might have contributed to low dissolved oxygen (www.pca.state.mn.us).

Phosphorus plays an important role in the development of aquatic plants (Martin, 1987) and considered as the limiting factor of eutrophication in temperate lakes

(Vollenweider *et al.*, 1980). Higher value of inorganic phosphorus was found in Tamor Lake, it may be because of the runoff water could carry phosphorous from forest (Bhattarai *et al.*, 2008) as Tamor Lake is located in an area of low urban density and core area of CNP. High value might also be due to natural disasters like flooding. Lower value in Chepang Lake may be due to the high rate of consumption by macrophytes and algae (Pandey and Devkota 2016). Higher value of nitrate was found in Beeshazar Lake which may be due to runoff of polluted water with agricultural fertilizers, pesticides and untreated industrial discharge as well as domestic wastes (Burlakoti, 2003; Suma and Rajeshwari, 2013; Bashir *et al.* 2018; Haile and Mohammed, 2019) and also may be due to higher microbial decomposition. Similar observation for nitrate value was also made by Haile and Mohammed (2019) in Lake Hawassa, Ethiopia. The lower value of nitrate in Kingfisher Lake, may be due to lower microbial activities as it had lower temperature as compared to other studied lakes. Highest total hardness value among studied lakes was found in Athaieshazar (133.5±2.48 mg/L). More similar value was found in summer by Choudhary *et al.*, (2014) Ponds of Sasaram and Burlakoti (2003) Beeshazar lake. The contents released from the dead moluscan shell (mostly snail) may increase total hardness (Khan and Chowdhury, 1994) and low release of calcium and magnesium ions from sediments and rocks (Jinwal and Dixit, 2008) in lake water might have decreases the value in Beeshazar Lake.

The free carbon dioxide concentration depends on the respiration of plants and photosynthesis rate (Choudhary *et al*., 2014). In the present study, the increase in free carbon dioxide in Athaieshazar can be attributed to the favourable temperature (Sukhija, 2007). CO_2 production was less in Tamor Lake which might be due to slow decomposition of organic matter (Patra *et al*., 2010). The water temperature in the present study ranged from 25˚C to 36˚C. pH value ranged from 4.5 to 8.3, which indicated that all the studied lakes had practically no carbonates (Jhingran, 1975) and total alkalinity in studied five lakes was only due to the functions of bicarbonates. Highest total alkalinity among studied lakes was found in Athaieshazar. Similar value was obtained in Beeshazar Lake in rainy season by Burlakoti (2003). The degradation of plants as well as other organism might be one of the reasons for increase in bicarbonate and thus the alkalinity (Chaurasia and Pandey, 2007). And Kingfisher Lake had lowest value of total alkalinity. Total alkalinity showed strong positive correlation with conductivity in the present study. Total solid matter (433.33±59.46 mg/L) was higher in Kingfisher Lake, which was found to be greater than Pravas Lake (223.65±115.7 mg/L; Ghimire, 2007), Beeshazar lake (350.22±254.07 ppm; Burlakoti, 2003), Ponds of Sasaram, Bihar (172 ppm; Choudhary *et al*., 2014) and Taudaha Lake (272.74±4.62 ppm; Bhatt *et al.*, 1999). As the Kingfisher Lake is situated near residential area of Tikauli, the high value of TSM in the lake might be due to addition of domestic waste water, garbage and sewage etc. in the natural surface water of lake from nearby residential area. And lower value of TSM (233.33±22.47 mg/L) was found in Tamor Lake among studied lakes as it is situated in low urban density area.

Conductivity value was found to be high in Athaieshazar lake which might be due to ionic concentration or dissolved inorganic substances (Mathur *et al*., 2008) present in the lake. The low conductivity in Chepang Lake might be responsible for the soft nature of the water (Mustapha, 2008) and also due to the high uptake of the ions by organism for their metabolism (Mustapha and Omotosho, 2005).

CONCLUSION

In conclusion, studied two lakes, i.e. Kingfisher and Athaieshazar had moderately hard water (i.e. hardness values ranges between 75-150 mg/L) whereas other three lakes, i.e. Tamor, Beeshazar and Chepang had soft water (i.e. hardness values ranges between 0-75 mg/L). Present study showed three lakes, i.e. Tamor Lake, Kingfisher Lake and Athaieshazar Lake had good water quality and two lakes, i.e. Beeshazar Lake and Chepang Lake had poor water quality in terms of DO. Variations on the physico-chemical characteristics of lakes implies the cumulative effect of excessive growth of the invasive macrophytes, high human and wild animal's disturbances as well as natural disasters. Richness in total nitrogen and phosphorus ranked all the studied lakes hyper-eutrophic. Runoff of polluted water with agricultural fertilizers, pesticides and untreated industrial discharge as well as domestic wastes from Khageri canal and excessive growth of invasive macrophytes are major threats of studied lakes. Therefore, the recognition of mechanisms of lake overgrowth and the chemistry of waters among lakes is crucial for proper assessment of water bodies, as well as planning protective activities and their management.

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Conflict of Interest. No.

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