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Ecological status of River Kosi, Bihar (India) special references: With water quality and Phytoplankton

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Abstract
The present investigation was conducted to find out the status of water quality and phytoplankton of Kosi River. Water quality and algal species have been analyzed from 10 sampling sites. Seasonal changes in the diversity of phytoplankton and its relationships to the water quality in Kosi River were studied during pre and post monsoon 2018 -19. pH values indicated the river water as neutral to moderately alkaline. The variations in conductively, total dissolved solids, total hardness, chloride, phosphate and nitrate were not significant in the river stretch investigated. Hardness values suggest the river water as moderately hard. The turbidity values increased apparently in whole stretch. COD is degraded in lower stretch of the river water compared to upland stretch. Altogether 39 genera and 108 species of phytoplankton have been identified in present investigation from all ten sampling station of Kosi River. Water quality index has been calculated by Ramakrishnaiah *et al*., 2009. Nygaard's index (Nygaard, 1949) [18], Palmer's algal pollution index (Palmer, 1969) [19] and Species Diversity Index (Shannon & Wiener index, 1949) [27] have been applied to know the pollution status.

Keywords: Water quality, algal species, River Kosi, Bihar

Introduction
Rivers and their landscapes are complex ecosystems that can be seen as an interaction between five main components: physical habitat, flow regime, the energy or food base of the system, biological interactions and water quality. A river is a well-defined geomorphological structure encompassing the main stream and several tributaries with a unidirectional flow of substantial loads of dissolved and suspended matter from both natural and human-induced activities (Shrestha and Kazama, 2007) [28]. Rivers are a dynamic system and are sensitive to change. Bio monitoring consists of the systematic use of biological responses to assess environmental changes, it can be considered as a way to assess the "health" of ecosystems (Buss, 1986) [5]. It serves as early-warning signals that reflect the health status of an aquatic system. Freshwater algae are considered as bio indicators in relation to water chemistry and its quality. The knowledge of Kosi river water quality and phytoplankton is fragmentary (Shama and Khan, 2002; Kumar *et al.* 2016 [13]; Singh *et al.* 2017 [29]; Rashmi and Arvind, 2018, 2020). The objective of the study is to assess the variation in type and abundance of phytoplankton in relation to water quality at different site of Kosi River. In the present study, an attempt was made to study water quality and the phytoplankton diversity index in the Kosi River from Dugyahi (India sites) to Kosi confluence (Kursela, Katihar, Bihar) i.e. whole stretch of Kosi River and is important for meanders, alluvial islands, and sandbars and also so many waste water drains. They will give the basic idea about the ecology of River Kosi about the water quality and phytoplankton.

Study area
Kosi River is one of the oldest rivers of India which originated from Himalayas. In Nepal, this river is commonly referred as 'Sapta Koshi' meaning 'Seven River'. This is because of its seven tributaries. These tributaries meet at Triveni, from where they are known as 'Sapta Koshi'. In Bihar, it is often responsible for flood therefore, it is referred as "Sorrow of Bihar". The worst affected districts in Bihar included Supaul, Araria, Saharsa, Madhepura, Purnia, Katihar, some parts of Khagaria and northern parts of Bhagalpur. Total stretch of River Kosi is 255km up to Ganga – Kosi confluence near Katihar district was covered during the investigation 2018-19. From the total stretch ten sampling sites from (Dugyahi, India site, After 5.39km from barrage – Lat- N 26° 30' 01.6'' to Long - E 86° 53' 55.4'') to Kosi confluence with Ganga river Katihar – Lat - N 25° 25' 033'' to Long - E 87° 14' 962'') were selected for the investigation (Fig. 1).

Fig 1: Showing different sampling sites of Kosi River (Bihar)

Materials and methods
Water samples were collected in pre and post monsoon 2018-19. Parameters like ambient and water temperature, conductivity, total dissolved solid, free carbon-dioxide and

bicarbonate, pH, and dissolved oxygen were analyzed on the spot. For the rest of the parameters, water sample was brought to the laboratory for further analysis. Standard methods were adopted to analyze the physico-chemical parameters (Trivedi and Goel, 1984; APHA, 2017) [1]. The WQI of Kosi River has been calculated considering relative weights of water quality parameter followed by Ramakrishnaiah *et al*., 2009.

Phytoplankton

Water samples of phytoplankton were collected in high quality plastic bottles from the surface by using phytoplankton net (100 mm pore size). 125 ml of the samples were preserved with 5 ml of 4% formaldehyde in the field for microscopic examination. Identifications of phytoplankton were made following West and West (1907), Desikachary (1959) [7], Randhawa (1959) [25], Philipose (1967) [21], Prescott (1969) [22], Cramer (1984) [6], Turner (1892) [31] and Sarode and Kamat (1984) [26]. Various pollution indices are calculated to estimate the water quality of the water bodies, such as Nygaard's index (Nygaard, 1949) [18], Palmer's algal pollution index (Palmer, 1969) [19], Species Diversity Index (Shannon & Wiener index, 1949) [27].

Result and discussions

Physico-chemical analysis and water quality index is in table-1. The ambient and water temperature of a river is very important, as many of the physical, biological and chemical characteristics of river are directly affected. The ambient and water temperature ranges from 16˚C to 39˚C and 15˚C to 36˚C respectively. Ambient temperature was maximum and minimum at site-6 in pre monsoon and post monsoon while the water temperature was maximum in pre monsoon at site-9 and minimum was in post monsoon at site-6.

Table 1*:* Physico-chemical analysis, WQI and WQI class of the Kosi River water at 10 Sampling Stations in 255 km stretch from Dugyahi (India site) to Kosi-Ganga confluence point near Kursela, Katihar, Bihar during pre and post monsoon 2018-19

SS	Seasons	Tur.	Cond.	TDS	pH	DO	FCO_2	HCO_3	TH	Cl^-	PO_4-P	NO_3-N	BOD	COD	WQI	WQI Class
1	Pre	52.2	187	98	8	6.8	16	24	80	15.9	0.06	0.046	1.7	18	140.56	Poor
	Post	126	132	67	8.4	13.6	56	12	76	7.99	0.022	0.019	1.6	12.21	175.89	Poor
2	Pre	53	176	88	8.1	7.2	32	22	89	12.8	0.068	0.039	1.6	13.22	101.67	Poor
	Post	130	132	67	8.6	13.5	46	14	72	7.99	0.022	0.019	1.3	10.1	163.87	Poor
3	Pre	64	126	73	7.8	7.6	28	23	68	13.9	0.058	0.03	1.2	17.7	79.6	Good
	Post	129	134	66	8.1	12.8	40	16	70	4.99	0.022	0.021	1.2	10	155.56	Poor
4	Pre	127	142	76	7.8	13.4	27	24	76	12.9	0.021	0.024	1.7	19	143.21	Poor
	Post	141	135	68	8	12.8	80	18	220	9.99	0.022	0.011	1	11.2	210.94	Very Poor
5	Pre	126	152	72	7.8	8.2	30	23	75	11.9	0.045	0.023	1.2	10.6	131.66	Poor
	Post	140	125	63	7.6	14	64	12	72	4.99	0.022	0.01	1.4	11.3	192.8	Poor
6	Pre	130	122	61	8.2	7.6	12	24	66	2.99	0.05	0.045	2.8	23.9	120.85	Poor
	Post	142	125	63	7.8	14.8	56	14	80	8.99	0.02	0.011	1.2	18.2	186.18	Poor
7	Pre	47.2	117	59	8.1	6.8	16	16	68	2.99	0.05	0.047	1.2	19.1	77.19	Good
	Post	153	135	72	7.7	10.8	48	24	280	9.99	0.02	0.011	2.3	25.7	182.03	Poor
8	Pre	47.1	113	57	8.8	8	14	16	37	2.99	0.05	0.046	2	23	81.57	Good
	Post	138	132	102	7.2	9.6	16	18	88	2.99	0.05	0.037	3.7	42.2	142.1	Poor
9	Pre	63.3	117	58	8.1	9.2	22	16	54	2.99	0.058	0.044	3.7	42	113.19	Poor
	Post	143	134	66	7.3	10.6	32	32	120	7.99	0.048	0.036	4.2	51.9	171.61	Poor
10	Pre	28.5	130	66	7.9	7.6	50	18	48	2.99	0.062	0.043	1.7	18.3	112.19	Poor
	Post	158.9	133	76	7.8	12.4	42	20	172	8.5	0.033	0.021	3.8	43.2	191.12	Poor

* Except p^H, all other variables expressed in ppm or mg/l or otherwise mentioned. TDS= Total Dissolve Solid, DO= Dissolved Oxygen, FCO_2 = Free carbon dioxide, HCO_3^- = Bicarbonate alkalinity, TH = Total Hardness, Cl^- = Chloride, PO_4–P = Phosphate – phosphorus, NO_3-N = Nitrate – nitrogen, COD = Chemical Oxygen Demand, BOD= Biological Oxygen Demand, WQI (Water quality index) and WQI Class (Water quality index class)

Turbidity expressed as the optical property of water in which the light is scattered by the present particles. The range of desirable and permissible limit for turbidity in drinking water set by BIS is 5 to10 NTU. The range of turbidity of analyzed water samples varied from 28.5 NTU to 158 NTU. All the water samples collected from different sampling station was above the permissible limit (IS 10500:2012). Turbidity was maximum in post monsoon at site-10 and minimum also at site-10 in pre monsoon. Turbidity is caused by suspended matters, such as clay, silt and finely divided organic and inorganic matter, soluble colored organic compounds. High turbidity shows presence of large amount of suspended solids (Mariappan and Vasudevan, 2002) [16].

Electrical conductivity is the capacity of water to conduct the electric current. This is due to the presence of cation and anion in the water. During the present research work, the value of EC range from 113-187µs/cm. EC is high during the pre-monsoon at site-1 and low in the pre monsoon and at site-8.

TDS is a measure of the solid materials dissolved in the water. This includes salts, some organic materials, and a wide range of other things from nutrients to toxic materials. In present study, TDS value ranged from 57 to 102 mg/l which were within the limits of drinking water standards. Both maximum and minimum value was at site-8 in post and pre monsoon respectively. The concentration of TDS is high during post monsoon, which may be due to addition of solids from runoff water, sewage and industrial effluents to the river.

pH is the concentrations of hydrogen ions (H^+) present in water and is a measure of acidity or alkalinity. Most of the aquatic organisms are very sensitive to pH change and pH can alter various metabolic activities of aquatic organisms. During present investigations the pH value ranged within 7.2-8.8. The high value of pH was recorded in the pre monsoon (Site-8) and low value in the post monsoon (Site-8).

The Dissolved oxygen measures the amount of life sustaining oxygen present in the water. The Dissolved oxygen concentration present in water reflects atmospheric dissolution, as well as autotrophic and heterotrophic processes that respectively produce and consume oxygen. During the present study the dissolved oxygen values ranged from 6.8 to 14.8 mg/l. The maximum dissolved oxygen was recorded in post monsoon (Site-6) while the lowest concentration in pre monsoon (Site-1). The dissolved oxygen is the most important indicator of water quality i.e. polluted water has low level of dissolved oxygen (Patil and Gorade, 2013) [20]. The maximum dissolved oxygen in post monsoon may be due to low atmospheric temperature and minimum dissolved oxygen in pre monsoon may be due to high metabolic rate of organisms (Edmondson, 1965) [8].

Alkalinity is the acid neutralizing capacity of water. Natural alkalinity of water depends mainly on salts of weak acids such as bicarbonates, carbonates, borates, silicates, phosphates and the salts of humic and fulvic acids (Budhlani *et al.*, 2014) [4]. Total alkalinity help to maintain the pH of the water body. Free carbon dioxide ranged from 14-80mg/l. Maximum was at site-4 in the post monsoon while the minimum was at site- 8 in the pre monsoon. Bicarbonate ranged from 12-32mg/l. Both maximum and minimum was in post monsoon at site-1 and 9 respectively.

Total hardness depends on the amounts of cations like calcium and magnesium present in the water body. In the present investigation total hardness was ranged between 48-280 mg/l. During present investigations, it was observed that, total hardness of the river was maximum in the post monsoon (Site-7) and minimum in pre monsoon (Site-10). In the present investigation water is categorized from moderate soft to very hard. Water samples at site-4 and 7 in post monsoon were in category very hard. Elevation of calcium and magnesium hardness is due to the addition sewage, detergents and large scale human use (Mohanta and Patra, 2000) [17].

Chloride is one of the most important inorganic anion in water. Due to its high solubility it is present naturally in all types of water body. The concentration of chloride in freshwater is an indicator of sewage pollution (Trivedy and Goel, 1984) [30]. In present study values of chloride ranged from 2.99-15.99. Chloride content of the sample was found within the permissible limit. High chlorides were recorded during pre-monsoon at site I while the minimum was at sites 7, 8, 9, and 10 (All pre monsoons). Similar observations were made by Arya *et al.*, 2011 [2].

Phosphate-phosphorus acts as an important regulating factor for productivity of water body. Only few sources of phosphate that occur naturally, major sources of their presence in water body are domestic waste, detergent and agricultural run-off containing fertilizer (Gopalkrusna, 2011). During the investigation phosphate-phosphorus ranged from 0.021-0.068. Both maximum and minimum value was in pre monsoon at site-2 and 4 also at site-7 in post monsoon.

Nitrate is the most stable form of nitrogen. Nitrates and nitrites are naturally ions that are the part of nitrogen cycle. Nitrate ions are undesirable in water because they can cause methaemoglobinaemia in infants less than 6 month old (Egereonu and Nwachukwu, 2005) [9]. High nitrate concentration can result in excess algal blooms. Principal source of nitrates is fertilizers, decayed vegetables and animal matter. During the present investigation the value of nitrate-nitrogen ranged from 0.021-0.068. Maximum nitrate-nitrogen was found in pre monsoon at site-7 and minimum was in post monsoon at site-6.

Biochemical Oxygen Demand (BOD): Biological Oxygen Demand (BOD) measures the amount of oxygen used by microorganisms to oxidize organic matter present within the samples. Water samples with the BOD less than 3.0 mg/l are considered clean. The BOD has been a fair measure of cleanliness of water on the basis that value less than 1-2 mg/l are considered clean, 3 mg/L fairly clean, 5 mg/L doubtful and 10 mg/L definitely polluted. In the present investigation BOD was ranged between 1 mg/l to 4.2mg/l. Maximum and minimum both was in post monsoon at site-9 and site-4 respectively. The value of site-8 (Post monsoon), site-9 (Pre monsoon and post monsoon), and site-10 (Post monsoon) were the above the permissible limit.

Chemical Oxygen Demand (COD): COD is a measure of the capacity of water to consume oxygen during the decomposition of inorganic chemicals such as nitrate and ammonia. The COD is related to BOD. BOD only measures the amount of oxygen consumed by microbial oxidation and is most relevant to water rich in organic matter (Franson, 1975) [10]. If the COD is higher it will contain greater

number of micro-organisms. In the present study COD had varied between a minimum of 10mg/l in post monsoon at site-3 and maximum of 51.9mg/l at site-9 in the pre monsoon. All the sites the COD was above the 10mg/l. According to Rajini *et al., (*2010) [23] and WHO (2011) standard for COD of good quality water is <10mg/l. If the COD is higher it will contain greater number of micro-organisms.

Water quality index has been calculated by Ramakrishnaiah *et al*., 2009. Water quality index represents the integrated effects of the relevant water quality variables. For Kosi river water, the rating of WQI of water samples was calculated. In the present study water of river Kosi was found to be in poor quality in pre and post monsoon at all the ten sampling sites except site 3, 7 and 8 in pre monsoon i.e. water quality class was good in categories but at site 4 in post monsoon it was in very poor in categories as the WQI ranged from 77.19 to 210.94. It may be due to the heavy suspended matters, such as clay, silt, organic and inorganic matter.

Altogether 39 genera and 108 species of phytoplankton have been identified in present investigation at all ten sampling station of Kosi River. They belong to Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae. The Bacillariophyceae forms outnumbered than the other groups and covered 18 genera and 64 species of the total number of the species. Chlorophyceae were next to Bacillariophyceae encompassing 11 genera and 25 species. Cyanophyceae population followed the Chlorophyceae and these were represented by 08 genera and 17 species. The Euglenophyceae were represented by 2 genera and 2 species. In all the sampling station Bacillariophyceae was dominant followed by Chlorophyceae and Cyanophyceae in pre and post monsoon. The phytoplankton count registered higher value in pre-monsoon at most of the sampling station. *Scenedesmus obliquus, Chlorella vulgaris, Synedra ulna, Melosira granulata, Cyclotella meneghiniana* and *Oscillatoria princeps* have been found in this stretch of the river Kosi and these are the most pollution tolerant species of algae (Palmer, 1969) [19].

By applying Nygaard's algal index (Nygaard, 1949) [18] of pollution site-1, site-2, site-3, and site-4, pre and post monsoon water of river Kosi was oligotrophic except site-4 in post monsoon while, the site-5 to 10 was eutrophic in both the pre and post monsoon.

By applying Palmer's algal pollution index of algal genus (Palmer, 1969) [19] site-1 (pre), site-2 (post), site-4 (post), site-5 and site-7 (post), site-8 (pre), site-9 (pre and post) and site-10 (post) was indicating high organic pollution while the site-1 and 5 in post monsoon, site-6 and 7 in pre monsoon indicating mild organic pollution and rest of the sites of pre and post monsoon was no pollution.

According to Shannon - Wiener diversity index proposed as diversity index greater than (>4) is clean water, between 3-4 is mildly polluted water; between 2-3 is moderately polluted water and less than 2(<2) is heavily polluted water. The result have been show in table -2. The index computed in the present investigation showed that phytoplankton species diversity ranged from 3.35-4.12 (Sampling station 1, 2 and 3) in the pre monsoon. The site-1 (4.12) indicating clean water, the site-2 (3.35) and 3 (3.95) indicating mildly polluted water, site-4 (2.05) and site-5 (2.05) indicating moderately polluted water while site-6 to site 10 ranged 0.15 to 1.55 indicating heavily polluted water in the pre monsoon. In the post monsoon site-1 (3.67) indicating mildly polluted water, site-2 (2.83), site-3 (2.75), site-4 (2.11) indicating moderately polluted water while, site-6 to site-10 ranged 0.2 to 1.12 indicating heavily polluted water. So in both season's site-6 and site-10 indicating heavily polluted.

The results of all the indices indicates lower region of river Kosi water was polluted. It may be due to establishment of dense population at lower region near the bank of river, cattle fecal matter and their drainage water fallen besides this dense agricultural practices by using fertilizers and insecticides on the maize crop because major crop was maize and wheat. Overall by analysis of water, water quality index and algal pollution index (Nygaard, 1949 [18], Palmer, 1969 [19] and Shannon & Wiener index, 1949) [27] indicates that the water quality of lower region of river Kosi is heading towards eutrophication.

Table 2: Species diversity index (Shannon and Wiener, 1949) in different sampling station of River Kosi, during 2018-19 pre and post monsoon

Seasons	SS-1	SS-2	SS-3	SS-4	SS-5	SS-6	SS-7	SS-8	SS-9	SS-10
Pre monsoon	4.12	3.35	3.95	2.67	2.05	1.55	1.33	1.27	1.24	0.15
Post monsoon	3.67	2.83	2.75	2.11	2.1	1.12	1.11	1.022	0.22	0.2

Index: > 4 clean water, 3–4 = mildly polluted water, 2–3 = moderately polluted water, < 2 = heavily polluted water.

Conclusion

This study was conducted to explore the ecological status of River Kosi of Bihar region. From the result it may be concluded that water quality of river might be attributed to a variety of physical and chemical factors. High nutrient contents of water contributed to the presence of phytoplankton which was densely populated. The presence of algal species like *Chlorella vulgaris, Cyclotella meneghiniana, Synedra ulna, Oscillatoria princeps*, and *Oscillatoria tenuis* suggested that river Kosi is organically polluted and advancing towards eutrophication.

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Author's Contribution

Braj Nandan Kumar (1st author), Rupa Dey (3rd author) and Shadia Rahman (4th author) contributed in laboratory analysis, taxonomic identification. They have also contributed in the preparation and writing of the manuscript.

Sunil Kumar Choudhary (2nd author) reviewed and revised the draft and approved the submission of the manuscript.

Conflict of interest: The authors declare that there is no conflict of interest regarding publication of this manuscript.

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