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Physico-chemical analysis of lotic and lentic water ecosystems in Samastipur, Bihar, India

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Abstract

Samastipur (25°51'N, 85°47'E) is an important city of North Bihar, India. Water qualities of five experimental sites, three of the river Burhi Gandak and two of the ponds at Samastipur were studied during two consecutive years on thirteen physico-chemical parameters viz., pH, Temperature, Transparency, Conductivity, Total Dissolved Solids, Dissolved Oxygen, Free Carbon di-oxide, Carbonate Alkalinity, Bicarbonate Alkalinity, Total Hardness, Calcium, Chloride and Silicate. Observed values of pond water on pH, Temperature, Carbonate Alkalinity, Chloride and Silicate were found comparatively higher than that of river water, whereas Transparency, Dissolved Oxygen, Bicarbonate Alkalinity, Total Hardness, Calcium of pond water were found lower than the river water.

Keywords: Samastipur, limnology, lotic, lentic, pond, Burhi Gandak.

Introduction

All the organisms including man are dependent on the environment of their habitat. They grow and their qualities are developed in a congenial environment. Any environment consists of biotic and abiotic components functioning together as a system known as "ecosystem". Both biotic and abiotic components interact to produce an exchange of materials. Not only interactions between the above two components take place but interactions amongst different factors of both the components also take place. Abiotic environment of fresh water ecosystems consists of physico-chemical nature of the water.

Bihar in general and North Bihar in particular, is very rich in inland water bodies (Figure-1). Samastipur is an important city of North Bihar. It is situated in at 25°51'N Latitude and 85°47'E Longitude covering around 2900 sq KM. It has an average elevation of 56 metres. The city has many perennial ponds and an important river of North Bihar, Burhi Gandak passes through the city. Mumtazuddin *et al.*, Choudhary and Ray *et al.* have studied physico-chemical properties of groundwater, soil and drinking water respectively in different location of Bihar[1-3]. In the present study thirteen parameters of physico-chemical parameters have been studied for both river and pond water bodies. These are: pH, Temperature, Transparency, Conductivity, Total Dissolved Solids, Dissolved Oxygen, Free Carbon di-oxide, Carbonate Alkalinity, Bicarbonate Alkalinity, Total Hardness, Calcium, Chloride and Silicate.

Materials and methods

Five different experimental sites, three of the river Burhi Gandak and two of ponds were selected for the study of the physico-chemical quality of water. The three sites of the river Burhi Gandak are: i. Near Rahmatpur as Site-I, under the bridge at Railway station as Site-II and near the village Bahadurpur as Site-III, two selected ponds are: Pond at B.R.B. College, Samastipur and Mahadev Pond at Lagunia (Figure-2).

Water samples were collected from these five sampling sites on seasonal basis from June 2015 to December 2016. Thirteen physico-chemical parameters were studied, these are: pH, Temperature, Transparency, Conductivity, Total Dissolved Solids, Dissolved Oxygen, Free Carbon di-oxide, Carbonate Alkalinity, Bicarbonate Alkalinity, Total Hardness, Calcium, Chloride and Silicate. Standard methods as described by APHA were followed for the determination of various physico-chemical parameters[4].

Results and discussion

Observations made under thirteen physico-chemical parameters are enumerated below.

pH: Table-1 shows that pH of the river water ranged from 7.1 to 8.5 during the observation period of two years. The maximum value of pH 8.5 was observed in the summer of 2015 at site-II and minimum 7.1 in the rain of 2015 at site-I and II. Yearly mean of the pH of the river water 7.8 in 2015 and 7.9 in 2016. The seasonal mean of pH was maximum 8.0 in the summer and minimum 7.7 in the winter.

As shown in the Table-2, pH of pond water ranged from 7.3 to 8.4 and 7.4 to 8.4 in pond-I and pond-II respectively. It is also evident that yearly mean of the pH of the pond water was 7.9 in 2015 and 8.0 in 2016. The seasonal mean of pH was maximum 8.3 during rain and minimum 7.4 during winter.

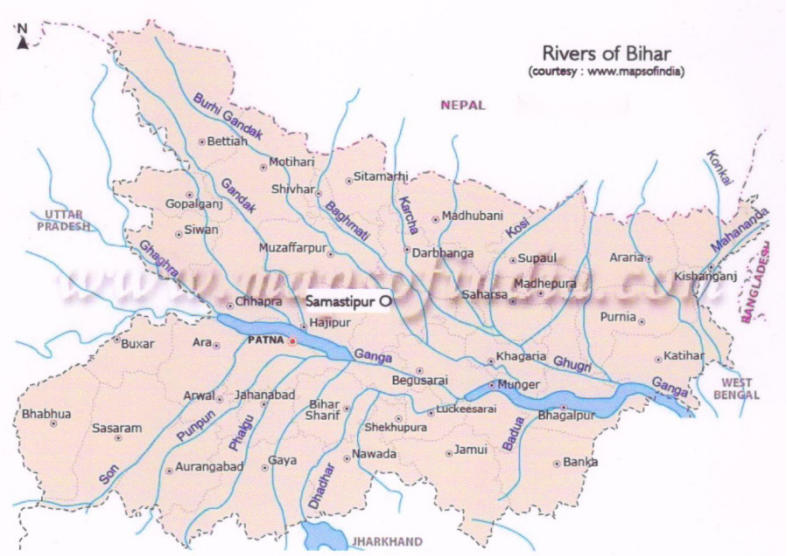

Figure-1: Map showing major rivers of Bihar. The river Burhi Gandak flows through Samastipur[5].

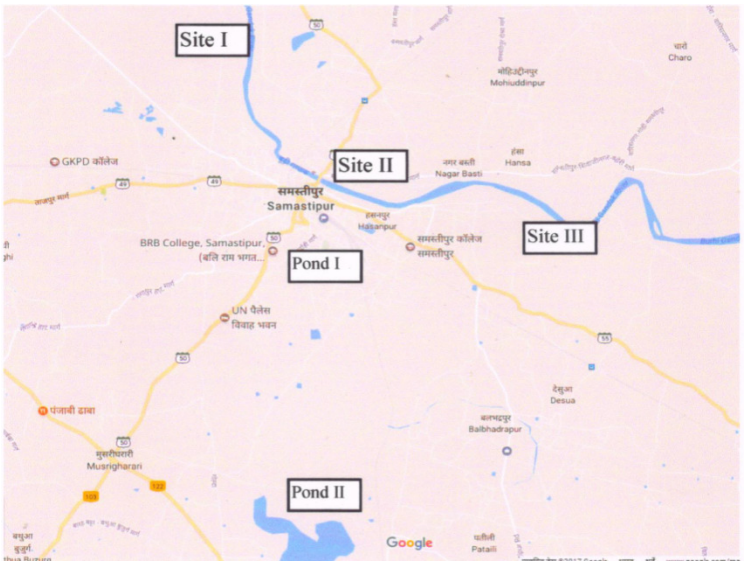

Figure-2: Google map of Samastipur showing river Burhi Gandak along with the experimental sites - Site I, II, III of River and Pond I -BRB College pond and Pond II -Mahadeva pond Lagunia[6].

Temperature (°C)**:** Table-1 shows that Temperature of the river water ranged from 19.0°C to 31.0°C during the observation period of two years. The maximum value of temperature 31.0°C was observed in the summer of 2015 at site-III and summer of 2016 at site-II and minimum 19.0°C in the winter of 2015 at site-I and at site II and III in 2016. Yearly mean of the temperature of the river water 26.4°C in 2015 and 26.1°C in 2016. The seasonal mean of Temperature was maximum 30.3°C in the summer and minimum 19.2 in the winter.

As shown in the Table-2, temperature of pond water ranged from 18.0°C to 35.5°C and 18.2°C to 35.0°C in pond-I and pond-II respectively. It is also evident that yearly mean of the temperature of the pond water was 28.4°C in 2015 and 27.8 in 2016. The seasonal mean of temperature was maximum 35.0°C during summer and minimum 18.4°C during winter.

Transparency (cm): Table-1 shows that Transparency of the river water ranged from 6.7cm to 63.6cm during the observation period of two years. The maximum value of transparency 63.6 cm was observed in the winter of 2015 at site-II and minimum 6.7cm in the rain of 2015 at site-III. Yearly mean of the transparency of the river water 29.0cm in 2015 and 27.3cm in 2016. The seasonal mean of transparency was maximum 53.1 in the winter and minimum 10.45 in the rain.

As shown in the Table-2, transparency of pond water ranged from 17.5cm to 30.4cm and 17.8cm to 29.0cm in pond-I and pond-II respectively. Yearly mean of the transparency of the

pond water was 23.7cm in 2015 and 23.0cm in 2016. The seasonal mean of transparency was maximum 27.63 during winter and minimum 19.4 during rain.

Conductivity (µmhos): Table-1 shows that Conductivity of the river water ranged from 295.0 µmhos to 673.0 µmhos during the observation period of two years. The maximum value of conductivity 673.0µmhos was observed in the winter of 2016 at site-II and minimum 295.0µmhos in the summer of 2015 at site-I and III. Yearly mean of the conductivity of the river water 386.1µmhos in 2015 and 467.1µmhos in 2016. The seasonal mean of conductivity was maximum 546.2µmhos in the winter and minimum 321.2 µmhos in the winter.

As shown in the Table-2, conductivity of pond water ranged from 228.4µmhos to 635.0µmhos and 236.0µmhos to 610.0 ppm in pond-I and pond-II respectively. Yearly mean of the conductivity of the pond water was 425.8µmhos in 2015 and 431.6µmhos in 2016. The seasonal mean of conductivity was maximum 615.0µmhos during rain and minimum 238.59µmhos during winter.

Total Dissolved Solid (TDS) (ppm): Table-1 shows that TDS of the river water ranged from 191.8ppm to 437.5ppm during the observation period of two years. The maximum value of TDS 437.5ppm was observed in the winter of 2016 at site-II and minimum 191.8ppm in the summer of 2015 at site-I and II. It shows yearly mean of the TDS of the river water was 251.0ppm in 2015 and 303.6ppm in 2016. The seasonal mean of TDS was maximum 355.0ppm in the winter and minimum 208.76 in the summer.

As shown in the Table-2, TDS of pond water ranged from 148.4ppm to 412.8ppm and 153.4ppm to 396.5ppm in pond-I and pond-II respectively. Yearly mean of the TDS of the pond water was 276.8ppm in 2015 and 280.5ppm in 2016. The seasonal mean of TDS was maximum 399.8 during rain and minimum 155.1 during winter.

Dissolved Oxygen (ppm): Table-1 shows that dissolved oxygen of the river water ranged from 5.9ppm to 10.0ppm during the observation period of two years. The maximum value of dissolved oxygen 10.0ppm was observed in the rain of 2015 at site-III and minimum dissolved oxygen 5.9ppm in the winter of 2015 at site-II. Yearly mean of the dissolved oxygen of the river water was 7.3ppm in 2015 and 8.3ppm in 2016. The seasonal mean of dissolved oxygen was maximum 9.2ppm in the winter and minimum 6.4 in the rain.

As shown in the Table-2, dissolved oxygen of pond water ranged from 5.2ppm to 8.6ppm and 5.2ppm to 8.3ppm in pond-I and pond-II respectively. Yearly mean of the dissolved oxygen of the pond water was 6.4ppm in 2015 and 2016. The seasonal mean of dissolved oxygen was maximum 8.1ppm during winter and minimum 5.4ppm during summer.

Free Carbon di-oxide (ppm): Table-1 shows that Free CO_2 of the river water ranged from 0 to 9.6ppm during the observation period of two years. The maximum value of free CO_2 9.6ppm was observed in the winter of 2016 at site-I and minimum Free CO_2 i.e., 0 in the winter of 2015, summer in 2015 and 2016, in winter in 2015 and 2016 at site-II and in summer 2015 and 2016 at site III and in winter 2015 at site-III. Yearly mean of the Free CO_2 of the river water 2.4ppm in 2015 and 4.7ppm in 2016. The seasonal mean of free CO_2 was maximum 7.2ppm in the rain and minimum 0.9 in the summer.

As shown in the Table-2, Free CO_2 of pond water ranged from 0 to 13.5ppm and 0 to 12.5ppm in pond-I and pond-II respectively. Yearly mean of the free CO_2 of the pond water was 6.0ppm in 2015 and 4.3ppm in 2016. The seasonal mean of Free CO_2 was maximum 11.6 during rain and minimum 0 summer.

Carbonate Alkalinity (ppm): Table-1 shows that Carbonate Alkalinity of the river water ranged from 0 to 16.0ppm during the observation period of two years. The maximum value of Carbonate Alkalinity16.0ppm was observed in the winter of 2015 at site-I and minimum Carbonate Alkalinity nil was found in most of other observation sites during 2015. Yearly mean of the Carbonate Alkalinity of the river water was 4.7ppm in 2015 and 1.7ppm in 2016. The seasonal mean of Carbonate Alkalinity was maximum 7.0 in the winter and minimum 0 in the rain.

As shown in the Table-2, Carbonate Alkalinity of pond water ranged from ppm to 0 and 18.4ppm and 0 to 18.2 in pond-I and pond-II respectively. Yearly mean of the Carbonate Alkalinity of the pond water was 6.1ppm in 2015 and 10.9ppm in 2016. The seasonal mean of Carbonate Alkalinity was maximum 16.7 ppm during summer and minimum 0 during rain.

Bicarbonate (ppm): Table-1 shows that Bicarbonate of the river water ranged from 96ppm to 194ppm during the observation period of two years. The maximum value of Bicarbonate 194.0ppm was observed in the rain of 2016 at site-III and minimum Bicarbonate 96ppm was found in 2015 in summer at site I. Yearly mean of the Bicarbonate of the river water was 131.2ppm in 2015 and 156.2ppm in 2016. The seasonal mean of Bicarbonate was maximum 163.3 in the winter and minimum 111.2 in the summer.

As shown in the Table-2, Bicarbonate of pond water ranged from 95.4ppm to 147.4ppm and 98.3 to 144.2 in pond-I and pond-II respectively. Yearly mean of the Bicarbonate of the pond water was 120.3ppm in 2015 and 126.5ppm in 2016. The seasonal mean of Bicarbonate was maximum 141.7ppm during summer and minimum 105.8ppm during winter.

Total Hardness (ppm): Table-1 shows that Total Hardness of the river water ranged from 106.0ppm to 176.0ppm during the observation period of two years. The maximum value of Total Hardness 176.0ppm was observed in the winter of 2016 at site-I and minimum Bicarbonate 106.0ppm was found in 2015 in rain at site-I. Yearly mean of the Total Hardness of the river water was 127.9ppm in 2015 and 148.7ppm in 2016. The seasonal

mean of Total Hardness was maximum 147.7 in the winter and minimum 123.3ppm in the summer.

As shown in the Table-2, Total Hardness of pond water ranged from 95.0ppm to 153.4ppm and 95.6 to 154.2 in pond-I and pond-II respectively. Yearly mean of the Total Hardness of the pond water was 120.9ppm in 2015 and 119.9ppm in 2016. The seasonal mean of Total Hardness was maximum 146.6ppm during rain and minimum 104.6ppm during summer.

Calcium (ppm): Table-1 shows that Calcium of the river water ranged from 8.1ppm to 41.7ppm during the observation period of two years. The maximum value of Calcium 41.7ppm was observed in the winter of 2015 at site-II and minimum Calcium 8.1ppm was found in 2016 in rain at site-III. Yearly mean of the Calcium of the river water was 26.5ppm in 2015 and 22.1ppm in 2016. The seasonal mean of Calcium was maximum 32.1 in the winter and minimum 18.6ppm in the summer.

As shown in the Table-2, calcium of pond water ranged from 12.5ppm to 28.8ppm and 12.2 to 27.8 in pond-I and pond-II respectively. Yearly mean of the Calcium of the pond water was 16.0ppm in 2015 and 20.6ppm in 2016. The seasonal mean of Calcium was maximum 25.1ppm during summer and minimum 14.8ppm during rain.

Chloride (ppm): Table-1 shows that Chloride of the river water ranged from 7.4ppm to 21.0ppm during the observation period of two years. The maximum value of Chloride 21.0ppm was observed in the winter of 2016 at site-I and minimum Chloride 7.4ppm was found in 2015 in rain at site-I. Yearly mean of the Chloride of the river water was 10.5ppm in 2015 and 13.0ppm in 2016. The seasonal mean of Chloride was maximum 14.0 in the winter and minimum 10.5ppm in the summer.

As shown in the Table-2, Chloride of pond water ranged from 50.5ppm to 124.3ppm and 55.3 to 122.4 in pond-I and pond-II respectively. Yearly mean of the Chloride of the pond water was 75.1ppm in 2015 and 78.7ppm in 2016. The seasonal mean of Chloride was maximum 117.3ppm during rain and minimum 45.4ppm during winter.

Silicate (ppm): Table-1 shows that Silicate of the river water ranged from 15.6ppm to 24.0ppm during the observation period of two years. The maximum value of Silicate 24.0ppm was observed in the winter of 2015 at site-II and minimum Silicate 15.6ppm was found in 2016 in summer at site-II. Yearly mean of the Silicate of the river water was 19.1ppm in 2015 and 20.2 ppm in 2016. The seasonal mean of Silicate was maximum 21.5 in the winter and minimum 17.7ppm in the rain.

As shown in the Table-2, Silicate of pond water ranged from 14.0ppm to 30.0ppm and 13.8 to 29.0 in pond-I and pond-II respectively. Yearly mean of the Silicate of the pond water was 22.9ppm in 2015 and 23.7ppm in 2016. The seasonal mean of Silicate was maximum 29.2ppm during winter and minimum 14.6ppm during rain.

Discussion: The physico-chemical analyses of the pond and river water have been made during different seasons of two years of observations. The detail of observations may be discussed in relation to the previous works done by the different workers.

Yearly mean of the pH was observed higher in pond water in comparison to river water whereas seasonal mean was same in - pond and river water during the summer but lower in river water during winter. pH is among the most important and commonly studied properties of the natural water. It is a measure of the level or intensity of acidic or basic character or the level of Hydrogen ion activity. The pH of water in nature varies widely due to the mixing of many acidic and basic salts. Most commonly it varies between six and eight. In commonest water, pH is slightly alkaline due to the presence of bicarbonates and carbonates of alkaline earth. Seulpthorpe has suggested that pH and carbon di-oxide are even more critical factors in the survival of aquatic plant and fishes than the oxygen supply[5]. Alternations in pH in natural waters are usually accompanied by changes in other physico-chemical factors also. It is therefore very essential to monitor the level of pH in a given water body regularly in view of its implications. Its level fluctuated in within a narrow range in conformity with the findings of various workers[8-14]. Values of pH are within the limits prescribed by WHO and Ministry of Works and Housing, Government of India for drinking water[15].

Temperature is amongst one of the important factors that has direct effect over the survival and existence of living organisms as well as physico-chemical quality of water. Temperature of the river and pond water showed typical seasonal fluctuation as it was recorded maximum in summer and minimum in winter. Yearly mean of the temperature was observed higher in pond water in comparison to river water whereas seasonal mean was higher in pond water during the summer but lower in winter. Vyas and Kumar[8] have found similar results.

The term transparency, visibility and turbidity are approximately equivalent terms and refer to the clarity of the water. Transparency of the water is the indicator of its physico-chemical status and activities of the aquatic lives are also being influenced to great extent through it. Yearly mean of transparency was higher in river water as compared to pond water whereas seasonal was maximum in winter and minimum in rain. The low annual mean value of transparency of pond water may be attributed to heavy suspension of dissolved solids and profuse phytoplanktonic growth. Review of literature on transparency shows a great deal of variation regarding the months of its maxima and minima[8,14,15,16,17]. Higher transparency in winter was also reported by Bhatt *et al.*[19]. However, Towheed *et al.*[20] observed maximum transparency during the winter. Minimum transparency was observed during the rains, has also been observed by several investigators including Bhatt *et al.* [19] and Towheed *et al.*[20].

Water becomes a conductor of electric current when substances are dissolved in it and its conductivity is proportionate to the amount of the substances dissolved in it. These substances are the ions which acts as conductor. Concentration, mobility and valency of ions directly affects the ability of conductance. Temperature of the medium also plays the role in regulating it. Inorganic substances show more conductance than the organic compounds. Thus conductivity gives us a good idea of ionic concentration of dissolved substances. Conductivity measurement is useful in monitoring the total salt level in pure water supply line, in rivers, lakes and ponds and effluent discharge channels. Yearly mean of conductivity was higher in pond water as compared to the river water but trend was reverse in the second year of observation.

Seasonal mean of conductivity of river water was maximum in winter and minimum in the summer whereas it was maximum during rain and minimum during winter in pond water. Bilgrami *et al.*[21], Sabater *et al.* [22], Reddy and Venkateswarlu[23] and Rana and Palria[24] have reported higher value of conductivity for polluted habitats.

Yearly mean of conductivity was higher in pond water as compared to the river water but trend was reverse in the second year of observation. Seasonal mean of conductivity of river water was maximum in winter and minimum in the summer whereas it was maximum during rain and minimum during winter in pond water.

Total Dissolved Solids (TDS) include both the suspended and dissolved solids. Water with high solid content is inferior and may be polluted. Rana and Palria[22] recorded increase in TDS values with increasing pollution in river Ayad, Udaipur. Pandey and Tripathy[23] also observed higher annual average of TDS in two polluted ponds at Kanpur. Bilgrami *et al.*[21] and Sengar *et al.*[24] are also of the opinion that TDS value increases with increasing pollution.

Oxygen is one of the most important factors in any aquatic system. All aerobic organisms require oxygen for their respiratory activities. Terrestrial plant and animal get it easily because it is abundant and freely present in the air. However, in water it is available from a small stock held in dissolved form. The main source of dissolved oxygen in any water body is from the atmosphere and from photosynthesis of the aquatic green plants. The amount of oxygen in water depends on the surface area exposed, temperature and salinity. Dissolved Oxygen is an important parameter for assessing water quality. Water, where organic matter is very high, has very little oxygen dissolved in it and self-purification of water system depends on the presence of sufficient amount of season dissolved in it. When oxygen is used up faster than it is replaced, the water quality begins to deteriorate. Yearly mean of dissolved oxygen was observed higher in river water as compared to the pond water. Seasonal mean of Dissolved Oxygen was maximum in winter in both the river and pond water. Minimum dissolved oxygen in river water was recorded in rainy season but in pond water during summer. Dissolved Oxygen was found to be maximum during the winters. This can be attributed to the prevailing lower temperature. Solubility of oxygen is dependent on temperature and it increases with decrease in water temperature[27]. Higher amount of Dissolved Oxygen during the winters have also been reported by Vyas and Kumar[8], Bhatt *et al.*[19], Voulgaropoulous *et al.*[28] and Towheed *et al.*[20]. Minimum content of Dissolved Oxygen was observed during the rains and summers, a result also observed by Das and Pandey[29], Singh and Swaroop[9], Bhatt *et al.* [19], Mallick and Bose[30], Verma and Munshi[31] and Towheed *et al.* [20].

Carbon di-oxide in free form is usually abundant in standing and flowing fresh water. In lakes, ponds and rivers, CO_2 content of surface water may fall down with rise in pH due to CO_2 consumption during photosynthesis. Yearly mean of Free CO_2 was higher in pond water in the first year but a bit lower in the second year as compared to river water. Seasonal mean was maximum during the rain and minimum during summer. Free CO_2 was consistently present only during the rains which can be due to the decrease photosynthetic activities because of low density of phytoplankton. Free CO_2 was recorded above the ISI tolerance limit (6 ppm) on several occasions. Water with concentration of Free CO_2 less than 5 ppm supports good fish production, whereas its high concentration in water leads to asphyxiation and often death of fishes[9]. As far as prediction of the trophic status of a water body on the basis of recording of annual mean values of free CO_2 is concerned, there are differences in opinions. Yadava *et al.*[18] and Hosmani[33] have observed decrease value of free CO_2 in eutrophic and polluted water bodies and on the other hand Hosmani and Bharti[10], Rana and Palria[24], Mesfin and Belay[13] have ascertained lower Free CO_2 content at unpolluted sites. Thus, CO_2 concentration appears to be no yard stick for predicting either the trophic level or magnitude of pollution of any water body.

Alkalinity is a measure of capacity of water to neutralize an acid. Water is said to be alkaline when the concentration of hydroxyl ion exceeds that of hydrogen ion. It is generally imparted by the salts of carbonates, bi-carbonates, phosphates, nitrates, borates and silicates etc. together with the hydroxyl ions in free state. Yearly mean of the carbonate alkalinity was higher in pond water as compared to the river water. Seasonal mean was maximum in winter and summer in the river water and pond water respectively and minimum during the rains in both the river and pond water. Yearly mean of the bicarbonate alkalinity was higher in river water as compared to the pond water. Seasonal mean was maximum in winter and minimum in summer in river water but the trend was just reverse in pond water.

Carbonate alkalinity was low whereas bicarbonate alkalinity was recorded fairly high. The lower levels carbonate alkalinity and higher level of bicarbonate alkalinity can be attributed to the pH range which favours more CO_3 to be present as HCO_3 ion[27]. High value of bicarbonate alkalinity in polluted water have been

reported by Khan and Seenayya[35], Prasad and Singh[35], Venu *et al.*[36], Singh[37] and Sahai *et al*.[35]. Based on alkalinity values, Moyle classified water into three categories: low productive with less than 20 ppm alkalinity, low to medium with 20-40 ppm alkalinity and medium to high with 40-90 ppm alkalinity[37]. Philipose[40] categories Indian water as low productive having 4-50 alkalinity, moderately high with 50-100 ppm alkalinity and fairly high with 100-200 ppm alkalinity. On the basis of these classifications, the river and pond under study appear to be of good productive value.

The property of water which prevents leather formation with soap is called hardness and is mainly caused by the calcium and magnesium cations. However, other cations and anions also contribute to hardness. Hard water is not suitable for various domestic purposes. It has no adverse effect on health but highest desirable limit of 100 mg/l and maximum permissible limit of 500 mg/l have been set by WHO for drinking water. However, Ministry of Works and Housing considers 200 mg/l as acceptable and a concentration of 600 mg/l as cause of rejection[15].

Yearly mean of hardness was found to be higher in the river water as compared to pond water. Maximum seasonal mean was observed in winter and rain in river and pond water respectively, whereas the minimum was observed during summer in both the cases. As per the highest desirable standard of WHO 100 ppm the level of total Hardness was recorded above with at all the sites throughout the observation period but the values were below the acceptable standard (200 ppm) of Ministry of Works and Housing[15]. Sawyer considers water with less than 75 mg/l of $CaCO_3$ as soft and above it as hard. Moyle, Yadava *et al*.[20] and Singh[40] are of the opinion that alkalinity higher than 40 ppm appears to be reasonably good chemical dividing line between hard and soft water.

On the basis of these classifications, the river and pond under study appear to be have hard water.

Calcium is an essential element for plant and animals, being a constituent of plant cell-wall in the form of calcium pectate and bones in man and animals. This element is quite abundantly found dissolved in water because of the abundance of calcareous rocks throughout the world. Water running across such rocks, dissolve calcium in form of bicarbonates. Besides natural sources industries and city sewage may also contribute calcium to the water body. Calcium is probably the most variable ion in most fresh water, lakes and streams. Soft water may contain less than 1 mg/l of calcium, whereas, hard water may contain up to 100 mg/l. Yearly mean of calcium was found to be higher in the river water as compared to pond water. Maximum seasonal mean was observed in winter and summer in river and pond water respectively, whereas the minimum was observed during summer and rain in river and pond respectively. Khan and Seenayya reported relatively higher mean average of calcium content (78.18 mg/l) in an industrially polluted Hussain Sagar lake, Hyderabad[34]. Hosmani analysed the water quality the water quality of a fresh water pond at Dharwar twice, first during 1972-74 when the pond exhibited the growth of 24 algal taxa with 54.85 pm of calcium content and second during 1978-80 when the calcium concentration increased to 242.85 ppm but the spectrum of the algae decreased to a considerable extent[33]. Mahadev *et al*. reported 68 mg/l and 88.4 mg/l calcium content in two ponds with 55236 and 192660 org/l of diatoms respectively[43]. Considering the above facts, the calcium level of the river and pond water under consideration is not too high to cause pollution and the level of calcium content in pond water and river water is suitable for diatoms.

Magnesium is an important major nutrient needed by all organisms, since it activates many enzyme systems. It is an essential constituent of the chlorophyll and is also involved in phosphorus transfer process. It is particularly associated with clay. It plays an important role in synthesis of ATP and ADP and inorganic phosphates. It is also an activator for many of the enzymes involved in carbohydrate metabolism. In the present study, yearly mean of magnesium was found to be higher in the river water in first year of observation and lower in second year of observation when compared with respective pond water. Contrary to this, seasonal mean was found lower in the river water in first year of observation and higher in second year of observation when compared with respective pond water. The annual mean averages of magnesium contents of river were found to be 15.7 mg/l and 21.47 mg/l and in pond water were19.74 ppm and 26.85 ppm in two years of observations respectively. The highest desirable limit of magnesium in drinking water prescribed by WHO and acceptable limit to Ministry of Works and Housing is 30 ppm. Thus existing level of magnesium in pond and river water is within the maximum desirable limit of WHO and acceptable limit of Ministry of Works and Housing. Prasad and Singh recorded higher values of magnesium of polluted station (35.36 ppm) in comparison with unpolluted station (17.13 ppm) of Gomati river at Lucknow[35]. Singh *et al.* during their study of the algal flora of sewage recorded the range of magnesium between 15.4 and 85.0 ppm[44]. Therefore, It may be concluded that the pond and river water under study is not polluted as far as magnesium is concerned.

Yearly and seasonal means of chloride of the river water were found quite less than that of pond water in both years of observations. None of the values exceeded desirable standard (200ppm) of WHO and Ministry of Works and Housing in the water of pond and river[13]. High chloride content in the polluted water has been reported by Govindan and Sundaresan[45], Prasad and Singh[35], Venkateswarlu and Sampath Kumar[46], Venu *et al.*[36], Reddy and Venkateswarlu[23] and Rana and Palria[24]. Somashekar and Ramaswamy have reported positive correlation between content of chloride with population density of diatoms in the river Kapila[46].

Silicon is one of the most abundant elements in the earth's crust. According to Claude[47], natural waters contains silicon in the

form of SiO_2 and in fresh water system its concentration ranges from 5 to 25mg/l. Annual average of silicate content of the river water was found to be slightly lower than that of pond water under study during both years of observations. Maximum value of silicate was found in rain of 2015 in the river water whereas in pond water it was found maximum in winter. Kumar and Kumar and Bohara have found the average silicate content of pond system slightly higher than that of riverine sites which is in contrast with observation of current study[48].

Table-1a: Observed value of physico-chemical parameters of water of the river Burhi Gandak at Samastipur during 2015-2016.

Year	Site	Seasons	pH	Temperature (C)	Transparency (cm)	Conductivity (μ mhos)	TDS (ppm)	DO (ppm)	Free CO_2 (ppm)
2015	Site I	Summer	7.5	30.0	20.6	295.0	191.8	6.4	3.4
		Rain	7.1	29.5	8.6	347.0	225.6	6.2	6.7
		Winter	8.0	19.0	53.5	432.0	280.8	9.4	0.0
	Site II	Summer	8.5	30.5	18.6	322.0	209.3	6.3	0.0
		Rain	8.1	29.5	13.3	375.0	243.8	5.9	6.3
		Winter	7.1	19.5	63.6	510.0	331.5	8.5	0.0
	Site III	Summer	8.1	31.0	21.3	295.0	191.8	6.7	0.0
		Rain	8.3	29.5	6.7	390.0	253.5	6.0	5.4
		Winter	7.7	19.0	55.2	509.0	330.9	10.0	0.0
2016	Site I	Summer	7.7	29.5	23.8	335.0	217.8	8.3	2.0
		Rain	7.5	28.0	14.2	397.0	258.1	6.4	8.0
		Winter	7.8	19.5	44.6	635.0	412.8	9.8	9.6
	Site II	Summer	8.1	31.0	23.5	345.0	224.3	9.3	0.0
		Rain	8.0	29.0	10.1	434.0	282.1	6.6	7.6
		Winter	7.5	19.0	55.8	673.0	437.5	8.4	0.0
	Site III	Summer	8.2	30.0	18.7	335.0	217.8	9.5	0.0
		Rain	8.3	29.5	9.8	532.0	345.8	7.5	9.2
		Winter	7.8	19.0	45.6	518.0	336.7	9.2	5.6
Annual Mean 2015			7.8±0.5	26.4±5.4	29.0±22.0	386.1±82.9	251.0±53.9	7.3±1.6	2.4±3.0
Annual Mean 2016			7.9±0.3	26.1±5.2	27.3±17.0	467.1±129.0	303.6±83.9	8.3±1.2	4.7±4.2
Seasonal Mean - Summer			8.0±0.4	30.3±0.6	21.1±2.2	321.2±21.5	208.8±14.0	7.8±1.5	0.9±1.5
Seasonal Mean - Rain			7.9±0.5	29.2±0.6	10.5±2.8	412.5±65.1	268.1±42.3	6.4±0.6	7.2±1.3
Seasonal Mean - Winter			7.7±0.3	19.2±0.3	53.1±7.1	543.2±90.0	355.0±58.5	9.2±0.7	2.5±4.1

Table-1b: Observed value of physico-chemical parameters of water of the river Burhi Gandak at Samastipur during 2015-2016.

Year	Site	Seasons	CA (ppm)	BA (ppm)	TH (ppm)	Calcium (ppm)	Chloride (ppm)	Silicate (ppm)
2015	Site I	Summer	0.0	96.0	110.0	14.0	9.3	18.3
		Rain	0.0	134.0	123.0	19.0	7.4	16.2
		Winter	16.0	110.0	106.0	28.1	16.0	22.6
	Site II	Summer	4.3	98.0	122.0	22.5	9.6	19.6
		Rain	0.0	140.0	134.0	18.0	9.3	15.7
		Winter	8.0	184.0	160.0	41.7	8.0	24.0
	Site III	Summer	4.2	117.0	122.0	17.0	10.5	19.3
		Rain	0.0	110.0	118.0	39.3	9.7	17.0
		Winter	10.0	192.0	156.0	39.3	14.6	19.6
2016	Site I	Summer	0.0	112.0	120.0	16.0	8.2	22.4
		Rain	0.0	178.0	160.0	28.1	12.2	18.6
		Winter	0.0	164.0	176.0	34.5	21.0	19.8
	Site II	Summer	3.8	118.0	136.0	27.5	12.8	23.6
		Rain	0.0	184.0	168.0	21.1	12.0	19.4
		Winter	8.2	160.0	136.0	26.5	12.0	22.0
	Site III	Summer	3.4	126.0	130.0	14.6	12.4	15.6
		Rain	0.0	194.0	160.0	8.1	14.0	19.3
		Winter	0.0	170.0	152.0	22.4	12.2	21.2
Annual Mean 2015			4.7±5.6	131.2±35.3	127.9±18.9	26.5±10.9	10.5±2.9	19.1±2.8
Annual Mean 2016			1.7±2.9	156.2±30.1	148.7±18.9	22.1±8.1	13.0±3.4	20.2±2.4
Seasonal Mean - Summer			2.6±2.1	111.2±11.9	123.3±8.9	18.6±5.3	10.5±1.8	19.8±2.9
Seasonal Mean - Rain			0±0	156.7±33.4	143.8±21.5	22.3±0.15	10.8±2.4	17.7±1.6
Seasonal Mean - Winter			7.0±6.2	163.3±28.8	147.7±24.1	32.1±7.6	14.0±4.4	21.5±1.7

Conclusion

The present study on water qualities of five experimental sites, three of the river Burhi Gandak (lotic ecosystem) and two of ponds (lentic ecosystem) at Samastipur, Bihar were conducted during two consecutive years on thirteen parameters viz., pH, Temperature, Transparency, Conductivity, Total Dissolved Solids, Dissolved Oxygen, Free Carbon di-oxide, Carbonate Alkalinity, Bicarbonate Alkalinity, Total Hardness, Calcium, Chloride and Silicate.

Values of pH, Temperature, Carbonate Alkalinity, Chloride and Silicate of pond water were found higher than that of river water, whereas Transparency, Dissolved Oxygen, Bicarbonate Alkalinity, Total Hardness, Calcium of pond water were found lower than the river water. Values of most of the physico-chemical parameters were found within the limits prescribed by World Health Organisation (WHO) and Ministry of Works and Housing for drinking water.

Table-2a: Observed value of physico-chemical parameters of water of two Ponds at Samastipur during 2015-2016.

Year	Site	Seasons	pH	Temperature (C)	Transparency (cm)	Conductivity (μ mhos)	TDS (ppm)	DO (ppm)	Free CO_2 (ppm)
2015	Pond I	Summer	8.3	35.5	24.0	405.0	263.3	5.6	0.0
		Rain	8.4	31.0	20.8	635.0	412.8	5.4	10.0
		Winter	7.4	18.5	28.5	245.0	159.3	8.6	7.6
	Pond II	Summer	7.4	35.0	24.5	415.0	269.8	5.7	0.0
		Rain	8.3	31.5	21.6	610.0	396.5	5.2	10.4
		Winter	7.4	19.0	22.6	245.0	159.3	8.3	7.8
2016	Pond I	Summer	8.4	35.0	21.0	470.0	305.5	5.2	0.0
		Rain	8.3	30.3	17.5	605.0	393.3	6.2	13.5
		Winter	7.3	18.0	30.4	228.4	148.4	7.8	0.0
	Pond II	Summer	8.4	34.5	22.0	440.0	286.0	5.3	0.0
		Rain	8.4	30.6	17.8	610.0	396.5	6.2	12.5
		Winter	7.4	18.2	29.0	236.0	153.4	7.8	0.0
Annual Mean 2015			7.9±0.5	28.4±7.7	23.7±2.7	425.8±169.5	276.8±110.2	6.4±1.5	6.0±4.8
Annual Mean 2016			8.0±0.5	27.8±7.7	23.0±5.5	431.6±169.1	280.5±110.0	6.4±1.1	4.3±6.7
Seasonal Mean - Summer			8.1±0.5	35.0±0.4	22.9±1.7	432.5±29.0	281.1±18.9	5.4±0.2	0±0
Seasonal Mean - Rain			8.3±0.1	30.9±0.5	19.4±2.1	615.0±13.5	399.8±8.8	5.7±0.5	11.6±1.7
Seasonal Mean - Winter			7.4±0.0	18.4±0.4	27.6±3.4	238.6±8.0	155.1±5.2	8.1±0.4	3.9±4.4

Table-2a: Observed value of physico-chemical parameters of water of two Ponds at Samastipur during 2015-2016.

Year	Site	Seasons	CA (ppm)	BA (ppm)	TH (ppm)	Calcium (ppm)	Chloride (ppm)	Silicate (ppm)
2015	Pond I	Summer	18.4	133.5	95.0	22.5	61.5	25.5
		Rain	0.0	115.0	153.4	12.5	110.3	14.0
		Winter	0.0	117.5	117.0	13.3	50.5	30.0
	Pond II	Summer	18.2	135,6	95.6	21.3	61.0	25.3
		Rain	0.0	123.5	154.2	14.3	112.3	13.8
		Winter	0.0	112.0	110.2	12.2	55.3	29.0
2016	Pond I	Summer	14.6	147.4	117.5	28.8	74.4	27.0
		Rain	0.0	135.7	141.5	15.4	124.3	15.4
		Winter	17.3	95.4	105.6	17.5	37.8	29.6
	Pond II	Summer	15.6	144.2	110.2	27.8	75.2	26.8
		Rain	0.0	138.2	137.2	17.2	122.4	15.3
		Winter	18.1	98.3	107.3	17.2	37.9	28.2
Annual Mean 2015			6.1±9.4	120.3±8.5	120.9±26.9	16.0±4.6	75.1±28.3	22.9±7.2
Annual Mean 2016			10.9±8.6	126.5±23.4	119.9±15.7	20.6±6.0	78.7±38.4	23.7±6.6
Seasonal Mean - Summer			16.7±1.9	141.7±7.3	104.6±11.1	25.1±3.7	68.0±7.8	26.2±0.9
Seasonal Mean - Rain			0±0	128.1±10.9	146.6±8.5	14.8±2.0	117.3±7.0	14.6±0.8
Seasonal Mean - Winter			8.9±1.2	105.8±10.7	110.0±5.0	15.1±2.7	45.4±9.0	29.2±0.8

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