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SEASONAL VARIATIONS IN PHYSICO-CHEMICAL CHARACTERISTICS AND WATER QUALITY OF KOSI RIVER AT BHAGALPUR AND KATIHAR DISTRICT OF NORTH BIHAR

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The aim of this study is to assess physico-chemical characteristics, pollution studies from January 2017 to October 2017 of lower Kosi area. The range of various parameters of river water (The ambient temperature ranged between 17.2°C – 32.4°C, water temperature 15°C-32°C, electrical conductivity 81-256 µS, depth 1-4 m total dissolved solids 41-130mg/l, pH 7.9-8.9, dissolved oxygen 8.8-16 mg/l, free carbon dioxide 4-60 mg/l, total alkalinity 14-26 mg/l, total hardness 32-158 mg/l, chlorides 1.9-9.9 mg/l, calcium hardness 60-140 mg/l, nitrate-nitrogen 0.017-0.117 mg/l, phosphate-phosphorus 0.11-0.2 mg/l, biochemical oxygen demand 0.4-4 mg/l, chemical oxygen demand 5.376-67.08 mg/l) exhibit seasonal fluctuations. Agricultural practices are performed both the side of river. This was due to allocthonous nutrients brought in to the river from the surrounding catchment area. The WQI at all sites III in pre-monsoon and winters at site II were in poor category. The above study indicated that the river water is slightly inclined towards eutrophication. Therefore, the conservation and management of this river water stretch is very much required.

Keywords: Kosi River, Physico-chemical parameters, Water quality index, Eutrophication , Conservation

Water is one of the most wonderful natural resources and abundant compound of the ecosystem. Water is an essential constituent for all living organisms on the earth. The Kosi River is an international river. The upper portion of river Kosi flows through Tibet and Nepal in Himalayan Mountains and the lower portion through plains of north Bihar.

The Kosi River in north Bihar plains is one of the major tributaries of the River Ganga which originates from Gosainthan situated in the north east of Kathmandu, Nepal across Kanchenjunga and enters the Terai region near Charta and then flows into plains of Bihar. There after it joins the River Ganga near Kursela in Katihar district. River Kosi, one of the largest tributaries of the Ganga, carries second highest load of silt and sediments in the world River water quality is of great environmental concern since it is one of the major available fresh water resources for human consumption. The aim of the present study was to generate base line data of water quality lower Kosi river at Bhagalpur to Katihar district of Bihar (India). Today human activities are constantly adding industrial, domestic and agricultural waste to ground water reservoirs at an alarming rate (Panda and Sinha 1991).

Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. The values of these parameters are harmful for human health if they occurred more than defined limits. Therefore, the suitability of water sources for human consumption has been described in terms of Water quality index (WQI), which is one of the most effective ways to describe the quality of water (Sinha *et al.* 2004 , Mohanta *et al.* 2000 and Kumar *et al*. 2009).

The objective of the present research is to provide information on the physico-chemical characteristics of Kosi river water in order to appreciate the impacts of unregulated waste discharge on the quality of the river as well as to discuss its suitability for human consumption based on computed water quality index values.

MATERIALS AND METHODS

The present study was done in the 44 km stretch of the area in lower Kosi river water flowing through Bhagalpur district to Katihar district of Bihar (India) in 2017. These sampling locations are Trimohan Ghats, Hario, Bihpur

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(25° 26′ 08" N, 86° 55′ 50″ E), Vijay Ghat, Naugachia (25° 25' 16″ N, 87°05' 04″E) and Kosi Ganga confluence at Kursela in Katihar (25° 24' 46″N 087° 15' 00″ E). Sampling sites II is approximately 19 km downstream of site I and Site III is approximately 25 km downstream of site II .

Water samples were collected from sampling each site. Kosi River in winter, pre monsoon and post monsoon seasons for one consecutive year. The water samples of Kosi River were collected from surface between 7.00AM to 11.30AM. Various physico-chemical parameters like temperature, pH, dissolved oxygen, electrical conductivity, Free carbon dioxide and Total dissolved solids were determined on the spot immediately and for the rest parameters water samples were brought in high quality plastic bottles to Environmental Biology Research laboratory , P.G. Department of Botany, T.M. Bhagalpur University ,Bhagalpur and samples were analysed using the standard methods (Welch 1952 , Trivedi and Goel 1984, APHA 2012) .

Water Quality Index (WQI) of the river Kosi has been calculated to find its suitability for drinking purposes by Weight Arithmetic index method. WQI was calculated considering 13 physicochemical parameters using ISI standard. The WQI has been calculated by using the standard of drinking water quality as recommended by BIS (2012) .The WQI has been calculation method prescribed by Ramakrishnaiah *et al.*2009 and Gebrehiwot *et al.* 2011.

RESULTS AND DISCUSSION

The seasonal physico-chemical analysis of water quality parameters along with water quality index of three sites are summarised in Table 1-4 and Fig-2.

Ambient temperature is one of the most important factors is temperature. The ambient temperature ranged between 17.2°C- 30.2°C for Site I, 18.4°C – 31.4 °C for Site II and 18.8°C - 32.4 for Site III. The maximum temperature was recorded during pre- monsoon season while the minimum temperature was observed during winter season.

The surface water temperature is important physical water quality parameters, which controls the rate of all chemical reactions, and affects aquatic environmental ecosystem. The surface water temperature of Kosi river water was found to be higher 32°C and lower 15 °C, the maximum temperature was recorded during pre- monsoon at site III and minimum during winter season Site I. The fluctuation in river water temperature usually depends on the season, geographic location, sampling time and temperature of effluents entering the stream (Ahipathy and Puttaiah 2006). Higher temperature during pre-monsoon was due to greater heating. Similar trends are also showed by Yadav and Srivastava (2011). It influences the solubility of gases and salts in water. Volume as well as density of water depends upon temperature. Water temperature showed positive correlation with DO, BOD (at .01% significant level) and negative correlation with PH, TDS, EC, TH (0.01% significant level).

Water depth level plays an important role in governing the water quality. Water level was recorded maximum in post-monsoon (4.7m) while minimum water level was recorded in winter (1m) during the study period.

Hydrogen ion concentration (pH) is negative logarithmic value of hydrogen ions. In the water pH is an indicator of acidity or alkalinity. The minimum pH was recorded 7.9 in post monsoon at site II and maximum pH values of the river water samples were recorded 8.9 in winter at site III. From these values, it may be interpreted that the water is alkaline.

In most of the instances where the water is neither very acidic nor very alkaline, the pH is regulated by the Co_2-HCO_3 system (Hutchinson1957). The river water seems to possess high buffering capacity as evidenced by pH fluctuation within a narrow range. Statistical analysis revealed its positive correlation with TH, Water temperature (at

Table 1: Seasonal variations in Physico-Chemical parameters of river Kosi river water at Site I, Site II and Site III

Parameters	Site-I			Site-II			Site-III		
	Winter	Pre- Mosoon	Post-Mosoon	Winter	Pre- Mosoon	Post- Mosoon	Winter	Pre-Monsoon	Post-Mosoon
Air Temp(°C)	16	31.4	30	18.2	32.5	29.1	21.3	34	30
WaterTemp(°C)	15	29	27	17	29	27.7	19.6	32	28
Water Depth	1	1.3	3	1.8	2.7	3	2.5	2.7	4.7
pH	8.8	8.6	8	8.8	8.7	8.1	8.9	7.9	8.3
TDS	78	41	80	130	63	75	89	56	71
Conductivity	153	181	175	256	125	148	200	110	141
DO	8.8	14	10.4	8.8	14	11.2	9.6	16	10.4
FCO_2	20	60	8	30	40	4	18	38	6
Total alkalinity	22	20	16	26	24	14	20	22	18
TH	90	50	36	156	46	32	158	70	44
CaH	90	84	60	120	74	66	140	120	60
Cl^-	5.9	6.9	1.9	4.9	7.9	2.9	6.9	9.9	1.9
PO_4-P	0.03	0.04	0.11	0.03	0.05	0.08	0.02	0.05	0.08
NO_3-N	0.019	0.025	0.019	0.017	0.0216	0.022	0.018	0.117	0.019
BOD	0.8	2.4	4	1.2	2	3.2	0.4	2	2.8
COD	25.1	49.88	5.376	26.9	17.2	6.528	27.1	67.08	14.607

Site I-Trimohan ghat Hario, Site II -Vijay ghat, Naugachia and Site III- Kosi Ganga Confluence Zone, Kursela

*All parameters are expressed in ppm or mg/l except temperature and pH

TDS= Total Dissolve Solid, DO=Dissolved Oxygen, FCO_2=Free carbon dioxide, CO^-_3=Carbonate alkalinity, HCO_3=Bicarbonate alkalinity, TH=Total Hardness, Cl^-=Chloride, PO_4-P=Phosphate phosphorus, NO_3-N=Nitrate nitrogen, BOD=Biological Oxygen Demand, COD=Chemical Oxygen Demand.

.01% significant level) and negative correlation with PO_4-P, BOD (.01% significant level).

Electric conductivity is an important water quality parameters. It ranges between 256 µS to 110 µS. The high value of conductivity was recorded during winter at site II and the lower in pre-monsoon season at site II. Statistically conductivity showed positive correlation with TH, (at .01% significant level) and negative correlation with DO (.01% significant level).

Free carbon dioxide (FCO_2) is present in water in the form of a dissolved and influences the acidity of water and thus can cause corrosion in the distribution system. The concentration of free CO_2 in water increases due to increasing algal blooms. The value of free CO_2 recorded in the water ranges between 4 mg/l to 60 mg/l. The minimum free CO_2 in the water was recorded during post monsoon season at sites II, whereas the maximum value of free CO_2 in water was recorded during pre- monsoon season at sites I. Agricultural runoff and nutrient richness cause in increasing free CO_2 in river water. FCO_2 showed positive correlation with Cl^-, COD (at .01% significant level).

Total Dissolved Solid (TDS) of Water with a high TDS indicates more ionic concentration, which is of inferior palatability and induce an unfavourable physico-chemical reaction in the consumers. The amount of TDS recorded in the Kosi river water ranges between 41 mg/l to 130 mg/l. Maximum value was recorded in winter season at site II and minimum in pre-monsoon at site I. TDS showed positive correlation with EC, TH (at .01% significant level) and negative correlation with DO (.01% significant level).

Alkalinity in water is mainly due to the presence of carbonates, bicarbonate and hydroxides, which may be derived from dissolved rocks, salts or sediments. It is the index of nutrient status of water body. The alkalinity values were recorded in the Kosi

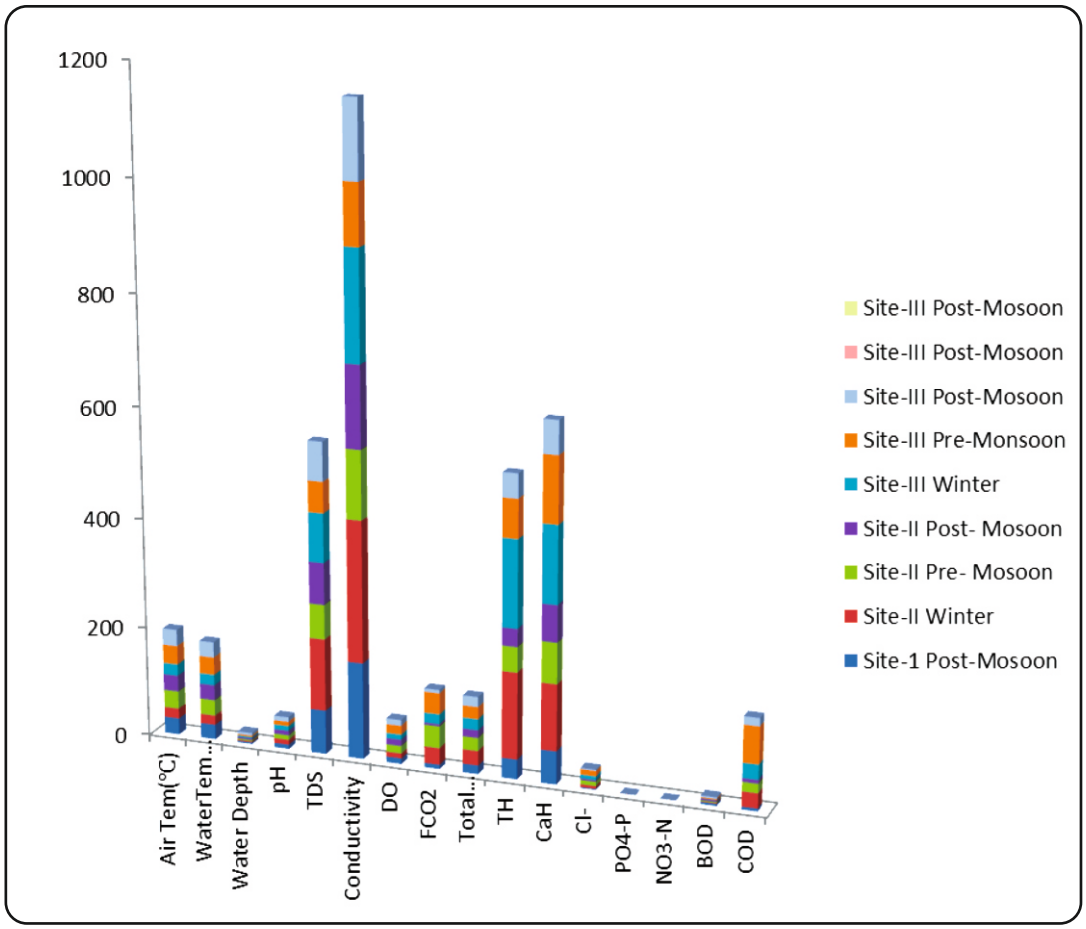

Figure 1: Seasonal variations of Physico-chemical parameters of river Kosi water at Site I, II and III

river water ranges between 14 mg/l to 26 mg/l. Alkalinity maximum value was recorded 26mg/l during winter season at site II whereas the minimum14mg/l in site II during post-monsoon. Alkalinity showed positive correlation with Cl^- (.01% significant level) and negative correlation with PO_4 - P, BOD (.01% significant level).

Chloride is one of the most vital inorganic ions in water. This is found in almost all water bodies as it is highly soluble. The amount of chloride recorded in the Kosi river water ranges between 1.9 mg/l to 9.9 mg/l. The maximum values of chloride in water was recorded during pre- monsoon season at site III, whereas minimum values of chloride in the water recorded during post- monsoon season at site I and site III. Chloride concentration during the study of the river water is found quite low. Chloride contents in water are due to weathering and dissolution of salt deposits and agriculture irrigation runoff. Statistically Chloride showed positive correlation with COD (at .01% significant level) and negative correlation with PO_4- P, BOD (.01% significant level).

Calcium Hardness (CaH) is an important constituent in natural water. Calcium and their salts are directly related to hardness. Calcium hardness recorded in the Kosi river water ranges between 60 mg/l to 140 mg/l. The minimum value was recorded during winter season at sites I and II, whereas the maximum was recorded during winter season at site III. Statistically CaH showed positive correlation with Cl^- (at .01% significant level) and negative

Table 2: Relative weight (Wi) of each Physico-chemical parameters

Parameter	ISI		Weight (wi)	Relative weight(Wi)
pH	6.5	8.5	4	0.093023
TDS	500	2000	4	0.093023
EC	1000	2000	2	0.046512
DO	5		4	0.093023
FCO_2	6*		3	0.069767
Alkalinity	150	300	3	0.069767
TH	300	600	3	0.069767
CaH	75	200	2	0.046512
Cl^-	250	1000	4	0.093023
$PO_4 - P$	0.1	1**	2	0.046512
$NO_3 - N$	45		5	0.116279
BOD	3		4	0.093023
COD	10	20**	3	0.069767
			?wi=43	

***ISI standard **WHO standard All parameters are in mg/L or ppm except pH, and Conductivity**

correlation with PO_4 - P, BOD (.01% significant level).

Total Hardness (TH) is an important parameter of water for its potability. Total hardness recorded in the Kosi river water ranges between 32 mg/l to 158 mg/l. The minimum value of hardness in the water of Kosi River was recorded during post monsoon season at sites II, whereas the maximum amount of hardness in water was recorded during winter season at site III. Water with less than 75mg/l of calcium carbonate is considered soft and above 75mg/l of $CaCO_3$ as hard (Sawyer 1960). In all the sites in winter water was above the 75mg/l, so it was in category of hard water. Higher values of total hardness during winter months are possibly to higher alkalinity and lower water temperature. The higher value of total hardness in winter season may be assumed to result from poor dilution owing to low precipitation rate. The lower values of TH in post monsoon season may be assumed that in the absence of carbon dioxide in free form, some of the half bound carbon (HCO_3) gets channelized into bound form (Co_3), thus resulting in low bicarbonate values. Statistically TH showed positive correlation with CaH (at .01% significant level) and negative correlation with PO_4 - P, BOD (.01% significant level).

Table 3: Physico-Chemical Characteristics and WQI of river Kosi river water

Parameters	Site-I			Site-II			Site-III		
	Winter	Pre-Mosoon	Post-Mosoon	Winter	Pre-Mosoon	Post-Mosoon	Winter	Pre-Monsoon	Post-Mosoon
pH	8.8	8.6	8	8.8	8.7	8.1	8.9	7.9	8.3
TDS	78	41	80	130	63	75	89	56	71
Conductivity	153	81	175	256	125	148	200	110	141
DO	8.8	14	10.4	8.8	14	11.2	9.6	16	10.4
FCO_2	20	60	8	30	40	4	18	38	6
Total alkalinity	22	20	16	26	24	14	20	22	18
TH	90	50	36	156	46	32	158	70	44
CaH	90	84	60	120	74	66	140	120	60
Cl^-	5.9	6.9	1.9	4.9	7.9	2.9	6.9	9.9	1.9
PO_4-P	0.03	0.04	0.11	0.03	0.05	0.08	0.02	0.05	0.08
NO_3-N	0.019	0.025	0.019	0.017	0.0216	0.022	0.018	0.117	0.019
BOD	0.8	2.4	4	1.2	2	3.2	0.4	2	2.8
COD	25.1	49.88	5.376	26.9	17.2	6.528	27.1	67.08	14.607
WQI	81.73	158.03	61.74	100.84	111.43	60.23	85.74	149.97	65.63
WQI Class	Good	Poor	Good	Poor	Poor	Good	Good	Poor	Good

Water quality Index (WQI) at Site-I-(Trimohan ghat Hario), site II-(Vijay ghat Naugachia) and site III-(Kosi Ganga Confluence Kursela).

Table 4: Pearson correlations among the different parameters of surface water from Site I, Site II and Site

	AT(°C)	*WT*(°C)	*Water Depth*	pH	TDS	Cond	DO	FCO_2	Talk	TH	CaH	Cl-	PO_4-P	NO_3-N	BOD	COD
AT(°C)	1															
WT(°C)	0.995**	1														
WD	0.500*	0.507*	1													
pH	-0.679**	-0.711**	-0.517*	1												
TDS	0.715**	-0.718**	-0.068	0.357	1											
Cond.	-0.704**	-0.713**	-0.040	0.357	0.984**	1										
DO	0.826**	0.829**	0.054	-0.434	-0.750**	-0.769**	1									
FCO_2	0.228	0.210	-0.568*	0.287	-0.393	-0.434	0.626**	1								
Talk	-0.344	-0.369	-0.464	0.589*	0.313	0.244	0.075	0.594*	1							
TH	-0.747**	-0.745**	-0.382	0.658**	0.702**	0.726**	-0.474	0.072	0.576*	1						
CaH	-0.437	-0.421	-0.403	0.418	0.366	0.398	-0.037	0.299	0.556*	0.873**	1					
Cl-	0.108	0.105	-0.471	0.236	-0.317	-0.327	0.622**	0.745**	0.624**	0.283	0.632**	1				
PO_4-P	0.546*	0.540*	0.640**	-0.782**	-0.186	-0.163	0.054	2-0.530*	-0.720**	-0.748**	-0.783**	-0.684**	1			
NO_3-N	0.443	0.482	0.047	-0.553*	-0.360	-0.384	0.705**	0.302	0.155	-0.092	0.344	0.612*	-0.049	1		
BOD	0.682**	0.680**	0.513*	-0.785**	-0.336	-0.332	0.251	-0.270	-0.684**	-0.829**	-0.800**	-0.572*	0.945**	-0.001	1	
COD	0.190	0.220	-0.377	-0.047	-0.371	-0.398*	0.626**	0.731**	0.442	0.200	0.574*	0.798**	-0.514*	0.767**	-0.352	1

Significant at *0.05% level, ** 0.01% level

Nitrate-nitrogen is an important crop nutrient that is applied by farmers to cropland. Nitrogen runoff from agricultural fields can enter water bodies resulting in eutrophication or increased algal growth .The other source of nitrogen in the river water is the decomposed organic matter due to microbial population. The values of nitrate recorded in the water of ranges between 0.017 mg/l to 0.117 mg/l. The minimum amount of nitrate in the water of river was recorded during winter season at site II and whereas the maximum amount of nitrate in water was recorded during pre- monsoon season at site III. NO3 – N content was low in winter, this might be due to its rapid rate of consumption by the phytoplankton. The prescribed limit of nitrate-nitrogen concentration in drinking water recommended by BIS is 45mg/l. Low level of Nitrate-nitrogen may be due to natural occurring sources (Shah and Joshi 2017). Statistically NO_3-N was positive correlation with COD (at .01% significant level). Pahwa *et al*. (1966) also made similar observations. NO_3-N was positively correlated to pH.

Phosphate-phosphorus content in surface water is a result of contamination from agricultural effluents with fertilizer. Surface water runoff, agriculture run off, washer man activity could have also contributed to the inorganic phosphate content. Phosphate is one of the limiting factors for phytoplankton productivity because of geochemical shortage of phosphate in drainage basin. The amount phosphate recorded in the water of River Kosi ranges between 0.11 mg/l to 0.2 mg/l. The minimum amount of phosphate in the water of river Kosi was recorded during winter season at site III, whereas the maximum amount of phosphate in water was recorded during post monsoon season at site I. Statistically PO_4-P showed positive correlation with BOD (at .01% significant level). PO_4 -P comes mainly from sewage, household effluents and detergents in to these water bodies. It is one of the most important nutrients for the growth of algal flora (Das *et al.*1956 and Round 1960).The

concentration of PO_4- P showed periodic fluctuations at different sites. The minimum concentration at site III in winter might be due to growth of maximum phytoplankton at that time. Similar conclusion was made by Lakshminarayan 1954 and Edmondson 1970 . However overall the increase in phosphorous content in all sites in post monsoon season may be possibly due to regeneration of phosphorous from the bottom as also reported by Singh (1962). An average increase in phosphorous contents during post monsoon season at all the sites might be possibly due to inflow of water, rich in colloidal clay particles containing various salts from extraneous sources (Ray *et al*.1966).

Dissolved Oxygen (DO) is one of the important parameter in water quality assessment. Its presence is essential to life in the water. The amount of dissolve oxygen recorded in the Kosi river water ranges between 8.8 mg/l to 16 mg/l. The minimum amount of DO in the water of river Kosi was recorded during winter season at site1 and sites II, whereas the maximum amount of DO in water was recorded during pre - monsoon season at sites III. Dissolved oxygen showed positive correlation with FCO_2, Cl^-, , and NO_3- N (at .01% significant level).

It is clear from the result that there was a low DO concentration during the winter season at site I and II that might be due to dependence of DO on temperature (Reid *et al.*1976, Mishra *et al.*1978) .They also made similar observations while studying physico-chemical factors of river and lake waters. The minimum level of DO during winter season might be due to turbidity effect which minimized the dissolve oxygen content or due to inflow of more town sewage with less oxygen content. Welch (1952), Rattner (1953) and Blum (1956) also reported the reduction of oxygen contents due to the entry of drainage water. Talling (1957) also made similar observation while studying the ecology of river Nile. The dissolve oxygen content was above the permissible limit in site I and site III in pre-monsoon season, this might be due to low water temperature. Dissolve oxygen content was below the limit in all sites in winter season assigned by Bureau of Indian Standards (2012). This might be due to increased respiration of plants, animals and aerobic bacteria and decay and decomposition of organic matter. Most of the causes of oxygen reduction mentioned above act simultaneously

Biological Oxygen Demand (BOD) is an important parameter of water indicating the health scenario of environmental ecosystem. BOD is the amount of dissolved oxygen required for the biochemical decomposition of organic compound and the oxidation of certain inorganic materials. The amount of BOD recorded in the Kosi river water ranges between 0.4 mg/l to 4 mg/l. The minimum amount of BOD in the water of river Kosi was recorded during winter season at site III, whereas the maximum amount of BOD in water was recorded during pot monsoon season at site I.

Chemical Oxygen Demand (COD) is another measure of organic materials contamination in water. COD is the amount of dissolved oxygen required to cause chemical oxidation of organic material in water. Both BOD and COD are key indicators of the environmental health of surface water. The amount of COD recorded in the Kosi River water ranges between 5.376 mg/l to 67.08 mg/l. The maximum amount of COD in water of Kosi river water was recorded during pre-monsoon at sites III and minimum amount at sites-I during post-monsoon. High COD in the water might be due to entry of organic matter and anthropogenic activities in the river.

The Water Quality Index (WQI) has been calculated by using the standard of drinking water quality as recommended by BIS (2012) and calculation methods prescribed by Ramakrishnaiah *et al.* 2009 and Gebrehiwot *et al*. 2011. Water quality index provides inclusive interpretation of the quality of surface water and its suitability for drinking purpose. The result showed that the higher value of WQI was found at site III in pre-monsoon season and in winter season at site II

was in poor category (Panigrahi *et al.*2012). The poor water quality of index is also contributed in Kosi river water by a large anthropogenic activities in nearby river banks such as bathing, transporting and agriculture runoff. The main cause of deterioration in water quality at these three sampling sites was due to anthropogenic activities, unprotected river sites, and agriculture runoff. Therefore, the conservation and management of this river water stretch are very much required.

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