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Impact of Pulp and Paper Mill Effluents on Phytoplanktonic Community Structure in Ganga River at Bijnor (Up), India

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ABSTRACT

Study of impact of pulp and paper mill effluents on the qualitative and quantitative aspect of phytoplankton was undertaken from the four selected sites on Ganga river in Bijnor (UP), India i.e. site-I (control point), site-II (discharge point), site-III (500 mts from discharge point) and site-IV (1000 mts from discharge point). A total of 43 genera belonging to 5 groups viz., *chlorophyceae* (16 genera), *bacillariophyceae* (12 genera), cyanophyceae (10 genera), *euglenophyceae* (4 genera) and *xanthophyceae* (1 genus) were recorded from four study sites with chlorophyceae exhibiting maximum abundance and generic diversity at all the sites. Site-II (discharge point) exhibited maximum generic diversity with 43 genera (31.1% percentage occurrence). Loss and appearance of genera as well as significant increase or decrease in the abundance of sensitive and tolerant indicator genera were also studied. *Synedra, Cocconeis* and *Spirulina* were significantly abundant at the discharge point (site-II) and downstream (sites- III and IV) indicating high tolerance to the various paper mill effluents. *Cladophora* and *Euglena* disappeared at site-III which are sensitive to the effluents. Abundance of *Botryococcus* and *Chlamydomonas* increased at sites-III and IV as compared to the sites-I and II which are indicators of deteriorating water quality. Diversity index of phytoplankton was ranged between 'H' (0.000-0.313) at site- I, ('H') (0.000-0.301) at site- II, 'H' (0.000-0.3666) at site- III and 'H' (0.000-0.333) at site- IV. Phytoplankton were found positively correlated with DO (0.721**) and BOD (0.659**) and total alkalinity (0.623**) while negatively correlated with free CO_2 (-0.593**), air temperature (-0.654**) and water temperature (-0.654**).

Keywords: Phytoplankton, Ganga river, pulp and paper, diversity.

1. Introduction

The importance of phytoplankton is beyond question since it occupies the center of the aquatic food chain. Primary productivity is entirely dependent on phytoplankton population. Phytoplankton generates 70% of the world's atmospheric oxygen. Water bodies in India are significantly polluted by paper mill effluents. The chemicals liberated from the effluents may inhibit the growth of phytoplankton and plants[1] and phytoplankton population is significantly affected, which leads to drastic changes in the food chain of aquatic environment[2]. As phytoplankton are very sensitive to the changes in the environment, any alteration may lead to the changes in the phytoplanktonic community. Therefore, they can be studied to assess the impact of various paper and pulp mill effluents on the water bodied receiving the effluent discharge. Hence present study was undertaken to investigate the impact of pulp and paper mill effluents on the phytoplankton community structure.

2. Material and methods

For the study of qualitative and quantitative analysis of phytoplankton, plankton net which is ring type net, fitted on a wide mouthed bottle and 20 liters of water was filtered through it and a total of 150 ml of sample was taken for the study from the four selected sites i.e. site-I (control point), site-II (discharge point), site-III (500 mts from discharge point) and site-IV (1000 mts from discharge point). For the counting of phytoplankton, the Sedgwick rafter cell was used which is generally a 50 mm long, 20 mm wide and 1 mm deep cell with volume of $1cm^2$ or 1 ml. The sample was agitated to distribute the organisms evenly and by using a pipette, one ml of sample was transferred into the cell.

Cover slip was placed on the cell carefully avoiding the air bubbles and allowed the plankton to settle for some time. All the phytoplankton present in the cell (in 1 mm) were counted by moving the cell horizontally and vertically and covering the whole area. For the identification of plankton, standard references like[3,4,5] were consulted.

Calculation

ni = (a×1000) c / L Where, ni = number of phytoplankton per liter
a = the number of phytoplankton per counting unit of 1 mm^2
c = volume of concentrated phytoplankton in ml
L = total volume of waters (filtered) in liters

3. Results

Species composition and species percentage composition of phytoplankton of all the study sites is given in Table 1 & 2. A total of 43 genera belonging to 5 groups viz., chlorophyceae (16 genera), bacillariophyceae (12 genera), cyanophyceae (10 genera), euglenophyceae (4 genera) and xanthophyceae (1 genus) were recorded from four study sites with chlorophyceae exhibiting maximum abundance and generic diversity at all the sites.

Site-II (discharge point) exhibited maximum generic diversity with 43 genera (31.1% percentage occurrence) followed by site- IV (35 genera, 25.3%), site-III (33 genera, 23.9%) and site-I (27 genera, 19.5%). A total of 27 genera belonging to 4 groups viz., chlorophyceae (11 genera, 40.7%), bacillariophyceae (8 genera, 29.6%), cyanophyceae (7 genera, 25.9%) and euglenophyceae (1 genus, 3.6%) were encountered from site- I. A total of 43 genera belonging to 5 groups with chlorophyceae (16 genera, 37.2%), bacillariophyceae (12 genera, 27.9%), cyanophyceae (10 genera, 23.2%), euglenophyceae (4 genera, 9.0%) and xanthophyceae (1 genus, 2.3%) were recorded from site- II. A total of 33 genera belonging to 4 groups were recorded from site- III viz., chlorophyceae (12 genera, 36.3%), bacillariophyceae (9 genera, 27.2%), cyanophyceae (8 genera, 24.2%), and euglenophyceae (4 genera, 12.1%). A total of 35 genera belonging to 4 groups were recorded from site- IV viz., chlorophyceae (12 genera, 34.2%), bacillariophyceae (11 genera, 31.4%), cyanophyceae (8 genera, 22.8%), and euglenophyceae (4 genera, 11.4%).

During the present investigation, upstream to downstream algal genera comparison was done. Loss and appearance of genera as well as significant increase or decrease in the abundance of sensitive and tolerant indicator genera were also studied (Table 2) *Synedra, Cocconeis* and *Spirulina* were significantly abundant at the discharge point (site-II) and downstream (sites- III and IV) indicating high tolerance to the various paper mill effluents. *Cladophora* and *Euglena* disappeared at site-III which are sensitive to the effluents. Abundance of *Botryococcus* and *Chlamydomonas* increased at sites-III and IV as compared to the sites-I and II which are indicators of deteriorating water quality.

Table 1: Upstream to downstream algal genera comparisons: loss and appearance of genera as well as significant increase and decrease in the abundance of sensitive and tolerant indicator genera

Class	Implication	Site-I	Site-II	Site-III	Site-IV
Chlorophyceae					
Chlamydomonas	Tolerant to nutrients	+	+	+	+
Cladophora	Sensitive	-	++	-	+
Botryococcus	Tolerant to nutrients	-	+	+	-
Bacillariophyceae					
Navicula	Pollution indicator	+	++	+	+
Synedra	Tolerant to nutrients	+	#	++	+
Cocconeis	Tolerant to nutrients	+	++	+	+
Gomphonema	Pollution indicator	-	+	+	+
Cyanophyceae					
Spirulina	Tolerant to nutrients	+	++	+	+
Euglenophyceae					
Euglena	Sensitive	-	+	+	+

- not found + present ++ abundant # dominant

Table 2: Site-wise generic diversity and percentage composition of phytoplankton recorded from Ganga river at Bijnor

Class	Site-I	Site-II	Site-III	Site-IV	Total genera/ percentage composition
Chlorophyceae	11 (40.7%)	16 (37.2%)	12 (36.3%)	12 (34.2%)	51 (36.9%)
Bacillariophyceae	08 (29.6%)	12 (27.9%)	09 (27.2%)	11 (31.4%	40 (28.9%)
Cyanophyceae	07 (25.9%)	10 (23.2%)	08 (24.2%)	08 (22.8%)	33 (23.9%)
Euglenophyceae	01 (3.0%)	04 (9.0%)	04 (12.1%)	04 (11.4%)	13 (9.4%)
Xanthophyceae	00	01 (2.3%)	00	00	01 (0.7%)
Total genera/ percentage composition	27 (19.5%)	43 (31.1%)	33 (23.9%)	35 (25.3%)	

Diversity index of phytoplankton was ranged between 'H' (0.000-0.313) at site- I, ('H') (0.000-0.301) at site- II, 'H' (0.000-0.3666) at site- III and 'H' (0.000-0.333) at site- IV. The maximum diversity index was reported at site-III as 0.366. Number of individual of phytoplankton recorded per liter was ranged between 150 – 5025/liter at site- I, 750-14,400/liter at site- II, 450 – 13,350/liter at site- III and 225 – 7125/liter at site- IV. Maximum number of individual of phytoplankton was recorded as 750-14,400/ liter at site-II. Number of individuals recorded per liter was recorded maximum during the winter seasons at all study sites.

Phytoplankton were found positively correlated with DO (0.721**) and BOD (0.659**) while negatively correlated with free CO_2 (-0.593**), air temperature (-0.654**) and water temperature (-0.654**) at site- I. Phytoplankton showed negative correlation with air temperature (-0.636**) and positive correlation with DO (0.516**) and total alkalinity (0.623**) at site- II. Phytoplankton showed positive correlation with DO (0.562**), with free CO_2 (0.544**) and a negative correlation with air temperature (-0.584**), water temperature (-0.624**) and turbidity (-0.544**) at site- III. Phytoplankton showed negative correlation with water temperature (-0.522**) and free CO_2 (-0.532**) at site- IV.

4. Discussion

Reddy and Venkateswarlu[6] investigated impact of pulp and paper mill on the abundance of algae in the river Tungabhadra in Karnataka by selecting three sampling sites i.e. before entering effluent in the river, after entering effluent in the river and at effluent channel. They observed that in the effluent channel the algae were present in very low numbers. Cyanophyceae represented 80% the total algae, whereas diatoms constituted only 20% in the channel. After the effluents were discharged in the river, blue green algae made their appearance in good number. Shrivastava and Patil[7] assessed the plankton population in the range of 4000 to 298,000 cells/l at the madras coast. *Nitzschia, Navicula* and *Peridinium* species were the main identified common species at all the sites. Same findings were also observed in the present study. Mishra *et al.*[8] pointed out that *Oscillatoria* sp., *Arthrospira* sp., *Euglena* sp. and *Phacus curvicauda* are the pollution indicator species and *Spirogyra, Pandorina*, *Pediastrum simplex* were considered as indicator of clean water. In the present study, *Arthrospira* species was noticed at discharge point, 500 m from discharge point and at 1000 m from discharge point. So it can be considered as pollution indicator species because it was not found at control point while *Spirogyra* was noticed at all the sites. Mukherjee and Pankajakshi[9] assessed the impact of detergents on plankton in freshwaters. Nutrients such as phosphates and nitrates were in excess, but the CO_2 with the temperature worked as limiting factor for the growth of algae. They observed that *Microcystis* was tolerant species to the toxic effects of detergents. They also stated that decrease in temperature (below 20 ^{0}C) during December and January restricts the growth of all species of algae and cycle begins afresh with the advent of March along with more congenial conditions. Joshi[10] observed the phytoplankton population in the river Sutlej of western Himalayas, when the river was influxed with the floods. The phytoplankton population in the river was poor with an average of 170 units/l, being maximum (306 units/l) in January and minimum (53 units/l) in August. He stated that the dilution effect of floods not only reduced the planktons density but also lowered the organic carbon productivity besides affecting the concentration of nutrients in the river and also stated that the high turbidity and dilution effect responsible for reducing the phytoplankton density from 298 unit/l(Jan) to only 32 unit/l (Aug). Similar effect of dilution has also been noted in river Ganga[11], River Mississippi[12], River Alaknanda[13] and River Jhelum[14]. In the present study this effect was also observed at site-IV. Sunder[14] assessed the planktonic community of Kumaon Himalayan river Gaula 2. They selected three sites i.e. 1. Jamrani Dam Site 2.2 km. upstream HMT watch factory at Rani bagh 3. 3km downstream the factory. They observed phytoplanktons in the range of 61-1013 units/l at upstream and 61-1033 units /l at downstream. They investigated that the diatoms formed the major group among the total phytoplankton while zooplanktons were recorded 7 units/l at upstream and 9 units/l at downstream. Water temperature and DO were the only limiting factor for the plankton growth; same findings were assessed in the present study.

Pandey *et al.* [15] observed cyanobacterial diversity and chemical composition of a fresh water reservoir, the Udai Sagar lake of Udaipur, Rajasthan. They noticed *Calothrix* sp., *Anabaena flos-aquae*, *Microcystis aeruginosa* and *Phormidium*. They also observed nutrient status (eutrophic) of the lake. They stated that cyanobacterial diversity decreased with receiving of urban industrial effluent. Similar observations were also made during the present investigation. Begam and Khan[16] checked out the impact of the pollution of river Burhi Gandak on plankton and macro-fauna at Mehsi, North Bihar due to sugar mills and mother of pearl Button industries. They selected five sites i.e. site- I above outfall, site- II at outfall, site- III 500m below the outfall, site- IV 1.5 km below the outfall and site-V 2 km below the outfall. They noticed a decrease in water temperature at out fall as compared to above out fall while dissolve oxygen concentration and number of phytoplankton and zooplankton was dropped in summer. The present investigation also reported the same result.

Gurbuz and Kivrak *et al.* [17] evaluated the water quality of the Karasu river of Turkey which is polluted by industrial, agricultural and urban wastes. They observed 43 diatoms taxa belonging to 22 genera by selecting 7 sampling stations. They noticed *Gomphonema*, *Nitchea palea, Navicula cryptocephala* as most pollution tolerant species, which was in high densities at the polluted stations. Mahadev and Hoshmani[18] reported that cyanophyceae are highly tolerant organisms and prefer to grow at higher temperature and in slightly alkaline conditions in the lakes of Mysore city. Adesalu and Nwankwo[19] have studied phytoplankton of Olero creek and Benin river of Nigeria. They found bacillariophyceae as the most abundant algal class. *Navicula* sp. was the most important diatoms in terms of frequency and abundance. Similar result was found in the present study as *Navicula* sp. was observed at all the sites in terms of frequency and abundance. Gupta and Sharma[20] identified various pollution indicators of Ban Ganga which originates from the Trikuta hills of Mata Vaishno Devi Shrine. They selected five stations i.e. station 1- pollution free, station 2-receiving huge amount of dung, station 3- mass bathing and washing activity, station 4- free from any anthropogenic activities. They classified macrobenthic species as pollution tolerant and pollution intolerant as *Ephemerella* sp. is inhabitant of pollution free water and dipterans are the inhabitant of polluted water.

Sridhar *et al.*[21] have studied the water quality and phytoplankton characteristic in the Palk Bay, south east coast of India where they observed that the dissolved oxygen varied with temperature. Same pattern has been recorded in the present study with higher values of dissolved oxygen in the winter season. Lower values in dissolved oxygen were also observed which can be due to organic pollution (lignin, cellulose etc) which also affected the phytoplankton and zooplankton frequency. Zargar and Ghosh[22] assessed the plankton population of Kadra reservoir polluted by Kaiga nuclear power plant of Karnataka state. They selected two zones i.e. within 500 m from discharge point and beyond 500 m from the discharge point. *Melosira* sp. and *Anacystis* sp. were found at both the zones. They also stated that higher temperature 30 ^{0}C and 33 ^{0}C was favorable for the species. Plankton showed high sensitivity to elevated temperature resulting in decreased diversity near the discharge point. Johnson[23] found that Banjara and Nadimi lakes were eutrophic and dominated by cyanophyceae and bascillariophycaen members. According to these workers the species and strains of *Anabaena*, *Aphanizomenon*, *Microcystis*, *Nodularia, Nostoc*, and *Oscillatoria* are the common toxic bloom algae in eutrophic and hyper eutrophic water bodies all over the world. Presence of certain species of cyanobacteria e.g. *Aphanizomenon*, *oscillatoria* and *Anabaena* in water create several problems in the management of aquatic environment as they produce highly toxic substance.

Mathivanan *et al.*[24] assessed the plankton population of Cauvery River at Tamil Nadu with reference to pollution by selecting two sites i.e.- Pannavadi- unpolluted site, Sankalimuni Appamkoil area-polluted site. They found that phytoplankton fluctuate monthly and

their productivity was high during June and low during December but in the present investigation, frequency of phytoplankton in December and January was more and low in June, July. Shekhar *et al.*, [25] assessed the phytoplankton as the index of water quality with reference to industrial pollution in river Bhadra of district Shimoga. They selected five stations i.e. site I-upstream of river Bhadra, site II- after the release of Mysore paper mill effluent, site III- after VISL industrial effluent, site IV- Nagathi Belagalu (10 km away from the Bhadravathi town, Site V- Holenpur (before river Bhadra joins river Tunga in kundli. They noticed the Shanon-Weaver index which was maximum (4.07) at site- I and minimum (1.64) at site- III in post monsoon season. They also reported that higher the Shanon- Weaver index, lesser the degree of pollution. They also observed that the water quality parameters such as temperature, pH and phosphate play a decisive role in altering the phytoplankton distribution. Polluted water at site-II favours the growth of algal groups cyanophyceae and euglenophyceae. These findings are in accordance with the findings of [26, 27, 28].

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