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ASSESSMENT OF POLLUTION ON WATER QUALITY AND PHYTOPLANKTON DIVERSITY IN CANAL SYSTEM OF RIVER GANGA

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ABSTRACT

Seasonal distribution of phytoplankton ecology and nutrient status of water were studied in River Ganga of Haridwar for a period of one year covering three seasons at two sites, Site 1(Bhimgoda Barrage – Control Site) and Site 2 is Bahadrabad. Maximum population density was observed in the summer season followed by winters and monsoon showing the increase in pollution load in Ganga Canal due to major anthropogenic activities in summers. Higher phytoplankton populations were encountered in Site 2 is Bahadrabad which corresponded to the fluctuation of existing turbidity, dissolved oxygen and better organic load. Numbers of species were identified but 3 dominant groups were identified *viz.*, Diatoms, Green algae and Blue green algae. Six species such as Diatoma, Fragilaria, Gomphonema, Amphora, Cymbella and Achnanthes belonging to Diatoms group were recorded maximum during the study period. Higher concentration of phytoplankton diversity at Site 2 indicates polluted nature of river water and can be used as an indicator of organic pollution in the river.

KEYWORDS: Ganga Canal, River Ganga System, Phytoplankton ecology, nutrient dynamics.

INTRODUCTION

India with a geographical area of about 329 MHa is criss-crossed by a large number of small and big rivers, some of them figuring amongst the mighty rivers of the world. The rivers have a greater significance in the history of Indian cultural development, religious and spiritual life. It may not be an exaggeration to say that the rivers are the heart and soul of Indian life. Therefore it is not difficult to realize why civilizations and habitats are settled and developed near the banks of important rivers and coastal areas (Kumar, 2013). But with the rapid increase in population and rapid increase in demand and supply of products, water resources has over strained. Industrial population and higher levels of human activities like disposal of industrial effluent, agricultural runoff to surface and ground water resources has overloaded the freshwater bodies with waste and chemical finally poisoning the water supplies (Matta et al. 2015). The crisis is the lack of access to safe water supply to millions of people as a result of inadequate water management and environmental degradation. The crisis also endangers the economic and social prosperity of the country (Matta et al., 2011, Matta, 2014; Matta and Kumar 2015; Matta 2015).

With increase in population and gap between demand and supply, the canal system has also increase throughout the world for maximum approach to freshwater. The Ganga basin accounts for a little more than one-fourth (26.3%) of the country's total geographical area and is the biggest river basin in India, covering the entire states of Uttarakhand (CPCB, 2013). At holy place Haridwar, the Ganga Canal emerging out from Ganga basin with great ritual importance among pilgrims and tourists. But today with all its importance the Canal is being polluted due to mass bathing, washing, disposal of sewage, industrial waste and these human activities are deteriorating its water quality (Seth et al. 2013; Matta 2015). Phytoplankton in water bodies are an important biological indicator for evaluating water quality of a reservoir (Matta et al. 2010, Tiwari et. al. 2010; Matta, 2010; Bhadauriya et. al. 2011). These are important primary produces and the base of food chain in aquatic ecosystem. Phytoplankton studies and monitoring are useful to understand the complexity of interactions between abiotic and biotic factor and also used to monitor the ecological quality and health of the water environment (Vishnoi et al. 2007; Keshre et al. 2007; Keshre et al. 2008; Chauhan et. al. 2009; Singh et al. 2010). To understand the abiotic interaction in terms of nutrients dynamics and biotic factors viz., phytoplankton with all the impact of anthropogenic activities, Ganga Canal water quality at two sites at Bhimgoda Barrage and Bahadrabad, Haridwar has been analyzed. The present study deals with the Ganga Canal of River Ganga in Haridwar. This canal system irrigates the Doab region lying between River Ganga and River Yamuna in India.

MATERIALS AND METHOD

Study Area

Study deals with 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 (Fig. 1). 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. 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.

Sample collection procedure

Sampling was carried out seasonally during 2011 – 2012. 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. Sampling was done in three different seasons viz. winter, summer and monsoon for the period of one year from 2011 to Oct 2012. Water samples 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.

Analytical Methods

The 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 (BIS, 1991), American Public Health Association (APHA, 2005) and

Edmondson (1977, 1992). The colorimetric analyses were done with UV Spectrophotometer Cary 60.

The statistical analysis was carried out using Minitab 16 to identify the correlation between selected water quality parameters.

RESULT AND DISCUSSION

The physico-chemical characteristics and Phytoplankton population of Site 1 (Bhimgoda Barrage) and Site 2 (Bahadrabad) sampling sites are appended in Table (1 to 3) and Figure (2 to 5). The water quality analysis of Ganga Canal showed that Site 2 was highly polluted because of the influx of sewage and domestic wastes in comparison to Site 1.

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 (Kumari et al. 2014). In present study the mean maximum temperature (19.67 ± 3.22^{0}C) of Ganga River was recorded at Site 2 in summer season as compared with Site 1. Maximum values of temperature might be due increasing rates of pollution and wastewater discharged at Site 2. Bhadula et al. (2014) reported 8.04% increase in temperature between two Sites of Sahastradhara stream at Dehradun District.

pH of water is important for the biotic communities because most of the aquatic organism are adapted to an average pH. Optimal pH range for sustainable aquatic life is pH 6.5-8.2. pH of an aquatic system is an important indicator of the water quality and the extent pollution in the watershed areas (Kumar et al. 2010; Singh, 2014). During the present study the overall highest value of pH were observed (8.1 ± 0.1) at Site 2 in comparison to Site 1. There was not much fluctuation recorded in pH values. 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. Pandey et al. (2014) reported that pH of aquatic system is an important indicator of the water quality and the extent pollution in watershed areas. 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.

DO is one of the important parameter in water quality assessment. Its presence is essential 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 (Singh, 2012; Sirajudeen et al., 2013). In the present study DO reduces during the summer season as compared 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 (7.89 ±0.46 mgl^{-1}) at Site 2 in comparison to Site 1. Chauhan and Singh, 2010 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 (Jan 2007) at site 3 and minimum 7.14 mg/L at site 2 during monsoon season (July 2008). Free CO_2 is vital in the life of plants and microorganisms. It is produced due to respiration of aquatic organisms. Free CO_2 in the present study was recorded maximum (1.85 ± 0.14mgl^{-1}) at Site 2 in comparison to Site 1. The lower values of Free CO_2 were observed in winter season and higher values were recorded in summer and monsoon season at Site 2. 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. Singh (2014) reported Free CO_2 varied from 39.3 - 61.7 mg/L in summer, monsoon and winter season at different sites. The lowest values (39.3 mg/L) of free CO_2 was recorded in winter season, whereas the highest values (61.7 mg/L) in summer season.

Nutrients concentrations of Site 1 and Site 2 was ranged for *Chl* a (3.13 to 5.04 mg m^{-3}), Na (0.44 to 0.51 mg L^{-1}), NO_3^- (0.027 to 0.057 mg L^{-1}), NO_2^- (0.009 to 0.014 mg L^{-1}), SiO_3 (0.032 to 0.057 mg L^{-1}), HCO_3 (45.74 to 87.60 mg L^{-1}), PO_4 (0.050 to 0.14 mg L^{-1}), Ca (11.3 to 17.00 mg L^{-1}) and Mg (3.02 to 5.05 mg L^{-1}) respectively. Much higher concentration of nutrients was associated with Site 2 in comparison to Site 1. It might be due increased anthropogenic sources such as sewage discharge, industrial effluent and surface runoff from agricultural field at Site 2. This was in conformity with Das and Panda (2010) who reported the higher concentration of NO_2^- (1.30 mg L^{-1}), HCO_3^- (204.70 mg L^{-1}), PO_4 (0.249 mg L^{-1}), Ca (123.00 mg L^{-1}) and Mg (79.30 mg L^{-1}) were encountered in Sikharpur (site 4) in comparison to Chahata (site 1), Gadagadia (site2) and Jobra (site3) Orrisa, India. Singh et al. (2013) 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. Khondker and Abed (2013) recorded higher concentrations of Chl-a (87.29 mg m^{-3}), silicate (10.33 mg L^{-1}) and NO_3^- (534.19 mg L^{-1}) River Turag of Bangladesh in summer season.

Generally, nitrites are formed in water due to bacterial action oxidation of ammonia and are readily oxidized to nitrates. Though they are seldom present in significant concentration in surface or other natural water. The nitrites in water are indicative of organic pollution. Phosphates are obtained from the rocks converting then in to its soluble forms and may also occur, in agricultural runoff, industrial wastes, municipal sewage and synthetic detergents. The high concentration of phosphate is always indicative of eutrophy (Verma and Saksena, 2010). In the present study concentration of nutrients such as $NO_{2,}$ NO_3 and PO_4were recorded higher at Site 2 in comparison to Site 1. This might be due to increasing anthropogenic activities at site-II. Bhatnagar et al. (2013) 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.

The tendency for a water to enter into cation- exchange reactions was commonly evaluated in terms of the “sodium percentage”. It is the percentage of total cations made up by sodium. Because divalent cations usually are preferentially held in exchange position on clay minerals, the extensive displacement of “Ca and Mg by Na“ is unlikely unless the sodium percentage is considerably higher than 50 or the total concentration of solutes is large (Khan and Abbasi, 2013). In the present study Na (0.51 ± 0.018 mgL^{-1}), Ca (17 ± 0.21 mgL^{-1}) and Mg (5.05 ± 0.21 mgL^{-1}) of Site 2 were recorded to be higher in summer season as compared to Site 1. Das *et al*., 2014 reported higher value of Mg (14.03 mgL^{-1}) and Na (4.45 mgL^{-1}) at Rottang site of river Shiang (Arunchal Pradesh) in summer season. Verma (2009) recorded maximum concentration of Ca (29.66 mgL^{-1}) in river Betwa, Bundelkhand (India). 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 (0.057 ±0.002 mgL^{-1}) and HCO_3

(87.60 ±3.60 mgL^{-1}) were observed at Site 2 in comparison to Site 1 in summer season. Kamal *et al*. (2014) 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.

A study on phytoplankton ecology of Ganga river water at two sites revealed that, Bahadrabad site with high temperature and better nutrient status harboured more phytoplankton. The quantitative and qualitative difference of phytoplankton population of two sites indicates that nutrient composition influences phytoplankton inhabitants of Ganga river water. The phytoplankton has proved to be eutrophic and polymixic in nature. A total of 3 groups of Phytoplankton were identified such as Total Diatoms, Green algae and Blue green algae. Six species such as Diatoma, Fragilaria, Gomphonema, Amphora, Cymbella and Achnanthes belonging to Total Diatoms group were recorded during the study period. The mean values of different phytoplankton groups and species fluctuated in all the samples. Maximum number of total phytoplankton during summer and winter indicates good physico-chemical conditions (Table 2 and 3).

In all three groups contributed to the phytoplankton community belonging to Total Diatoms (1623.4 ± 737.15), Green algae (229.6 ± 120) and Blue green algae (53 ± 21.74). Total Diatoms was the dominant group at both the sites followed by Green algae and Blue green algae. Changes in the phytoplankton populations were 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. Bhatnagar et al. (2013) have also reported a similar trend of phytoplankton dominance in River Yamuna. During the present study maximum population of various species under total diatom group of Ganga River water such as Diatoma (253.4 ± 165.45), Fragilaria (205 ± 162.36), Gomphonema (192.4 ± 124.5), Amphora (154.29 ± 107.97), Cymbella (206.6 ± 156.04) and Achnanthes (168.2 ± 74.25) were recorded at Site 2 in comparison to Site 1.

High concentration of these species at Site - 2 indicates polluted zone of the Ganga River. This is because at these sites the river receives sewage from human habitations enriching the water body with high load of nutrients (Bhakta and Adhikary, 2012). In the present study maximum numbers of total phytoplankton species such as Diatoma, Fragilaria, Gomphonema, Amphora, Cymbella and Achnanthes were found during summer at both the sites and minimum during monsoon season. This was in accordance with the findings of Mathivanan et al., (2007) 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). Das and Panda, 2013 reported maximum population of phytoplankton species such as Chlorophyceae, Bacillariophyceae and Myxophyceae in summer season at Zobra site (551.30) and shikarpur site (587.40) of river Mahanadi, Orissa (India).

During the present study pH, F.CO_2, Chl-a, Na, NO_2, SiO_3, HCO_3, Ca and Mg substantially found high at Site 2. Deterioration of water quality at Site 2 is attributed to drains of industrial effluents and domestic sewage. The study also shows that Diatom was dominant at Site 2. Dominance of Diatom population in polluted habitat has also been reported earlier (Ayoade et al., 2009) for Bhagirathi and Bhilangana river of Uttarakhand and (Kumari et al., 2014) for Narmada River, M.P. India. PO_4 and NO_3^- contents play a vital role in their distributional pattern. The species composition in two sites shows marked difference with change in habitat and nutrients concentration (Table 3). A total of 6 species belonging to Diatom group were recorded during the study period. The study also shows that Diatoma, Fragilaria and Gomphonema were the most abundant species followed by Amphora, Cymbella and Acnanthes. The occurrence of these species might be due to capability of these groups of phytoplankton's 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.

Correlation matrix

To develop the 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 phytoplankton diversity of Ganga Canal (Bhandari and Nayal, 2008; Joshi et al., 2009). 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 (Mudgal et al. 2009). 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, Cymbella, Acnanthes and physic-chemical parameters such as Na, NO_2, NO_3^-, SiO_3, HCO_3, PO_4, Ca, Mg at both the Sites 1 and 2. DO was recorded to negatively correlated with different phytoplankton species at both the Sites 1 and 2. F.CO_2 showed positive correlation with Na, NO_2, NO_3^-, SiO_3, HCO_3, PO_4, Ca, Mg, Diatoma, Fragilaria, Gomphonema, Amphora, Cymbella and Acnanthes at site I, while it was found to be negatively correlated with these sites at Site 2. *Chl* a was found to be positively correlated with phytoplankton species at both the sites, while it was positively correlated with Na, NO_2, NO_3^-, SiO_3, HCO_3, PO_4, Ca and Mg at Site 2.

Fig.1. Map showing the view of Bhimgoda Barrage (Site 1- control Site) and (Site 2 - Bahadrabad).

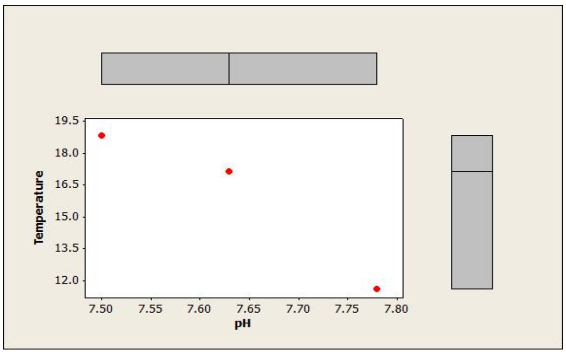

Fig.2: Marginal Plot of Temperature and pH at Site – 1.

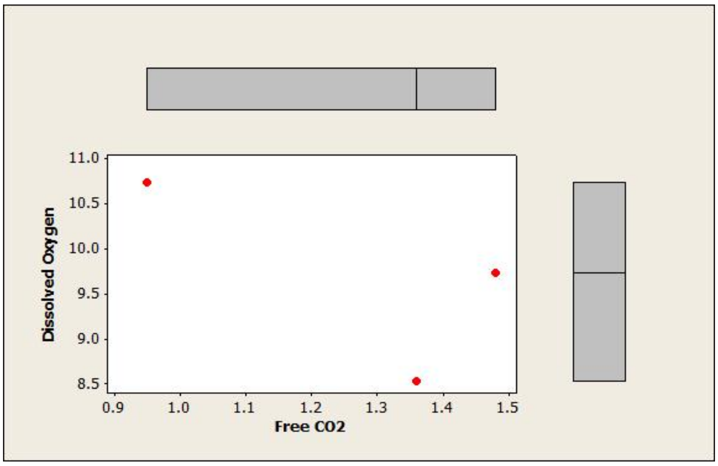

Fig.3: Marginal Plot of DO and Free CO_2 at Site – 1.

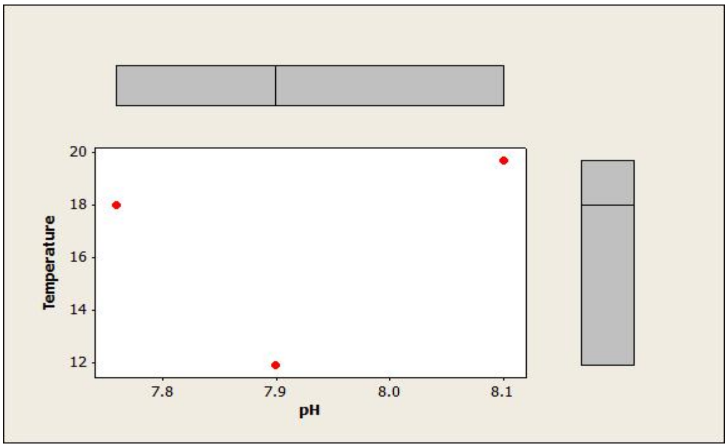

Fig.4: Marginal Plot of Temperature and pH at Site – 2.

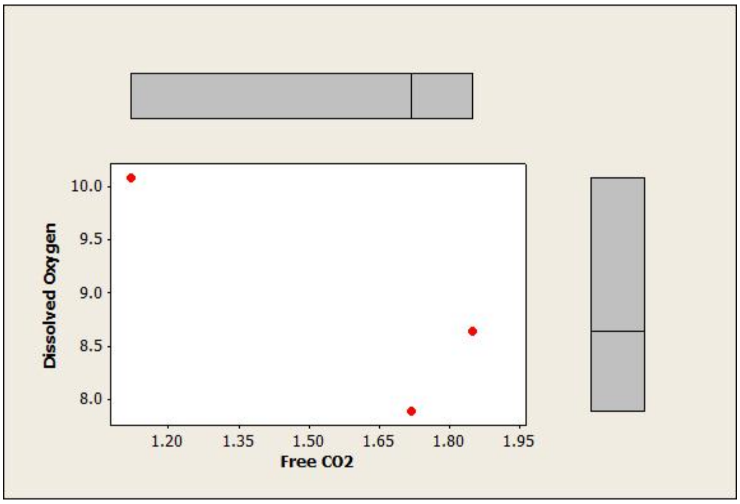

Fig.5: Marginal Plot of DO and Free CO_2 at Site – 2.

Table1. Physico-chemical parameters of Ganga river water at Site-I (Bhimgoda arrage) and Site-II (Bahadrabad), Haridwar, Uttarakhand, India.

PHYSICO-CHEMICAL PARAMETERS OF BHIMGODA BARRAGE (CONTROL SITE) SITE-1									
Seasons	Chl a	Na	NO_3^-	NO_2^-	SiO_3	HCO_3	PO_4	Ca	Mg
Winter	4.06 ±0.15	0.46 ±0.03	0.040 ±0.01	0.010 ±0.00	0.043 ±0.003	45.74 ±4.41	0.054 ±0.012	13.4 ±1.56	4.07 ±0.21
Summer	5.04 ±0.26	0.50 ±0.02	0.042 ±0.006	0.011 ±0.001	0.050 ±0.00	52.39 ±2.69	0.068 ±0.009	15.5 ± 0.22	4.45 ±0.24
Monsoon	3.68 ±0.47	0.44 ±0.03	0.027 ±0.003	0.009 ±0.001	0.0316 ±0.003	34.89 ±2.70	0.05 ±0.00	11.3 ±0.37	3.02 ±0.43
PHYSICO-CHEMICAL PARAMETERS OF BHADARABAD SITE-2									
Seasons	Chl a	Na	NO_3^-	NO_2^-	SiO_3	HCO_3	PO_4	Ca	Mg
Winter	2.68 ±0.17	0.48 ±0.03	0.047 ±0.0064	0.012 ±0.001	0.047 ±0.008	84.3 ±5.57	0.081 ±0.014	14.73 ±1.64	4.66 ±0.27
Summer	3.135 ±0.25	0.51 ± 0.018	0.057 ± 0.005	0.014 ±0.001	0.057 ±0.002	87.60 ±3.60	0.14 ±0.02	17 ±0.21	5.05 ±0.21
Monsoon	2.48 ±0.26	0.45 ±0.032	0.028 ±0.002	0.009 ±0.001	0.039 ±0.004	60.60 ±7.52	0.069 ±0.007	14.14 ±0.70	4.43 ±0.15

Table 2. Phytoplankton population of Ganga river water at Site-I (Bhimgoda barrage) and Site-II (Bahadrabad), Haridwar, Uttarakhand, India.

Total Phytoplankton population at Bhimgoda Barrage (Site-I)				
	Total Phytoplankton	Total Diatoms	Green algae	Blue green algae
Winter	1425.041 ± 568.4755	1230.2 ± 491.39	156.4 ± 45.57	47.75 ± 29.63
Summer	1906 ± 832.2061	1623.4 ± 737.15	229.6 ± 120	53 ± 21.74
Monsoon	936.3033 ± 309.1056	811.32 ± 268.44	101.6 ± 41.91	24.88 ± 16.39
Total Phytoplankton population at Bhadrabad (Site-II)				
Winter	1212.105 ± 478.6622	985.39 ± 343.28	181.2 ± 145.1	53.8 ± 30.37
Summer	1930.4 ± 499.5261	1592.8 ± 440.97	283.8 ± 98.09	59.47 ± 43.48
Monsoon	823.9535 ± 269.3877	698.13 ± 229.64	109.3 ± 67.65	29.99 ± 23.61

Table 3. Diatom species of Ganga river water at Site-I (Bhimgoda barrage) and Site-II (Bahadrabad), Haridwar, Uttarakhand, India.

Total Diatom species at Bhimgoda Barrage (Site-I)						
Seasons	**Diatoma**	**Fragilaria**	**Gomphonema**	**Amphora**	**Cymbella**	**Acnanthes**
Winter	206.49 ± 119.12	183.87 ± 116.27	167.73 ± 98.498	102.4 ± 41.41	153.492 ± 115.37	127.5 ± 79.19
Summer	240.8 ± 161.33	201.8 ± 162.92	190.2 ± 102.64	152.88 ± 93.176	204.4 ± 162.46	137 ± 60.45
Monsoon	93.722 ± 70.345	88.828 ± 60.83	82.845 ± 52.091	92.012 ± 37.822	87.9971 ± 36.67	72.34 ± 33.28
Seasons	**Total Diatom species at Bhadrabad (Site-II)**					
	Diatoma	**Fragilaria**	**Gomphonema**	**Amphora**	**Cymbella**	**Acnanthes**
Winter	217.67 ± 150.26	193.98 ± 125.01	189.1 ± 102.7	138.2 ± 127.46	156.008 ± 65.97	142.6 ± 92.87
Summer	253.4 ± 165.45	205 ± 162.36	192.4 ± 124.5	154.29 ± 107.97	206.6 ± 156.04	168.2 ± 74.25
Monsoon	99.786 ± 80.63	95.799 ± 64.312	93.959 ± 62.132	95.853 ± 38.634	88.9729 ± 44.54	94.5 ± 29.58

Table 4. Correlation matrix among the various physico-chemical parameters and phytoplanktonic species at Site-I (Bhimgoda barrage) (significant level at 0.05).

	Temp	pH	DO	F.CO_2	Chl-a	Na	NO_2	NO_3^-	SiO_3	HCO_3	PO_4	Ca	Mg	Diatoma	Fragilaria	Gomphonema	Amphora	Cymbella	Acnanthes
Temp	1.00																		
pH	0.269	1.00																	
DO	-0.922	-0.602	1.00																
F.CO2	0.547	0.657	-0.736	1.00															
Chl-a	0.120	-0.330	0.048	-0.147	1.00														
Na	0.316	0.831	-0.560	0.514	0.243	1.00													
NO2	0.003	0.850	-0.285	0.398	0.019	0.895	1.00												
NO_3^-	0.153	0.902	-0.424	0.414	-0.084	0.894	0.974	1.00											
SiO_3	0.206	0.893	-0.500	0.621	0.102	0.967	0.937	0.913	1.00										
HCO_3	0.041	0.946	-0.398	0.466	-0.543	0.669	0.778	0.834	0.753	1.00									
PO_4	0.422	0.928	-0.664	0.655	-0.317	0.758	0.813	0.898	0.809	0.837	1.00								
Ca	0.344	0.937	-0.654	0.757	-0.040	0.919	0.832	0.841	0.961	0.799	0.831	1.00							
Mg	0.128	0.927	-0.494	0.732	-0.249	0.785	0.770	0.758	0.885	0.868	0.754	0.949	1.00						
Diatoma	-0.071	0.943	-0.271	0.999	0.853	0.883	0.995	0.956	0.987	0.987	0.820	0.956	0.999	1.00					
Fragilaria	-0.147	0.914	-0.196	0.998	0.811	0.844	0.999	0.930	0.972	0.972	0.774	0.930	0.994	0.997	1.00				
Gomphonema	-0.096	0.934	-0.247	0.999	0.840	0.871	0.997	0.948	0.983	0.983	0.806	0.948	0.998	0.999	0.999	1.00			
Amphora	0.557	0.949	-0.806	0.784	0.994	0.985	0.722	0.935	0.877	0.877	0.999	0.935	0.809	0.789	0.739	0.773	1.00		
Cymbella	0.155	0.994	-0.480	0.973	0.949	0.966	0.947	0.997	0.998	0.998	0.928	0.997	0.982	0.974	0.954	0.969	0.907	1.00	
Acnanthes	-0.159	0.910	-0.185	0.997	0.804	0.838	0.999	0.926	0.969	0.969	0.766	0.926	0.992	0.996	0.999	0.998	0.731	0.951	1.00

Table 5. Correlation matrix among the various physico-chemical parameters and phytoplanktonic species at Site-I (Bhadrabad) (significant level at 0.05).

	Temp	pH	DO	F.CO_2	Chl-a	Na	NO_2	NO_3^-	SiO_3	HCO_3	PO_4	Ca	Mg	Diatoma	Fragilaria	Gomphonema	Amphora	Cymbella	Acnanthes
Temp	1.00																		
pH	0.302	1.00																	
DO	-0.990	-0.431	1.00																
F.CO2	0.999	0.266	-0.985	1.00															
Chl-a	0.999	0.993	-0.534	0.378	1.00														
Na	0.412	0.995	-0.337	0.167	0.976	1.00													
NO2	0.204	0.961	-0.166	-0.010	0.922	0.984	1.00												
NO_3^-	0.028	0.977	-0.227	0.053	0.944	0.993	0.998	1.00											
SiO_3	0.090	0.999	-0.397	0.230	0.988	0.998	0.971	0.984	1.00										
HCO_3	0.266	0.871	0.068	-0.241	0.807	0.917	0.973	0.956	0.889	1.00									
PO_4	-0.205	0.975	-0.651	0.508	0.989	0.934	0.856	0.887	0.955	0.713	1.00								
Ca	0.540	0.999	-0.472	0.475	0.994	0.947	0.876	0.904	0.966	0.740	0.999	1.00							
Mg	0.507	0.999	-0.044	0.310	0.997	0.989	0.948	0.904	0.996	0.848	0.977	0.984	1.00						

Diatoma	0.346	0.921	0.088	-0.131	0.869	0.955	0.993	0.966	0.935	0.994	0.787	0.810	0.902	1.00					
Fragilaria	-0.094	0.861	0.088	-0.261	0.796	0.908	0.968	0.983	0.880	0.999	0.699	0.726	0.837	0.991	1.00				
Gomphonema	-0.225	0.828	0.150	-0.321	0.757	0.880	0.950	0.950	0.848	0.997	0.653	0.681	0.801	0.981	0.998	1.00			
Amphora	-0.285	0.938	-0.090	-0.086	0.891	0.968	0.997	0.929	0.950	0.988	0.815	0.836	0.920	0.999	0.984	0.971	1.00		
Cymbella	-0.049	0.983	-0.260	0.087	0.956	0.997	0.995	0.990	0.990	0.946	0.902	0.918	0.974	0.976	0.939	0.916	0.985	1.00	
Acnanthes	0.124	0.962	-0.168	-0.007	0.924	0.985	0.999	0.998	0.972	0.972	0.858	0.877	0.948	0.992	0.967	0.949	0.997	0.996	1.00

CONCLUSION

Clean and adequate freshwater is vital to survival of all living organisms and the smooth functioning of ecosystems, communities and economies. Declination in water quality has become a global issue of concern as human population grow, industrial and agricultural activities expand and climate change threatens to cause major alterations to the hydrological cycle. During the study of Ganga Canal in Haridwar it is clearly found that due to large number of human activities the river water is flowing towards the declination. Not only the domestic and commercial but in last decade industrial setups has also increased in areas near to water body in this region, increasing the load of pollution on the canal. The present study concluded that physico-chemical and phytoplanktonic characteristics of Ganga Canal showed seasonal variation. Three groups of phytoplankton and six species of diatoms were recorded in the river water at Site 1 and 2. The phytoplankton showed positive significant relation with Na, NO_2, NO_3^-, SiO_3, HCO_3, PO_4, Ca, Mg at both the Sites 1 and 2. The high value of phytoplankton diversity at Site 2 indicates polluted nature of river water and can be used as an indicator of organic pollution in the canal. Appropriate biological and chemical treatment of domestic sewage and industrial effluents before discharge to river system is suggested. Hence it is essential to undertake regular monitoring and surveillance of important aquatic ecosystems.

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