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Assessment of water quality using physico-chemical parameters in two floodplain Lakes (*Chaurs*), North Bihar, India

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Abstract

This study was aimed to assess status of physico-chemical characteristics of two floodplain lakes, Tarawe chaur and Gamharia chaur of north Bihar, India. Floodplain lakes are fresh water wetlands situated on the flood plains of river Kosi at 26°8' N latitude and 65°5' E longitude. The lakes get inundated with flood water during monsoon season and retain perennially. Monthly changes in physico-chemical variables were analyzed from November 2012 to October 2013. The existing water quality in two floodplain lakes was identified in terms of physico-chemical characteristics. Rainfall, evaporation, changes in water level, water from catchment and climate are major factors that determine quality of water in the floodplain lakes. The physico-chemical parameters, such as transparency, conductivity, pH, dissolved oxygen, chloride, nitrate-nitrogen and phosphate-phosphorus and BOD show lacustrine and riverine conditions. The water quality variables suggested that floodplain lakes offer a good habitat to supports many aquatic species. Results of present study indicate pollution free water at Tarawe chaur, and slight poor water quality at Gamharia chaur due to the waste water inflow from nearby village. The obtained value of physico-chemical parameters compare with the range reported from wetlands of other regions. The relationships among water quality parameters were tested by correlation co-efficient (r) analyses.

Keywords: Floodplain wetlands, Physico-chemical parameters, Variation, Water quality.

Introduction

Wetlands located on floodplains of major rivers are common feature in India. The flood plain wetlands are the lands transitional between terrestrial and aquatic systems, where water table is at/or near the surface, or the land is covered by shallow water[1]. The north-eastern region of India has approximately more than 0.2 million hectare of floodplain wetlands, mostly situated in the states of Assam, Bihar and West Bengal. Northern part of Bihar has a long stretch of flood plains in the Gandak and Kosi river basins characterized by shallow-water bodies, commonly known as *mauns* (ox-bow lakes), *chaurs* (depressed landmass/tectonic) and *dhars* (old-channels) covers estimated area of 40,000 ha[2].

The wetlands located on the flood plains are generally characterized by dense growth of free-floating and submerged macrophytes besides seasonal flooding. The floodplain wetlands provide good habitat for varieties of aquatic species organisms, like plankton, periphyton, macrophytes, invertebrates and other aquatic animals including fishes. Besides supporting wild fishery, floodplain wetlands serves as spawning and nursery ground for many riverine species. They have great potential for fishery development[3].

Presently, not much information is available on floodplain wetlands of India. However, a few investigations have been made on water quality of ox-bow lakes and *beels* of West Bengal[4,5] and Assam[6-8]. Besides these, some studies have been carried out on physical and chemical characteristic of waters either in relation to fishery[9-11] or deals with plankton ecology[12-14]. Earlier studies reveal that water quality of flood plains wetlands is determined by precipitation, runoff from catchments, topography, climate and decomposition of organic matter including metabolic activities of aquatic plants and animals.

However, over last few decades, water quality of flood plains wetlands is degrading due to siltation, eutrophication and accumulation of agricultural runoff and encroachment as human settlement[2,4].

Presence of floodplain lakes in north Bihar has many advantages. The floodplain lakes are the lifeline of this region. Inspite of maintaining ground water, lakes provide water for fishing, irrigation, cultivation of aqua-fruits ‘makhana’ and offers source of livelihood for millions of people. Despite of playing major role in state fishery, not much studies has been carried out on physical, chemical and biological characteristics of the floodplain lakes, particularly information on the water quality is far from satisfactory. Therefore, the present investigation was undertaken to analyze physico-chemical characteristics of water in floodplain lakes (*chaurs*) of north Bihar, India.

Materials and methods

Study area: Study area comes under the subtropical climate, maximum temperature ranging from 35°C to 40°C and minimum 7°C to 9°C, the month of April and May experiences hot wave due to dry wind and the month of January experiences low temperature. Normal rainfall is about 1231 mm. Heaviest rainfall occurs during June to September (approx. 81% of the total rainfalls), when the flood plains widely inundated with rains and floodwater.

The present study was carried out in two floodplain lakes, Gamharia *chaur* and Tarawe *chaur* of north Bihar, India. Floodplain lakes are the fresh water wetlands situated on the flood plains of Kosi river located in Gamharia block of Madhepura district at 26°8'N latitude and 65°5'E longitude. Of the selected water bodies, Gamharia *chaur* is situated close to Gamharia village and adjacent NH-106. It lies about 23km away from Madhepura town. It is a small shallow water body covering an area of 10 ha with maximum depth of 2.1 m and average depth of 1.4 m. This wetland is densely infested by free-floating and submerged aquatic macrophytes and receives waste water from village continuously through drains. Tarawe *chaur* is located in same localities lying about 3 km away from former *chaur*. It is a large water body occupies an area of 21 ha with maximum depth of 3.7 m and average depth of 1.9 m. Selected lakes are seasonally flooded by river Kosi during monsoon and retain perennially, therefore, offers a good aquatic habitat for aquatic species. Besides fishing, water from floodplain lakes is used for irrigation, aqua-fruit 'makhana' (*Euryale ferox* Salisbury) cultivation and several other livelihood activities.

Sample collection and analysis: Water samples were collected from each floodplain lake monthly from November 2012 to October 2013. Samples were taken between 7am to 9am directly in 2-liter polyethylene cans at 30cm below water surface. Water temperature and transparency was recorded directly using Celsius thermometer and Secchi disc of 20cm diameter. Physico-chemical parameters, such as dissolved oxygen, pH, free carbon dioxide, carbonate and bicarbonate were analyzed at sites. Remaining parameters, like conductivity, calcium, magnesium, chloride, nitrate-nitrogen, phosphate-phosphorus and biochemical oxygen demand (BOD) were measured in the laboratory.

The pH of sample water was determined by pH meter and conductivity was recorded using digital conductivity meter. Free carbon dioxide, carbonate and bicarbonate of sample water were analyzed titrimetrically using phenolphthalein and methyl orange indicators. Calcium was determined by titrating sample water with standard solution of ETDA using murexide as indicator and magnesium was obtained by calculation. Chloride was measured by titrating sample with silver nitrate solution using potassium chromate as indicator. Both nitrate-nitrogen and phosphate-phosphorus were estimated by spectrophotometer (at 520 and 690 nm) following phenol disulphonic acid and ammonium molybdate method. Dissolved oxygen of sample water was determined by Winkler's titration method. The biochemical oxygen demand was measured in two steps- the initial oxygen content of sample water was recorded immediately and the sample was then incubated for five days in dark for 5 days at 20°C and after 5 days final dissolved oxygen reading was taken and BOD was measured from the dissolved oxygen depletion. All the physico-chemical parameters were analyzed by standard methods[15,16] and the obtained data were subjected to correlation coefficient (*r*) analysis.

Results and discussion

The physico-chemical characteristics provide a fair idea of water quality in any water body. The results of physico-chemical parameters are summarized in Table-1 and illustrated in Figure-1 to 6. The correlation coefficient analyses (*r*) data is given in Table-2 and 3.

Water temperature: Water temperature is an important factor in assessing water quality. The temperature influence several other parameters and alters physical and chemical properties of water. Temperature regulates the life process like feeding, reproduction and metabolic rates of aquatic organisms[17]. The temperature has direct effect on dissolved oxygen, in turn causes great variability in plants and animals distribution in aquatic environments. Variation in water temperature depends on various factors including seasonal and local climates. Water temperature in this study shows minor difference among the lakes ranged from 18.5°C to 35.3°C at Tarawe *chaur* and 18.3°C to 33.2°C at Gamharia *chaur*. Mean annual water temperature was 27.92±5.25°C and 26.88±4.49°C (Table-1). The obtained value of water temperature is similar to the range reported from wetlands of West Bengal[18], Assam[19-21] and Tripura[22].

Variation in water temperature shows pattern of a subtropical climate starts increasing from January reached highest in June and then decline in July might be due to addition of rains and flood waters (Figure-1). The water temperature was high in summer could be due to high atmospheric temperature and decline in water level.

It remains higher in monsoon might be due to the greater atmospheric temperature, while, the lowest during winter probably attributed to the low atmospheric temperature and short sunshine durations. Similar trend was reported from *beels* of Assam[20,23] and wetlands of Gujarat[24], but the trend differs from wetlands of Assam[8,10]. Slight higher water temperature at Tarawe *chaur* than of Gamharia *chaur* might be due to differences in the geographical characters. Water temperature reveals significant ($p>0.001$) positive correlation with BOD ($r=0.868$) and negative correlation with pH ($r=-0.826$) at Tarawe *chaur*. While, it shows significant ($p>0.001$) positive correlation with BOD ($r=0.827$), phosphate ($r=0.838$) and bicarbonate ($r=0.857$) and negative correlation with carbonate ($r=-0.859$) at Gamharia *chaur* (Table-2 and 3).

Table-1: Range and mean ± SD values of physico-chemical variables of water in floodplain wetlands.

Parameters	Tarawe	Chaur	Gamharia	Chaur
	Range	Mean±SD	Range	Mean±SD
Water temperature	18.5-35.3	27.92±5.25	18.3-33.2	26.88±4.49
Transparency	9.9-59.6	37.85±17.86	9.7-49.5	29.71±12.10
Electrical conductivity	89.6-227.4	160.32±43.39	109.3-461.8	284.04±108.24
pH	6.9-8.3	7.50±0.41	6.2-7.9	7.00±0.47
Dissolved oxygen	5.0-9.1	6.97±1.15	4.8-7.6	6.13±0.87
Free CO_2	4.7-9.4	6.72±1.91	5.2-15.2	10.30±3.44
Carbonate alkalinity	10.4-16.1	13.20±1.55	12.8-22.1	16.95±2.64
Bicarbonate alkalinity	99.6-168.4	131.61±19.44	121.7-243.7	183.49±32.56
Calcium	18.1-29.5	23.80±3.49	9.4-26.9	18.58±4.92
Magnesium	6.0-10.5	7.87±1.26	7.0-13.4	9.83±2.04
Chloride	6.3-16.2	11.44±3.00	15.2-35.7	26.82±5.42
Nitrate nitrogen	0.11-0.41	0.27±0.10	0.31-0.72	0.50±0.11
Phosphate phosphorus	0.04-0.20	0.11±0.04	0.08-0.21	0.14±0.04
BOD	1.2-3.0	2.22±0.52	1.9-6.1	4.15±1.37

All parameters are expressed in mg/L, except pH, water temperature (°C), transparency (cm) and conductivity (µ mho/cm).

Table-2: Correlation co-efficient (r) values between physico - chemical variables of water at Tarawe *chaur.*

Parameters	Temp.	Transp.	EC	pH	DO	FCO_2	CO_3	HCO_3	Ca	Mg	Cl	NO_3- N	PO_4-P	BOD
Temp.	_	-0.697	-0.610	-0.826*	-0.762	0.176	0.751	0.715	0.035	0.236	0.056	0.728	0.776	0.868*
Transp.		_	0.911*	0.885*	0.915*	-0.026	0.655	-0.950*	0.593	0.488	0.571	-0.920*	-0.936*	-0.899*
EC			_	0.848*	0.866*	0.311	0.540	-0.937*	0.678	0.537	0.670	-0.911*	-0.838*	-0.773
pH				_	0.915*	0.739	0.771	-0.900*	0.446	0.261	0.411	-0.856*	-0.886*	-0.897*
DO					_	0.637	0.815	-0.860*	0.512	0.325	0.390	-0.900*	-0.955*	-0.923*
FCO_2						_	absent	0.174	-0.175	0.027	-0.671	0.146	-0.626	-0.232
CO_3							_	-0.590	-0.064	-0.331	-0.296	-0.599	-0.799	-0.739
HCO_3								_	-0.542	-0.436	-0.598	0.891*	0.855*	0.868*
Ca									_	0.909	0.914*	-0.538	-0.450	-0.313
Mg										_	0.919*	-0.361	-0.319	-0.148
Cl											_	-0.491	-0.345	-0.246
NO_3- N												_	0.888*	0.851*
PO_4-P													_	0.931*
BOD														_

* Significant at p>0.001.

Table-3: Correlation co-efficient (r) values between physico - chemical variables of water at Gamharia *chaur*.

Parameters	Temp.	Transp.	EC	pH	DO	FCO_2	CO_3	HCO_3	Ca	Mg	Cl	NO_3- N	PO_4-P	BOD
Temp.	_	-0.724	-0.725	-0.780	-0.808	0.697	-0.859*	0.857*	0.209	0.136	0.009	0.800	0.838*	0.827*
Transp.		_	0.944*	0.936*	0.938*	-0.683	0.812	-0.848*	0.423	0.425	0.586	-0.927*	-0.928*	-0.943*
EC			_	0.944*	0.953*	-0.624	0.843*	-0.831*	0.435	0.474	0.590	-0.917*	-0.905*	-0.936*
pH				_	0.945*	-0.754	0.791	-0.873*	0.319	0.331	0.466	-0.957*	-0.906*	-0.953*
DO					_	-0.753	0.873*	-0.854*	0.320	0.394	0.486	-0.934*	-0.957*	-0.941*
FCO_2						_	absent	0.910*	-0.805	-0.811	-0.445	0.722	0.700	0.485
CO_3							_	-0.824*	-0.454	-0.279	-0.400	-0.770	-0.872*	-0.828*
HCO_3								_	-0.154	-0.231	-0.326	0.876*	0.848*	0.879*
Ca									_	0.902*	0.915*	-0.283	-0.213	-0.237
Mg										_	0.872*	-0.307	-0.264	-0.291
Cl											_	-0.442	-0.374	-0.420
NO_3- N												_	0.892*	0.961*
PO_4-P													_	0.926*
BOD														_

* Significant at p>0.001.

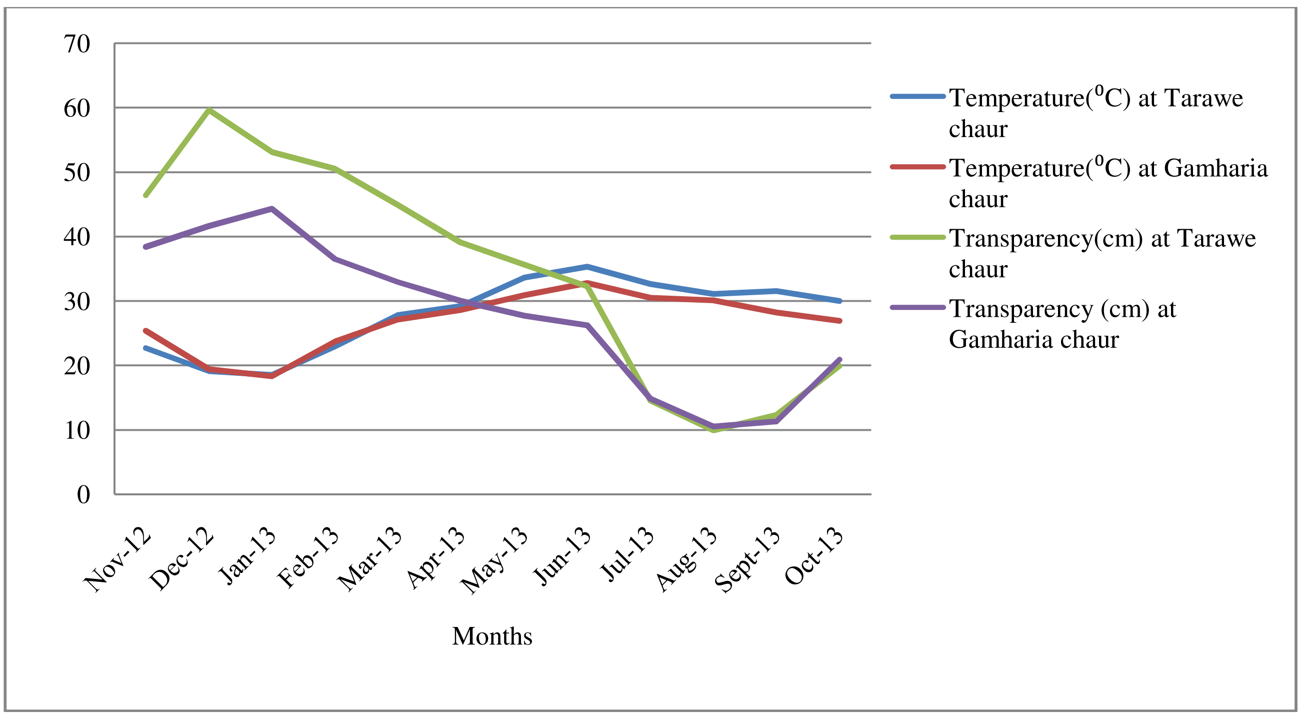

Figure-1: Seasonal variation in water temperature and transparency.

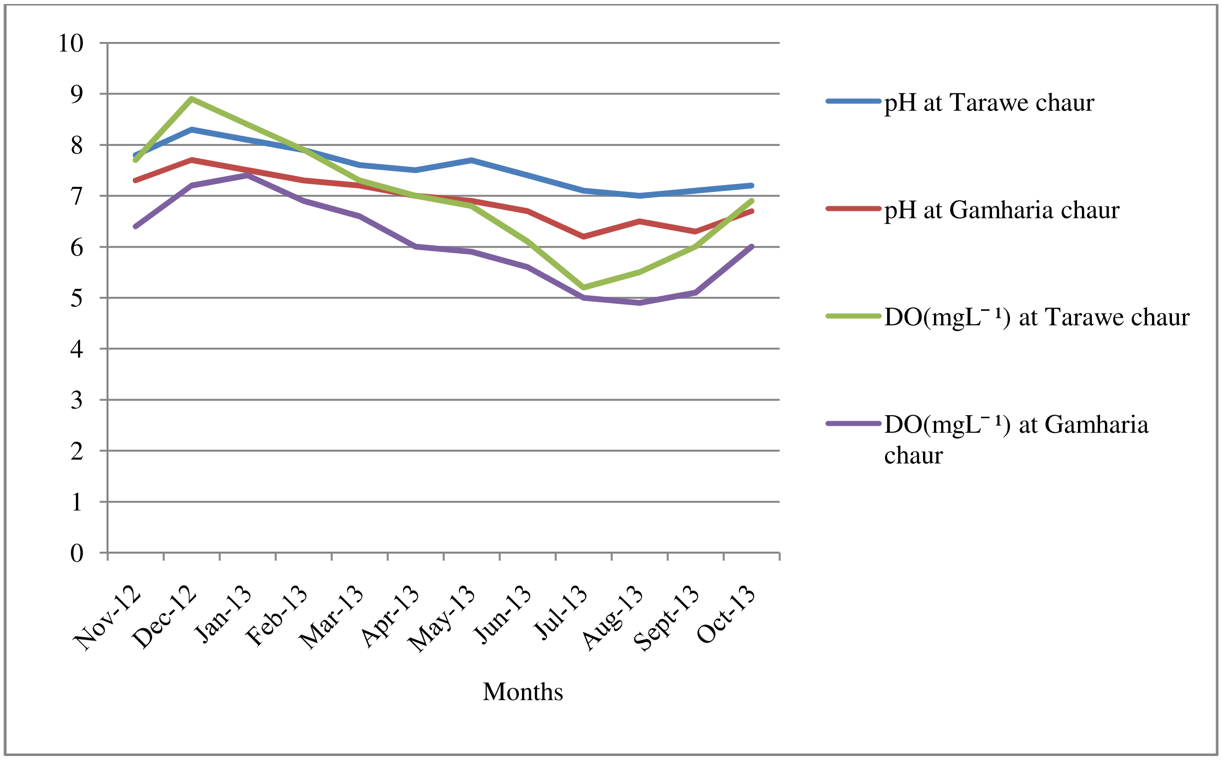

Figure-2: Seasonal variation in pH and DO.

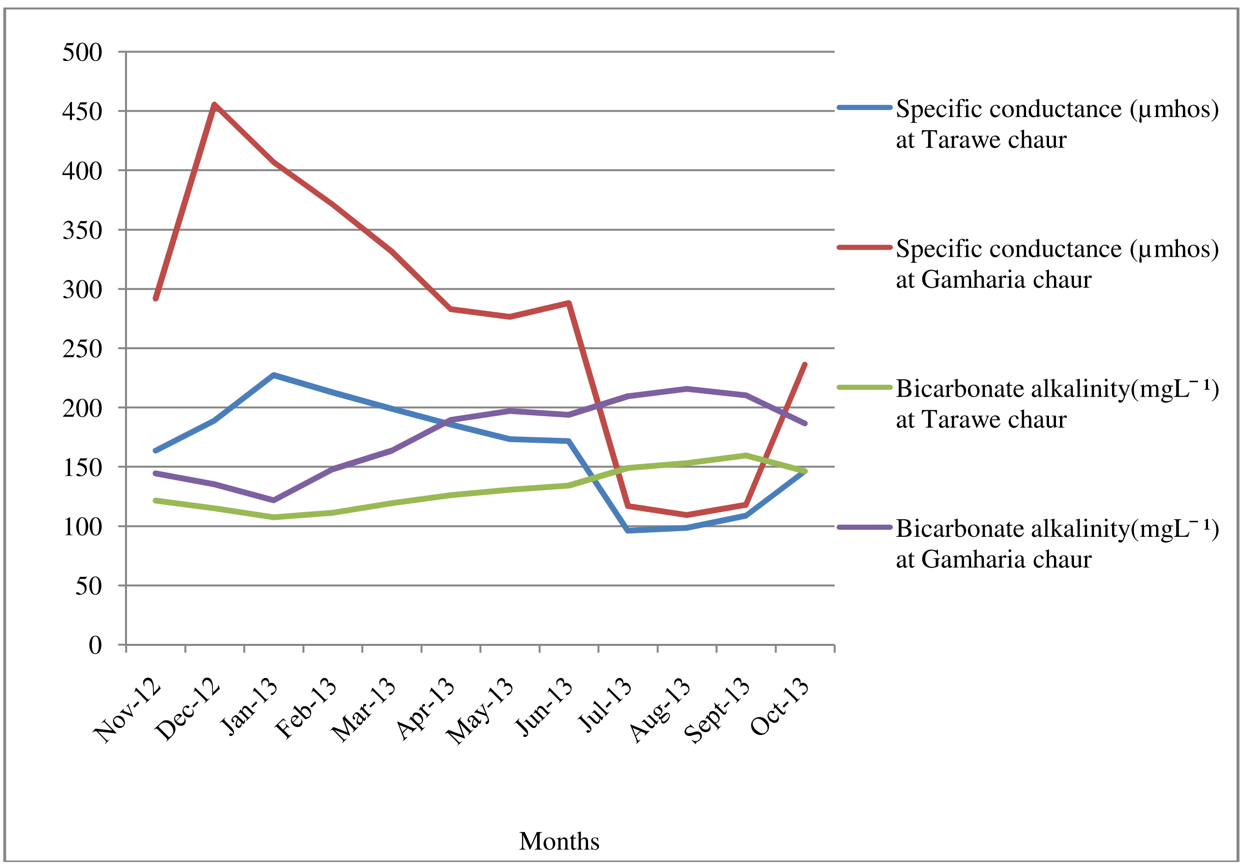

Figure-3: Seasonal variation in sp. conductivity and bicarbonate.

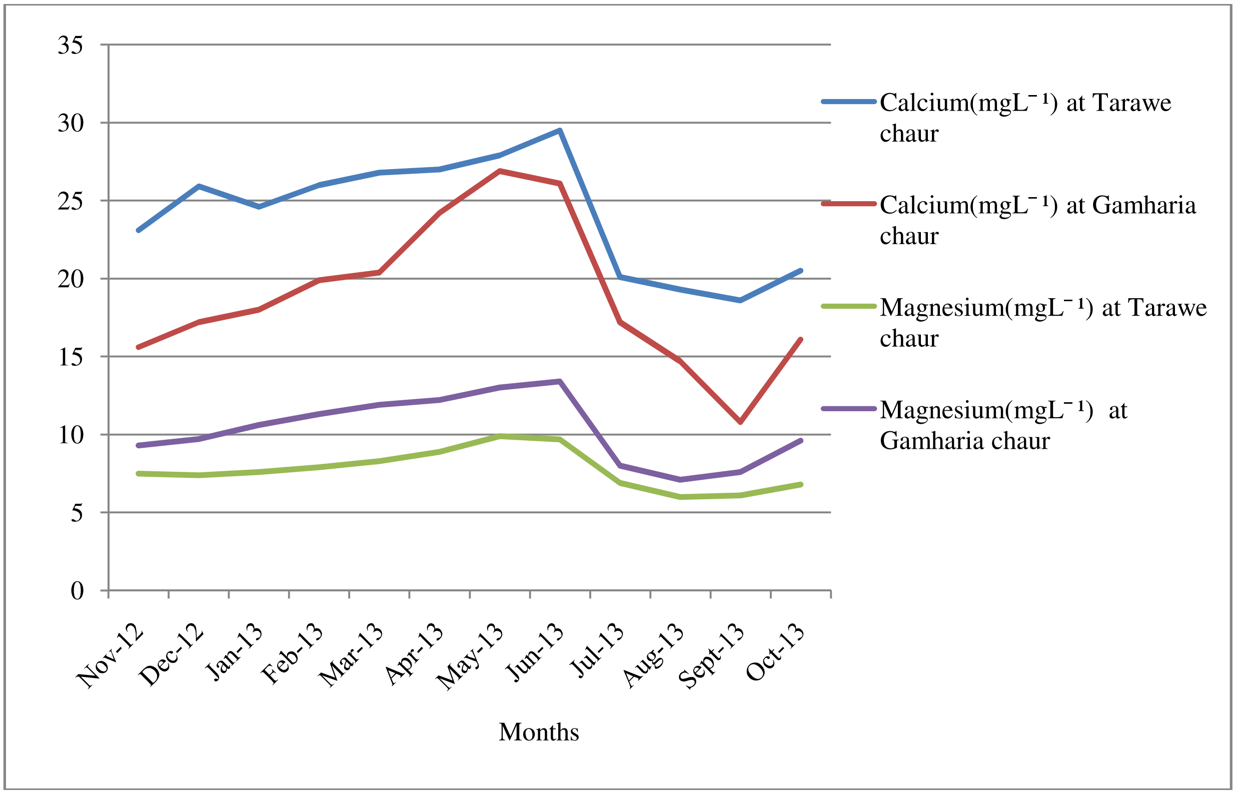

Figure-4: Seasonal variation in calcium and magnesium.

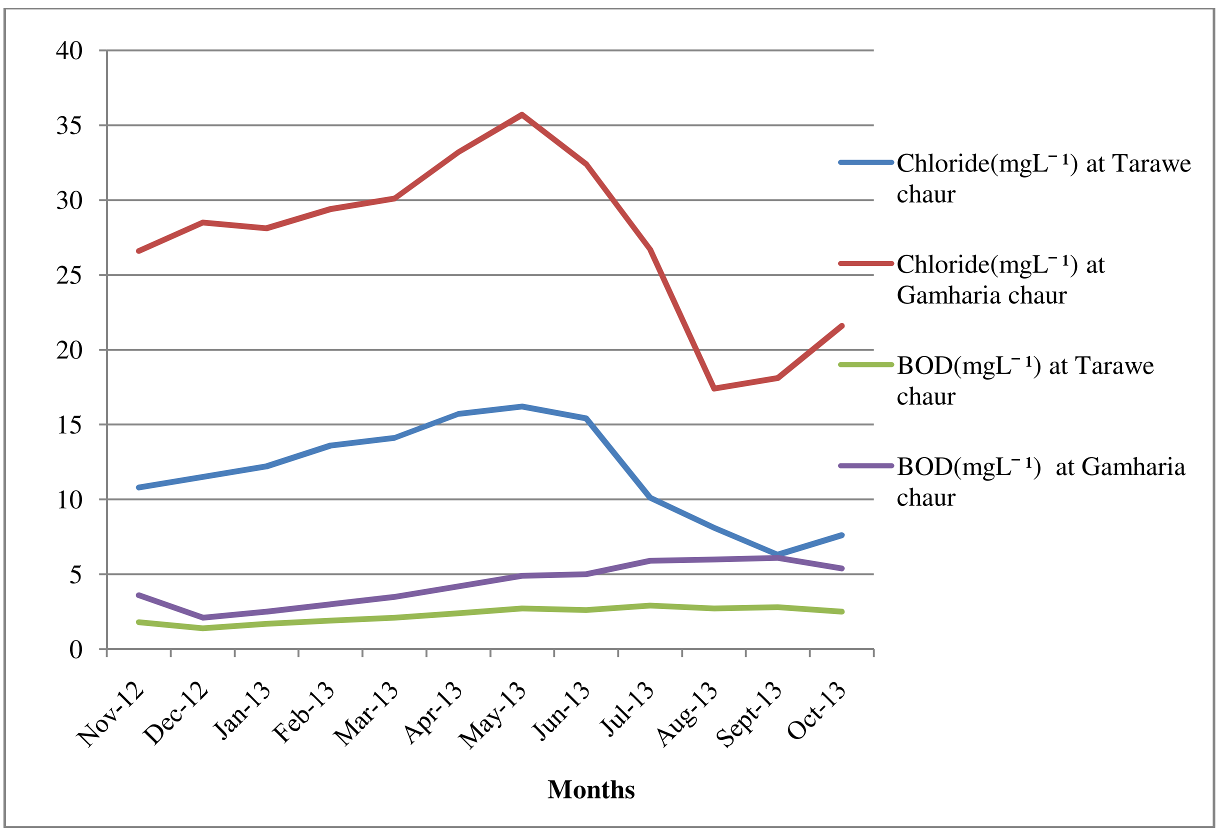

Figure-5: Seasonal variation in chloride and BOD.

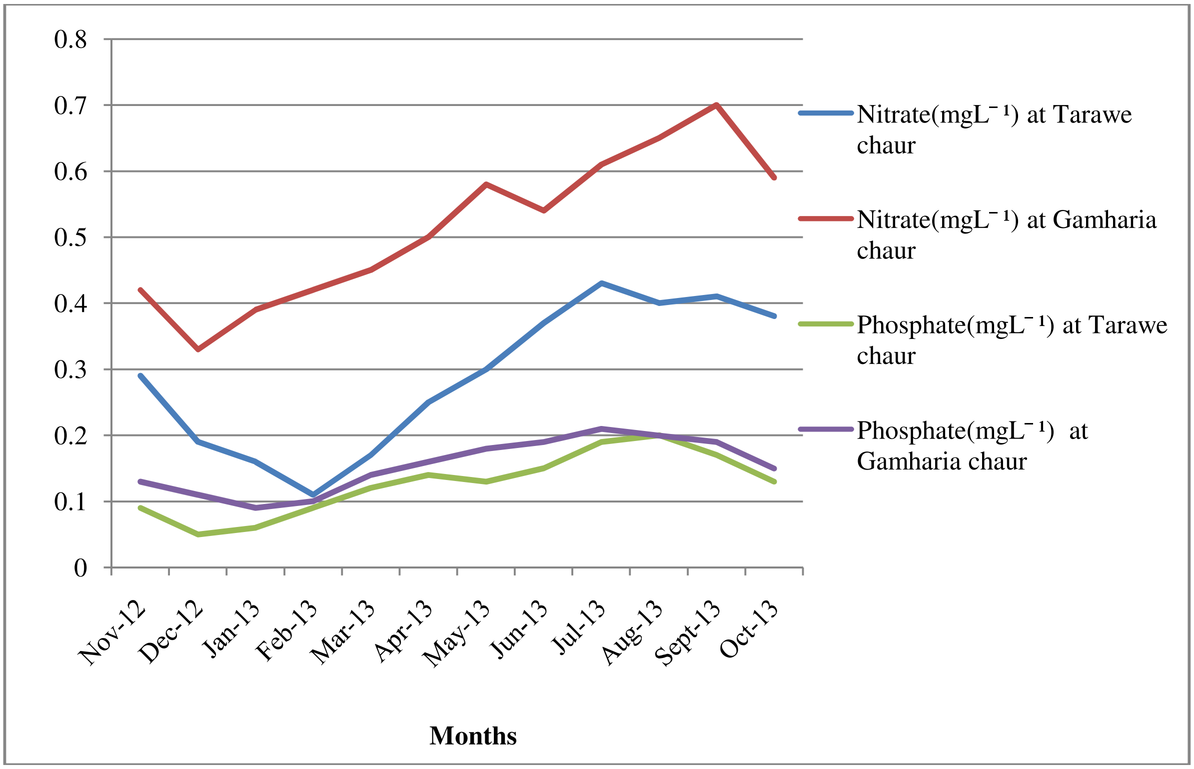

Figure-6: Seasonal variation in nitrate and phosphate.

Transparency: Clarity of water is measured by transparency value that indicates the amount of sunlight penetrate in the water column, the clearer the water greater the lights will penetrate. Phytoplankton and other vegetation growing in the water need sunlight to complete photosynthesis. Water transparency is influenced by solar intensity, plankton density and suspended soils, solids such as clay and silt particles. In this study, the water transparency is measured as Secchi depth ranged from 9.9 cm to 63.8 cm at Tarawe *chaur* and 9.7 cm to 49.5 cm at Gamharia *chaur*. Average annual transparency was 37.85±17.86 cm and 29.7±12.10 cm (Table-1). The recorded value of water transparency is lower than the range reported from *beels* of Assam[8, 12].

Seasonal impact on water clarity was seen in this study, starts rising from November, reached highest in December and then decline upto August (Figure-1). Floodplain lakes water was more transparent during winter probably due to absence of rains, runoff and floods. With the settling of suspended particles water clarity getting higher agreed with the findings of previous workers[25]. Decline in water clarity in monsoon could be attributed to higher silts load and suspended matter washed into lakes makes water turbid. After receding of flood water, the lotic condition of lakes becomes lentic, the suspended material settled on bottom makes water transparent. However, some workers reported higher transparency in monsoon and lower during post-monsoon[18], and some other reported highest in post-monsoon and lowest during winter[19], while, a few others recorded high in summer and low during monsoon[8]. Water was less transparent at Gamharia *chaur* probably due to the waste water inflow from village alters water clarity. Abundance of free-floating macrophytes, *Eichhornia crassipes* further allows less sunlight to penetrate into water, thus causing low transparency. The water transparency reveals significant ($p>0.001$) positive correlation with dissolved oxygen ($r=0.915$) and conductivity ($r=0.911$) and negative correlation with bicarbonate ($r=-0.950$), phosphate ($r=-0.936$), nitrate ($r=-0.920$) and BOD ($r=-0.899$) at Tarawe *chaur*. While, it shows significant ($p>0.001$) positive correlation with dissolved oxygen ($r=0.938$), pH ($r=0.936$) and conductivity ($r=0.944$) and negative correlation with BOD ($r=-0.943$), phosphate ($r=-0.928$) and nitrate ($r=-0.927$) at Gamharia *chaur* (Table-2 and 3).

Electrical conductivity (EC): Electrical conductivity is a measurement of the ability of water to carry an electrical current. It is an important parameter in assessing water quality. Most aquatic biota evolved to functions and survives within an optimal range of conductivity[26]. In the present study, conductivity ranged from 89.6 μ mho/cm to 227.4 μ mho/cm at Tarawe *chaur* and 109.3 μ mho/cm to 461.8 μ mho/cm at Gamharia *chaur*, with average annual value of 160.32±43.39 μ mho/cm and 284.04±108.24 μ mho/cm (Table-1). The obtained value of conductivity is lower than the range reported from wetlands of West Bengal[18] and *pats* of Manipur[27], and higher than the value reported from floodplain lakes of Assam[19]. Water with conductivity greater than 500 μ mho/cm is classified as eutrophic[28], hence the investigated lakes fall under the category of mesotrophic.

Overall conductivity of studied lakes was low, although, it shows a well marked trends, starts rising from November reached highest in December and then decline upto August (Figure-3). The conductivity was higher in winter might be due to the presence of large amount of organic residue in water, while, the lower during monsoon could be due to dilution of dissolved ions with rains and floodwater[17]. Similar trend was reported from *beel* of Assam[11]. Contrary to this, some workers observed highest and lowest conductivity during monsoon and winter[19]. Higher conductivity at Gamharia *chaur* might be due to waste water inflow from nearby human settlement add organic content in the water consequently degradation of organic substance elevating conductivity[29]. Conductivity shows significant ($p>0.001$) positive correlation with pH ($r=0.848$), dissolved oxygen ($r=0.866$) and nitrate ($r=0.911$) and negative correlation with bicarbonate ($r=-0.937$) and phosphate ($r=-0.838$) at Tarawe *chaur* (Table-2). While, it demonstrates significant ($p>0.001$) positive correlation with pH ($r=0.944$), dissolved oxygen ($r=0.953$) and carbonate ($r=0.843$) and negative correlation with nitrate ($r=-0.917$) and phosphate ($r=-0.905$) and BOD ($r=-0.936$) at Gamharia *chaur* (Table-3).

pH: The pH is an index of hydrogen ion (H^+) activity in water. pH is a measure of the acidic or alkaline water. Most chemical and biological processes in water depend on pH. Majority of aquatic organism survives within a narrow range of pH[30]. Too low and too high pH is harmful to aquatic species. pH range of 6.7 to 8.4 supports a rich aquatic life[31]. In water, variation in pH is affected by carbonic system and interaction between carbonates and bicarbonates. In the present study, pH ranged from 6.9 to 8.3 at Tarawe *chaur* and 6.2 to 7.9 at Gamharia *chaur* (Table-1). Mean annual pH was 7.50±0.41 and 7.00±0.47. The obtained range of pH is similar to the value reported from floodplain wetlands of West Bengal[18,32], Assam[8,21] and Gujarat[24]. During the investigation period, water was generally alkaline mainly due to the presence of carbonate.

The fluctuations in pH of water depend on many factors. In this study, the pH starts rising from November reached highest in December and then decline upto July (Figure-2). The pH was higher in winter might be attributed to algae and other aquatic plants removes carbon dioxide from water during photosynthesis, in turn, rising pH. Similar view was also expressed by some workers[33,34]. Decline in pH value during monsoon could be due to the stirring effect of incoming water and increased microbial respiration release carbon dioxide in water. pH decreases with rainfall was also reported by some workers[35]. However, some workers reported maximum pH in monsoon and minimum during pre-monsoon[18,36] and a few others reported high and low during post-monsoon and monsoon[19] while a few recorded highest and lowest in summer and winter[7,8]. Plants remove carbon dioxide from water *via* photosynthesis might be reason of higher pH at Tarawe *chaur*. The pH decreases at Gamharia *chaur* probably due to the increased microbial respiration and decomposition of macrophytes release carbon dioxide in water. The waste water release from village influenced pH of lakes water. pH shows significant ($p>0.001$) positive correlation with dissolved oxygen ($r=0.915$) and negative correlation with phosphate ($r=-0.886$), nitrate ($r=- 0.856$), bicarbonate ($r=-0.900$) and BOD ($r=-0.897$) at Tarawe *chaur*, while, it reveals significant ($p>0.001$) positive correlation with dissolved oxygen ($r=0.945$) and negative correlation with bicarbonate ($r=-0.873$), nitrate ($r=-0.957$), phosphate ($r=-0.906$), BOD ($r=-0.953$) and at other *chaur* (Table-2 and 3).

Dissolved Oxygen: Dissolved oxygen is one of the most essential parameters in assessing water quality, an adequate amounts of oxygen is necessary for a good water and survival of aquatic organisms. Occurrence of dissolved oxygen in water depends on temperatures, quantity of plants and numbers of aquatic animals. Photosynthesis elevates and respirations reduce amounts of oxygen in water. Decomposition of organic matter consumes much of oxygen from water. In natural water oxygen is less than 10 mg/L[35]. Water with oxygen greater than 5 mg/L favours the growth of aquatic species[37]. Dissolved oxygen was congenial in this study ranged from 5.0 mg/L to 9.1 mg/L at Tarawe *chaur* and 4.8 mg/L to 7.6 mg/L at Gamharia *chaur*. Average annual dissolved oxygen was 6.97±1.15 mg/L and 6.13±8.7 mg/L (Table-1). The obtained range of dissolved oxygen is similar to the value reported from floodplain wetlands of West Bengal[18], Assam[7, 35] and *pats* of Manipur[27].

No significant difference was observed in the concentration of dissolved oxygen of two lakes, but, it decreases with increasing water temperature was recorded. This might be due to poorer ability of water to holds greater oxygen at higher temperature. Dissolved oxygen was higher in winter (Figure 2) probably due to lower water temperature and higher transparency, this in turn rising photosynthetic activity by algae and other aquatic plants, thus rising oxygen levels in water. Decline in dissolved oxygen levels during monsoon could be attributed cloudy weather and higher temperature, in turn, elevating metabolic rates of aquatic biota which consume oxygen from water. Similar variation was reported form lakes of Barak Valley[19] and *beels* of Assam[8-10]. After receding flood water, phytoplankton density increase sharply, in turn, rising photosynthesis activity produce more oxygen in water. Water was well oxygenated at Tarawe *chaur* might be due to deeper light penetration in water increasing photosynthetic zone in the water body, in turn, producing more oxygen. Reduced oxygen levels at Gamharia *chaur* could be due to the presence of excess amounts of organic content causing oxygen depletion. Free-floating macrophytes further reduce oxygen production by limiting the light penetration in water. Dissolved oxygen reveals significant ($p>0.001$) negative correlation with bicarbonate ($r=-0.860$), phosphate ($r=-0.955$) and nitrate ($r=-0.900$) and BOD ($r=-0.923$) at Tarawe *chaur*. While, it shows significant ($p>0.001$) positive correlation with carbonate ($r=0.873$) and negative correlation with phosphate ($r=-0.957$), nitrate ($r=-0.934$) and BOD ($r=-0.941$) at Gamharia *chaur* (Table-2 and 3).

Free Carbon dioxide: Carbon dioxide is present in water in the form of dissolved gas. Carbon dioxide, carbonate, bicarbonate and pH are interrelated in the water systems. Decomposition of organic content and respiration produce carbon dioxide in water. The carbon dioxide, thus release is used by phytoplankton and other aquatic plants to create new organic matter *via* photosynthesis[38]. Surface water normally contains less than 10 mg/L of carbon dioxide. In this study, free carbon dioxide ranged from 4.7 mg/L to 9.4 mg/L at Tarawe *chaur* and 5.2 mg/L to 15.2 mg/L at Gamharia *chaur* (Table-1). Mean annual carbon dioxide was 6.72±1.91 mg/L and 10.30±3.44 mg/L. The obtained value of free carbon dioxide is similar to the range recorded from wetlands of Assam[10,19,21] and *pats* of Manipur[27], while higher than the value reported from Potiasola *beel*, Assam[7], and low than the range reported from Dhir *beel*, Assam[11]. In the present study, carbon dioxide was recorded only in monsoon might be due to increased bacterial activities and rapid decomposition of organic material released carbon dioxide in water[17]. Lacking of free carbon dioxide in other seasons could be due to its utilization by phytoplankton and other aquatic plants *via* photosynthesis or/and retain by calcium in form of the calcium bicarbonate. Higher free carbon dioxide at Gamharia *chaur* could be due to decaying plants and algae release carbon dioxide in water. The free carbon dioxide shows significant positive correlation with bicarbonate (r=0.910, p>0.001) at Gamharia *chaur*.

Carbonate and bicarbonate: Carbonate and bicarbonate ions occur in water due to dissolution of carbon dioxide[30] and both represent the most important form of alkalinity in natural water[39]. Concentration of carbonates in natural waters is a function of dissolved carbon dioxide, temperature, pH and many dissolved salts. In this study, carbonate ranged from 10.4 mg/L to 16.1 mg/L at Tarawe *chaur* and 12.8 mg/L to 22.1 mg/L at Gamharia *chaur*. Mean annual carbonate was 13.20±1.55 mg/L and 16.95±2.64 mg/L (Table-1). During the investigation period, the carbonate was recorded when the free carbon dioxide was absent. Carbonate was higher in winter might be due to the dissociation of bicarbonate into carbonate. Decrease in carbonate levels during monsoon could be due to dilution factors. Similar trend was recorded from wetlands of West Bengal[18] and Assam[40]. Carbonate shows significant (p>0.001) negative correlation with bicarbonate (r=-0.824), phosphate (r=-0.872) and BOD (r=-0.828) at Gamharia *chaur* (Table-3).

Bicarbonate is a natural component of all waters. In the present study, the bicarbonate was higher than the carbonate ranged from 99.6 mg/L to 168.4 mg/L at Tarawe *chaur* and 121.7 mg/L to 243.7 mg/L at Gamharia *chaur* (Table-1). Average annual bicarbonate was 131.61±19.44 mg/L and 183.49±32.56 mg/L. Bicarbonate was higher in monsoon might be due to the dissociation of carbonic acid. Decline in bicarbonate levels during winter could be attributed to its utilization by phytoplankton and other aquatic plants as source of carbon during photosynthesis. Some workers reported highest and lowest bicarbonates during winter and monsoon[24]. The bicarbonate value was high at Gamharia *chaur* might be due to accumulation of organic wastes from catchment areas, while the lower levels at Tarawe *chaur* indicates that water was poorly buffered. Bicarbonate shows positive significant correlation with nitrate, phosphate and BOD at both lakes (Table-2 and 3).

Calcium and Magnesium: Calcium and magnesium are two most common minerals in water mostly responsible for water hardness and both minerals influence the physiological functions of aquatic biota[41]. Calcium in natural water is more abundant than magnesium often occur in combination with carbonate ions as $CaCO_3$. The calcium serves as micronutrient for most aquatic organisms. The calcium in this study occur in fairly low range varied from 18.1 mg/L to 29.5 mg/L at Tarawe *chaur* and 9.4 mg/L to 26.9 mg/L at Gamharia *chaur*. Mean annual calcium was 23.80±3.49 mg/L and 18.58±4.92 mg/L (Table-1). The recorded value of calcium is lower than the range reported from wetlands of West Bengal[18] and *beels* of Assam[8, 19, 36] and higher than the value reported from *pats* of Manipur[27]. Variation in calcium was seen, starts increasing from November reached highest in June and then decline upto September (Figure-4). Calcium was higher in summer might be due to high rates of evaporation, declining water level concentrates salts in water, while, low during monsoon probably due to dilution factors. Calcium shows significant (p>0.001) positive correlation with magnesium (*r*=0.909) and chloride (r=0.914) at Tarawe *chaur*, while, it shows significant (p>0.001) positive correlation with chloride (r=0.915) and negative with magnesium (*r*=-0.902) at Gamharia *chaur* (Table-2 and 3).

Magnesium often associated with calcium in natural, but its concentrations remain low than of calcium. In this study magnesium ranged from 6.0 mg/L to 10.5 mg/L at Tarawe *chaur* and 7.0 mg/L to 13.4 mg/L at Gamharia *chaur* with average annual value of 7.87±1.26 mg/L and 9.83±2.04 mg/L (Table-1). Similar range was recorded from wetlands of Assam[19]. The magnesium was higher in summer probably due to the high evaporation rates concentrate content. Decrease in magnesium levels during monsoon could be due to dilution factors. Some workers reported maximum and minimum magnesium during post-monsoon and pre-monsoon[19], while, some other recorded highest and lowest during winter and monsoon[24]. Higher magnesium at Gamharia *chaur* might be due to the waste water inflow from village, while, the lower levels at Tarawe *chaur* could be due to its utilization by algae and other aquatic plants. The magnesium shows significant positive correlation with chloride at both lakes (Table-2 and 3).

Chloride: The chloride in water exists in varying range might be due to higher solubility[42]. Disposal of sewage and industrial wastes are important sources of chloride in natural water[43]. Higher chloride concentrations indicate high degree of organic pollution mainly of animal origin[44]. In this study chloride was not harmful, usually occur in lower range varies from 6.3 mg/L to 16.2 mg/L at Tarawe *chaur* and 15.2 mg/L to 35.7 mg/L at Gamharia *chaur* (Table-1). Mean annual chloride was

11.44±3.00 mg/L and 26.82±5.42 mg/L. The obtained value of chloride is similar to the range reported from *pats* of Manipur[27], while, higher than the value recorded from wetlands of Assam[8] and West Bengal[18] and lower than range reported from lakes of Assam[19] and wetlands of West Bengal[32] and Tripura[22]. The chloride was higher in summer might be due to high evaporation rates, declining water level concentrates content, while, the lower during monsoon could be due to dilution factors (Figure-5). The chloride was quite low at Tarawe *chaur* might be due to the presence of little amounts of organic content in water. Higher chloride at Gamharia *chaur* could be due to addition of large amount of organic wastes, primarily of animal origin.

Nitrate-nitrogen: Nitrogen is a critical nutrient generally used and reused by algae and other aquatic plants within natural water systems. Excess nitrate is not toxic to aquatic life, but increased nitrogen may results in overgrowth of algae, when they die resulting bacterial decomposition consumes oxygen from water, thus, harming aquatic species. Nitrogen enters into wetland water *via* human and animal wastes and runoff from agriculture lands. In natural water nitrogen found as nitrate. In the present study, nitrate-nitrogen ranged from 0.11 mg/L to 0.41 mg/L at Tarawe *chaur* and 0.31 mg/L to 0.72 mg/L at Gamharia *chaur* (Table-1). Average annual nitrate-nitrogen was 0.27±0.10 mg/L and 0.50±0.11 mg/L. The obtained value of nitrate-nitrogen is similar to the range reported from floodplain wetlands of West Bengal[18, 32] and *pats* of Manipur[27].

Seasonal impact on nitrate-nitrogen was also seen in this study, starts increasing from March reached highest in June and then decline upto October at Tarawe *chaur*, but, the trend differs at Gamharia *chaur*, where, it starts rising from January reached highest in September and then decline in August (Figure-6). The nitrate-nitrogen was higher in monsoon might be due to rainwater carries large amounts of nitrogen from catchment areas, while, the lowest during winter probably due to its assimilation by algae and other aquatic plants. Higher nitrate-nitrogen at Gamharia *chaur* could be attributed to release of waste water from village. The decaying macrophytes further elevate nitrate content in water. Nitrate-nitrogen absorbed by algae and other aquatic plants could be the reasons of low levels at Tarawe *chaur*. The nitrate-nitrogen shows significant positive correlation with phosphate and BOD at both floodplain lakes.

Phosphate-phosphorus: Phosphorus is an essential nutrient for all aquatic life, but, its higher concentrations may leads to eutrophication causing water quality problems by forming algal bloom. The major source of phosphorus in natural water is domestic sewage and agriculture runoff. Phosphorus in water commonly exists as phosphate. In the present study, phosphate-phosphorus found in very low range varies from 0.04 mg/L to 0.20 mg/L at Tarawe *chaur* and 0.08 mg/L to 0.21 mg/L at Gamharia *chaur* (Table-1). Mean annual phosphate-phosphorus was 0.11±0.04 mg/L and 0.14±0.04 mg/L. The obtained range of phosphate-phosphorus is similar to the value reported from wetlands of West Bengal[32] and Uttar Pradesh[45] and *pats* of Manipur[27].

Variation in phosphate-phosphorus show increasing trend from winter, reached highest in monsoon and then decline gradually (Figure-6). Similar trend was reported from *beels* of Assam[6]. Phosphate-phosphorus was higher in rainy season might be due to rainwater brought large amount of phosphorus from agricultural fields, while, lowest during winter could be due to its absorption by algae and other aquatic plants. Higher phosphate-phosphorus at Gamharia *chaur* could be attributed to addition of phosphorous-loaded substances through domestic drains and surface runoff. Phosphate-phosphorus utilized by phytoplankton and other aquatic plants and sedimentations could be the reason of phosphate-poor water at Tarawe *chaur*. Phosphate-phosphorous reveals significant positive correlation with BOD at both lakes (Table-2 and 3).

Biochemical Oxygen Demand: The BOD is a measure of the amounts of dissolved oxygen used by aerobic bacteria in oxidation of organic matter in aquatic environment. The BOD is a reliable parameter uses to measure degree of organic pollution in water. Water with BOD less than 4 mg/L is considered as unpolluted, while, more than 10 mg/L regarded as polluted[35]. In this study BOD was found in low range varied from 1.2 mg/L to 3.0 mg/L at Tarawe *chaur* and 1.9 mg/L to 6.1 mg/L at Gamharia *chaur*. Mean annual BOD was 2.22±0.52 mg/L and 4.15±1.37 mg/L (Table-1). The recorded value of BOD is similar to the range reported from wetlands of Assam[19], West Bengal[32] and Uttar Pradesh[46].

Variation in BOD was seen in this study, starts rising from January reached highest in September and then decline in October (Figure-5). BOD was higher in monsoon might be due to increased microbial respiration and decomposition of organic matter consumes oxygen from water. The lowest BOD during winter could be due to the low temperature holding more oxygen[46]. Some workers reported maximum BOD during winter and minimum in summer[32] and some other recorded higher and lower during pre-monsoon and post-monsoon[47]. The lower BOD at Tarawe chaur shows pollution free water. While, slight high BOD at Gamharia *chaur* could be attributed to accumulation of large amount of organic substance in water consumes oxygen, thereby, increasing BOD.

Conclusion

The study indicates that the floodplain lakes associated with river systems is a complex and dynamic systems. The physico-chemical variables of water show feature of a typical tropical climatic. All the physico-chemical parameters fall within favourable range to support sustainable growth of aquatic organisms. Results of the present study show good water at Tarawe *chaur* hence it offers an ideal habitat for aquatic life. Though, slight poor water quality at Gamharia *chaur* pointing towards eutrophic condition. Correlation co-efficient analyses show significant relationships amongst the physico-chemical variables.

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