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WATER CHEMISTRY OF A TECTONIC LAKE OF ASSAM WITH REFERENCE TO PRIMARY NUTRIENTS

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AUTHORS' CONTRIBUTIONS

The work was carried out in collaboration among all authors. Authors SSG and PD designed, wrote the protocol and performed the study. Authors SSG and PD wrote the first draft of the paper. Author KS guided the study and provided inputs for the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out to study the variations of the physicochemical properties and primary nutrient parameters of Chandubi Lake, a tectonic lake. Water quality parameters such as water temperature, dissolved oxygen, free carbon dioxide, pH, total hardness, total alkalinity, total carbon, bicarbonate ion and primary nutrients nitrate, orthophosphate and potassium were estimated. The study revealed low levels of total hardness and total alkalinity which is unique in the present investigation for the state of Assam. The presence of free carbon dioxide was recorded throughout the study period indicating the absence of carbonate alkalinity in all zones of Chandubi Lake. The investigation also revealed that the nutrient input in Chandubi Lake is of autochthonous origin. ANOVA (p = 0.05) revealed that there were significant difference in water quality parameters dissolved oxygen (DO), total carbon dioxide (CO_2), total hardness (TH) and primary nutrient orthophosphate among the studied zones. The Pearson correlation (p = 0.05) showed that, water temperature has a negative correlation with DO (r = - 0.72), pH (r = - 0.64), dissolved oxygen (DO) has a negative correlation with free carbon dioxide (FCO_2) (r = -0.91) and potassium (K) (r = - 0.86), while having a positive correlation with nitrate (NO_3) (r = 0.71) and free carbon dioxide (FCO_2) having a negative correlation with pH (r = - 0.90). The overall water quality condition was found to be excellent, which was evident from WQI (< 25%).

Keywords: Physicochemical parameters; primary nutrients; tectonic lake; chandubi; autochthonous; water quality index.

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1. INTRODUCTION

Water covers, 70% of the Earth's surface of which, only 2.5% freshwater, of which 68.7% is perpetually locked in as ice and 29.9% is groundwater. About 0.26% of liquid freshwater on Earth is in lakes, reservoirs, and rivers [1]. The Northeastern region of India has an enormous and diverse array of freshwater bodies in the form of lotic ecosystems especially rivers, lentic ecosystems like reservoirs, beels, lakes, swamps, pond and mini barrage and low lying paddy cum fish culture [2]. Assam, the second largest state of Northeast India, lying in the Indo-Burma biodiversity hotspot is also rich in aquatic resources, having high faunal diversity supported by sub-tropical climate, ecological and geographical conditions along with auto-stocking capacity [3]. These fresh water ecosystems are always in a state of flux due to climate change, aquatic invasive species, land use changes and increasing chemical input due to anthropogenic activities. All these leads to changes in physicochemical properties of the water body, which ultimately influences the structure and functions of aquatic biota [4,5]. Therefore, regular monitoring of the dynamics of physicochemical parameter of the water body becomes essential in understanding the aquatic ecosystem. The present study was carried out to understand the dynamics of the physicochemical parameters of Chandubi Lake, a tectonic lake of Assam which was created by the devastating earthquake of 1897 in Shillong plateau. Information produced in this study were exposed to multivariate statistical analysis to assess and explain temporal and spatial variations in ecological factors of water brought about by regular and anthropogenic elements. Chandubi Lake is one of the most important aquatic body of the South Kamrup region of Assam. It is a popular tourist destination and a source of livelihood for the indigenous Rabha tribe that reside around the lake.

2. METHODOLOGY

2.1 Study Area

The study was carried out from March 2019 to February 2020 in Chandubi Lake. The Southern Kamrup region of Assam is rich in flood plain wetland diversity, with Chandubi Lake being one of the three most important water bodies in the region, the other two being Dora and Salsala wetlands. Surrounded by the states of Assam and Meghalaya, Chandubi Lake is located at foothills of Garo hills (Latitude 25.8815° N and Longitude 91.4235° E). Chandubi Lake, a tectonic lake was formed by devastating earthquake of 1897, during which the forest went down and became the lake. The climate is moderate and humid with most rainfall during monsoon (May-Sept.). Chandubi Lake is located on the central part of the Kulsi catchment, where it is connected to Kulsi River by a channel on the south-western part of the lake boundary. Presently, the lake receives water from the surrounding catchment during the monsoon through 2nd and 3rd order streams dominantly from the southern flank of the hills [6]. It is quite interesting to note that, the lake instead of receiving water from the river, is contributing to the river discharge through a spill-over channel known as Lokai Jan originating from the south-western margin of the lakes flowing towards north-west [6]. Between the years 1911–1913 and 2002, the Chandubi Lake has shrinked in its water holding capacity from 10.23 to 1.19 km^2 loosing 88.36% of its water spread [7].

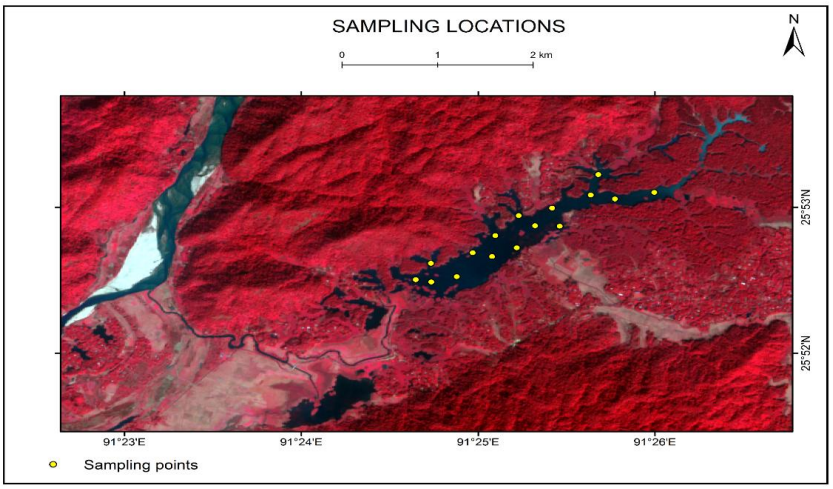

Fig. 1. Map of Chandubi Lake with locations of sampling zone

2.2 Physicochemical Parameters

Monthly water samples of the surface layer were collected at the sampling points following Jhingran et al., [8]. The water samples were collected in the morning hours between 8.00 A.M. to 8.30 A.M. The parameters were analyzed following "Standard Methods for Examination of Water and Waste Water", A.P.H.A., [9] and "Manuals on Water and Waste Water Analysis", N.E.E.R.I., [10].

2.3 Water Quality Index (WQI)

Water quality index of Chandubi Lake water was calculated by weighted arithmetic index method (Brown *et al.* 1972) [11] and the formula is given below

$$WQI = \frac{\sum q_n W_n}{\sum W_n}$$

Where,
$q_n = 100 [(Vn-Vio) / (Sn-Vio)]$
qn = Quality rating for the nth water quality parameter. Vn = Estimated value of the nth parameter at a given sampling station. Sn = Standard permissible value of the nth parameter. Vio = Ideal value of nth parameter in pure water. i.e., 7.0 for pH, 9.2 $mg.l^{-1}$ at 20^0C for DO and 0 for all other parameters

2.4 Statistical Analysis

The statistical analysis were performed in PAST statistical software version 4.03. One-way analysis of variance (ANOVA) followed by Tuckeys' HSD (A) post-hoc test was employed to find out the differences in physicochemical parameters among the studied zones of the lake. Pearson's correlation was used to assess the relationship between different water quality parameters.

3. RESULTS AND DISCUSSION

The seasonal fluctuations of the physicochemical parameters and primary nutrients in four zones, Zone A, Zone B, Zone C and Zone D from March 2019 to February 2020 are presented in Table 1; Fig 2 to 9 and Table 2; Fig 10 to 12 showing their respective ranges, mean and SD.

The ANOVA revealed that there were significant difference in water quality parameters dissolved oxygen (DO) (f = 5.818, p = 0.05), total carbon dioxide (CO_2) (f = 2.87, p = 0.05), total hardness (TH) (f = 4.156, p = 0.05) and primary nutrient orthophosphate (f = 2.87, p = 0.05) among the studied zones. The Pearson correlation (p = 0.05) showed that, water temperature has a negative correlation with DO (r = - 0.72), pH (r = - 0.64), dissolved oxygen (DO) has a negative correlation with free carbon dioxide (FCO_2) (r = -0.91) and potassium (K) (r = - 0.86), while having a positive correlation with nitrate (NO_3) (r = 0.71) and free carbon dioxide (FCO_2) having a negative correlation with pH (r = - 0.90).

The seasonal variation of water temperature is depicted in (Fig. 2). The water temperature and its seasonal variation have a great impact on the ecology and productivity as witnessed in the wetlands of Assam [12,13]. During the study it was observed that, the differences of water temperature is not well marked. Zone A have a tendency towards increased water temperature than other zones, while in Zone B, lower temperature has been recorded throughout the study period. The water temperature ranges from 33℃ to 21℃ and average of 26.74 ± 3.84 ℃ in Zone A, 30℃ to 18℃ with an average of 24.78 ± 4.09 ℃ in Zone B, 31.5℃ to 19.8℃ having an average of 26.08 ± 3.74 ℃ in Zone C and 32℃ to 19.5℃ with an average 26.18 ± 3.99 ℃ in Zone D. The higher temperature recorded in Zone A may be due to the presence of submerged macrophytes (*Hydrilla verticillata and Utricularia vulgaris)* present in high density. This same phenomenon is recorded in Zone C which also has a higher density of submerged macrophytes. Submerged macrophytes dissipates heat to the surrounding aqua media thereby increasing the water temperature [14, 15].

The trend of DO in the studied zones of Chandubi Lake is depicted in Fig. 3. The DO exhibit higher range of fluctuations in all zones. The range in Zone A, 5.7 $mg.l^{-1}$ to 10.3 $mg.l^{-1}$ with an average of 8.29 ± 1.63 $mg.l^{-1}$ is maximum than the other zones. However, lower range of fluctuations is maintained by Zone C with an average of 6.69 ± 0.90 $mg.l^{-1}$. In the present investigation, the DO was found to be mainly contributed by dense submerged macrophytes and sparsely distributed phytoplankton as the water is found to be clear. The higher DO recorded from October to April and lower from May to September may be due to the effect of water temperature, decomposition and vegetative growth of macrophytes [16]. The higher DO recorded in October to April indicates a negative correlation with temperature (r = - 0.72) as lower temperature increases solubility of dissolved oxygen and causes less degradation of organic substances [17,18,19]. The free carbon dioxide (FCO_2) concentration in all zones of Chandubi are presented in Fig. 4. FCO_2 act as a limiting factor and total carbon dioxide (CO_2) is a

stimulating factor in productivity [20]. The FCO_2 ranges from 2.5 mg.l^{-1} to 7.5 mg.l^{-1} with an average of 4.42 ± 1.65 mg.l^{-1} in Zone A; 3.5 mg.l^{-1} to 12.0 mg.l^{-1} with an average of 6.67 ± 2.87 mg.l^{-1} in Zone B; 4.5 mg.l^{-1} to 14.0 mg.l^{-1} with an average of 7.50 ± 2.84 mg.l^{-1} in Zone C and 3.5 mg.l^{-1} to 16.0 mg.l^{-1} with 7.0 ± 3.89 mg.l^{-1} in Zone D. The present study exhibit low concentration of FCO_2, which may be attributed to its quick utilization by autotrophs [21] and its presence throughout the year. In monsoon months, rain water enhances FCO_2 [22] but it is subsequently balanced through its utilization by the photosynthetic activity of submerged macrophytes. The presence of free carbon dioxide throughout the study period indicates the absence of carbonate alkalinity in all zones of Chandubi Lake. It is also observed that concentration of total carbon dioxide (CO_2) (Fig. 5) lies from 14.62 mg.l^{-1} to 34.62 mg.l^{-1} in Zone A, 19.44 mg.l^{-1} to 29.0 mg.l^{-1} in Zone B, 22.60 mg.l^{-1} to 38.64 mg.l^{-1} in Zone C, and 23.86 mg.l^{-1} to 30.74 mg.l^{-1} in Zone D. Regarding bicarbonate ion (HCO_3^-) (Fig. 6), Zone A experiences massive fluctuations with an average of 26.23 ± 10.97 mg.l^{-1} with the least fluctuations shown by Zone D with an average of 27.86 ± 1.67 mg.l^{-1}. The total CO_2 is less in Zone A, is a result of high photosynthetic activity of macrophytes. There is no carbonate ion recorded in the present study and bicarbonate ion (HCO_3^-) is found to be maximum in Zone C as a result of high decomposition rate of macrophytes as the zone is shallow.

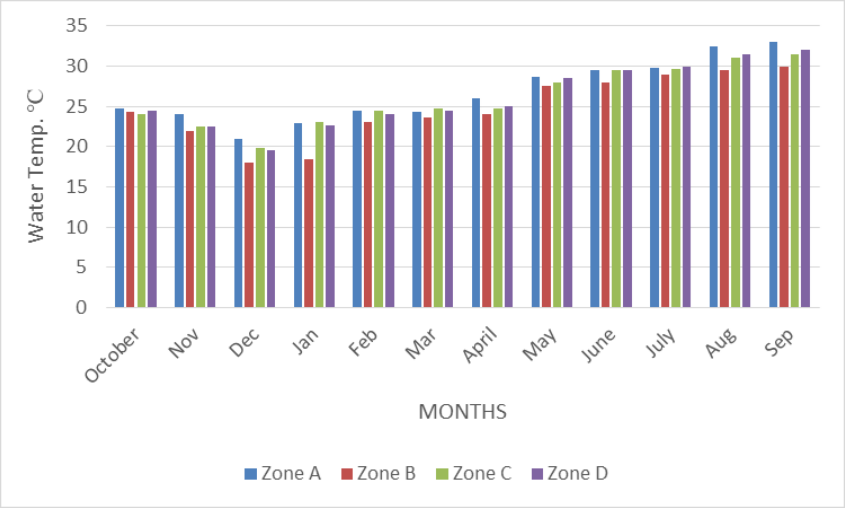

Fig. 2. Fluctuations of water temperature among different zones of the lake

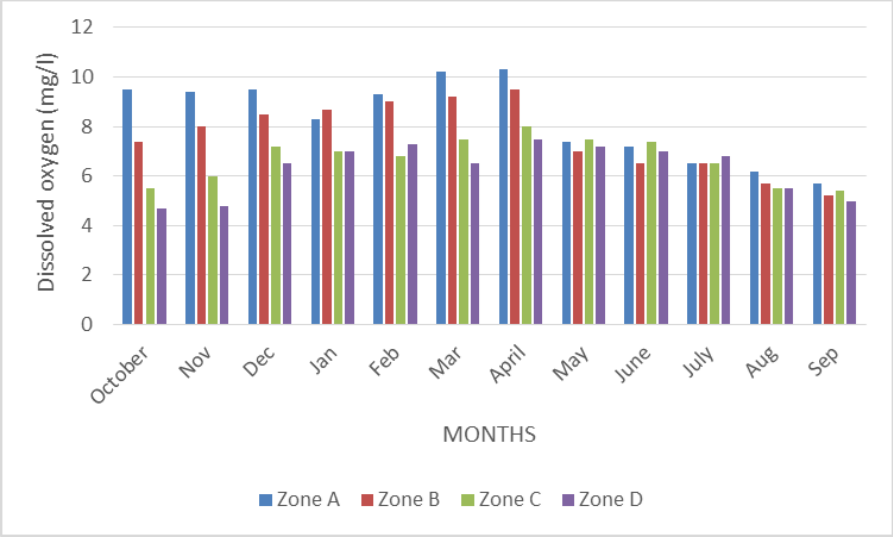

Fig. 3. Fluctuations of dissolved oxygen among different zones of the lake

Table 1. Physicochemical parameters of Chandubi Lake, 2019 – 2020

Parameters	Zone A		Zone B		Zone C		Zone D	
	Range	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**
WT (℃)	21 – 33	26.74 ± 3.84	18 – 30	24.78± 4.10	19.8 – 31.5	26.08 ± 3.74	19.5 – 32.0	26.18 ± 3.99
DO ($mg.l^{-1}$)	5.7 – 10.3	8.29 ± 1.63	5.92 – 9.5	7.60 ± 1.43	5.4 – 8.0	6.69 ± 0.90	4.7 – 7.5	6.32 ± 1.03
FCO_2 ($mg.l^{-1}$)	2.5 – 7.5	4.42 ± 1.65	3.5 – 12.0	6.67 ± 2.87	4.5 – 14.0	7.50 ± 2.84	3.5 – 16.0	7.0 ± 3.89
CO_2 ($mg.l^{-1}$)	14.62 – 34.62	23.34 ± 6.67	19.44 – 29.0	23.34± 2.69	22.6– 38.64	29.24 ± 5.73	23.86 – 30.74	27.09 ± 3.83
HCO_3^- ($mg.l^{-1}$)	12.81 – 44.53	26.23 ± 10.97	15.25 – 30.5	22.98± 5.43	24.4 – 37.4	30.14 ± 4.52	24.4 – 30.5	27.86 ± 1.67
pH	6.13 – 7.9	7.05 ± 0.57	6.05 – 8.0	7.13 ± 0.65	6.1 – 6.75	6.75 ± 0.35	6.08 – 6.68	6.68 ± 0.48
TA ($mg.l^{-1}$)	10.5 – 36.5	21.50 ± 8.99	12.5 – 25.0	18.83± 4.45	20.0 – 30.5	24.71 ± 3.70	20.0 – 25.0	22.83 ± 1.37
TH ($mg.l^{-1}$)	5.0 – 35.0	15.88 ± 11.36	5.5 – 13.5	8.96 ± 2.86	10.0 – 25.0	15.67 ± 5.81	10.0 – 17.5	14.38 ± 2.18

WT = water temperature, DO = dissolved oxygen, FCO_2 = free carbon dioxide, TA = total alkalinity, TH = total hardness, CO_2 = carbon dioxide, HCO_3 = bicarbonate

Table 2. Primary nutrients of Chandubi Lake, 2019 – 2020

Parameters	Zone A		Zone B		Zone C		Zone D	
	Range	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**
NO_3^-($mg.l^{-1}$)	0.27 – 0.65	0.40 ± 0.10	0.27– 0.47	0.37 ± 0.06	0.20 – 0.50	0.36 ± 0.09	0.25 – 0.50	0.37 ± 0.09
PO_4^{3-}($mg.l^{-1}$)	0.05 – 0.23	0.10 ± 0.05	0.06– 0.16	0.11 ± 0.03	0.04 – 0.1	0.07 ± 0.02	0.05 – 0.12	0.08 ± 0.02
K ($mg.l^{-1}$)	1.85 – 5.1	3.14 ± 1.01	2.35 – 3.7	2.88 ± 0.41	2.0 – 4.0	2.81 ± 0.71	2.1 – 3.1	2.63 ± 0.34

NO_3^- = nitrate, PO_4^{3-} = orthophosphate, K = potassium

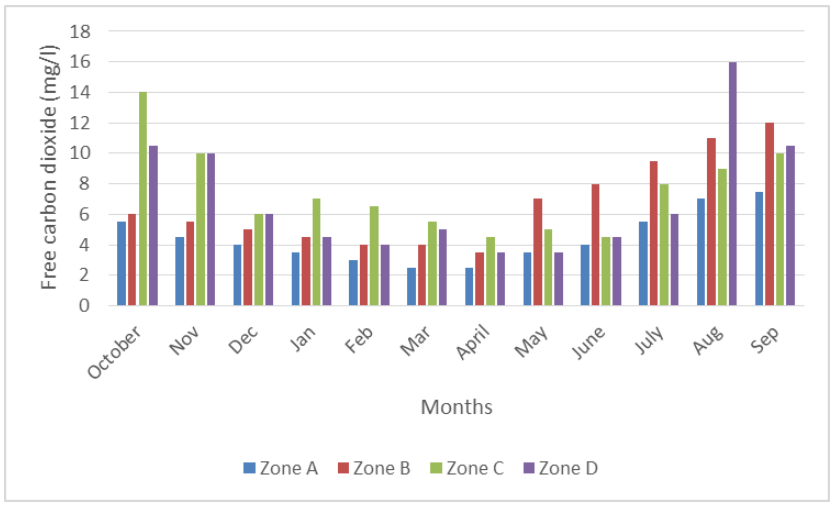

Fig. 4. Fluctuations of free carbon dioxide among different zones of the lake

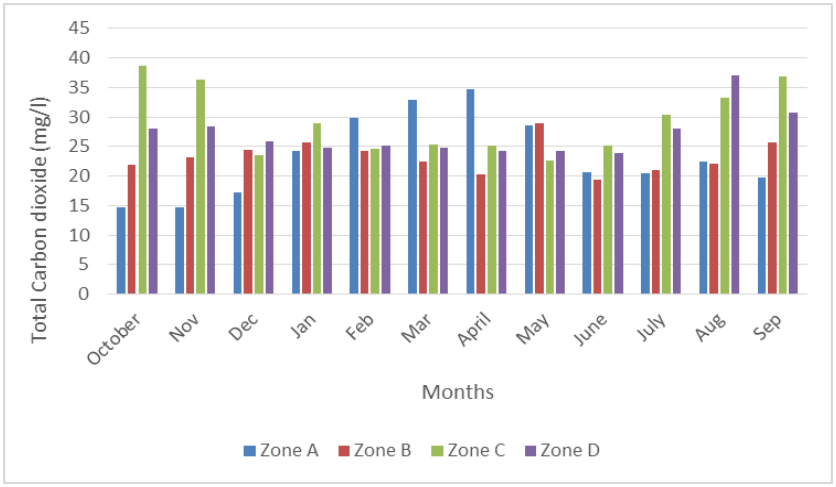

Fig. 5. Fluctuations of total carbon dioxide among different zones of the lake

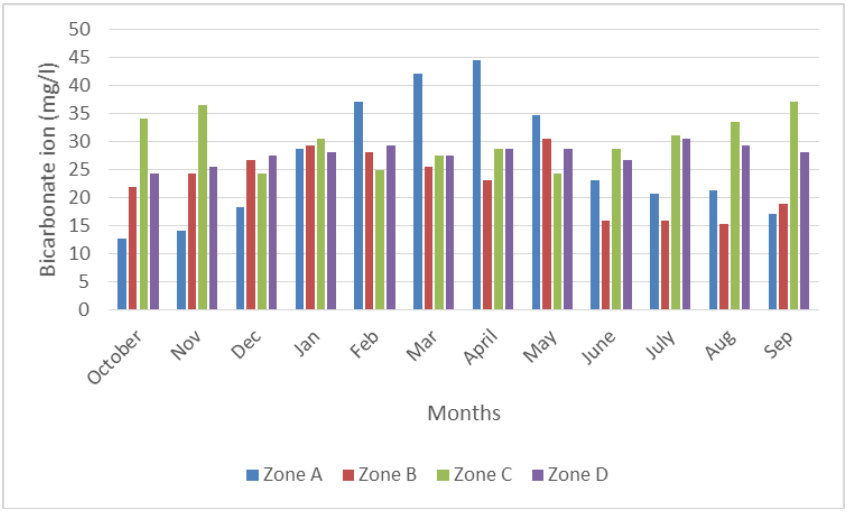

Fig. 6. Fluctuations of bicarbonate ion among different zones of the lake

The pH of the water in the studied year have been depicted in Fig. 7. pH has been found to have a profound effect on aquatic biota as, the metabolic activities are pH dependent [23]. The values of pH shows a fluctuating range between acidic to slightly neutral to alkaline with 6.13 to 7.9 in Zone A; 6.05 to 8.0 in Zone B; 6.1 to 6.75 in Zone C; 6.08 to 6.68 in Zone D. The lower range of pH recorded in all zones suggest acidic condition. The upper ranges are found in normal range [24]. The water of Zone B was found to be more alkaline than all the other zones, which may be due to high photosynthetic activity [25].

The total alkalinity (TA) trend is shown in Fig. 8. The TA fluctuation was recorded between 10.5 mg.l^{-1} to 36.5 mg.l^{-1} in Zone A; 12.5 mg.l^{-1} to 25.0 mg.l^{-1}; 20 mg.l^{-1} to 30.5 mg.l^{-1} in Zone C; 20.0 mg.l^{-1} to 25.0 mg.l^{-1} during the study period. However, it is interesting to note that in February to May, higher value of TA is recorded in Zone A and in October and November, Zone C shows an elevating trend. Total hardness (TH) (Fig. 9) fluctuates between 5 mg.l^{-1} to 35.0 mg.l^{-1} with an average of 15.88 ± 11.36 mg.l^{-1} in Zone A is quite interesting as the fluctuation is maximum. In Zone B and Zone D as depicted in Figure. show more or less the same trend of fluctuations. However in Zone C the TH fluctuation recorded with an average of 15.67 ± 5.81 mg.l^{-1}, is interesting. It is to be noted that throughout the study period, non-alkaline hardness was not recorded. The chemistry behind Chandubi lake having a low degree of total alkalinity (TA) and total hardness (TH) is very intriguing and interesting as such low values have not been recorded from other aquatic systems of Assam and it results from the non-blending of normal lotic water of the surrounding aquatic ecosystem (Kulsi river) with the lake water, alongside its rain-fed properties.

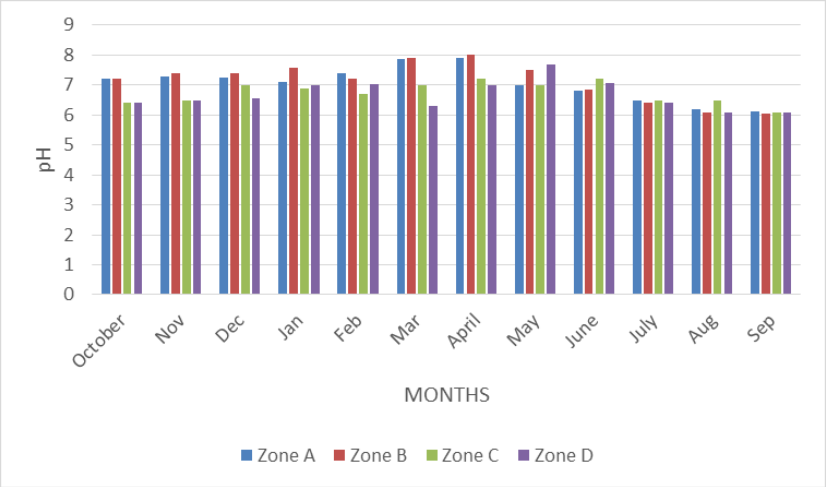

Fig. 7. Fluctuations of pH among different zones of the lake

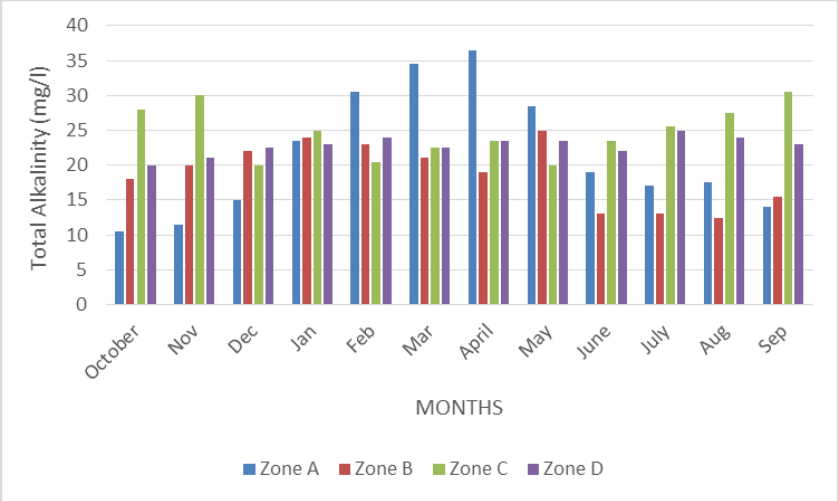

Fig. 8. Fluctuations of total alkalinity among different zones of the lake

The nutrient input in Chandubi lake has been observed to be chiefly of autochthonous origin. The monthly variations of the primary nutrients namely nitrate (NO_3^-), orthophosphate (P) and potassium (K) are shown in Fig. 10, Fig. 11 and Fig. 12 respectively. NO_3^- ranged from 0.27 mg.l^{-1} to 0.65 mg.l^{-1} with an average of 0.40 ± 0.10 mg.l^{-1} in Zone A; 0.27 mg.l^{-1} to 0.47 mg.l^{-1} with an average of 0.37 ± 0.06 mg.l^{-1} in Zone B; 0.20 mg.l^{-1} to 0.50 mg.l^{-1} having an average of 0.36 ± 0.09 mg.l^{-1} in Zone C and 0.25 mg.l^{-1} to 0.50 mg.l^{-1} with an average of 0.37 ± 0.09 mg.l^{-1} in Zone D. The fluctuations of the NO_3^- is mainly due to its building up during the decomposition period of macrophytes and its subsequent reduction due to its uptake by growing macrophytes and phytoplankton. Similar findings were also reported by Deka [16]. The phosphorous is found to be below optimum level in all seasons of the year with an average value of 0.10 ± 0.05 mg.l^{-1} in Zone A, 0.11 ± 0.03 mg.l^{-1} in Zone B, 0.07 ± 0.02 mg.l^{-1} in Zone C and 0.08 ± 0.02 mg.l^{-1} in Zone D being recorded. The sub-optimal level recorded during the investigation is a unique feature of Assam, with its soil being highly acidic in nature which locks available orthophosphate with the iron present in soil [26]. The potassium (K) shows a fluctuating range with the highest average value of 3.14 ± 1.01 mg.l^{-1} in Zone A, while rest of the zones showed a similar trend. This is due to the presence of *Eichhornia crassipes* in higher density which controls the dynamics of potassium (K) [16, 27, 28, 29].

The water quality index is a tool which provides a single number that convey the overall water quality of the selected sampling location of the water body based on different water quality parameters. WQI is useful in conveying complex water quality parameters by means of turning them into simple information easily understandable by general public. In the present study, seven parameters were chosen to calculate the water quality index (Table 3, Table 4 and Table 5). The standards used were as per recommended by Bureau of Indian Standards [30]. Zone A recorded a WQI of 28.92 which indicates a good water quality. Zone B, Zone C and Zone D recorded a WQI of 21.76, 22.65 and 22.0 respectively indicating excellent water quality. Zone A has a higher WQI with respect to other zones as the area is prone to leaching of minerals due to the deposition of slit from the erstwhile connected confluence of Kulsi river. This is subsequently diluted in other zones due to surface runoff and presence of dense submerged macrophytes. Similar findings was also reported by Dennison *et al*., Thakor *et al*., Rameshkumar *et al*., [31-33]. During the study, Arsenic was not detected in waters of Chandubi Lake, which is line with the findings of Hussain *et al*, [34].

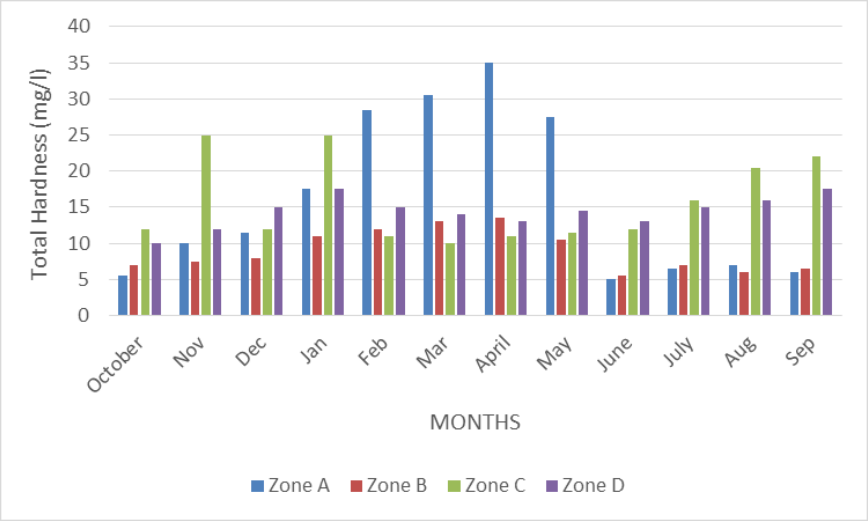

Fig. 9. Fluctuations of total hardness among different zones of the lake

Table 3. Water quality index (WQI) and water quality status (Brown *et al*., 1972)

Water quality index	Water quality status
0 – 25	Excellent water quality
26 – 50	Good water quality
51 – 75	Poor water quality
76 – 100	Very poor water quality
> 100	Unsuitable for drinking

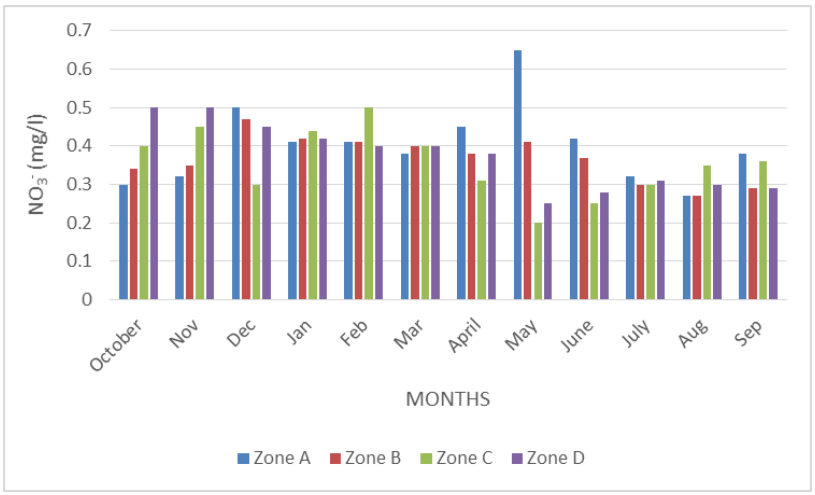

Fig. 10. Variation of nitrate among different zones of the lake

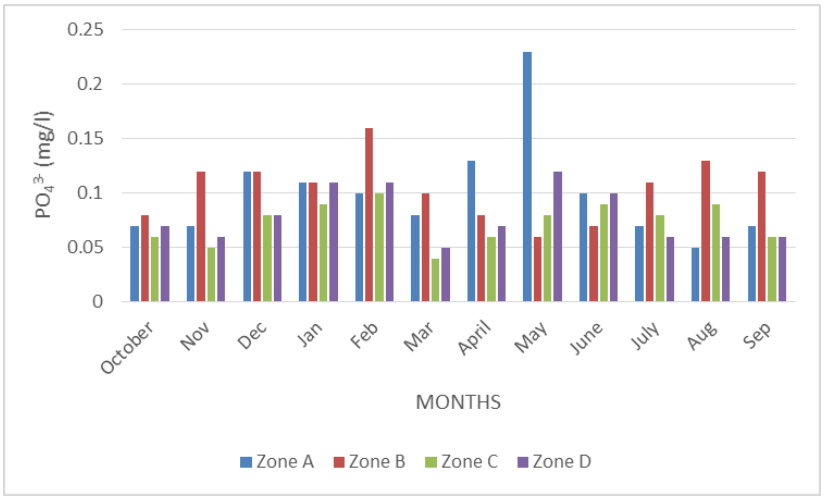

Fig. 11. Variation of orthophosphate among different zones of the lake

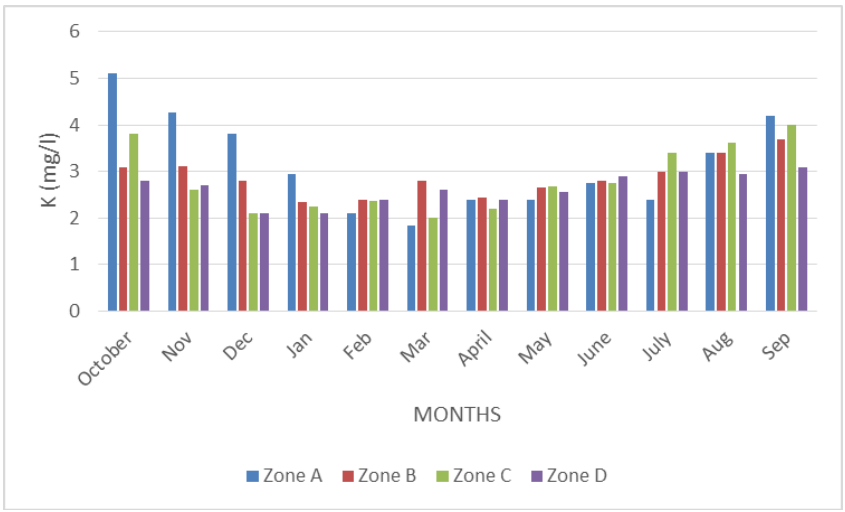

Fig. 12. Variation of potassium among different zones of the lake

Table 4. Water quality index of Zone A and Zone B

Parameters	Standard value (s_n)	Unit weight (W_n)	Zone A			Zone B		
			Observed value	Quality rating (q_n)	W_nq_n	Observed value	Quality rating (q_n)	W_nq_n
DO (mg/l)	5	0.1290	8.29	21.67	2.79	7.6	38.1	4.916
TA (mg/l)	200	0.0032	21.5	10.75	0.034	18.83	9.415	0.030
TH (mg/l)	200	0.0032	15.88	7.94	0.025	8.96	4.48	0.014
pH	8.5	0.0759	7.05	3.3	0.250	7.13	8.67	0.658
TDS	500	0.0012	8	1.6	0.002	9	1.8	0.0023
F (mg/l)	1	0.6451	0.2	20	12.903	0.05	5	3.225
Turbidity (NTU)	5	0.1290	5	100	12.903	5	100	12.903
NO_3^- (mg/l)	45	0.0143	0.4	0.8888	0.0127	0.37	0.8222	0.0117
Total		1.00			28.93			21.76
WQI					28.93			21.76

Table 5. Water quality index of Zone C and Zone D

Parameters	Standard value (s_n)	Unit weight (W_n)	Zone C			Zone D		
			Observed value	Quality rating (q_n)	W_nq_n	Observed value	Quality rating (q_n)	W_nq_n
DO (mg/l)	5	0.1290	6.69	59.76	7.710	6.32	59.76	7.710
TA (mg/l)	200	0.0032	24.71	12.355	0.039	22.83	11.415	0.036
TH (mg/l)	200	0.0032	15.67	7.835	0.025	14.38	7.19	0.023
pH	8.5	0.0759	6.75	-16.7	-1.267	6.68	-16.7	-1.267
TDS	500	0.0012	5	1	0.0012	10	2	0.0025
F (mg/l)	1	0.6451	0.05	5	3.225	0.04	4	2.580
Turbidity (NTU)	5	0.1290	5	100	12.903	5	100	12.903
NO3 – (mg/l)	45	0.0143	0.36	0.8	0.011	0.37	59.76	7.7109
Total		1.00			22.65			22.79
WQI					22.65			22.79

4. CONCLUSION

Surface waters are subjected to degradation by natural processes such as precipitation inputs, erosion, leaching of minerals and anthropogenic disturbances. For proper management of aquatic resources, regular monitoring is essential. This monitoring can be possible by assessing the physicochemical properties of water and checking their deviations from the standard qualities by utilizing guidelines set by one or the other public or worldwide bodies [35]. This will help to take appropriate measure for conservation or restoration of the aquatic body. The present findings shows an interesting physicochemical character of water with low alkalinity and hardness with no carbonate alkalinity recorded throughout the year. This leads to low productivity. The low nutrient particularly orthophosphate recorded in the present investigation may be result of autochthonous nutrient input. Interestingly, WQI of Chandubi Lake ranges from good to excellent in the studied sampling zones with the absence of Arsenic being an important factor. Although the local people do not use lake water directly for drinking purposes as most have tube wells and open wells, but the lake influences in maintaining the ground water table of the area. Thereby the physicochemical parameters of the lake do have some impact on the water used by the local people for their domestic purposes. The loss of connection with lotic ecosystem is causing harm to the lake and due to aquatic macrophytes growth the lake is turning shallow thereby. Thus it is important to take appropriate measures to ensure the continuity of this pristine natural tectonic lake.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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