Effect of water quality on phytoplankton ecology of Upper Ganga Canal

Gagan Matta

Abstract— The Ganga, a glacier fed river is the most sacred and worshipped river of the Hindus. The river is now become one of the most polluted rivers of the country. The seasonal variation of physico-chemical characteristics and phytoplankton population of River Ganga at Haridwar with its two sites viz., Site 1(Bhimgoda barrage - Control Site) and Site 2 is Bahadrabad was studied for a period of one year. Maximum population density was observed in the winter season followed by summer and monsoon. Higher phytoplankton populations were encountered in Site 2 is Bahadrabad (site 2) which due to the fluctuation of existing turbidity, dissolved oxygen and better organic load. Number of group's *viz*., Diatoms, Green algae and Blue green algae and species like Diatoma, Fragilaria, Gomphonema, Amphora, Cymbella and Achnanthes belonging were recorded during the study period. Higher concentration of diatom species in summer season at Site 2 indicates polluted nature of river water and can be used as an indicator of organic pollution in the river. Many genera were seasonally and monthly absent at different times in the canal; however the overall diversity was found to be maximum in winter and summer. Correlation between the hydrological attributes showed good relationship and Na, NO_2, NO_3^-, SiO_3, HCO_3, PO_4, Ca and Mg were found to be most important variables in shaping benthic faunal assemblage.

Keywords— nutrient dynamics, phytoplankton ecology, Ganga canal, River Ganga

1 Introduction

Water, like primordial elements was revered and worshipped since Vedic times. The Rig Veda says: "Agni and water are givers and sustainers of life, they are affectionate mothers and givers of all givers of life with have powers". Through our history, water has been a natural resource critical to human survival (1,2). India is a land of farmers and agriculture is the foundation of Indian economy (3,4). Need for the mere purpose of survival is compounded by the need of water for industries, agriculture, livestock maintenance and other activities, (1,5,6).

The River Ganga is a part and parcel of everyday life in the city and thousands of people bath daily in the River Ganga, also a major source of freshwater to more than 50 million people in Asia. Today the global consumption of water is doubling every 20 years, more than twice the rate of already lack access to fresh drinking water (7), the pressure on the rivers is also increasing enormously due to ever increasing population, industrialization and urban growth in the river basins (7,8,9,10). Before the existence of canal system, Indian farming system is chiefly dependent on monsoon due to which farmers suffer most of the time. The spread of agricultural settlements to less fertile and irrigated area led to co-operation in irrigation advances and the materialization of irrigation works in the form of reservoirs and canals. Ganga Canal comes into life in Hardwar from River Ganga, located at latitude 29^0 57′ N and longitude 78^0 10′ E. This canal system irrigates the Doab region lying between River Ganga and River Yamuna in India. The canal is primarily an irrigation canal, although parts of it were also used for navigation. Since constructed it has been greatly enlarged. With presently a capacity of 10,500 cusecs and a main canal of 482.803 km with 6258.00 km of distribution channels. The canal system irrigates nearly 9,000 km² of fertile agricultural in ten districts of Uttar Pradesh and Uttarakhand (Northern Division Ganga Canal, Field visit). The present study deals with the water quality in terms of nutrient dynamics of Ganga Canal in Haridwar. Water quality productivity and health of aquatic bodies is an essential link in the food chain, capable in affecting the entire aquatic biota. (11,12,13). It is quite essential that the natural environment of the water body should be conducive to the extent that water should be used for drinking purpose; therefore besides considering limnolgical status, it is essential to monitor the quality of water (6).

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2 Materials and Method

2.1 Study Area

During the study assessment of pollution status of Ganga canal in Haridwar, located in newly carved state of Uttarakhand with reference to nutrient level and phytoplankton ecology. Samples were taken from two locations in Haridwar. Site 1(Bhimgoda barrage) (29^0 57′ 26.66″ N - 78^0 10′ 33.84″ E), is control site for the study. Situated at Har Ki Pauri, Haridwar on the River Ganga with primary purpose of irrigation but it also serves to provide water for hydroelectric power production and control floods. The area behind the barrage is known as the Neel Dhara, a well known spot for migratory birds and tourists. Next site 2 is Bahadrabad (29^0 54′ 36.30″ N - 78^0 01′ 58.48″ E), a place few meters before the barrage (this barrage feed water to a power plant situated in Bahadrabad) and because of this water flow at this sampling site is slow relative to other sampling sites here. Throughout the course human activity like bathing and cleaning, discharge of sewage, commercial waste is very common phenomenon.

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This site is at a distance of 17.5 KM from Bhimgoda Barrage. Here, the floor of the canal is sandy and depth is not so high.

2.2 Sample collection procedure

Sampling was taken out seasonally during 2012 – 2013. Given the fact that water quality of the Ganga canal had been strongly influenced by discharge of sewage from various locations, bathing and cloth washing activities, discharge of industrial effluent and commercial waste water was regarded as the primary principle to choose certain sampling sites. Seasonal sampling was done viz. winter, summer and monsoon for the period of one year from 2012 to Oct 2013. Samples from canal were collected from 0.5 m depth from the surface of canal using a clean plastic bucket, transferred to clean plastic bottles and transported to the laboratory on ice and stored in a deep freezer (-20^{o}C) till analysis. Samples were collected in triplicate from each Site and average value for each parameter was reported.

2.3 Analytical Methods

Physic-chemical parameters like pH, Temperature, DO and Free CO_2 are recorded/fixed on the spot while other parameters like Phytoplankton Chlorophyll Conc., Ammonium Conc., Nitrate Conc., Nitrite Conc., Silicate, Bicarbonate, Phosphate, Calcium, Magnesium, Dissolved Oxygen were analyzed in laboratory after samples preservation as per Bureau of Indian Standards, American Public Health Association (14, 15, 16). The colorimetric analyses were done with UV Spectrophotometer Cary 60.

The statistical methods do provide reasonable results; these are essentially incapable of capturing complexity and non-linearity (17). The statistical analysis was carried out using Minitab 16 to identify the correlation between selected water quality parameters.

3 Results and Discussion

To assess the present status of nutrient dynamics and its effect on phytoplankton ecology of Site 1 (Bhimgoda Barrage - control site) and Site 2 (Bahadrabad) are appended in Table (1 and 2) and Fig. (1 and 2). Among the physico-chemical characteristics and Phytoplankton population of Site 1 and Site 2 of Ganga Canal showed that Site 2 is with more nutrient enrichment due to influx of sewage and domestic wastes in comparison to Site 1. The excess of artificial and unwanted nutrient enrichment not only decline the water quality but also causes unfit for daily needs. This was in conformity with Singh (18) who reported that discharge of waste generated due to developmental activities and demographic explosion in the basin degraded the water quality of River Ganga at Varanasi at its two sites such as Raj Ghat highly polluted and Shiwala Ghat was least polluted.

Temperature is one of the most important parameters that influence almost all the physical, chemical and biological properties of water and thus the water chemistry. It never remains constant in rivers due to changing environmental conditions (19). During the study maximum temperature (18.63 ±0.63^{0}C) of Ganga River was recorded at Site 2 in summer season as compared with Site 1 (Fig. 1 & 2).

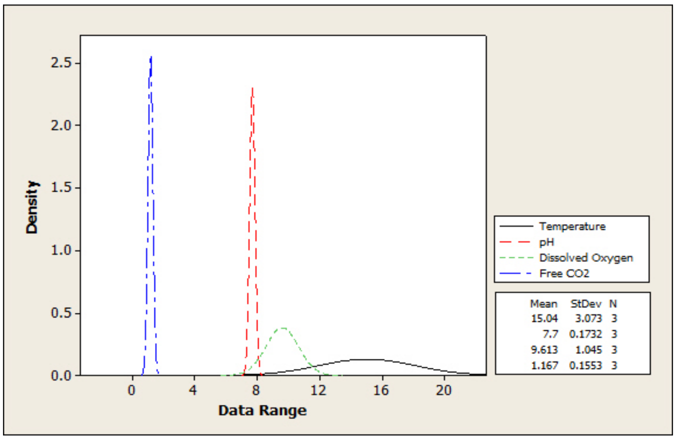

Fig. 1. Histogram of Temperature, pH, DO, Free CO_2 at Site – 1

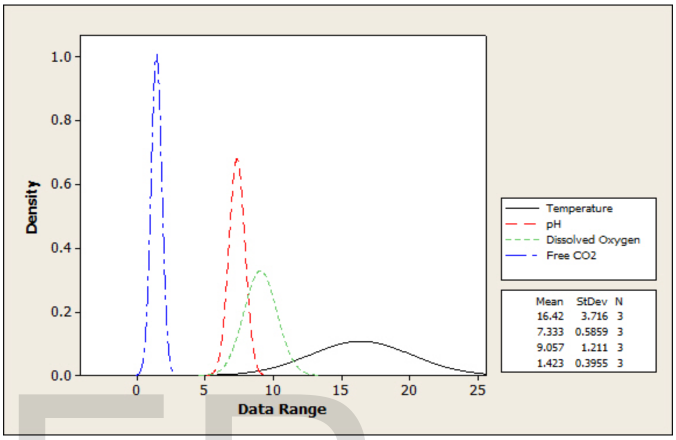

Fig. 2. Histogram of Temperature, pH, DO, Free CO_2 at Site – 2

Maximum values of temperature might be due increasing rates of pollution and wastewater discharged at Site 2. pH of water is important for the biotic communities because most of the aquatic organism are adapted to an average pH. During the study the highest value of pH were observed (8.0 ± 0.192) at Site 2 in comparison to Site 1. There was not much fluctuation recorded in pH values (Table 1). The highest pH was recorded in the summer seasons than winter and rainy seasons. Higher value of pH in summer season may be due to influx of sewage effluents disposal and low level of water. Optimal pH range is 6.5-8.2. pH of aquatic system and also it is an important indicator of the water quality and the extent pollution in the watershed areas (31). They recorded pH to be varying from 8.3-8.48 in summer, while as 8.22-8.42 in monsoon and 8.12-8.22 in winter during the study period at River Ganga at Allahabad (20).

Researchers reported that maximum DO in winter season including Chauhan and Singh (10, 29) reported that Ganga water contained highest DO during winter season, followed by a gradual decrease to its lowest values during monsoon season. The higher concentrations of DO were recorded during winter season mainly due to low turbidity and increased photosynthetic activity of the green algae found on the submerged stones and pebbles. The maximum 12.10 mg/L oxygen content of water was recorded in winter season (January 2007) at site 3 and minimum 7.14 mg/L at site 2 during monsoon season (July 2008). In the present study DO reduced during the summer season as compared

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to winter and monsoon months, it may be due to higher temperature, oxygen demanding wastes, inorganic reductant and seasonal variation. In the present study the overall lowest of DO was observed (7.95 ± 0.44 mgL^{-1}) at Site 2 in comparison to Site 1 (Table 1). Presence of DO is very important to maintain variety of forms of life in the water and the effect of waste discharge in a water body are largely determined by the oxygen balance of the system (21). During the study Free CO_2 was recorded maximum (1.88 ±0.22 mgl^{-1}) at Site 2 in comparison to Site 1. The lower values of Free CO_2 were observed in winter season following with summer and monsoon season at Site 2 (Table 1). The increase in carbon dioxide level during these months may be due to decay and decomposition of organic matter due the addition of large amount of sewage, which was the main causal factor for increase in carbon dioxide in the water bodies.

In the present study the nutrient factors were fluctuated from minimum to maximum viz. Chl a (5.08 ± 0.35 mgm^{-3} to 2.31 ± 0.16 mgm^{-3}), Na (0.61 ± 0.016 mg L^{-1} to 0.44 ± 0.034 mg L^{-1}), NO_3^- (0.048 0.010 mgL^{-1} to 0.025 ± 0.005 mg L^{-1}), NO_2^- (0.019 ± 0.001mg L^{-1} to 0.009 ± 0.000 mg L^{-1}), SiO_3 (0.032 ± 0.002 mg L^{-1} to 0.056 ± 0.008 mg L^{-1}), HCO_3 (83.27 mg L^{-1} to 32.85 ± 3.012 mg L^{-1}), PO_4 (0.087 ± 0.015mg L^{-1} to 0.14 ± 0.016), Ca (17.00 ± 0.78 mg L^{-1} to 10.68 ± 0.66 mg L^{-1}) and Mg (5.15 ± 0.16 mg L^{-1} to 2.80 ± 0.47 mg L^{-1}). Anthropogenic activities like sewage discharge, industrial effluent and surface runoff from agricultural field at Site 2 are the major cause of this rise in nutrient value. Singh (30) recorded higher concentrations of Ca (19.05 mg/l for Imphal river, 13.42 mg $L^{-1}$for Iril River), Mg (9.24 for Imphal River, 12.37 for Nambul river and 7.85 for Iril river mg L^{-1}), NO_2^- (0.26 for Imphal river, 0.53 for Nambul River mg L^{-1}) and PO_4 (0.277 for Nambul river mg L^{-1}) in summer season. In the present study concentration of nutrients such as NO_2, NO_3 and PO_4 were recorded higher at Site 2 in comparison to site 1. This might be due to increasing anthropogenic activities at Site 2. Bhatnagar et al. (22) also reported higher concentration of these nutrients in the water quality of river Yamuna at Station-2 (S2) lies 4-5 Kms downstream from station S1 at middle reach of the river where the mill effluents joins the river (Haryana) in comparison to Station-1(S1) lies in village Kalanaur at upstream of the river before the influx of discharges, Station-3 (S3) at 5 Kms downstream from station-S2 after the influx of discharges. During the water quality assessment parameters like Na also ranged from lower to higher (0.44 ± 0.034mgL^{-1} to 0.61± 0.016 mgL^{-1}), Ca (10.68 ± 0.066 mgL^{-1} to17 ± 0.78 mgL^{-1}) and Mg (2.80 ± 0.47 mgL^{-1} to 5.15 ± 0.16 mgL^{-1}) from Site - 1 and Site 2. The weathering of rock-forming minerals with additional contribution from cyclic sea salt spray (due to proximity to the ocean) and possibly anthropogenic sources may be the major sources of ions in this river and, in turn, could control the water chemistry (Prasad and Ramanathan, 2009). In the present study higher concentrations of SiO_3 (0.056 ± 0.008 mgL^{-1}) and HCO_3 (83.27 ± 6.99 mgL^{-1}) were observed at site-II in comparison to site-I. Kamal *et al.* (23) reported higher concentrations of SiO_3 (259.8 mgL^{-1}) and HCO_3 (121.6 mgL^{-1}) in Ganga river water in summer season at upper Gangetic plain, a case study of J P Nagar, Uttar Pradesh, India.

Assessment of phytoplankton ecology in Ganga canal water at two sites showed that higher phytoplankton populations were encountered in Site 2 is Bahadrabad due to the fluctuation of existing turbidity, dissolved oxygen and better organic load. Number of group's *viz.*, Diatoms, Green algae and Blue green algae and species like Diatoma, Fragilaria, Gomphonema, Amphora, Cymbella and Achnanthes belonging were recorded during the study period. Higher concentration of diatom species in summer season at Site 2 indicates polluted nature of river water and can be used as an indicator of organic pollution in the river. Many genera were seasonally and monthly absent at different times in the canal; however the overall diversity was found to be maximum in winter and summer. The mean values of different phytoplankton groups and species fluctuated in all the samples (Table 2). In all three majorly recorded groups contributed to the phytoplankton community belonging to

Table1. Physico-chemical parameters of Ganga River water at Site-I and Site-II

PHYSICO-CHEMICAL PARAMETERS OF BHIMGODA BARRAGE (CONTROL SITE) SITE-1									
	Chl a	Na	NO_3^-	NO_2^-	SiO_3	HOC_3	PO_4	Ca	Mg
Winter	5.08 ±0.35	0.45 ±0.02	0.029 ±0.00	0.009 ± 0.00	0.051 ± 0.00	48.25 ±5.23	0.051 ±0.006	15.30 ±0.27	4.40 ±0.18
Summer	4.37 ±0.57	0.51 ±0.007	0.039 ±0.008	0.013 ±0.001	0.044 ± 0.006	52.50 ±4.97	0.06 ±0.004	13.23 ±1.89	4.30 ±0.35
Monsoon	3.72 ±0.66	0.44 ±0.034	0.038 ±0.003	0.009 ±0.000	0.032 ±0.002	32.85 ±3.01	0.048 ±0.003	10.68 ±0.66	2.80 ±0.47
PHYSICO-CHEMICAL PARAMETERS OF BHADARABAD SITE-2									
	Chl a	Na	NO_3^-	NO_2^-	SiO_3	HOC_3	PO_4	Ca	Mg
Winter	3.26 ±0.32	0.48 ±0.026	0.025 ± 0.005	0.011 ± 0.001	0.056 ± 0.008	83.27 ±6.99	0.14 ±0.016	17 ±0.78	5.15 ±0.16
Summer	2.67 ± 0.32	0.61 ± 0.016	0.048 ± 0.010	0.019 ± 0.001	0.046 ±0.00	79.44 ±9.46	0.087 ±0.015	14.63 ± 1.54	4.4 ± 0.27
Monsoon	2.31 ± 0.16	0.53 ± 0.01	0.047 ± 0.005	0.012 ± 0.001	0.034 ±0.003	55.46 ±6.08	0.069 ±0.007	14.5 ± 0.29	4.85 ± 0.13

Diatoms (1551.4 ± 735.36 Unit/L), Green algae (255 ± 110.3 Unit/L) and Blue green algae (54.4 ± 13.63 Unit/L). Diatoms were dominant group at both the sites followed by Green algae and Blue green algae. Change in phytoplankton numbers at Site 2, clearly evident more in relation to physical than to chemical conditions of the water. Changes in water- level, nutrients contents and temperature affected the growth of the phytoplankton. Maximum concentration of bicarbonate and pH increased the growth of growth of diatoms and blue-green algae. Higher concentrations of phosphates and silicates with nitrates and nitrites contents were responsible for high phytoplankton yields in summer and winter seasons. During the study maximum population of various species under diatoms in Ganga Canal were Diatoma (247.80 180.5 Unit/L), Fragilaria (204.80 ± 145.8 Unit/L), Gomphonema (177.40 ± 96.41 Unit/L), Amphora (148.80 ± 102.53 Unit/L), Cymbella (172.40± 89.80 Unit/L) and Achnanthes (153.60 ± 64.08 Unit/L) were recorded in winter season at Site 2 in comparison to Site 1. Mathivanan et al. (24) who reported maximum phytoplankton population (76.00) at station-I (Pannavadi) and (66.00) at station II (Sankalimuniappan Koil area) of river Cauvery at Salem District, Tamil Nadu (India).

Table 2. Phytoplankton population of Ganga River water at Site-I and Site-II

Total Phytoplankton population at Bhimgoda Barrage (Site-I)				
	Total Phytoplankton	***Total Diatoms***	***Green algae***	***Blue green algae***
Winter	1713.2 ± 833.86	1451.4 ± 735.36	223.8 ± 79.83	38 ± 22.75
Summer	1431.17 ± 586.24	1226.1 ± 484.78	159 ± 81.66	46.95 ± 28.66
Monsoon	905.88 ± 323.78	804.57 ± 271.8	83.13 ± 64.16	20.12 ± 17.88
Total Phytoplankton population at Bhadrabad (Site-II)				
	Total Phytoplankton	***Total Diatoms***	***Green algae***	***Blue green algae***
Winter	1909.80 ± 651.09	1600.4 ± 539.01	255 ± 110.3	54.4 ± 13.63
Summer	1530.21 ± 776.86	1318 ± 663.28	172.5 ± 83.42	42.13 ± 34.93
Monsoon	951.81 ± 330.09	846.86 ± 276.37	86.77 ± 67.5	20.21 ± 16.97

Table 3. Diatom species of Ganga River water at Site-I and Site-II

Total Diatom species at Bhimgoda Barrage (Site-I)						
	Diatoma	***Fragilaria***	***Gomphonema***	***Amphora***	***Cymbella***	***Achnanthes***
Winter	230.2 ± 172.18	197 ± 140.98	184.6 ± 127.29	154.2 ± 150.31	147.4 ± 101.145	178.8 ± 61.78
Summer	203.24 ± 88.639	167.6 ± 124.26	171.66 ± 94.434	143.86 ± 68.496	162.029 ± 102.035	144.4 ± 102.5
Monsoon	89.575 ± 65.493	90.371 ± 55.272	88.819 ± 50.242	80.072 ± 42.967	96.6127 ± 42.4834	93.97 ± 33.12
Total Diatom species at Bhadrabad (Site-II)						
	Diatoma	***Fragilaria***	***Gomphonema***	***Amphora***	***Cymbella***	***Achnanthes***
Winter	247.8 ± 180.5	204.8 ± 145.8	177.4 ± 96.412	148.8 ± 102.53	172.4 ± 89.8014	153.6 ± 64.08
Summer	220.1 ± 145.61	156.96 ± 136.3	178.48 ± 101.89	142.31 ± 82.086	155.16 ± 106.326	140.4 ± 95.22
Monsoon	109.14 ± 73.54	94.052 ± 48.77	89.675 ± 54.479	87.67 ± 36.227	88.09 ± 42.9165	85.33 ± 34.37

Current study reveals that parameters like pH, F.CO_2, Chl-a, Na, NO_2, SiO_3, HCO_3, Ca and Mg substantially found maximum at Site 2, showing the decline in water quality due to drains of industrial effluents and domestic sewage. The study also shows that Diatoms were dominant in Ganga Canal system in Uttarakhand. Dominance of Diatom population in polluted habitat has also been reported earlier (25) for Bhagirathi and Bhilangana river of Uttarakhand and (19) for Narmada River, M.P. India. PO_4 and NO_3^- play very important role in their distributional pattern. The species composition in two sites shows marked difference with change in habitat and nutrients

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concentration (Table 2). The study also shows that Diatoma, Fragilaria and Gomphonema were the most abundant species followed by Amphora, Cymbella and Acnanthes in Ganga canal in study area. The occurrence of these species might be due to capability of these groups of phytoplankton species to survive in unfavourable conditions and to adjust with the environment and can be used as an indicator of organic pollution in the river.

4 CORRELATION MATRIX

For understanding significant correlation among the biotic and abiotic parameters during the study statistical analysis has been carried out by Pearson's correlation coefficient of water quality parameters and phytopnakton diversity of Ganga Canal (26,27). The data analysis yielded an R-value, which is a correlation representing the linear relationship between the data pairs. A linear association implies that as one variable increases, the other increases or decreases linearly. Values of the correlation coefficient close to +1 (positive correlation) imply that as one variable increases, the other increases nearly linearly. Values close to 0 imply little linear correlation between the variables or no correlation (28). When data are truly independent, the correlation between data points is zero. The values of coefficient correlation were determined using MINITAB software version 16 in all the seasons. In the present study the correlation coefficient (r) between every parameter and phytoplankton species for Site 1 and Site 2 is shown in Table 4 and 5. A strongly significant (≥0.05) positive correlation was recorded for phytoplankton species such as Diatoma, Fragilaria, Gomphonema, Amphora,

Table 4. Correlation matrix among the various physico-chemical parameters and phytoplanktonic species at Site-I

	Chl-a	Na	NO_3^-	NO_2	SiO_3	HCO_3	PO_4	Ca	Mg	Temp	pH	DO	F.CO_2	***Diatoms***	***Green algae***	***Blue green algae***	Diatoma	Fragilaria	Gomphonema	Amphora	Cymbella	Acnanthes
Chl-a	1.000																					
Na	0.107	1.000																				
NO_3^-	-0.831	0.464	1.000																			
NO_2	-0.025	0.991	0.577	1.000																		
SiO_3	0.985	0.279	-0.721	0.150	1.000																	
HCO_3	0.728	0.760	-0.224	0.667	0.837	1.000																
PO_4	0.215	0.994	0.363	0.971	0.383	0.827	1.000															
Ca	0.996	0.191	-0.781	0.060	0.996	0.783	0.298	1.000														
Mg	0.881	0.565	-0.469	0.451	0.950	0.966	0.652	0.918	1.000													
Temp	-0.853	0.427	0.999	0.543	-0.749	-0.263	0.325	-0.806	-0.505	1.000												
pH	-0.025	0.991	0.577	1.000	0.150	0.667	0.971	0.060	0.451	0.543	1.000											
DO	0.981	0.300	-0.706	0.171	1.000	0.848	0.403	0.994	0.957	- 0.734	0.171	1.000										
F.CO2	-0.959	-0.385	0.639	-0.260	-0.994	-0.893	-0.484	-0.979	-0.979	0.670	-0.260	-0.996	1.000									
Diatoms	***0.980***	***0.301***	-0.705	0.173	1.000	0.849	0.404	0.994	0.957	- 0.733	0.173	1.000	-0.996	1.000								
Green algae	0.997	0.177	-0.790	0.045	0.994	0.774	0.284	1.000	0.912	- 0.814	0.045	0.992	-0.976	0.992	1.000							
Blue green algae	0.635	0.836	-0.099	0.756	0.761	0.992	0.891	0.699	0.925	- 0.139	0.756	0.774	-0.829	0.775	0.688	1.000						
Diatoma	0.933	0.457	-0.576	0.335	0.982	0.925	0.552	0.960	0.992	- 0.609	0.335	0.986	-0.997	0.986	0.956	0.870	1.000					
Fragilaria	0.961	0.376	-0.646	0.251	0.995	0.888	0.476	0.981	0.977	- 0.677	0.251	0.997	-1.000	0.997	0.978	0.823	0.996	1.000				
Gomphonema	0.911	0.507	-0.529	0.388	0.969	0.945	0.598	0.943	0.998	- 0.563	0.388	0.974	0.991	0.975	0.938	0.897	0.998	0.989	1.000			
Amphora	0.913	0.503	-0.533	0.384	0.970	0.944	0.595	0.945	0.997	- 0.567	0.384	0.975	-0.991	0.976	0.940	0.895	0.999	0.990	1.000	1.000		
Cymbella	0.722	0.765	-0.216	0.673	0.832	1.000	0.831	0.779	0.964	- 0.256	0.673	0.844	-0.889	0.845	0.769	0.993	0.922	0.885	0.943	0.941	1.000	
Acnanthes	0.991	0.239	-0.750	0.108	0.999	0.813	0.344	0.999	0.936	- 0.776	0.108	0.998	-0.988	0.998	0.998	0.733	0.973	0.990	0.958	0.959	0.808	1.000

(Significant level at 0.05)

Table 4. Correlation matrix among the various physico-chemical parameters and phytoplanktonic species at Site-II

	Chl-a	Na	NO_3^-	NO_2	SiO_3	HCO_3	PO_4	Ca	Mg	Temp	pH	DO	F.CO_2	***Diatoms***	***Green algae***	***Blue green algae***	Diatoma	Fragilaria	Gomphonema	Amphora	Cymbella	Acnanthes
Chl-a	1.000																					
Na	0.107	1.000																				
NO_3^-	0-831	0.464	1.000																			
NO_2	-0.025	0.991	0.577	1.000																		
SiO_3	0.985	0.279	-0.721	0.150	1.000																	
HCO_3	0.728	0.760	-0.224	0.667	0.837	1.000																
PO_4	0.215	0.994	0.363	0.971	0.383	0.827	1.000															
Ca	0.996	0.191	-0.781	0.060	0.996	0.783	0.298	1.000														
Mg	0.881	0.565	-0.469	0.451	0.950	0.966	0.652	0.918	1.000													
Temp	-0.853	0.427	0.999	0.543	-0.749	-0.263	0.325	-0.806	-0.505	1.000												
pH	-0.025	0.991	0.577	1.000	0.150	0.667	0.971	0.060	0.451	0.543	1.000											
DO	0.981	0.300	-0.706	0.171	1.000	0.848	0.403	0.994	0.957	-0.734	0.171	1.000										
F.CO2	-0.959	-0.385	0.6639	-0.260	-0.994	-0.893	-0.484	-0.979	-0.979	0.670	-0.260	-0.996	1.000									
Diatoms	***0.980***	***0.301***	-0.705	0.173	1.000	0.849	0.404	0.994	0.957	-0.733	0.173	1.000	-0.996	1.000								
Green algae	0.997	0.177	-0.790	0.045	0.994	0.774	0.284	1.000	0.912	-0.814	0.045	0.992	-0.976	0.992	1.000							
Blue green algae	0.635	0.836	0.099	0.756	0.761	0.992	0.891	0.699	0.925	-0.139	0.756	0.774	-0.829	0.775	0.688	1.000						
Diatoma	0.933	0.457	-0.576	0.335	0.982	0.925	0.552	0.960	0.992	-0.609	0.335	0.986	-0.997	0.986	0.956	0.870	1.000					
Fragilaria	0.961	0.376	-0.646	0.251	0.995	0.888	0.476	0.981	0.977	-0.677	0.251	0.997	-1.000	0.997	0.978	0.823	0.996	1.000				
Gomphonema	0.911	0.507	-0.529	0.388	0969	0.945	0.598	0.943	0.998	-0.563	0.388	0.974	-0.991	0.975	0.938	0.897	0.998	0.989	1.000			
Amphora	0.913	0.503	-0.533	0.384	0.970	0.944	0.595	0.945	0.997	-0.567	0.384	0.975	0.991	0.976	0.940	0.895	0.999	0.990	1.000	1.000		
Cymbella	0.722	0.765	-0.216	0.673	0.832	1.000	0.831	0.779	0.964	-0.256	0.673	0.844	-0.889	0.845	0.769	0.993	0.922	0.885	0.943	0.941	1.000	
Acnanthes	0.991	0.239	-0.750	0.108	0.999	0.813	0.344	0.999	0.936	-0.776	0.108	0.998	-0.988	0.998	0.998	0.733	0.973	0.990	0.958	0.959	0.808	1.000

(Significant level at 0.05)

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Cymbella, Acnanthes and physico-chemical parameters such as Na, NO_2, NO_3^-, SiO_3, HCO_3, PO_4, Ca, Mg at both the Sites 1 and 2.

5 Conclusion

Study was conducted on physico-chemical parameters, diversity and abundance of phytoplankton in Ganga Canal at Haridwar from Oct 2012 to Oct 2013. The study concluded that the deterioration of water quality in the Ganga River due to sewage influx, industrialization and human activities. Appropriate biological and chemical treatment of domestic sewage and industrial effluents before discharge to river system is suggested. The study also showed that physico-chemical and phytoplankton characteristics of Ganga River showed seasonally variation. Three majorly recorded groups of phytoplankton and six major species in the canal water at Site 1 and 2. The phytoplankton showed positive significant relation with, NO_2, NO_3^-, SiO_3, HCO_3, PO_4, Ca, Mg at both the Sites 1 and 2. In the presence of nutrient at different levels in the canal water throughout the study period offer an excellent opportunity to characterize the quality of the water but on the other hand it's also very important to monitor and manage the excess of nutrients. The point and non point sources of pollutions enriching the nutrient content for biological community but also decreasing the water quality for human use. In present status of the canal water in study are found to be fairly good for the growth and survival of phytoplankton but it is essential to undertake regular monitoring and surveillance of important aquatic ecosystems as along with phytoplankton human survival, agricultural needs etc. are also depended on the same canal in North India.

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