

IMPACT OF ANTHROPOGENIC WASTES ON DIVERSITY OF LIVE FOOD SPECTRUM OF RIVER GOMTI AT DALIGANJ IN LUCKNOW (INDIA)

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ABSTRACT : Daliganj site of river Gomti receives sewage and industrial wastes from the thickly populated locality of Lucknow. The water quality was poor with higher nitrate (22.70 mg l⁻¹) and phosphate (2.40 mg l⁻¹). Chlorophyll 'a', 'b' and 'c' were high with Chlorophyceae being the dominant phytoplankton group comprised chiefly *Closteridium*, *Cladophora*, *Gonatozygon* and *Cosmarium* while zooplankton contents were low. Cladocerans (*Moinodaphnia*, *Ceriodaphnia*) and copepods (*Cyclops*) dominated the zooplankton fauna. The benthic fauna which serves food for most of the bottom feeding fishes was exceptionally rich. High population density of benthos was due to oligochaetes (*Lumbriculus*, *Limnodrilus*, *Branchiura*, *Chaetogaster*, *Nais* and *Tubifex*) and *Chironomus* larvae. *Branchiura*, *Tubifex*, *Chironomus* and Diptera (*Culicoid* larvae), the organic pollution indicators, dominated the fauna. Shannon-Wiener Diversity Index (H) of benthic organisms was less than 1 for oligochaetes, Diptera, Coleoptera and Gastropoda indicating stressed environment. Though the benthic density was high, it may not contribute to the food chain. Relatively low abundance of plankton population and biomass in spite of high nutrient budget of the system appears to be due to the high infestation of water quality by pollutants suggesting extreme state of deterioration of water quality with non-conducive ecological regime for fisheries development.

Key words : Biological diversity index, food spectrum, river Gomti, Lucknow, India.

INTRODUCTION

Disposal of wastes into the aquatic environment has long been an accepted fact but it is being done without considering the possible consequences it may pose to the water bodies (Edmondson 1959; Pandey *et al*, 1999; Singh and Singh, 2007). Though, the aquatic environment has a good deal of assimilation capacity, excessive load of pollutants does pose threat to the very survival of the ecosystem (Lal and Pandey, 1999; Pandey *et al*, 1999; Varshney, 2006; Verma and Saksena, 2010; Varshney *et al*, 2012a, b). The river Gomti at Lucknow city is exposed to pollution due to industrialization and urbanization (Singh *et al*, 2005a, b; Pandey *et al*, 2008) and high concentration of the seven heavy metals-cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn) have been recorded in this tributary (Gaur *et al*, 2005; Lohani *et al*, 2008; Dutta *et al*, 2011). The quantity of domestic and industrial sewage produced in Lucknow is more than 325 MLD (Anon, 1993). The water quality strongly influence distribution and extent biodiversity of the planktons as well as benthic organisms which are critically linked to changes in the ambient environment.

The species present either become tolerant to the rigorous chemical malice or lose the very presence, in turn, affecting the entire ecological niche (Sharma, 2010; Ahmed *et al*, 2010; Habeeba *et al*, 2012). Since river Gomti is highly polluted at Lucknow (Gaur *et al*, 2005; Pandey *et al*, 2008; Srivastava *et al*, 2011), the present study has been made on the biological diversity of the live food spectrum (phytoplankton, zooplankton and benthic fauna) of the river at Daliganj station (Lucknow). Besides live food spectrum, physico-chemical parameters like temperature, pH, dissolved oxygen, free carbon dioxide, alkalinity, hardness, chemical oxygen demand (COD), nutrients (nitrite, nitrate and phosphate) and soil quality were also recorded.

MATERIALS AND METHODS

The sampling station, Daliganj, is situated in heart of Lucknow (26° 55'N; 80° 59'E) in a thickly populated area (Fig. 1). It is close to industrial units discharging the wastes directly into the river, the quantum of discharge is about 9.00 MLD at this location (Varshney *et al*, 2012a). It is a fishermen locality as well as washer-men wash the clothes on both sides of the bank. On this spot, the soil of

river bed is black because of the decomposition of organic wastes discharged by the distillery as well as city nullahs and the area is badly affected by foul smell. Though this locality is also utilized for night soil, the area is dominated by industrial effluents apart from the sewage.

Samples were collected at monthly intervals during October, 2003-April 2005 for soil and water quality, phytoplankton, zooplankton and benthos studies. Sediments for the benthos were collected using Ekman grab with covered area of 0.1 m². After collection of the samples, the larger organisms were picked out immediately and sieved through 0.5 mm screen and those retained were preserved in 5% formalin. Environmental parameters like air and water temperature, pH, dissolved oxygen (DO), dissolved CO₂, alkalinity, hardness, nitrite, nitrate and phosphate contents in the water were analyzed following the standard methods (APHA, 1999). Identification and analysis of phytoplankton, zooplankton and benthos were made by the methods given by Ward and Whipple (1959), Needham and Needham (1962), Holome and McIntyre (1971) and Pennak (1978).

RESULTS AND DISCUSSION

Water Quality Parameters

Variations in the water parameters at Daliganj sampling station (Lucknow) during the study period have been summarized in Table 1.

Temperature: The range of air temperature recorded was from 15.00 (January 2004)-36.00°C (May 2004). The water temperature varied from 14.00 (January 2005)-32.70°C (October 2004) during the study period. The mean values of air and water temperatures for entire period of study were 26.13°C and 24.03°C, respectively. Seasonally, values were comparable during pre-monsoon and monsoon and lowest during post-monsoon.

pH: pH of water during the period of study varied from 7.20 (May 2004)-8.20 (December 2004). Mean pH value for the period of study was 7.30. Seasonally, highest value (7.80) was observed during post-monsoon period which was comparable to monsoon (7.75) and pre-monsoon (7.57) periods.

Carbon dioxide: CO₂ content in water varied from Nil (August 2004)-30.00 mg l⁻¹ (October 2004), the mean value being 8.18 mg l⁻¹. Seasonally, the values were 7.00, 9.27 and 7.80 mg l⁻¹ during pre-monsoon, monsoon and post-monsoon periods, respectively. There was a gradual decrease in CO₂ content during February 2005-April 2005.

Dissolved oxygen: The dissolved oxygen (DO) content of water ranged from 0.80 (May 2004)-6.26 (December 2004) mg l⁻¹ during the period of study. The

mean value was 3.38 mg l⁻¹. Seasonally, higher mean value 5.36 mg l⁻¹ was observed during post-monsoon period followed by pre-monsoon (3.03 mg l⁻¹.) and monsoon (2.70 mg l⁻¹).

Alkalinity: The maximum alkalinity in river Gomti was 560.00 mg l⁻¹ (May 2004) while minimum was 90.00 mg l⁻¹ (October 2004), the mean alkalinity being 282.05 mg l⁻¹. It is also noticed that alkalinity increases during October, 2004-April, 2005, except during February and March 2005. High mean value of alkalinity was noticed during pre-monsoon (334.50 mg l⁻¹) followed by post-monsoon (238.0 mg l⁻¹) and monsoon (198.50 mg l⁻¹).

Hardness: The hardness of water varied from 98.00-420.00 mg l⁻¹ (February 2004), the mean value for the period being 249.83 mg l⁻¹. Mean seasonal values of hardness at Daliganj were 233.5, 233.5 and 219.5 mg l⁻¹ during pre-monsoon, monsoon and post-monsoon, respectively.

Phosphate: Phosphate content at Daliganj site ranged from 0.60 (March 2005)-8.00 mg l⁻¹ (August 2004). The average value during study period was 2.72 mg l⁻¹. Mean seasonal values observed were 1.14, 1.96 and 1.0 mg l⁻¹ during pre-monsoon monsoon and post-monsoon, respectively.

Nitrite: Nitrite varied in a narrow range of 0.02 (January 2005)-5.23 (June 2004) mg l⁻¹ (June 2004), the mean value being 1.00 mg l⁻¹. The higher concentration noticed during pre-monsoon (1.98 mg l⁻¹) followed by monsoon (0.99 mg l⁻¹) and post-monsoon (0.22 mg l⁻¹).

Nitrate: Nitrate in river Gomti at Daliganj ranged from 5.82 (April 2004)-74.70 mg l⁻¹ (April 2005). The average nitrate content during the study period was 30.60 mg l⁻¹. The highest value was noticed in pre-monsoon (44.63 mg l⁻¹) followed by post-monsoon (23.53 mg l⁻¹) and monsoon (24.31 mg l⁻¹).

Chemical oxygen demand (COD): The COD in river Gomti at Daliganj varied from 6.40 (January 2005)-252.00 mg l⁻¹ (October 2004). The mean COD value was 48.90 mg l⁻¹ during the period of study.

Soil Quality Parameters

The soil parameters included were pH, CaCO₃, water retention capacity and organic carbon. The texture of soil was clayey and black colour due to highly decomposed organic matter emitting foul smell. Variations in the soil quality parameters at Daliganj sampling station (Lucknow) have been summarized in Table 2.

pH: The soil pH varied from 6.30-8.00 with the highest value (8.00) recorded on many occasions such as April 2004, November 2004, December 2004, January 2005

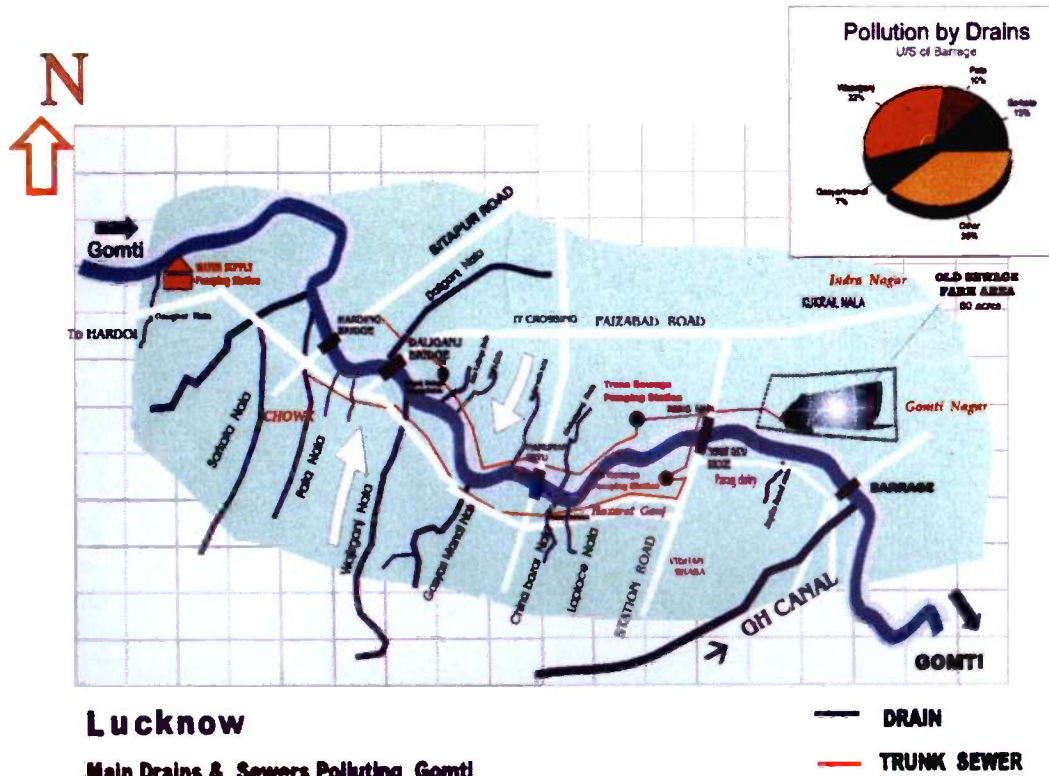


Fig. 1 : Map of Lucknow showing Daliganj sampling station on river Gomti.

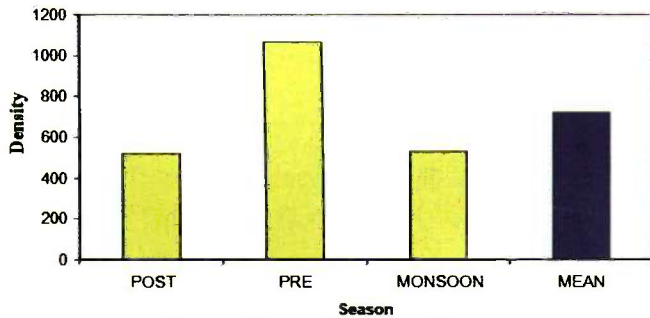


Fig 2 : Mean phytoplankton density.

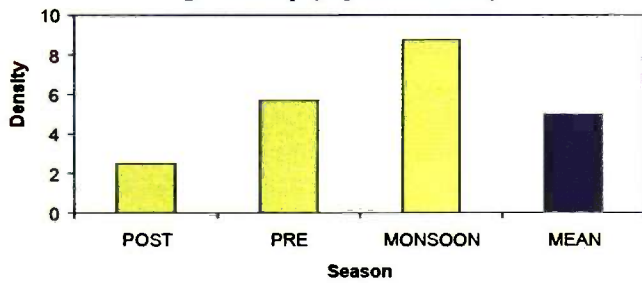


Fig. 3 : Mean zooplankton diversity.

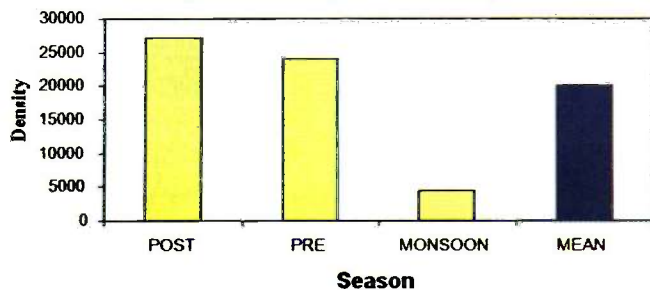


Fig. 4 : Mean benthic density.

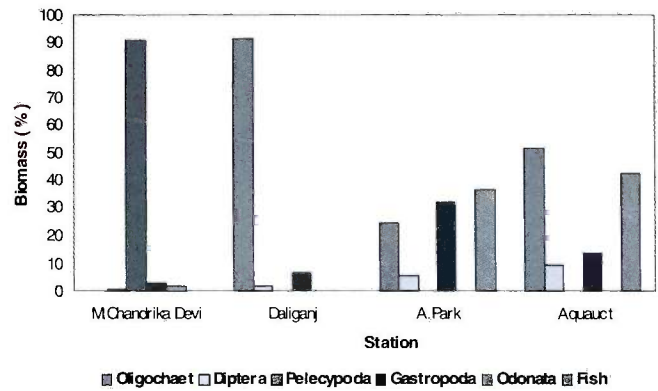


Fig. 5 : Variation in biomass of major benthic groups.

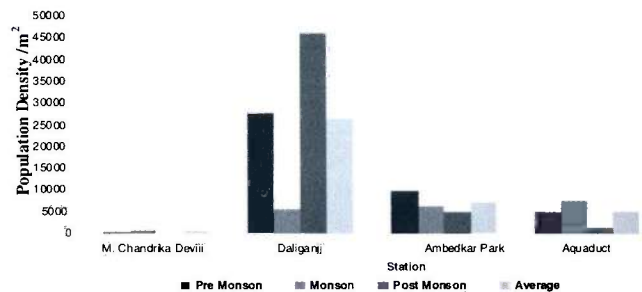


Fig. 6 : Seasonal variations in population density of benthos.

and February 2005 while lowest pH (6.30) was observed in March 2005. The average pH was 7.42.

Calcium carbonate: Calcium carbonate (CaCO_3) of the river water ranged from 1.25-28.75%. The highest value was recorded in March 2005 while the lowest in September 2004. The mean calcium carbonate content was 10.62% which decreased gradually from May 2004-September 2004.

Water retention capacity: Water retention capacity of river Gomti at Daliganj varied from 29-57%. The maximum water retention capacity was observed in July 2004 and the lowest in September 2004. The average water retention capacity for study period was 38.80%. Seasonally, it varied from 35.52-38.25 % during pre- and post-monsoon. The highest value (38.25%) was recorded during monsoon.

Organic carbon: Organic carbon was noticed less than 1.00% except in May and July 2004. The value varied from 0.08-2.04%. The average value of organic carbon for the study period was 0.67%.

Biological Parameters

Variations in the biological parameters at Daliganj site of river Gomti have been summarized in Tables 3-4 as well as in Figs. 2-64

Phytoplankton: Variations in phytoplankton density at Daliganj site of river Gomti at Lucknow have been presented in Fig. 2. The phytoplankton were represented by four phyla Chlorophyceae, Bacillariophyceae, Cynophyceae and Pyrrophyceae. Chlorophyceae was the dominant with maximum number of genera such as *Gonatozygon*, *Mougeotia*, *Closteridium*, *Ulothrix*, *Cladophora*, *Cosmerium*, *Spriogyra*, *Penium*, *Sphaeroszoma*, *Ankistrodesmus*, *Closteriopsis*, *Microsterias* and *Sphaeroeystis*. The genera comprising Bacillariophyceae were *Synedra*, *Fragillaria*, *Navicula*, *Gomphonema* and *Meridion*. Under phyla Cynophyceae and Pyrrophyceae, the genera observed were *Maelosira* and *Peridinium*, respectively. The genera-wise contribution of phytoplanktons were *Gonatozygon* (8.69%), *Closteridium* (27.00%), *Ulothrix* (15.25%), *Cladophora* (28.03%) and *Cosmerium* (8.32%). Bloom of *Ulothrix* was reported only once in the month of May 2004. Seasonally, higher values of phytoplanktons were reported during pre-monsoon followed by monsoon and post-monsoon periods.

Chlorophyll contents: Variations in different types of chlorophylls of the water at Daliganj site of river Gomti, Lucknow have been summarized in Table 3. The range of biomass of chlorophyll 'a' varied from 1.023 mg m⁻³

(January 2005)-99.18 mg m⁻³ (November 2004). Seasonally, mean higher value (30.265 mg m⁻³) was observed during post-monsoon. Exceptionally higher peak reported for chlorophyll 'a' was (99.180 mg m⁻³) in November 2004.

Zooplankton: Variations in zooplankton diversity at Daliganj site of river Gomti at Lucknow have been shown in Fig. 3. Phylum Protozoa has only one genera *Euglena*. Ostracoda was represented by two genera *Cypris* and *Cyprinotus*. The genera of Rotifera were *Filinia*, *Asplanchna*, *Conchilus*, *Testudinella*, *Brachionus*, *Trichocera*, *Monostyla* and *Hexorthra*. The cladocerans were *Daphnia*, *Moinodaphnia*, *Ceriodaphnia*, *Moina*, *Simocephalus*, *Macrothrix* and some unidentified forms. The genera Cyclops and Diaptomus belong to Copepoda. Worms were *Nais*, *Tubifex* and *Chironomus* larvae. Apart from all these, Hydra (Coelenterata) was also noticed. Dominant genera recorded were *Brachionus* (12.60%), *Hexorthra* (5.26%), *Daphnia* (4.21%), *Moinodaphnia* (17.89%), *Ceriodaphnia* (4.21%), *Cyclops* (20.00%) and worms (8.42%). Maxima for population density was observed in April 2004 and July 2004. Seasonally, higher values for zooplankton density were noticed during monsoon followed by pre-monsoon and post-monsoon.

Benthos

Seasonal variations in biomass of major benthic groups and population density of benthic fauna at Daliganj site of river Gomti, Lucknow have been summarized in Figs. 4-6.

Biomass: The biomass of major benthic groups at Daliganj site of river Gomti varied from 0.891-63.547 gm⁻², the maximum was recorded in April 2005 and lowest in May 2004. Seasonally, the maximum biomass (39.00 gm⁻²) was observed during post-monsoon while minimum (12 gm⁻²) during monsoon. Average biomass being 25.179 gm⁻² at Daliganj site for entire study period (Fig. 5). The biomass was found to increase from May-December, 2004 except during September-October, 2004. The oligochaetes constituted 91.34% of total biomass followed by gastropods 6.58% and dipterans 2.05%.

Population density: The benthic population density at Daliganj site of river Gomti varied from 1,320-75,300 m⁻². The maximum population density was in April 2005 while the lowest in May 2004. Average population density was 26,490 m⁻². Seasonally, it was 27,658, 5,562 and 45,960 m⁻² for pre-monsoon, monsoon and post-monsoon, respectively (Fig. 6).

Faunal composition: Fauna was chiefly contributed by oligochaetes followed by Diptera. Other faunal groups, represented by Ephemeroptera, Coleoptera and

Table 1 : Water quality parameters of river Gomti at Daliganj station, Lucknow.

Sl. No.	Parameters	Range(Mean)
1.	Temperature (°C)	
a	Air	15.00-36.00(26.13)
b	Water	14.00-32.70(24.03)
2	pH	7.20-8.20(7.20)
3	DO ₂ (mg l ⁻¹)	0.80-6.26(3.38)
4	CO ₂ (mg l ⁻¹)	Nil-30.00(8.18)
5	Alkalinity (mg l ⁻¹)	90.00-560.00(282.05)
6	Hardness (mg l ⁻¹)	98.00-420.00(249.83)
7	Phosphate (mg l ⁻¹)	0.60-8.00(2.72)
8	Nitrite (mg l ⁻¹)	0.02-5.23(1.00)
9	Nitrate (mg l ⁻¹)	5.82-74.70(30.60)
10	COD (mg l ⁻¹)	6.40-252.00(48.90)

Gastropoda, were also present occasionally. A total of 6 groups and 24 genera were present in this locality.

Oligochaeta: Oligochaetes predominated the fauna and constituted 96.82% of the total population density, the higher density (72,700 m⁻²) observed in April 2005. *Tubifex tubifex* was the dominant species and contributed 86.27% among oligochaetes followed by *Chaetogaster* spp. (2.76%). *Nais*, *Dero*, *Lumbriculus*, *Limnodrilus*, *Branchiura*, *Stylaria* and *Pristina* spp. were also present at Daliganj site of river Gomti.

Diptera: Diptera was the second largest group and contributed 3.05% of the total population density. Dipterans population density was higher in February 2005. Among the dipterans, *Chironomus* larvae contributed 99.43% at Daliganj site of river Gomti.

Gastropoda: Gastropoda constituted 0.064% of total population density at Daliganj site of river Gomti and were represented by *Pomacea*, *Vivipara*, *Aplexa*, *Lymnaea* and *Valvata* spp.

Others: The other groups like Nematoda, Ephemeroptera and Coleoptera were also present in fauna at Daliganj site of river Gomti. Though their contribution was negligible but important.

Diversity Indices

The diversity indices of benthic organisms at Daliganj site of river Gomti at Lucknow have been summarized in Table 4. The highest Sannon-Weaver Index (H) was observed for Gastropoda (1.290) followed by Coleoptera (0.980), Oligochaeta (0.512) and the poorest (0.127) for Diptera. Simpson's Dominance Index (S1) ranged from 0.980 (Diptera) to 0.250 (Gastropoda). For Oligochaeta and Coleoptera, it was 0.960 and 0.540, respectively. McIntosh Index (Mc) and Species Dominance Index (D) for all the groups was less than 1.00. Maximum McIntosh

Table 2 : Soil parameters of river Gomti at Daliganj station, Lucknow.

Sl. No.	Parameters	Range(Mean)
1	pH	6.30-8.00(7.42)
2	CaCO ₃ (%)	1.25-28.75(10.62)
3	Water retention capacity (%)	29.00-57.00(38.80)
4	Organic carbon (%)	0.08-2.04(0.67)

Index (Mc) was observed for Gastropoda (0.750) followed by Coleoptera (0.460), Oligochaeta (0.040) and minimum for Diptera (0.020). The highest Species Dominance Index (D) was 0.990 for Diptera and 0.980 for Oligochaeta followed by Coleoptera (0.500) and Gastropoda (0.290). Simpson Reciprocal Index for all the groups was almost 1.00, except Gastropoda (4.000).

In the present study, the water temperature, in general, followed the trend of atmospheric temperature. The difference between air and water temperature was almost similar. Similar pattern has been noticed by other workers in the Indian rivers, especially in Ganga near Barauni industrial area (Pandey *et al*, 1999; Singh and Singh, 2007) and Khushavati river in Goa (Kulkarni, 2002). Presence of black coloured soil with foul odour due to decomposition of organic wastes was observed in the present study at Daliganj Station of river Gomati in Lucknow. Khare and Khare (2012) also recorded similar finding at the discharge of industrial waste waters near Central Drug Research Institute (Chhattarmanjil Palace) and Talkatora Industrial Area of Lucknow. pH of the Gomti river water at Daliganj site did not show significant fluctuation and remained alkaline throughout the year. The mean pH was high during pre-monsoon. Similar observations have also been recorded in water at other sites of the river (Varshney *et al*, 2012a, b).

Mean dissolved oxygen (DO) value was 3.38 mg l⁻¹ during the study period with the highest value in December 2004 which may probably be due to diffusion from air. Khare and Khare (2012) have also recorded similar content of DO at Gaughat site of river Gomti in Lucknow. High mean alkalinity (282.05 mg l⁻¹), hardness (249.83 mg l⁻¹), nitrite (1.00 mg l⁻¹), nitrate (30.60 mg l⁻¹) and phosphate (2.72 mg l⁻¹) were observed at Daliganj station of river Gomti, perhaps due to sewage and industrial wastes. Varshney (2006), Agrahari *et al*. (2007, 2008) and Varshney *et al*. (2012a, b) also observed the deteriorated water quality of the river Gomti in downstream stations due to discharge sewage as well as industrial wastes into the river without treatment.

Higher concentration of nutrients, especially nitrite (NO₂⁻) and nitrate (NO₃⁻) as well as chemical oxygen

Table 3 : Chlorophyll contents in river Gomti at Daliganj station, Lucknow.

Sl. No.	Months	Chlorophyll 'a' (mg m ⁻³)	Chlorophyll 'b' (mg m ⁻³)	Chlorophyll 'c' (mg m ⁻³)
1	June 2004	10.179	0.624	4.574
2	July 2004	57.526	28.551	—
3	August 2004	—	—	—
4	September 2004	8.33	8.515	15.412
5	October 2004	8.74	4.841	7.124
6	November 2004	99.18	2.807	8.650
7	December 2004	8.07	11.13	13.558
8	January 2005	1.023	1.294	1.525
9	February 2005	12.786	10.816	5.868
10	March 2005	13.888	—	3.832
11	April 2005	—	—	—

Table 4 : Diversity indices of benthic organisms of river Gomti at Daliganj, Lucknow.

Taxa	Shannon- Weiner Index (H')	Simpson's Dominance Index (S1)	McIntosh Index (Mc)	Species Dominance Index (D)	Simpson Reciprocal Index
Oligochaeta	0.512	0.960	0.040	0.980	1.020
Diptera	0.127	0.980	0.020	0.990	1.020
Coleoptera	0.980	0.540	0.460	0.500	1.850
Gastropoda	1.290	0.250	0.750	0.290	4.000

demand (COD) were encountered during pre-monsoon which may be due to low precipitation and influx of effluents in summer. Phosphate values were high during monsoon probably due to runoff from agricultural fields. Higher values of nutrients coincide with high population density of phytoplankton and benthos during pre-monsoon period (Varshney, 2006).

Planktons, particularly phytoplankton, have been used as indicators of water quality for quite long time (Palmer, 1959, 1969). Some species flourish in highly eutrophic waters while others are very sensitive to organic and/or chemical wastes. Some species develop noxious blooms, sometimes creating offensive taste and odour or anoxic or toxic conditions resulting in animal deaths or human illness. The species assemblage of phytoplankton and zooplankton may also be useful in assessing the water quality.

The phytoplankton represented were Chlorophyceae (13 genera), Bacillariophyceae (05 genera), Cynophyceae (01 genera) and Pyrrophyceae (01 genera). The maximum contribution was made by genera *Gonatozygon* (8.69%), *Closteridium* (27.00%), *Cladophora* (28.3%), and *Cosmarium* (8.32%) under Chlorophyceae. *Ulothrix* was encountered only once in abundance.

Chlorophyll 'a', 'b' and 'c' are the important plant pigments present in the phytoplankton show unimodal distribution with higher production either during monsoon or post-monsoon (Parsons *et al*, 1984). The mean (24.413 mg m⁻³) chlorophyll 'a' (the major pigment) and

chlorophyll 'b' and 'c' values were high in present study as compared to those observed for Gomti river water at Ambedkar Park, Maa Chandrika Devi and Picnic Spot in Lucknow (Agrahari *et al*, 2007, 2008; Varshney *et al*, 2012a, b). Higher values of chlorophyll were noticed during post-monsoon period.

Abundance and fluctuations of phytoplankton population showed a great deal of seasonal variations, being the maximum during pre-monsoon while the low population values were comparable during monsoon and post-monsoon periods. Phytoplanktons always dominated over the zooplanktons during the period of study. Gorai *et al* (2003) observed the maximum population during post-monsoon and minimum during monsoon as well as domination of phytoplankton over the zooplankton for the wetland (Kaithkola) of North Bihar. The greater abundance of Chlorophyceae observed during pre-monsoon may be due to relatively better aquatic regime in terms of nutrient availability and decline in macrophyte stand owing to influx of monsoon runoff. *Closteridium* and *Cladophora*, the most predominant green algae, were perennial in distribution.

Among the zooplanktons, copepods and the cladocerans were the most predominant groups in a sequence of rotifers, planktonic oligochaetes, ostracoda, protozoa and *Hydra*. Gurumayum *et al* (2002) reported the occurrence of cladocerans, rotifers and protozoans in the rivers of Meghalaya. Seasonal variations in

zooplankton abundance is a common phenomenon owing to changes in climatic conditions thereby, physico-chemical parameters of the water. Mean maxima for zooplankton was observed during monsoon while minimum density was recorded during post-monsoon period. Decline in zooplankton density during post-monsoon was also observed by many workers in major Indian rivers like Hooghly (Chakraborty *et al*, 1995) and rivers of Meghalaya (Gurumayum *et al*, 2002). Highest number of rotifer genera (8) followed by cladocerans (6) were encountered at Dalibagh sampling station of river Gomti at Lucknow.

The population of zooplankton is comparatively low as compared to phytoplankton. Increasing number of rotifers followed by cladocerans and copepods indicate the aquatic regime with substantial load of organic matters (Baruah, 1993). Besides, the protozoan also contributed in the community structure of zooplankton which too indicates organic load in the ecosystem. Relatively low abundance of zooplankton could be attributed to less availability of energy for their growth probably in a polluted environment. Pathak *et al* (2001-river Brahmaputra) and Gurumayum *et al* (2002-rivers of Meghalaya) also recorded relatively low abundance of zooplankton which could be attributed to less availability of energy for their growth.

The benthic fauna (macrobenthos) form the major component of the freshwater bodies and establish an important link in the food chain. It serves as food for the most of the bottom feeding fishes. The knowledge of their composition, abundance and distribution help to evaluate their significance as fish food. Mean benthic population was exceptionally high (26,490 m⁻²). High population density mainly contributed by worms like oligochaetes and *Chironomus* larvae. Numerically, high population density of macrobenthos have been reported from the stressed localities compared to unpolluted environment off Versova and Mahim in Mumbai (Varshney *et al*, 1988; Varshney and Govindan, 1995) and Picnic Spot of river Gomti in Lucknow (Agrahari *et al*, 2008). Seasonally, high population of benthic organisms was noticed in the present study during post-monsoon and lower in monsoon season at Daliganj station of river Gomti in Lucknow. Low population during monsoon may be attributed to disturbances in the substrata due to influx of huge monsoon waters and high values in post-monsoon period may be due to stabilization of the bottom sediment gradually from monsoon onward. Similar observations were also recorded in the polluted aquatic environment in and around Lucknow (Varshney, 2006; Varshney *et al*, 2012a, b).

In earlier studies, *Branchiura*, *Tubifex* (oligochaetes), *Chironomus* (Diptera), Culicidae larvae and *Lymnaea*

(Gastropoda) have been identified as pollution indicator benthic species from river Gomti (Varshney *et al*, 2012a, b). The oligochaetes recorded at Daliganj station of river Gomti in Lucknow in the present study were *Lumbriculus*, *Limnodrilus*, *Branchiura*, *Chaetogaster*, *Nais*, *Tubifex* and larvae of *Chironomus* as well as Culicidae. Moza and Kolekar (2001) have also described these organisms as pollution indicator species of river Yamuna and explained *Branchiura*, *Tubifex* (oligochaetes) and *Chironomus* (Diptera) as pollution resistant or saprophilic species while oligochaete like *Nais* as a pollution sensitive.

Shannon-Wiener Diversity Index (H) of benthic organisms was less than 1.00 for oligochaetes, Diptera, Coleoptera and Gastropods. Shannon-Wiener Diversity Index of less than 1.00 indicates the stressed environment. Agrahari *et al* (2008) also noticed the Shannon-Wiener Diversity Index (H) less than 1.00 in polluted environment of Lucknow. Simpson Dominance Index (D), McIntosh Index and Species Dominance Index for all the groups studied was also less than 1.00. Simpson Reciprocal Index was always more than one for all the species. It was very high for gastropods. Similar observations have also been recorded from the polluted water of river Gomti near Lucknow (Varshney *et al*, 2012a, b).

The phytoplankton and zooplankton population observed at Daliganj station of river Gomti at Lucknow was very poor. Since the biomass of phytoplankton and zooplankton could not be observed in the present study, it is not possible to work out the fishery potential of the area. Though the benthic density was on higher side due to the presence of worms like oligochaetes and *Chironomus* larvae which may not contribute to the food chain. Abundance of a these groups of organisms in the deteriorated and polluted environment may not transfer the energy at higher trophic level.

Because of their short life-cycle, planktons respond quickly to environmental changes and hence their standing crop and species composition are most likely to indicate the quality of water mass in which they are found. They strongly influence certain non-biological aspects of water quality such as pH, colour, taste and odour and in a very practical sense they are a part of water quality. Certain taxa are often useful in determining the origin or recent history of a given water mass. Because of their transient nature and often patchy distribution, however, the utility of planktons as water quality indicators may be limited.

Relatively low abundance of plankton population and biomass in spite of high nutrient budget of the system are indicative of the great infestation of water quality by pollutants suggesting extreme state of pollution/deterioration

of water quality leading to un-conducive ecological regime for fisheries development at Daliganj station of river Gomti in Lucknow. The available energy in the system is largely lost and little is available for luxuriant growth of pelagic organisms like planktons, an important component in aquatic grazing chain (Gorai *et al*, 2003; Varshney *et al*, 2012 a, b).

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