Indian Journal of Plant Sciences ISSN: 2319–3824(Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jps.htm
2015 Vol.4 (1) January-March, pp.78-86/Rishi and Awasthi
Research Article

BIODIVERSITY OF CYANOBACTERIA IN RIVER GANGA AT KANPUR, UTTAR PRADESH, INDIA

***Vinod Rishi[1] and Awasthi A.K.[2]**
[1]Mahatma Gandhi Chitrakoot Gramoday University Chitrakoot, Satna, M. P.
[2]Brahmanand Degree College, Kanpur, U.P.
**Author for Correspondence*

ABSTRACT
Cyanobacteria are an important group of gram-negative photosynthetic prokaryotes which play a vital role in all kind of aquatic ecosystems. The biodiversity of cyanobacteria from five sampling stations (Bithoorghat, Ranighat, Sarsaiyaghat, Golaghat and Jajmaughat) of River Ganga at Kanpur has been estimated, between Bithoorghat to Jajmaughat, during the period from February 2013 to January 2014. Total 114 species of cyanobacteria belonging to 2 orders (Chroococcales and Nostocales), 4 families (Chroococcaceae, Oscillatoriaceae, Nostocaceae and Rivulariaceae) and 23 genera have been identified from different sampling stations of river Ganga during the study period. The minimum of cyanobacteria have been recorded at Bithoorghat and maximum at Jajmaughat. During the entire study the most dominating genera were *Anabaena, Aphanizomenon, Chroococcus, Cylindrospermum, Lyngbya, Microcystis, Nodularia, Nostoc, Oscillatoria, Phormidium* and *Spirulina.*

Keywords: *Cyanobacteria, Diversity, River Ganga, Pollution*

INTRODUCTION
Kanpur is a biggest city of the Uttar Pradesh and known as the commercial capital of state and situated on the right bank of river Ganga. The major industries of city are leather, textile, chemical, machinery and pharmaceuticals etc. These industries generate a wide variety of organic and inorganic wastes such as oils, plastics, phenols, heavy metals, pesticides, herbicides etc. Due to indiscriminate removal and discharge of the above mentioned harmful substances the river Ganga gets high amount of contaminated substance and become highly polluted in Kanpur. Such condition of river water provides the great opportunity to proliferate various kinds of algae including cyanobacteria and these can serve as indicators of declining water quality.

Cyanobacteria are chlorophyll containing gram-negative photosynthetic prokaryotes, found in huge variety of environments ranging from Antarctic lakes, nutrient poor oceans to highly nutrient rich ponds, lakes and rivers (Whitton and Potts 2000; Castenholz 2001a, b). In tropical and sub-tropical regions cyanobacteria may dominate at any time of year or persist throughout the year (Mur, *et. al*. 1999; Huisman and Hulot, 2005). They are morphologically diverse having unicellular, colonial and filamentous forms (Whitton and Potts 2000). They play a vital role in the various biogeochemical cycles such as nitrogen, carbon, Phosphorus and oxygen. For a long time, the economic importance of cyanobacteria was limited to their use as bio-fertilizer in agriculture but during the last few decades they have been recognized for their high potential in a wide variety of biotechnological applications (Thajuddin and Subramanian, 2005; Spolaore, *et.al,* 2006). They are major components of water blooms which are extremely toxic due to presence of cyanotoxins (Sivonen and Jones, 1999) and thus, pose a health risk to humans and other aquatic and domestic organisms (Kuiper-Goodman, *et. al.*, 1999).

Cyanobacteria are commonly found in polluted and unpolluted water and due to this behavior they are generally considered useful to determine the quality of water at very low cost. These are very suitable organisms for the determination of the impact of toxic substances on the aquatic ecosystems because any effect on the lower level of the food chain will also have consequence on the higher level. Clean water would support a great diversity of organisms, whereas polluted water would yield just a few organisms, with one or few dominant forms (Trainor, 1984). Few reports have been available on cyanobacterial flora from different regions of India (Desikachary, 1959; Prasad and Saxena, 1980; Tarar and Bodkhe, 1997;

Mahadev and Hosmani, 2004; Parikh, *et. al.*, 2006; Gupta, *et. al*., 2006; Sankaran, 2006; Chaudhary and Kumar Mukesh, 2006; Saha, *et. al*., 2007; Kumar Mukesh, 2010; Kumar, Mukesh, *et.al*., 2011). Some algal infestations have been reported from Kanpur by various workers in time and space (Ahmad, 1973; Shukla, 1983; Tripathi and Pandey, 1989; Tiwari, *et. al*., 2001; Tiwari and Shukla, 2007, Rishi and Awasthi, 2012).

During the past few decades research on cyanobacteria were academic interest only and mostly unnoticed as nuisance but, now they are proved as potential candidates for much biotechnological utilization (Richmond, 1990; Sundararaman and Sekar, 2001; Thajuddin and Subramanian, 2005). The main objective of the present study to exploit the occurrence and distribution of cyanobacteria from different sampling stations (Ghats) of River Ganga at Kanpur, between Bithoorghat to Jajmaughat, during the period from February 2013 to January 2014.

MATERIALS AND METHODS

Study Area: Kanpur is situated at 26.46^0 N latitude and 80.35^0 E longitudes at an elevation of 126 meters from sea level on the right bank of river Ganga. It is one of the oldest industrial townships of North India and known as Manchester of North India. The major industries of city are leather, textile, chemical, machinery and pharmaceuticals etc. It is famous for leather industries. The entire length of river between Bithoor to Jajmau is approximate 24-25 Kilometers (Fig.1).

Sampling Stations: Five sampling stations were carefully inspected and selected for the entire River Ganga at Kanpur form Bithoor to Jajmau for the sampling of cyanobacteria.

Bithoorghat: Bithoor is situated on the Kannauj Road, 27 km from center of Kanpur and Situated on the banks of the river Ganga. Its coordinates are 26.36^0 North and 80.16° East. The pollution load at Bithoorghat is reported lesser than nearby stations of Kanpur. There are no such major industries in this rural area except minor sewage channels and agricultural runoff adds to pollution.

Ranighat: Ranighat is situated at Nawabganj, Kanpur and near the Ganga Barrage and its coordinates are 26.30° North and 80.19° East. Ranighat is the first station of river Ganga which gets more domestic and industrial wastes. Pollution load at this station is higher than Bithoor.

Sarsaiyaghat: This ghat is situated at 26.28° North and 80.21°East. Sarsaiyaghat has been selected for sampling due to presence of microbial diversity.

Golaghat: Golaghat is a famous ghat in Kanpur city, the industrial hub of Uttar Pradesh in North India. It is situated on the bank of River Ganga at Kanpur and its coordinates are 26.27° North and 80.22° East. This ghat gets high amount of domestic and industrial effluents.

Jajmaughat: The coordinates are 26.45° North and 80.35° East and situated near Jajmau. It is home to some of the Biggest Leather tanneries in Northern India.

***Collection, Preservation, Identification and Quantification of Cyanobacteria*:** An exhaustive collection of cyanobacterial samples have been made from different sampling sites with a view to record their diversity in river Ganga at Kanpur in first week of each month from February 2013 to January 2014. Due to heavy rainfall and flood the sampling have not been done in July and August, 2013. The cyanobacterial samples were collected by using 20μ mesh size plankton net by filtering 50 liters water and preserved in 50 ml water containing FAA for further analysis. For quantitative analysis, one drop of sample was taken on a clean glass slide and cyanobacteria were counted by drop count method. The results obtained are expressed as number of cells/units per Liter of sample.

Total cells/units per liter = $A^* (1/L)^* (n/v)$

Where, A= Number of cells/units per drop

L= Volume of filtered water through plankton net (liter)

n= Volume of concentrated sample (ml.)

v= Volume of one drop (ml.)

Identification of different genera and species of cyanobacteria has been made by using standard texts and monographs *i.e.* Desikachary, 1959; Prescott 1962 etc. on the basis of their structures and measurements. Occurrence and distribution of cyanobacteria has been made for all sampling stations.

Indian Journal of Plant Sciences ISSN: 2319–3824(Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jps.htm
2015 Vol.4 (1) January-March, pp.78-86/Rishi and Awasthi
Research Article

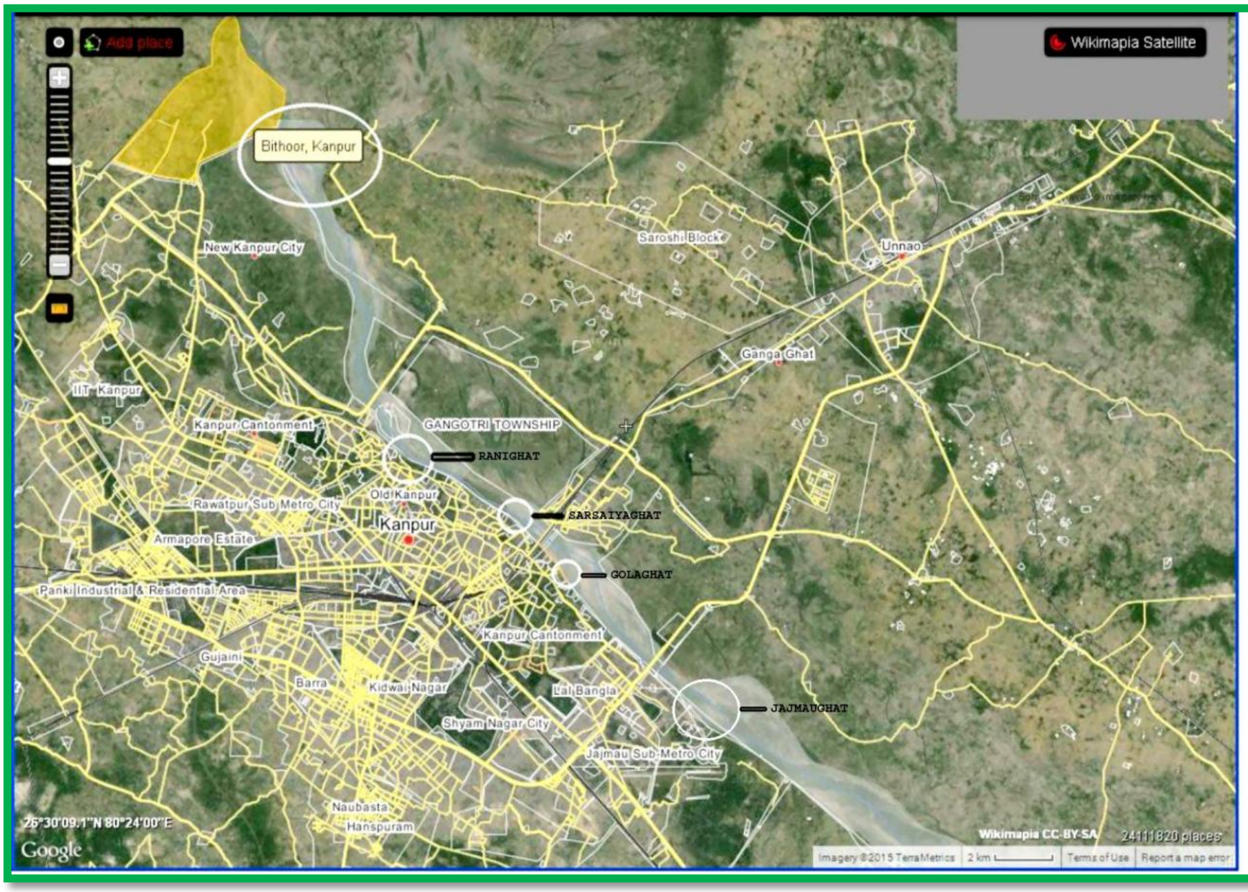

Fig.1: Satellite map of river Ganga at Kanpur, showing different Ghats (sampling stations) in white circles (Source wikimapia).

RESULTS AND DISCUSSION

In the present study, the cyanobacterial community of river Ganga at Kanpur was represented by the members of four families. Total 114 species of cyanobacteria belonging to 2 orders (Chroococcales and Nostocales) , 4 families (Chroococcaceae, Oscillatoriaceae, Nostocaceae and Rivulariaceae) and 23 genera have been identified from different sampling stations of river Ganga at Kanpur, between Bithoor to Jajmau during the period of February 2013 to January 2014 and their site wise occurrence has been given in Table 1. Result showed that the minimum species have been recorded at Bithoorghat (15 genera and 52species) and maximum at Jajmaughat (21 genera and 89 species) (Table 1). The minimum density (540 units/liter) has been recorded at Bithoorghat and maximum (3680 units/liter) at Golaghat (Table 2). The observed genera such as *Aphanocapsa*, *Aphanothece*, *Chroococcus*, *Gloeocapsa*, *Gloeothece*, *Merismopedia*, *Microcystis*, *Synechococcus* and *Sycechocystis* belong to the family Chroococcaceae; *Arthrospira*, *Lyngbya*, *Oscillatoria*, *Phormidium* and *Spirulina* belong to family Oscillatoriaceae; *Aphanizomenon*, *Anabaena*, *Cylindrospermum*, *Nodularia*, *Nostoc* and *Raphidiopsis* belong to family Nostocaceae and *Calothrix*, *Gloeotrichia* and *Rivularia* belong to family Rivulariaceae. During the entire study the most dominating genera were *Anabaena*, *Aphanizomenon*, *Chroococcus*, *Cylindrospermum*, *Lyngbya*, *Microcystis*, *Nodularia*, *Nostoc*, *Oscillatoria*, *Phormidium* and *Spirulina*. Site wise detailed analysis as follows:

Bithoorghat: Total 52 species belonging to 15 genera have been identified. Their minimum density 540 units/litter were recorded in the month of September, 2013 and maximum 1720 units/litter in the month of June, 2013. The most significant genera of this station were *Anabaena*, *Aphanizomenon*, *Chroococcus*, *Lyngbya*, *Oscillatoria*, *Phormidium* and *Spirulina* (Table: 1& 2; Fig. 2).

Research Article

Table 1: Occurrence of Cyanobacteria in Different Ghats of River Ganga at Kanpur

S. No.	Species of Cyanobacteria	I	II	III	IV	V
1.	*Anabaena ambigua*	+	+	+	-	+
2.	*A. circinalis*	+	+	-	+	+
3.	*A. fertilissima*	+	-	+	-	-
4.	*A. flos-aquae*	-	-	+	+	+
5.	*A. iyengarii*	+	+	-	+	+
6.	*A. iyengarii var. tenuis*	+	+	+	+	+
7.	*A. oscillariodes*	-	-	+	+	+
8.	*A. sphaerica*	-	+	+	+	+
9.	*A. variabilis*	+	+	+	+	+
10.	*Aphanocapsa biformis*	-	-	-	+	-
11.	*A. littoralis*	+	-	-	+	-
12.	*A. montana*	+	-	-	+	+
13.	*A. muscicola*	+	-	-	+	+
14.	*A. pulchra*	+	-	-	-	+
15.	*Aphanothece castagnii*	-	-	+	+	-
16.	*A. naegelii*	-	+	+	-	-
17.	*A. pallida*	-	+	-	+	-
18.	*A. saxicola*	-	-	-	+	-
19.	*Aphanizomenon gracile*	+	+	+	+	+
20.	*A. flos-aquae*	+	+	+	+	+
21.	*Arthrospira platensis*	+	-	-	+	+
22.	*A. spirulinoides*	+	-	-	+	+
23.	*Calothrix bharadwajae*	-	-	-	+	-
24.	*C. clavata*	-	-	-	+	+
25.	*C. elenkinii*	-	-	-	-	+
26.	*C. indica*	-	-	-	+	+
27.	*C. scytonemicola*	-	-	-	+	+
28.	*Chroococcus giganteus*	-	+	+	+	+
29.	*C. minor*	+	+	+	-	+
30.	*C. turgidus*	+	-	+	+	-
31.	*C. tenax*	-	+	-	+	+
32.	*Cylindrospemum lichenifome*	-	+	-	+	+
33.	*C. majus*	-	-	+	+	-
34.	*C. muscicola*	-	+	+	-	+
35.	*C. stagnale*	-	-	+	+	+
36.	*Gloeocapsa compacta*	+	+	-	-	+
37.	*G. kuetzingiana*	-	+	-	+	+
38.	*G. quaternata*	+	+	-	+	-
39.	*Gloeothece distans*	+	-	+	-	+
40.	*G. rhodochlamys*	+	-	+	-	-
41.	*Gloeotrichia echinulata*	-	-	-	-	+
42.	*G. indica*	-	-	+	-	+
43.	*G. intermedia*	-	-	+	-	-
44.	*G. natans*	-	-	-	+	+
45.	*G. raciborskii var. conica*	-	-	+	+	+
46.	*G. raciborskii var. longispora*	-	-	+	+	+
47.	*Lyngbya confervoides*	+	-	+	+	+
48.	*L. contorta*	-	+	-	-	+

49.	*L. infixa*	+	+	+	+	+
50.	*L. limnetica*	-	-	+	+	-
51.	*L. majuscula*	+	+	+	+	+
52.	*Merismopedia glauca*	+	+	-	+	+
53.	*M. punctata*	+	-	-	-	-
54.	*M. tenuissima*	-	+	-	+	+
55.	*Microcystis aeruginosa*	-	+	+	+	+
56.	*M. aeruginosa var. major*	-	+	+	+	+
57.	*M. flos-aquae*	-	-	+	+	+
58.	*M. marginata*	-	+	+	-	-
59.	*M. robusta*	-	+	-	+	-
60.	*M. viridis*	-	-	+	-	+
61.	*Nodularia herveyana*	-	-	+	-	+
62.	*N. spumigena*	-	-	+	+	+
63.	*N. spumigena var. major*	-	-	+	+	+
64.	*Nostoc commune*	+	+	+	+	+
65.	*N. ellipsosporum*	-	+	+	-	-
66.	*N. linckia*	+	+	-	+	+
67.	*N. linckia var. arvense*	+	+	-	+	+
68.	*N. muscorum*	-	+	+	+	+
69.	*Oscillatoria agardhii*	+	+	+	+	+
70.	*O. acuminata*	+	+	+	-	+
71.	*O. acuta*	+	+	+	-	-
72.	*O. amoena*	-	-	+	+	+
73.	*O. amphibia*	+	+	+	-	-
74.	*O. anguina*	-	+	+	+	+
75.	*O. annae*	+	+	+	-	+
76.	*O. boryana*	+	-	+	+	+
77.	*O. chalybea*	+	+	+	+	+
78.	*O. chlorina*	-	+	+	+	+
79.	*O. curviceps*	+	+	-	+	+
80.	*O. foreaui*	+	+	+	+	+
81.	*O. formosa*	+	+	+	+	+
82.	*O. hameli*	-	-	+	+	+
83.	*O. irrigua*	-	+	+	+	+
84.	*O. laete-virens*	+	+	-	+	+
85.	*O. limnetica*	+	-	-	+	+
86.	*O. limosa*	+	+	-	+	+
87.	*O. nigroviridis*	+	+	-	+	+
88.	*O. okeni*	-	+	+	+	+
89.	*O. peronata*	+	+	+	+	-
90.	*O. princeps*	+	+	+	+	+
91.	*O. pseudogeminata*	-	+	+	+	+
92.	*O. raciboraskii*	-	+	+	+	+
93.	*O. rubescens*	+	+	+	+	+
94.	*O. sancta*	-	-	+	-	+
95.	*O. subbrevis*	-	+	+	+	+
96.	*O. subuliformis*	+	+	+	+	+
97.	*O. tenuis*	-	+	+	+	+
98.	*O. terebriformis*	+	+	+	+	-

99.	*O. wellei*	-	-	+	+	+
100.	*Phormidium ambiguum*	+	+	+	+	+
101.	*P. fragile*	+	+	-	-	-
102.	*P. molle*	-	-	-	+	+
103.	*P. tenue*	-	-	+	+	+
104.	*Raphidiopsis curvata*	+	-	-	+	-
105.	*R. indica*	+	-	+	+	-
106.	*Rivularia aquatica*	-	+	+	+	+
107.	*R. hansgiri*	-	-	-	+	+
108.	*Spirulina gigantea*	+	+	+	+	+
109.	*S. laxissima*	-	-	+	-	+
110.	*S. major*	+	+	+	+	+
111.	*S. subsalsa*	-	-	-	+	+
112.	*S. subtilissima*	-	+	+	+	-
113.	*Synechococcus aeruginosus*	+	+	-	-	+
114.	*Synechocystis aquatilis*	-	-	+	+	+

(Abbreviations: + =Present; - = Absent; I=Bithoorghat; II=Ranighat; III=Sarsaiyaghat; IV=Golaghat; V=Jajmaughat)

Table 2: Monthly Density of Cyanobacteria at different sampling stations of River Ganga at Kanpur during the period from February 2013 to January 2014

Months	**Bithoorghat (Units/Liter)**	**Ranighat (Units/Liter)**	**Sarsaiyaghat (Units/Liter)**	**Golaghat (Units/Liter)**	**Jajmaughat (Units/Liter)**
February	920	1220	1660	2580	2760
March	1220	1480	2120	3020	3100
April	1500	1740	2320	3520	3260
May	1660	1820	2440	3520	3400
June	1720	1860	2460	3680	3540
July	0	0	0	0	0
August	0	0	0	0	0
September	540	820	980	1860	1580
October	720	1000	1140	1900	1800
November	840	1140	1460	2060	2320
December	880	1400	1580	1920	2640
January	740	1160	1320	1820	2420

Indian Journal of Plant Sciences ISSN: 2319–3824(Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jps.htm
2015 Vol.4 (1) January-March, pp.78-86/Rishi and Awasthi
Research Article

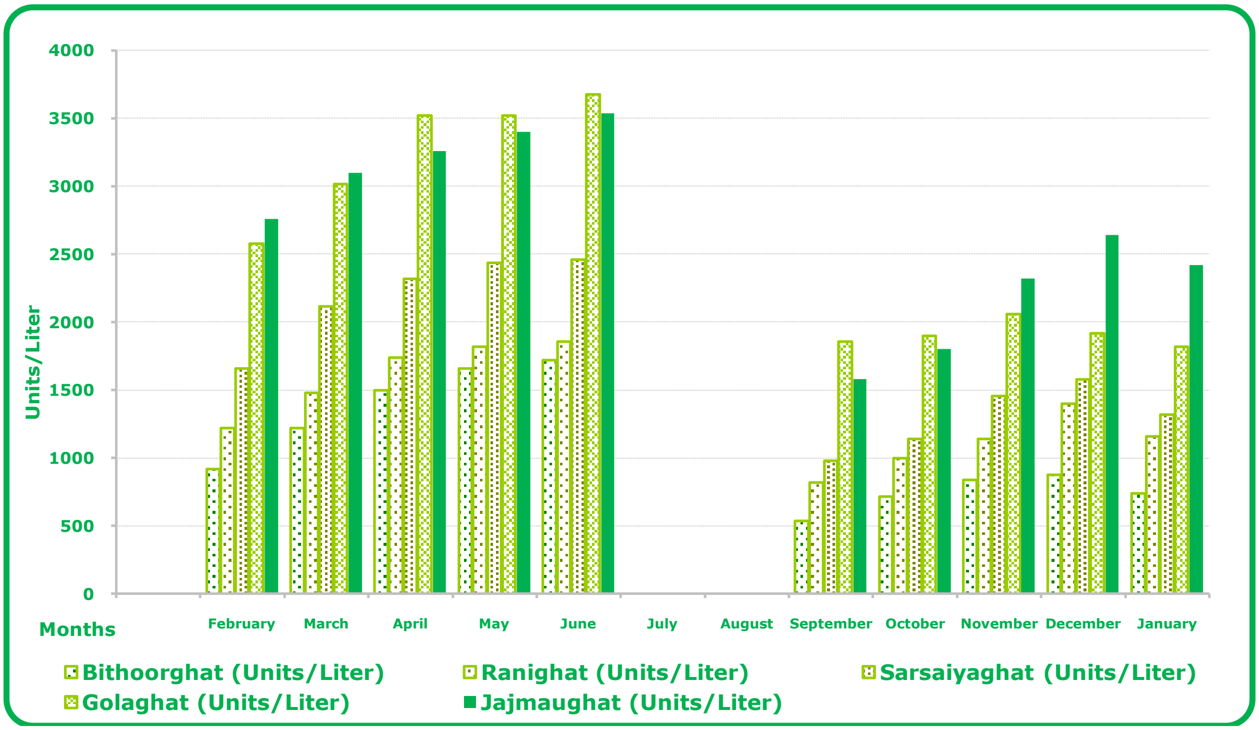

Figure 2: Graphical representation of Cyanobacteria densities at different sampling stations of River Ganga at Kanpur during the period from February 2013 to January 2014

***Ranighat**:* Total 61 species belonging to 15 genera have been identified. Their minimum density 820 units/litter were recorded in the month of September, 2013 and maximum 1860 units/litter in the month of June, 2013. The most significant genera of this station were *Anabaena, Aphanizomenon, Chroococcus, Lyngbya, Merismopedia, Microcystis, Nostoc, Oscillatoria, Phormidium* and *Spirulina* (Table: 1& 2; Fig. 2).

***Sarsaiyaghat**:* Total 73 species belonging to 17 genera have been identified. Their minimum density 980 units/litter were recorded in the month of September, 2013 and maximum 2460 units/litter in the month of June, 2013. The most significant genera of this station were *Anabaena, Aphanothece, Aphanizomenon, Chroococcus, Lyngbya, Merismopedia, Microcystis, Nodularia, Nostoc, Oscillatoria, Phormidium* and *Spirulina* (Table:1& 2; Fig. 2).

***Golaghat**:* Total 87 species belonging to 21 genera have been identified. Their minimum density 1820 units/litter were recorded in the month of January, 2014 and maximum 3680 units/litter in the month of June, 2013. The most significant genera of this station were *Anabaena, Aphanocapsa, Aphanothece, Aphanizomenon, Chroococcus, Cylindrospermum, Lyngbya, Merismopedia, Microcystis, Nodularia, Nostoc, Oscillatoria, Phormidium* and *Spirulina* (Table:1& 2; Fig. 2).

***Jajmaughat**:* Total 89 species belonging to 21 genera have been identified. Their minimum density 1580 units/litter were recorded in the month of September, 2013 and maximum 3540 units/litter in the month of June, 2013. The most common genera of this station were *Anabaena, Aphanocapsa, Aphanothece, Aphanizomenon, Chroococcus, Cylindrospermum, Lyngbya, Merismopedia, Microcystis, Nodularia, Nostoc, Oscillatoria, Phormidium* and *Spirulina* (Table:1& 2; Fig. 2).

During the present investigation several unicellular, colonial and filamentous species have been recorded both as planktonic and benthic micro flora. These genera were *Aphanocapsa, Aphanothece, Chroococcus, Gloeocapsa, Gloeothece, Merismopedia, Microcystis, Synechococcus,* and *Synechocystis* as unicellular and colonial types and *Ananbaena, Aphanizomenon, Arthrospira, Calothrix, Cylindrospermum, Gleoetrichia, Lyngbya, Nodularia, Nostoc, Oscillatoria, Phormidium, Raphidiopsis, Rivularia and Spirulina* as filamentous types.

Their environmental sensitivity, short life cycles and rapid species turnover are helpful to use them as biological indicators in environmental assessment studies. Although, cyanobacteria make positive contributions to the global biodiversity and the environment especially through the carbon and nitrogen fixation but they also cause severe problems in fresh water ecosystems and sewage treatment facilities through the production of toxic substances which are known as cyanotoxins (Carmichael, 1994). It has already been known that certain species form the water blooms in polluted waters. The most significant bloom forming genera are *Anabaena, Aphanizomenon, Chroococcus, Cylindrospermum, Microcystis, Nodularia, Oscillatoria, Phormidium* etc. and they have the capability to produce various kinds of cyanotoxins such as Microcystins, Anatoxins, Cylindrospermopsin and Nodularin. Sometimes these blooms could be massive.

Conclusion

The river Ganga is the major source of water for various purposes and it is an important example of natural system. The Kanpur city is situated on the bank of this river thus, river gets high amount of domestic and industrial effluent from various channels. Due to this reason the river's environment provides the great opportunity for the growth and development of various micro-organisms including Blue-Green Algae or Cyanobacteria. The cyanobacteria have both, harmful and useful properties. So, they are important organisms for the future prospects because recent researches indicate that they have ability to produce various types of metabolites which may be useful in various diseases. The most important goal of present study to exploit the diversity of cyanobacteria in river Ganga at Kanpur, between Bithoorghat to Jajmaughat. In future these cyanobacteria can be used for various useful applications such as for the production of antimicrobial metabolites, enzymes, biodiesel and bioplastics. They can be used as bio-fertilizers to increase the production of various crops.

REFERENCES

Ahmad MR (1972). Algae of Allen Forest Lake, Kanpur, India. I. Cynaophyceae. *Nova Hedwigia* **23**(1) 125-129.

Carmichael WW (1994). The toxins of Cyanobacteria. *Scientific American* **270**(1) 78-86.

Castenholz RW (2001a). Oxygenic photosynthetic bacteria. In: *Bergey's Manual of Systematic Bacteriology,* 2nd edition, edited by Boone DR and Castenholz RW (New York, USA, Springer-Verlag) 474.

Castenholz RW (2001b). General characteristics of the cyanobacteria. In: *Bergey's Manual of Systematic Bacteriology,* 2nd edition, edited by Boone DR and Castenholz RW (New York, U.S.A., Springer-Verlag) 474-487.

Chaudhary MK and Kumar M (2005). Epiphytic Chroococcales of freshwater bodies of Rishikesh (Dehradun) Uttarakhand. In: *National Seminar on Sustainable Water Management,* edited by Kumar A 233–242.

Desikachary TV (1959). Cyanophyta. *Indian Council of Agricultural Research*, New Delhi.

Gupta PK, Tiwari P and Gupta R (2006). Cyanobacteria and associated environmental factors in Lake Nainital, Uttaranchal, India. *Journal of Ecophysiology and Occupational Health* **6** 175-183.

Huisman J and Hulot FD (2005). Population dynamics of harmful cyanobacteria. In: *Harmful Cyanobacteria,* edited by Huisman J, Matthijs HCP and Visser P, Dordrecht (The Netherlands, Springer) 143-176.

Kuiper-Goodman T, Falconer I and Fitzgerald J (1999). Human health aspects. In: *Toxic Cyanobacteria in Water, A Guide to their Public Health Consequences, Monitoring and Management,* edited by Chorus I and Bartram J, E & FN Spon, London, Great Britain, WHO 113-153.

Kumar Mukesh (2010). Cyanoprokaryotes of Guptsahastradhara (H.P.) *Biohelica* **1**(2) 32-35.

Kumar Mukesh, Gupta RK, Bhatt AB and Tiwari SC (2011). Epiphytic cyanobacterial diversity in the sub-Himalayan belt of Garhwal region of Uttarakhand, India. *Journal of Plant Science* **8** 77–89.

Mahadev J and Hosmani SP (2004). Community structure of cyanobacteria in two polluted lakes of Mysore city. *Nature Environment and Pollution Technology* **3** 523-526.

Mur LR Skulberg OM and Utkilen H (1999). Cyanobacteria in the environment. In: *Toxic Cyanobacteria in Water, A Guide to their Public Health Consequences, Monitoring and Management,* edited by Chorus I and Bartram J, E & FN Spon, London, Great Britain, WHO 15-40.

Parikh A, Shah V and Madamwar D (2006). Cyanobacterial flora from polluted industrial effluent. *Environmental Monitoring and Assessment* **116** 91- 102.

Prasad BN and Saxena M (1980). Ecological study of blue green algae in river Gomti. *Indian Journal of Environmental Health* **22**(2) 151-168.

Prescott GW (1962). *Algae of the Western Great Lakes Area* (Wm. C. Brown Company Publishers). Dubuque, *I*owa.

Richmond A (1990). Large scale microalgal culture and applications; In: *Algal Biotechnology- progress in Phycological Research*, edited by Round FE and Chapman DJ (Biopress Ltd) Bristol, U.K. 1–61.

Rishi V and Awasthi AK (2012). Pollution Indicator Algae of River Ganga at Kanpur. *Journal of Golden Research Thoughts* **1**(7) 51-53.

Saha SK, Das R, Bora KN and Uma L (2007). Biodiversity of epilithic cyanobacteria from freshwater streams of Kakoijana reserve forest, Assam, India. *Indian Journal of Microbiology* **47** 219–232.

Sankaran V (2006). Cyanobacterial biodiversity of the tributaries of the river. *Indian Hydrobiology* **9**(1) 61-64.

Shukla BK (1983). Studies on algae and their significance. Ph. D. Thesis, Kanpur University.

Sivonen K and Jones G (1999). Cyanobacterial toxins. In: *Toxic Cyanobacteria In Water, A Guide to their Public Health Consequences, Monitoring and Management,* edited by Chorus I and Bartram J, E & FN Spon, London, Great Britain, WHO 41-111.

Spolaore P, Joannis-Cassan C, Duran E and Isambert A (2006). Commercial applications of microalgae. *Journal of Bioscience and Bioengineering* **101** 87–96.

Sundararaman M and Sekar S (2001). Biotechnological potential of cyanobacteria; *Algal Biotechnology*, edited by Trivedi PC (Pointer Publishers) Jaipur, India 31–52.

Tarar JL and Bodkhe S (1997). Cyanobacteria from the polluted habitat of Nagpur City. In: *Algal Biotechnology,* edited by Trivedi PC Pointer Publishers) Jaipur, India 149-157.

Thajuddin N and Subramanian G (2005). Cyanobacterial biodiversity and potential applications in biotechnology. *Current Science* **89**(1) 47–57.

Tiwari D and Shukla M (2007). Algal biodiversity and trophic status of some temporary water bodies of Kanpur. *Nature Environment and Pollution Technology* **6**(1) 85-90.

Tiwari D, Patrik JM and Singh S (2001). Algal Dynamics of the river Ganga at Kanpur. *Phykos* **5** 115-126.

Trainor FR (1984). Indicator Algal Assay Laboratory and fields approaches. In: *Algae as Ecological Indicators,* edited by Shubert (Academic press) London 3-14.

Tripathi AK and Pandey SN (1989). Studies on algae of polluted ponds of Kanpur II. Qualitative, quantitative and periodical occurrence of the blue-green algae of Chandrai pond. *Research Journal of Plant, Animal and Environmental Sciences* **5**(1) 89-93.

Whitton BA and Potts M (2000). Introduction to the cyanobacteria. In: *The Ecology of Cyanobacteria: Their Diversity in Time and Space,* edited by Whitton BA and Potts M, Dordrecht (Kluwer Academic Publishers) 1-11.