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Ecological Integrity of River Water Quality: in Relation to Primary Productivity and Cyanotoxin Occurrence

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Abstract

In order to develop a method of predicting and assessing running water which is serious environmental problems, the present study was performed (during June 2014 to May 2015) to measure water quality variables, primary productivity, chl-a and biomass of phytoplankton at river stream around Allahabad city. Continuous influx of untreated sewage in the urban river site carry enormous amount of pollutants, leading to professed growth of invasive phytoplankton and affecting algal photosynthesis. Quantitative and qualitative analysis of cyanotoxin (microcystin), nutrient influx/ nutrient transport, and their interaction with phytoplankton/ toxin producing algal species were also described. The maximum chl-a concentration and biomass of phytoplankton/ toxin producing algal species were found to be 433.5 µg/l and 425.88 mg/l in water sample of Yamuna while 302 µg/l and 366.5 mg and 210 µg/l and 274 mg in Sangam and Ganga, respectively in the case of *Microcystis aeruginosa*. Ecological parameters to evaluate GPP, NPP and CR were found to be 297.00, 134.00 and 189.99 mgCm3/h in Yamuna which is higher than Sangam and Ganga, respectively. A poor association existed between chl-a and GPP. Temporal variations (Photosynthetic rate) were also observed to evaluate the productivity of water stream. These running water quality deterioration which may be due to insufficient water availability, flow and pollution.

Keywords: Fresh water, Organic load, Hydrological status, Primary productivity.

Introduction

Rivers are complex system characterized by intensive spatial and temporal dynamics of the biotic and abiotic conditions. Within the last decades, limnologists have aimed at describing the structure and function of streams; a short review of concept in river ecology is given a Townsend (1996). As Karr et al., (1986) pointed out, the time is ripe for stream ecologists to use their science more effectively in protecting water resources. The demand was for a more integrated assessment of rivers system that could evaluate the various and wide-reaching impacts of anthropogenic activities on the aquatic environment (e.g., Chovanec, 1995; Friedrich, 1998; Mauch, 1990; Moog & Chovanec, 1998; see also Cairns et al., 1993; Rapport, 1992; Schneider, 1992). These activities, including wastewater discharge, changes of habitat structure and connectivity aspects, as well as altered flow regimes, are often complex and difficult to describe directly in terms of their ecological repercussions.

Muncipal wastewater and urban storm water are potential pollution sources to downstream running water ways and may seriously impact of water quality. Water quality of running water (rivers) are perhaps the most vulnerable habitats and are most likely to be changed by the activities of man. This essential resources is becoming increasingly scare in many parts of the world due to the severe impairment of water quality. Phytoplankton encountered in the water body reflects the average ecological condition and therefore, they may be used as indicator of water quality & assessing the degree of pollution (Bubb et al., 1993; Bhatt et al., 1999; Saha at el., 2000; Dwivedi and Pandey, 2001; Pande and Dwivedi, 2002; Dwivedi and Pandey, 2002; Dwivedi and Pandey, 2003a,b; Shiddamallayya & Pratima, 2008). Over the years, the water quality of these sacred rivers is fast deteriorating. Organic and inorganic stress on rivers is reflected in active microbial growth and change in Physico-chemical parameters (Dwivedi, et al., 2012, Dwivedi, 2015).

Measurement of primary productivity is important in food chain studies in aquatic reservoir. The daily and seasonal carbon flow of a system forms the basis for the structure of the annual pyramid and can be used to asses the water quality of running water (rivers). Though information on primary production from Indian fresh water is abundant (Tallberg et. at., 1999; Krishna Rao and Shakuntala, 1999 and Dwivedi and Pandey, 2003a), concurrent data on toxin producing algal species biomass and chl-a is scarce.

However, there are no such studies from this region and therefore present work was conducted to evaluate the water quality along with phytoplankton/ toxin producing algal species (TPAsp.) and their interaction with biomass, chlorophyll-a and nutrient influx in way of anthropogenic persuit.

Materials and Methods

Sterilized poly-propylene jar and standard water sampler were used to collect water sample on a monthly basis for months during June 2014 to May, 2015 of Ganga, Yamuna and their confluence, Sangam). The samples (three from each site) were collected at a uniform depth of 10-15 cm and two feet from the river bank, at the confluence. Physico-chemical factors i.e. Temperature (air & surface), pH, turbidity, conductivity, DO, BOD, hardness, Ammonia, N, P of the sample were done as per standard methods (APHA et al., 2007). Optical density (OD) was adjusted to zero using (distilled water) control as blank with the help of UV-visual spectrophotometer (perkin). Bacterial enumeration were done employing serial dilution technique, Serially diluted suspension (0.1 ml) were spread over the solid nutrient agar plates and incubated at 37 ± 1^0 C for three to five days. Total numbers of bacteria were determined as a colony forming unit ml^{-1} (CFU ml^{-1}). The rate of primary production at the surface was estimated using in-situ light and dark bottle technique (APHA et, al., 2007). Productivity values were obtained at every 4 h intervals from dawn to dusk. The rate of Gross Primary Productivity (GPP), Net Primary Productivity (NPP) and community respiration (CR) were calculated according to to the formula given by CIFRI (1969). Average hourly rates were multiplied by the hours of sunshine to get the daily rates. Chlorophyll (Chl-a) of the toxin producing algal species (TPAsp.) sample of the water was determined by filtration through whatman GF/C litre. The pigment was extracted in alkaline acetone. The filters were stored over a desicacant and deep frozen unit analysis, which was undertsaken within 24 h (Krishna Rao and Shakuntala, 1999). The cell pellet was extracted twice in 80% acetone and then resuspended in a 0.2M sodium acetate buffer (pH 5.5). The absorvance was measured at 625, 678, 725 nm. Toxin producing algal species biomass was calculated form cell counts multiplied with average cell volumes estimated by assuming simple geometrical bodies and measuring the necessary dimensions from about 40 cells/ taxon. Correlation-coefficient was done between TPAsp. and their chal-a and biomass for the reality and significance of the result. The relevance of these component for an integrated river assessment is comprehensively discussed as in Naiman et al., (1992); Muhar & Jungwirth (1998) and Muhar et al., (2000).

Results and Discussion

The data on important parameters and microbial growth of running water (river) Yamuna, Ganga and Sangam in Table 1, 2; 3,4 and 5, respectively. The patern/ encounterind trend of DO and BOD were showed in Fig.1. while Zero order matrix of correlation of major parameters in Table 6. The data revealed that the value for turbidity, ammonia, BOD, were high at Sangam followed by Yamuna and Ganga, it is due to organic load and heavy phyto bloom. The ph value to be within limit of the standard at all the sampling point, however maximum value was recorded at Sangam. The diurnal variations of DO with BOD showed that the maximum bathing took place. The organic load and Faecal coliform density was directly propotional and that had was maximum at Sangam in comparison to Ganga and Yamna because of intense bathing activity is confined area (Table 4 and 5). Total hardness was also positively correlated with turbidity, chloride, conductivity. In the study high value of nitrate and phosphate were recorded in Sangam followed by Ganga Yamuna, which gradually decline in efficient water flow. Wetzel (1983) stated that ammonia was generation by heterotrophic

Table-1 Physico-Chemical quality of water at River Yamuna

S.No. Parameters	Water Quality					
	River Yamuna U/s Kerala Bagh, Allahabad			River Yamuna D/s Kila Ghat, Allahabad		
	Min.	Maxi.	Avg.	Min.	Maxi.	Avg.
1. Water Temp.	10.4	11.0	10.9	10.5	20.0	13.7
2. Air Temp.	10.6	10.1	10.6	10.8	20.5	15.5
3. Conductivity	0.42	0.55	0.43	0.53	0.54	0.53
4. Turbidity	8.0	10.0	9.0	69.0	70.0	69.09
5 Hardness	178.98	180.1	178.0	168.0	210.0	190.0
6. COD	29.00	31.00	30.0	38.0	48.0	43.3
7. Chloride	46.3	50.2	47.5	48.9	50.6	48.9
8. Ammonia	0.91	0.99	0.94	0.56	1.17	0.98
9. Nitrate	0.33	0.34	0.33	0.61	0.92	0.70
10. Phosphate	0.16	0.15	0.162	0.19	0.42	0.292
11. Fluoride	0.67	0.81	0.74	0.67	0.73	0.70
12. Sulphate	24.6	23.9	25.0	22.0	23.8	22.8
13. Alkalinity	340.0	400.0	371.98	258.8	268.12	262.0
14. Total Nitrogen	1.85	2.02	1.9	24.9	28.9	26.92

Except Temperature (^{O}C), pH, conductivity (mhos cm^{-1}) and Turbidity (NTU) all values are in mg/l (Mean $\pm$SEM of three replicate)

Table-2 Physico-Chemical and Bacteriological (Key Parameters) quality of water at Yamuna river

S.No	Parameters	Water Quality					
		River Yamuna U/S Kerala Bagh, Allahabad			River Yamuna D/S Kila Ghat, Allahabad		
		Min.	Max.	Avg.	Min.	Max.	Avg.
1.	pH	7.6	7.7	7.65	7.4	7.8	7.6
2.	DO	8.2	8.4	8.3	6.0	8.1	6.5
3.	BOD	2.0	2.4	2.2	4.0	9.0	6.0
4.	Total Coliform	1000	2000	1500	100000	200000	144000
5.	Faecal Coliform	300	900	600	4000	17000	12000

Except Total Coliform and Faecal Coliform (MPN/ 100ml) all values are in mg/l (Mean $\pm$SEM of three replicate)

Table-3 Physico-Chemical quality of water at river Ganga

S.No. Parameters	Water Quality								
	River Ganga U/s phaphamau Bridge			River GangaD/s Sangam			River Ganga Chhatnag		
	Min.	Maxi.	Avg.	Min.	Maxi.	Avg.	Min.	Maxi.	Avg.
1. Water Temp.	10.8	10.9	10.9	10.5	20.7	13.7	10.4	21.1	13.2
2. Air Temp.	10.8	10.9	10.6	10.2	20.4	13.5	10.1	22.9	13.8
3. Conductivity	0.46	0.45	0.53	0.53	0.54	0.53	0.50	0.61	0.55
4. Turbidity	15.0	18.0	16.5	10.4	11.0	10.0	06.09	10.0	8.2
5 Hardness	100	168	134	188	205	203	282	340	320
6. COD	18.0	28.0	22.0	31.0	50.0	43.2	90.0	180	123
7. Chloride	14.5	17.8	16.0	20.0	25.0	22.0	43.5	46.5	46.5
8. Ammonia	0.98	0.99	0.99	1.11	1.07	1.17	0.98	1.3	1.09
9. Nitrate	0.91	0.93	0.94	0.79	0.81	0.80	0.58	0.61	0.70
10. Phosphate	0.18	0.22	0.20	0.27	0.28	0.28	0.19	0.27	0.23
11. Fluoride	0.67	0.70	0.68	0.74	0.73	0.72	0.68	0.97	0.83
12. Sulphate	19.9	21.2	20.5	18.4	19.0	18.7	21.5	26.0	23.6
13. Alkalinity	220	240	230	180	200	204	285	340	325
14. Total Nitrogen	12.57	12.67	12.5	13.9	14.6	14.4	13.6	20.8	16.9

Except Temperature (^{O}C), pH, conductivity (mhos cm^{-1}) and Turbidity (NTU) all values are in mg/l (Mean $\pm$SEM of three replicate)

Table-4 Physico-Chemical and Bacteriological (Key Parameters) quality of water at River Ganga

	Parameters	Water Quality								
		River Ganga U/s Phaphamau Bridge			River Ganga D/s Sangam			River Ganga Chhatnag Ghat		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1.	pH	7.7	7.8	7.76	7.5	7.9	7.63	7.5	7.8	7.65
2.	DO	5.5	6.5	6.0	6.5	6.5	6.5	7.0	7.8	7.5
3.	BOD	5.5	8.4	6.9	5.6	5.8	5.8	4.9	8.5	6.5
4.	Total Coliform	120000	250000	1850000	120000	150000	150000	690000	880000	800000
5.	Fecal Coliform	60000	12000	9000	8000	18000	12000	27000	29000	28500

Except Total Coliform and Faecal Coliform (MPN/ 100ml) all values are in mg/l (Mean +SEM of three replicate)

Table- 5 Sangam Water Quality in Comparison to Yamuna & Ganga

S.No.	Parameters	River Yamuna D/s 100m U/s of Sangam			Sangam Location-1			Sangam Location-2			River Ganga 100m U/s of Sangam Bridge-1		
		Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
1.	Air Temperature	10.5	20.0	13.7	23.2	20.0	14.8	10.0	23.6	14.1	10.5	20	13.6
2.	Water emperature	10.8	20.5	15.8	10.1	20.0	12.4	10.1	20.0	12.2	10.5	20.0	13.9
3.	Turbidity	69.0	71.0	69.0	60	121	92.9	73.0	156	116	10.0	10.4	10.8
4.	COD	18	29	24	64	111	84.8	65.2	149	99.0	30	50.3	42.8
5.	Conductivity	0.53	0.61	0.54	0.64	0.81	0.72	0.49	0.62	0.53	0.49	0.54	0.54
6.	Chloride	48.9	50.5	51.1	72.0	111	88.3	76.9	156	101	14.6	17.6	16.9
7.	Alkalinity	256.99	278	267	198.9	271	226	201	300	237	187	201	200
8.	Hardness	168	211	190.8	167	200	177.98	168	201	184	189	192	191
9.	Fluoride	0.68	0.76	0.69	0.53	0.71	0.67	0.54	0.92	0.81	0.73	0.73	0.75
10.	Calcium	41.1	44.9	42.6	37	47.2	39.8	40.1	51.8	46.8	38.8	41.7	40.3
11.	Sulphate	22.9	23.8	22.7	16.8	20	18.2	17	22.7	18.9	18.9	19.5	18.9
12.	Total Kjehldal Nitrogen	2.5	2.88	2.7	15.2	27.3	19.9	17.1	30.4	20.1	13.6	15	14.4
13.	Ammonia	0.54	1.18	0.98	0.99	1.14	1.11	0.98	1.19	1.01	1.07	1.1	1.08
14.	Nitrate	0.65	0.91	0.71	1.4	1.65	1.49	1.08	1.32	1.19	0.98	0.89	0.81
15.	Phosphate-P	0.21	0.43	0.29	0.19	0.31	0.231	0.98	0.29	0.27	0.29	0.30	0.32

Min = Minimum; Max= maximum; Av= Average

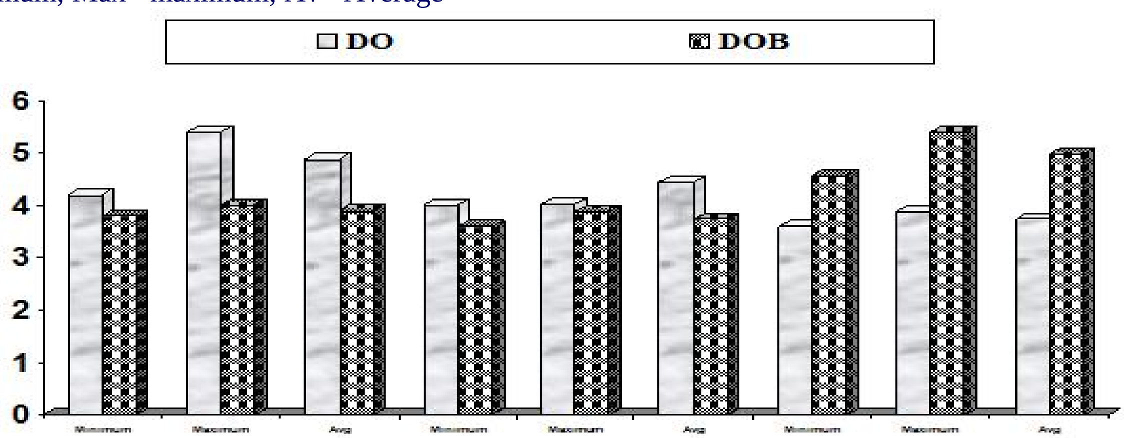

Fig-1 Assessment of Ganga (A), Yamuna (B) and Sangamk (C) microbes as a primary end product of decomposition of organic matter directly from protein or from the organic compound. Due to a greater level in organic loading at the confluence and localizes human interference maximum activity is reported from the confluence which also has highest microbial count (Table-5) therefore, indicating a great degree of pollution via organic loading at this site. Similar observation has been reported by Hosetti and Frost, 1997; Dwivedi et al., 2012 and . Dwivedi, 2015.

The pH , DO meets the standard limit while maximum BOD was exceeded the limit at D/S of Yamuna probably because of bathing actually at the bank of river Yamuna. The Faecal Coliform was found within the bathing Standard limit (MPN/ 100ml) at U/s whereas at D/s of Yamuna due to open defection since sanitary arrangement inadequate. The organic load was maximum at Sangam in comparison to U/s Yamuna and U/s Ganga because of intense human load in confined area. The study indicated that the water was not fit for drinking as well as bathing purposes.

Correlation coefficient of major parameters (Table-6) were undertaken to derive relation among the important parameters. pH has been positively with TC, FC, BOD, turbidity, Chloride and Conductivity. Maximum correlation coefficient with FC was 0.585. The results indicate that the existing pH is directly proportional to the organic load. The correlation coefficient of DO is negatively correlated with all the parameters tested. Most significant was found to be BOD, which is inversely proportional to DO. It is interesting to note that none of the parameters exhibited positive correlation with DO as observed with inorganic constituents. Like BOD, TC is also positively correlated with all the parameters. Maximum positive correlation 0.580 was found with Faecal Coliform in terms of organic load and with chloride 0.608 in terma of inorganic load. Faecal Coliform does not follow the same trend as with BOD and TC. It is negatively correlated with alkalinity, hardness and turbidity where as slight positive correlation was achieved with COD, chloride and conductivity. As regards alkalinity, it is positively correlated with other parameters except conductivity. Total hardness is also positively correlated with turbidity, chloride, conductivity and COD.

Table-6 Zero order matrix of correlation of major parameters at Sangam

Paramet ers	pH	DO	BOD	TC	FC	Alka linity	hardness	Turbidity	Chlori de	Conductivity	COD
pH	1	-0.32	0.31	0.41	0.585	-0.48	-0.007	0.317	0.322	0.306	-0.076
DO		1	-0.91	-0.74	-0.20	-0.55	-0.435	-0.717	-0.452	-0.316	-0.074
BOD			1	0.648	0.285	0.578	0.200	0.483	o.550	0.170	0.505
Total coliform				1	0.580	0.166	0.342	0.448	0.608	0.546	0.212
Faecal Coliform					1	-0.359	-0.003	-0.091	0.122	0.532	0.072
Alkalinity						1	0.360	0.334	0.240	-0.259	0.324
Hardness							1	0.550	0.067	0.267	0.397
Turbidity								1	0.178	0.173	0.203
Chloride									1	0.312	0.589
Conduc.										1	-0.252
COD											1

The silent feature of chl-a, biomass of phytoplankton/ TPAsp and Primary productivity in terms of GPP, NPP, CR their ratio were given in Table 7 and Table 8, respectively. The number of phytoplankton/ toxin producing algal species increased no. of cells/ ml dramatically. In Yamuna river were found high as comparison to Sangam and Ganaga. This difference was due to a combination of factors such as nutrient concentration by better nutrient replenishment and instantiated bathing pattern. Similar observation has been reported by Dwivedi and Pandey (2003) from other water reservoir.

Table-7 Chlorophyll-a and Biomass of Phytoplankton which are sorce of toxin producing algal species at Ganga, Yamuna & Sangam.

Toxin producing	Yamuna river		Ganga		Sangam	
Algal sp.	Chl-a	Biomass	Chl-a	Biomass	Chl-a	Biomass
Microcystis sp.	425.88	493.00	280.5	155.5	315.0	385
M. protocystis	398	321	190	124	145	197
M. aeruginosa	433.5	528	210	274	302	366.5
M. lotralis	345	390	128.6	73	142	180
M. incerta	294	350	222	265	143	173
Oscillatoria sp.	235	260	128	105	142	186
O. princeps	265	349	130	121	121	165
O. limosa	350	431	130	319	121	200
Lyngbya sp.	265	356	-	-	109	123
L. majuscula	325	398	-	-	109	205
Nostoc	361	317	206	164	180	251
Anabaena	225	488	131	190	155	223

Value (Mean) of Chl-a and Biomass expressed as µg/l, mg/l, respectively of three replicates.
(-) represents as absence of values because species were not present.

Table-8 The gross primary productivity (GPP), net primary productivity (NPP), community respiration (CR) rate, ratio of net primary productivity (NP:GP), ratio of productivity and respiration rate (P:R) and percentage of respiration in Gross production in Ganga, Yamuna & Sangam.

Parameters	Ganga river	Yamuna	Sangam
Gross rimary productivity (mg cm^3 /h)	273.00	297.00	216.00
Net primary productivity (mg cm^3 /h)	122.00	134.00	118.00
community respiration rate (mg cm^3 /h)	169.00	189.99	106.00
N.P. : G.P., ratio	0.45	0.46	0.52
P : R	0.47	0.72	0.92
Gross production % respiration	0.65	0.63	0.58

High nutrient influx and TPAsp have been observed during study period, In Yamuna river at before Sangam, Microcystis species (*Microcystis protocystis. M. aeruginosa, M. lotoralis, M. incerta, M. princeps*) constitute > 50 %0 of the biomass and in Sangam toxin producing algal species share of the biomass rose towards the end of summer season < 50%. The highest inumeration of toxin producing algal species was highly correlated with the Chl-a. The maximum chl-a concentration and biomass of phytoplankton / toxin producing algal species were found to be 433.5 µg/l and 425.88 mg/l in water sample of Yamuna while 302 µg/l and 366.5 mg and 210 µg/l and 274 mg in Sangam and Ganga, respectively in the case of *Microcystis aeruginosa* (Table 7). Tallberg et al., 1999 have also noticed the same pattern in eutrophicated water reservoir.

Ecological parameters to evaluate GPP, NPP and CR were found to be 297.00, 182.99 and 134.00 mg Cm3/h in Yamuna which is higher than Sangam and Ganga and also exist significant change (Table 9). The ratio of NPP and GPP never exceeded 0.65 in all site. The percentage of respiration rate to GPP ranged from 0.58-0.65. It always remained above 50%, the level which has been suggested for polluted water bodies. Most of the production was confirmed as low variation between both site Yamuna and Sangam along with D/s of Ganga In all site lower production were characterized as per unit volume and absence of marked maxima (when the river was stratified and had high water level). The GPP depicted a declining trend from phytoplanktonic load impact/ nutrient influx as on as 297, 273 and 216 mgCm^3/h in Yamuna, Sangam and Ganga, respectively. The trend of variation of NPP value was not occurred with a truncation of the period (summer) marked maxima and higher production per unit volume coinciding with low water level and higher toxin producing algal biomass. High respiration rate of Yamuna river particularly in summer season reveals that is more polluted than Sangam followed by Ganga.

In conclusion, during the period of our study microbial numerical abundance observed in water samples of the river water was indicative of the facts that the rivers posses the capacity for self-regeneration due to sustainable bacterial population. In the confluence of these two rivers, where maximum activities of both these obtained, is also the site of most human interference, though variable time, human interference, nutrient inputs and urban/ sewage discharge in to the running water. These running water ecological integrity are being incorporated into the urban critical deficits water supply/ treatment infrastructure in view of their religious and ecological importance in general and running water.

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