Biospectra : ISSN: 0973-7057, Vol. 15(1), March, 2020, pp. 59-64
An International Biannual Refereed Journal of Life Sciences

Animal Science

ISSN : 0973-7057

Int. Database Index: 663 www.mjl.clarivate.com

Analysis of water quality parameters of tributaries of the river Kosi Madhepura district, North Bihar

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Received : 09th December, 2019 ; Revised : 11th January, 2020

Abstract: The present study was undertaken to analyze water quality parameters in tributaries of Kosi River in Madhepura district of North Bihar, India. Three different tributaries, named locally as Kirkhidhar, Gomtidhar and river Sursar were selected for investigations. These, over flow channels and old river bed of Kosi River, are one of the prime sources of water in the study area. Though, these water resources are continuously subjected to tremendous anthropogenic pressure leads to degradation of water quality and depletion of biota. The samples were collected monthly from January 2018 to December 2018. Physico-chemical parameters analyzed were temperature, transparency, conductivity, pH, dissolved oxygen, free carbon dioxide, total alkalinity, calcium, magnesium, chloride, nitrate, phosphate and BOD. Frequent flooding during monsoon season decreases some variables to a considerable extent. Correlation coefficient analysis showed high significant positive and negative correlation. The recorded parameters were within the prescribed limit of WHO and BIS except nitrate-nitrogen. With respect to water quality, tributaries studied was not highly polluted, water is suitable for irrigation and domestic purposes. But, there is an indication of increasing pollutant due to disposal of human and animal wastes and agricultural runoff, therefore, a proper monitoring of water quality is needed to avoid contamination.

Key words: Kosi River, Tributaries, Physico-chemical parameters, Correlation, Threats

INTRODUCTION

India has a vast network of rivers and its tributaries[1]. These are one of the important natural water resources uses for drinking, irrigation, transportation, electricity and provide livelihoods for thousand and thousand people all over country. Several studies have reported status of rivers after receiving a variety of pollutants altering physico-chemical and biological characteristics[2,3].

Kosi basin located in north of the Ganga River in Bihar state has a vast aquatic resource in terms of rivers and its tributaries. Kosi River is attributed as a major river of Kosi basin. It rises in Tibet, travels a distance of 724 Km southwards before merging with Ganga near Kursela. On its way to plain, Kosi River is joined by a good number of old river beds and over flow channels 'dhars'. These water bodies were reportedly yielding a good quantity of fish till recently[4].

Kosi River and its tributaries drain the plain of north Bihar is an important water resources for irrigation and domestic purposes. Tributaries of this river are currently facing tremendous pressure due to anthropogenic activities and agricultural runoff leading to degradation of water quality and depletion of biota. Most of the tributaries remain less examined aquatic ecosystems with regard to the baseline information. Therefore, the present study is

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an attempt to provide the basic data on physico-chemical characteristics of water in three tributaries of river Kosi located in Madhepura district of North Bihar.

MATERIALS AND METHODS

The present study has been carried out in Kosi basin (24º55' N to 27º31' N latitudes and 83º21'E to 88º17' E longitudes) to examine water quality status of three different tributaries of river Kosi at Madhepura district of North Bihar. The selected tributaries are termed locally as Bhirkhi dhar, Gomati dhar and river Sursar. Water current and size of these tributaries vary extensively during monsoon and non-monsoon season and rises many times during the flood periods. Samples were taken at monthly basis from January 2018 to December 2018.

Samples were collected by using polyethylene bottle of two liter capacity. Sampling bottles were first cleaned with water and then socked in 1:1 HNO_3 for 24 hours. Bottles were finely rinsed with distilled water. Again bottles were rinsed with sample water before filling. Sample was collected by immersing bottle directly from the depth of 10-15 cm below the surface water. The physico-chemical parameters analyzed on spot were water temperature, transparency, pH, DO and alkalinity. Samples were brought to the laboratory to analyze electrical conductivity, calcium, magnesium, chloride, nitrate-nitrogen, phosphate-phosphate and BOD. Analysis of the samples was done as per standard methods[5, 6].

RESULTS AND DISCUSSION

The results of the present study with respect to range (the maximum and the minimum), mean and standard deviation are presented in Table 1 and correlation data in Table 2 to 4.

Temperature regulates rate of chemical reactions and biological activities within water. High temperature decreases solubility of DO[7]. Water temperature ranged from 18.3-33.2 (26.9±4.5)ºC in Bhirkhi dhar, 19.2-34.9 (27.9±4.7)ºC in Gomti dhar and 19.5-35.8 (27.8±4.9) ºC in river Sursar (Table 1). The minimum temperature was recorded during winter and maximum observed in summer. Variation in temperature depends on the season, geographic location, atmospheric temperature and sampling time[8]. Water temperature was fairly high in all tributaries as located in subtropical region. Temperature showed a high negative correlation with DO and pH and a high positive correlation with magnesium and BOD (Table 2 to 4).

Secchi disc transparency measures the ability of water to transmit sunlight through the water column. The penetration of light is necessary for photosynthesis. Water transparency varied from 6.1-41.8 (25.1±11.7) cm in Bhirkhi dhar, 9.12-42.3 (26.7±10.3) cm in Gomti dhar and 9.6-43.2 (26.4±11.1) cm in Sursar river (Table1). The minimum transparency was recorded in monsoon and the maximum recorded during winter. The reduction in the light *penetration in water during monsoon* limits photosynthesis causes lowering of pH and DO consequently affects aquatic life. From monsoon onward water transparency increases and reaches higher in winter. Transparency of tributaries water more controlled by the suspended silt particles and less by the phytoplankton. Water transparency showed a high positive correlation with EC (r=0.805; p>0.001) in Bhirkhi dhar and a moderate negative correlation with free carbon dioxide (r=-0.781;p>0.001) in Gomti dhar (Table 2 and 3).

Water capability to transmit electric current is known as electrical conductivity and serves as tool to assess the purity of water. EC is affected by suspended impurities and depends on amount of ions present in water. EC ranged from 89.7-216.6(160.3±44.96) ìmohs/cm in Bhirkhi dhar, 115.5-396.9 (242.2±88.06) ìmohs/cm in Gomti dhar and 126.7-445.9 (290.8±96.16) ìmohs/cm in river Sursar (Table 1). EC was potable, soft and good to water quality. The maximum EC was observed during summer and the minimum recorded in monsoon.EC was affected by dilution factors, low EC during monsoon could be due to increase water level dilutes dissolved salts and ions, whereas, high EC in summer might be related to decrease water level concentrates content[9]. EC was much below the value recommended by WHO[10]. EC showed a high positive correlation with chloride, nitrate-nitrogen and phosphate-phosphorus in all tributaries, however, revealed a high positive correlation with calcium and alkalinity and a negative correlation with free carbon dioxide in Gomati dhar and river Sursar (Table 2 to 4).

pH measures relative amounts of free hydrogen and hydroxyl ions present in water. Water with more free hydrogen ions is acidic and with more free hydroxyl ions is basic[11]. pH varied within the range of 7.1-7.8 (7.4±0.2) in Bhirkhi dhar, 7.3-8.1 (7.7±0.2) in Gomti dhar and 7.2

to 8.0 (7.7±0.2) in river Sursar. pH range was alkaline in nature ranging within the permissible limit (6.5-8.5) recommended by WHO[10].The pH is good for promoting high primary productivity. The minimum pH was recorded during summer and the maximum observed in winter. Low pH observed during summer might be due to high temperature and decrease water level, whereas, high pH in winter could be due to greater phytoplankton density consequently removal of free carbon dioxide by photosynthetic uptake increasingpH[12]. With respect to the pH, water of all tributaries is suitable for drinking, bathing, washing, and irrigation. The pH exhibited a moderate positive correlation with DO (r=0.759; p>0.001) in Kirkhi dhar and a strong positive correlation (r=0.845; p>0.001) in Gomti dhar and (r=0.888;p>0.001) in river Sursar (Table 2 to 4).

Dissolved oxygen (DO) affects the growth, survival, distribution, behavior and physiology of aquatic organisms. The principal source of oxygen in water is atmospheric air and photosynthetic plankton and plant. DO range within the range of 4.7-6.7(5.3±0.5) mg/l in Bhirkhi dhar, 5.0-7.9 (5.9±0.8) mg/l in Gomti dhar and 5.0-7.5 (6.1±0.7) mg/l in rivers Sursar (Table 1). The maximum DO was recorded during winter and the minimum was observed in summer. High DO coincided with low temperature probably due to oxygen solubility increases with decreasing temperature[13].

The highest DO was recorded in summer due to low solubility of oxygen at high temperature and elevated microbial activities for degrading organic matter consume more oxygen.

Free carbon dioxide exists in water in the form of dissolved gas. The carbon dioxide released in water during respiration by biota and during decomposition of organic matter by microbes. Free carbon dioxide varied from 1.2-3.5 (2.5±1.1) mg/l in Bhirkhi dhar, 1.7-6.5(4.2±1.7) mg/l in Gomti dhar and 1.2-4.7(2.9±1.3) mg/l in river Sursar (Table 1). Tributaries studied were contain less amounts of free carbon dioxide which is below the permissible limit (22 mg/l) recommended by WHO[10]. The maximum free carbon dioxide was recorded during monsoon and the minimum observed in winter, though, it was not recorded in some months. The highest free carbon dioxide in monsoon could be due to addition of agricultural runoff contains biodegradable organic wastes consequently elevated microbial activities releases more carbon dioxide. The free carbon dioxide showed a strong negative correlation with alkalinity (r=-0.863; p>0.001) and calcium (r=-0.819; p>0.001) in Gomti dhar (Table-3).

Total alkalinity (TA) is important for aquatic life because of its buffering capacity against the rapid pH change[14, 15].The alkalinity varied from 95.5-137.9 (118.5±11.4) mg/l in Bhirkhi dhar, 102.4-150.9 (129.1±12.9) mg/l in Gomti dhar and 101.0-154.4 (130.6±29.1) mg/l in river Sursar (Table 1). The alkalinity was within the permissible range (50-200 mg/l) recommended by BIS[16]. The maximum alkalinity was recorded during summer and the minimum observed in monsoon. Water alkalinity was primarily due to bicarbonate concentration. Total alkalinity showed a strong positive correlation with calcium, chloride, nitrate-nitrogen and phosphate-phosphorus in Gomati dhar and in river Sursar (Table 3 and 4).

The calcium dissolved in natural water is one of the most common mineral that contribute to water hardness. Calcium plays various structural and functional roles in living organism[17].The calcium content ranged from 10.7-23.3 (15.7±3.6)mg/l in Bhirkhi dhar, 8.2-25.2 (18.3±4.3)mg/l in Gomti dhar and 9.6-26.3 (17.9±5.1)mg/l in river Sursar (Table 1). Calcium was much below the guideline value (75mg/l) recommended by BIS[16]. The minimum calcium was recorded in monsoon and the maximum observed during summer. Variation in calcium content might be due to dilution effects, decrease in calcium during monsoon could be attributed to increase water level dilutes content, whereas increase in calcium in summer could be related to decrease water level concentrates content. Calcium exhibited a strong positive correlation with chloride, nitrate-nitrogen and phosphate-phosphorus (Table 2 to 4).

Magnesium is often associated with calcium in all kinds of natural waters. Magnesium requires for *chlorophyll* synthesis and acts as a limiting factor for the growth of phytoplankton[17].The magnesium ranged from 4.1-14.1(9.0±2.6) mg/l in Bhirkhi dhar, 5.2-16.1(10.7±3.5) mg/l in Gomti dhar and 6.1-15.6 (10.1±2.9) mg/l in river Sursar (Table 1). Magnesium was below the guideline value (35 mg/l) recommended by BIS[16]. In terms of the magnesium, water is good for irrigation. The maximum magnesium was recorded in summer and the minimum

during winter. The highest amount of magnesium was recorded during summer might be due to decrease water level concentrates content. Magnesium showed a high positive correlation with BOD (r=0.868; p>0.001) in Sursar river (Table 4).

Chloride is widely distributed in natural water as salts of sodium chloride (NaCl), potassium chloride (KCl) and calcium chloride ($CaCl_2$). Higher concentration of chloride indicates organic pollution mainly of animal origin[18]. Chloride ranged within the range of 6.9-21.9(12.9±4.3) mg/l in Bhirkhi dhar, 8.8-28.5(16.8±6.1) mg/l in Gomti dhar and 8.7-28.1 (17.9±6.3)mg/l in Sursar river. The chloride was much below the maximum permissible limit (250 mg/l) recommended by WHO[10]. This could be attributed to absence of industrial and domestic wastewater discharge in the studied tributaries. In terms of chloride, all tributaries are unpolluted. The maximum chloride was recorded during summer and the minimum observed was in monsoon. Variation in chloride was due to dilution factors, the increase water level during monsoon dilutes content and decrease water level in summer concentrates content. Concentration of chloride was high in river Sursar could be attributed to human and animals waste contamination. The chloride ions cannot remove from water body biologically, as it is highly soluble in water. Chlorides how a strong positive correlation with nitrate-nitrogen and phosphate-phosphorus in all tributaries (Table 2 to 4).

The nitrate ion is the common form of nitrogen found in all kinds of natural waters, though, only little *amount of nitrate occur in water*[19]. Nitrate-nitrogen varied in the range of 0.007-0.177 (0.101±0.1)mg/l in Bhirkhi dhar, 0.014-0.273 (0.123±0.1)mg/l in Gomti dhar and 0.008-0.198 (0.094±0.1)mg/l in river Sursar (Table 1). Nitrate-nitrogen is much below the permissible limit (45 mg/l) recommended by WHO[10]. The maximum nitrate-nitrogen was recorded during summer and the minimum observed in monsoon. The lowest nitrate-nitrogen was recorded in monsoon might be due to addition of rain and floodwater dilutes content, however, highest during summer probably due to decaying nitrogenous organic matter adding nitrogen and decrease water level concentrates content. The concentration of nitrate-nitrogen was relatively higher in Gomti dhar due to added agricultural runoff and anthropogenic contamination. The nitrate-nitrogen showed a high positive correlation with phosphate-phosphorus(r=0.908; p>0.001) in Bhirkhi dhar, (r=0.925; p>0.001) in Gomti dhar and (r=0.888; p>0.001) in Sursar river (Table 2 to 4).

Phosphorus is the first limiting nutrient supports *growth* of algae and *plants* which offer food and *habitat* for fish and smaller organism living in *water*. The most common form of phosphorus used by biological organisms is phosphate. Phosphate-phosphorus concentration ranged from 0.039-0.394(0.173±0.1) mg/l in Bhirkhi dhar, 0.051-0.427 (0.191±0.1)mg/l in Gomti dhar, and 0.052-0.408 (0.194±0.1) mg/l in river Sursar. Phosphate-phosphorus was above the guideline value (0.1 mg/l) prescribed by WHO[10]. The maximum phosphate-phosphorus was recorded in summer and the minimum observed during monsoon. Agricultural runoff from adjacent paddy fields contain high phosphorus is main source of phosphate in the studied tributaries. Variation in phosphate-phosphorus was due to dilution factors, decrease water volume concentrates content might be the reason of high phosphate during summer, however frequent flooding in monsoon dilutes content. At the recorded level, phosphate-phosphorus not possesses any threat to human health. Phosphate-phosphorus showed a positive correlation with BOD in Gomati dhar (0.725; p>0.001) and in Sursar river (0.793; p>0.001).

Biochemical Oxygen Demand (BOD) is amounts of dissolved oxygen required by microbes to break down organic material in the water body. BOD value indicates degree of water pollution could be attributed to the maximum and the minimum biological activities. BOD of unpolluted waters should be less than 2mg/l while those receiving waste waters may have value up to 10 mg/l[20]. BODin the tributaries water ranged from 1.5-3.2 (2.2±0.5) mg/l in Bhirkhi dhar, 1.5-3.6 (2.5 ±0.6) mg/l in Gomti dhar and 1.7-3.9 (2.6±0.7) mg/l in river Sursar. BOD was much below the permissible limit (6 mg/l) recommended by WHO[10]. The maximum BOD was recorded during summer and the minimum recorded was in winter. BOD directly affects the amounts of dissolved oxygen in tributaries water. The BOD was highest during summer might be due to the high temperature and high decomposition rate of organic matter by microbes consume more oxygen[21, 22]. However the BOD was lowest in winter due to low temperature reducing microbial activity that consumes less oxygen.

Table-1: Range (min. and max.), mean and standard deviation of physico-chemical parameters.

	Bhirkhi dhar			Gomati dhar			Sursar river			WHO (2004) limits
Parameters	**Min.**	**Max.**	**Mean ± SD**	**Min.**	**Max.**	**Mean ± SD**	**Min.**	**Max.**	**Mean SD**	
Water Temperature	18.3	33.2	26.9 ± 4.5	19.2	34.9	27.9 ± 4.7	19.5	35.8	27.8 ± 4.9	30-35
Transparency	6.1	41.8	25.1 ± 11.7	9.12	42.3	26.7 ± 10.5	9.6	43.2	26.4 ± 11.1	N/A
Electrical Conductivity	89.7	216.6	160.3 ± 44.9	115.5	396.9	242.2 ± 88.0	126.7	445.6	290.8 ± 96.1	750
pH	7.1	7.8	7.4 ± 0.2	7.3	8.1	7.7 ± 0.2	7.2	8.0	7.7 ± 0.2	6.5-8.5
Dissolved Oxygen	4.6	6.7	5.3 ± 0.5	5.0	7.2	5.9 ± 0.8	5.1	7.5	6.1 ± 0.7	5.0-7.0
Free Carbon Dioxide	1.2	3.5	2.5 ± 1.1	1.7	6.5	4.2 ± 1.7	1.4	4.7	2.9 ± 1.3	22
Total Alkalinity	95.5	137.9	118.5 ± 11.4	102.4	150.9	129.1 ± 12.9	101.0	154.4	130.6 ± 29.1	50-200 (BIS, 2004)
Calcium	10.7	23.3	15.7 ± 3.6	8.2	25.2	18.3 ± 4.3	9.6	26.3	17.9 ± 5.1	75 (BIS, 2004)
Magnesium	4.1	14.1	9.0 ± 2.6	5.2	16.1	10.7 ± 3.5	6.1	15.6	10.1 ± 2.9	35 (BIS, 2004)
Chloride	6.9	21.9	12.9 ± 4.3	8.8	28.5	16.8 ± 6.1	8.7	28.1	17.9 ± 6.3	250
Nitrate-Nitrogen	0.007	0.177	0.101 ± 0.1	0.014	0.273	0.123 ± 0.1	0.008	0.198	0.094 ± 0.1	45
Phosphate-Phosphorus	0.039	0.394	0.173 ± 0.1	0.051	0.427	0.191 ± 0.1	0.052	0.408	0.194 ± 0.1	0.1
BOD	1.5	3.2	2.2 ± 0.5	1.7	3.6	2.5 ± 0.6	1.7	3.9	2.6 ± 0.7	6.0

*Values in mg/l,except Temp. (°C), Transp. (cm), EC (µmohs/cm) and pH.

Table-2: Correlation coefficient (*r*) matrix of physico-chemical parameters of Bhirkhi dhar.

Parameter	Temp.	Trans.	E.C.	pH	DO	Free CO_2	TA	Ca^{2+}	Mg^{2+}	Cl^{1-}	NO_3^--N	PO_4^{2-}-P	BOD
W. Temp.	_	-0.515	-0.149	-0.732	-0.892*	0.265	-0.210	0.127	0.878*	0.290	0.216	0.300	0.738
W. Trans.		_	0.805*	0.482	0.650	-0.740	0.527	0.504	-0.179	0.538	0.561	0.564	-0.221
EC			_	0.088	0.367	-0.863*	0.731	0.788	0.150	0.832*	0.861*	0.838*	0.225
pH				_	0.759*	-0.187	0.223	-0.069	-0.674	-0.127	-0.246	-0.169	-0.534
DO					_	-0.446	0.374	0.147	-0.743	0.002	0.013	-0.021	-0.587
Free CO_2							-0.714	-0.719	0.022	-0.662	-0.681	-0.659	-0.115
TA							_	0.736	-0.059	0.652	0.674	0.543	0.248
Ca^{2+}								_	0.374	0.892*	0.877*	0.844*	0.519
Mg^{2+}									_	0.511	0.501	0.569	0.732
Cl^{1-}										_	0.916*	0.951*	0.559
NO_3^--N											_	0.908*	0.515
PO_4^{2-}-P												_	0.485
BOD													_

*Significant at p>0.001

Table-3: Correlation coefficient (*r*) matrix of physico-chemical parameters of Gomti dhar.

Parameter	Temp.	Trans.	E.C.	pH	DO	Free CO_2	TA	Ca^{2+}	Mg^{2+}	Cl^{1-}	NO_3^--N	PO_4^{2-}-P	BOD
W. Temp.	_	-0.627	0.154	-0.786	-0.957*	0.314	0.046	0.077	0.754	0.289	0.245	0.349	0.728
W. Trans.		_	0.613	0.711	0.736	-0.781	0.604	0.598	0.118	0.518	0.521	0.462	-0.100
E.C.			_	0.157	0.003	-0.744	0.886*	0.879*	0.528	0.954*	0.951*	0.947*	0.538
pH				_	0.845*	-0.399	0.166	0.122	-0.481	0.068	-0.008	0.001	-0.479
DO					_	-0.436	0.091	0.067	-0.639	-0.123	-0.112	-0.191	-0.604
Free CO_2						_	-0.863*	-0.819*	-0.155	-0.642	-0.693	-0.619	-0.102
TA							_	0.917*	0.468	0.837*	0.841*	0.852*	0.438
Ca^{2+}								_	0.561	0.844*	0.889*	0.825*	0.424
Mg^{2+}									_	0.615	0.588	0.642	0.716
Cl^{1-}										_	0.944*	0.976*	0.661
NO_3^--N											_	0.925*	0.596
PO_4^{2-}-P												_	0.725
BOD													_

*Significant at p>0.001

Table-4: Correlation coefficient (*r*) matrix of physico-chemical parameters of river Sursar.

Parameter	Temp.	Trans.	E.C.	pH	DO	Free CO_2	TA	Ca^{2+}	Mg^{2+}	Cl^{1-}	NO_3^--N	PO_4^{2-}-P	BOD
W. Temp.	_	-0.565	0.127	-0.809*	-0.913*	0.204	0.027	0.017	0.846*	0.299	0.230	0.409	0.817*
W. Trans.		_	0.711	0.539	0.675	-0.692	0.693	0.693	-0.202	0.555	0.583	0.477	-0.066
E.C.			_	-0.010	0.090	-0.711	0.881*	0.874*	0.464	0.918*	0.878*	0.926*	0.626
pH				_	0.888*	-0.117	0.121	0.078	-0.596	-0.149	-0.092	-0.211	-0.614
DO					_	-0.250	0.189	0.135	-0.690	-0.137	-0.070	-0.183	-0.638
Free CO_2						_	-0.658	-0.717	-0.060	-0.689	-0.609	-0.574	-0.231
TA							_	0.894*	0.350	0.889*	0.895*	0.846*	0.487
Ca^{2+}								_	0.304	0.887*	0.900*	0.785*	0.496
Mg^{2+}									_	0.576	0.520	0.647	0.868*
Cl^{1-}										_	0.948*	0.938*	0.716
NO_3^--N											_	0.888*	0.633
PO_4^{2-}-P												_	0.793
BOD													_

*Significant at p>0.001

CONCLUSION

While assessing the results of various parameters, it was observed that all tributaries (dhars and river) have a good water quality suitable for irrigation, fisheries, cattle watering and other domestic uses. Physico-chemical parameters recorded were within the permissible limit, except phosphate. The studied tributaries are not polluted till date but there is an indication of increasing pollutant mainly due to the disposal of anthropogenic wastes and agricultural runoff, therefore, to prevent further contamination a proper monitoring of water quality of tributaries is needed.

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