IMPACT OF EFFLUENTS ON PHYTOPLANKTON DYNAMICS IN DAL LAKE OF KASHMIR HIMALAYA

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ABSTRACT

The present study was undertaken during Dec. 2001 to Nov. 2002 in four different basins of Dal lake for assessing the impact of effluents on phytoplankton population. Clear variations were recorded for physico-chemical parameters of water. The sites in the vicinity of drains recorded low dissolved oxygen content and higher values of conductivity and major plant nutrients like phosphorus and nitrogen compared to the corresponding sites in the open water area. A total of 134 species of phytoplankton were recorded during the present investigation. The seasonality of phytoplankton depicted a definite seasonal succession being dominated by diatoms during spring, green algae during summer, blue-green algae during autumn and diatoms again during winter. Species like *Asterionella formosa*, *Pediastrum tetras* and *Tetraedron regulari*, restricted their presence only near the regions receiving sewage outfalls and species like *Pediastrum ovatum*, *Merismopedia glauca* and *Trachelomonas* sp. were found only at open water sites

Key words: Dal lake, phytoplankton, succession, open water, drain, effluent, Himalaya

INTRODUCTION

The natural lakes of Kashmir experience varied anthropogenic pressures. Among these Dal lake is of special ecological and socio-economic interest for being an important tourist attraction. Recently there has been a great concern about the fast deterioration of the lake ecosystem. The entry of domestic sewage into lake and contionuous siltation have not only resulted in excessive growth of macrophytes but also has resulted in undesirable changes in the biotic set up and deterioration of water quality- a manifestation of cultural eutrophication (Pandit, 1996, 1999, 2002). It also promotes the algal growth and leads to phytoplankton blooms particularly those of blue-green algae producing obnoxious odour besides reducing the oxygen availability in water. Since planktonic algae are sensitive to chemical changes, particularly phosphorus and nitrogen content, any alteration in the physio-chemical properties of water are bound to change the composition and abundance of the microcosm community (Kaul *et al.*, 1978, Pandit, 1998). It is in this backdrop, the present investigation has been undertaken to assess the changes of planktonic plants under the impact of effluent discharge.

MATERIAL AND METHODS

The present study was carried out from Dec. 2001 to Nov. 2002 in the urban valley lake, Dal, in Kashmir which is multibasined with Boddal (SI), Gagribal

(SII), Nagin (SIII) and Hazratbal (SIV), forming its four basins. For the present study, two sites in each basin were selected, one near the entrance of the drain bringing sewage and other in open water area about 100 meters away from the drain. Surface water samples were collected on monthly basis from each study site and the analysis was carried out within 24 hours of sampling as per standard methods (APHA, 1989; Welch, 1948; Golterman and Clymno, 1969). Plankton samples were collected after sieving five litre water sample through plankton net (mesh size 64 μm). The samples were then centrifuged and the plankton residue was raised to certain volume. Preservation was done in 4% formaline and Lugol's solution. Qualitative and quantitative analysis of the planktons was done by using standard works of Heurck (1896), Fritsch (1935), Prescott (1939), Deshikacharya (1959), and Cox (1996).

RESULTS AND DISCUSSION

A total of 134 species of phytopl-ankton was recorded during the present investigation of which Chlorophy-ceae constituded 63 species, followed by Bacillariobyceae (44 species), Cyanophy-ceae (19 species), Euglenophy-ceae (5 species), Dinophyceae (2 species) and Chry-sophyceae (1 species) in a decree-sing order (Table 1).

Table 1. Most common phytoplankton species recorded from Dal Lake during Dec. 2001-Nov.2002

Cyanophyceae	*Anabaena* sp., *Anacystis* sp., *Gomphospheria* sp., *Lyngbya* sp., *Merismopedia elegans, Merismopedia punctata, Nostoc* sp. and *Oscillatoria proteus*
Chlorophyceae	*Botryococcus braunii, Chlorella* sp., *Closterium* sp., *Coelastrum* sp., *Cosmarium* sp., *Pediastrum duplex, Pediastrum ovatum, Pediastrum simplex, Scenedesmus quadriquada,* and *Spirogyra* sp.,
Bacillariophyceae	*Acnanthes* sp., *Amphora ovalis, Amphora* sp., *Asterionella Formosa, Cocconies placentula, Fragilaria capucina, Diatama elongatum, Navicula cuspidate, Niztschia acicularis* and *Synedra ulna*
Euglenophyceae	*Euglena acus, Euglena rubra* and *Phacus* sp.,

The annual mean values of transparency showed fluctuations from 121.21±13.30 at Site II (open water) to 230.21±37.75 at Site III (open water). The lake waters were usually turbid; the low values of transparency being attributed to silt impregnated waters from the catchment responding the growth of phytoplankton. The observations on temperature registered during the present investigation showed a close relationship with the atmospheric temperature. The water temperature showed variation from 16.68±8.89 at open water of Site III to 17,60±9.13 near drain at Site IV. The different groups of algae may have different temperature ranges for growth. In fresh water the optimum temperature for the majority of algae lies between 20-25 °C (Prescott, 1984). However, a few algal species e.g. *Cosmarium bioculatum*, *Cosmarium renilli*, *Closterium acerosium*, *Gonium* sp. during the present study were found to exist and grow in a wide range of temperature and are thus categorized as eurythermal species. Much lower values of dissolved oxygen were recorded near drains (0.90±0.10 mg/L) as compared to open water sites (7.51±1.32). the extent of variation appears due to higher site of photosynthetic activity and high content of dissolved organic matter. The dissolved oxygen of water is necessary for survival and growth of aquatic plants and animals. In general, the oxygen level showed inverse relation with temperature as the solubility of oxygen in water decreases as the temperature of water increases. A direct relation between dissolved oxygen and different groups of algae has been observed. Dissolved oxygen showed positive correlation with Chlorophyceae (0.86, 0.19), Bacillariophyceae (0.91, 0.49) and Euglenophyceae (0.51, 0.90) near drains and open water sites respectively and negative correlation with Cyanophyceae (-0.14), a pollution tolerant group, which is in the agreement with the results obtained by Verma and Mohanty (1995). The pH of Dal lake waters were in alkaline range and fluctuated between 7.62 ± 0.42 and 8.59 ± 0.31. The shifting pH was not sudden as the lake water seems to be well buffered. The actual fluctuation in the pH value depends upon density of algae and other plants and also upon the buffering capacity of lake water. The pH at open water sites was slightly more alkaline than at their corresponding effluent sites. The effluent concentration lowers the species diversity and produce dense population of few species (eg, *Asterionella formosa*, *Pediastrum tetras*, *Cymbella gastroides*) which are resistant to pollution (Table 2)

Table 2. Variations (annual mean±S.D) in various physico-chemical parameters of water at different selected sites during Dec. 2001-Nov. 2002.

PARAMETERS	SITES			
	S I		S II	
	Drain	Open	Drain	Open
Depth (cm)	n.r	248.83±9.05	n.r	132.96±11.40
Transparency (cm)	n.r	184.58±46.12	n.r	121.21±13.30
Water temperature (°C)	17.47±9.14	16.88±8.84	17.28±8.83	16.70±9.04
Dissolved Oxygen (mg/L)	1.94±0.45	7.06±1.91	2.05±0.88	6.33±1.47
pH	7.68±0.33	8.40±0.48	7.62±0.42	8.42±0.52
Conductivity (μs Cm^{-1})	365.50±92.86	297.17±68.25	357.92±61.14	285.08±64.23
Bicarbonate (mg/L)	114.50±18.05	93.50±8.50	125.00±29.79	103.83±27.25
Carbonate (mg/L)	5.42±5.72	3.83±4.86	8.58±7.32	4.92±4.89
Alkalinity (mg/L)	119.96±21.44	97.36±11.72	133.66±32.15	108.74±30.26
Chloride (mg/L)	30.25±0.96	25.29±1.60	40.29±6.55	29.38±1.80
Calcium (mg/L)	21.63±3.04	22.53±2.07	25.42±3.47	22.55±4.56
Magnesium (mg/L)	2.93±0.33	2.31±0.34	3.66±0.51	2.67±0.30
Orthophosphate (μg/L)	123.32±12.89	76.35±9.54	145.12±27.28	74.64±7.23
Total phosphorus (μg/L)	759.75±129.59	378.08±32.04	659.50±61.70	391.00±13.10
Nitrate-nitrogen (μg/L)	651.33±65.20	421.88±49.35	643.92±75.53	399.63±47.45
Ammonical -nitrogen (μg/L)	623.96v20.13	417.17±15.33	624.67±23.26	368.00±18.20
Silicate (mg/L)	4.83±1.39	3.98±0.82	4.37±0.76	3.79±0.55

Cont...

PARAMETERS	SITES			
	S III		S IV	
	Drain	Open	Drain	Open
Depth (cm)	n.r	357.38±24.89	n.r	199.08±16.22
Transparency (cm)	n.r	230.21±37.75	n.r	180.58±9.64
Water temperature (°C)	17.58±8.37	16.68±8.89	17.60±9.13	16.87±9.20
Dissolved Oxygen (mg/L)	2.09±0.94	6.04±1.18	1.88±0.70	7.51±1.32
pH	7.70±0.29	8.59±0.31	7.76±0.28	8.45±0.45
Conductivity (µs Cm^{-1})	389.65±56.27	291.50±64.06	398.42±87.21	283.00±68.18
Bicarbonate (mg/L)	132.92±29.03	110.33±28.44	126.92±57.23	105.00±39.90
Carbonate (mg/L)	9.17±9.96	7.25±7.23	1.42±2.04	2.67±5.33
Alkalinity (mg/L)	142.18±37.44	118.06±35.60	128.34±58.81	107.67±44.58
Chloride (mg/L)	33.50±2.66	30.03±4.68	35.83±2.29	25.27±4.84
Calcium (mg/L)	20.57±2.58	25.17±3.64	26.46±3.40	23.61±3.19
Magnesium (mg/L)	4.65±1.58	3.48±1.27	4.30±1.19	4.18±1.78
Orthophosphate (µg/L)	135.23±34.22	78.93±14.61	122.98±20.55	87.33±9.58
Total phosphorus (µg/L)	729.42±87.12	400.25±14.99	779.25±110.65	389.40±40.22
Nitrate-nitrogen (µg/L)	617.98±63.79	389.75±41.70	631.83±54.69	380.83±40.46
Ammonical - nitrogen (µg/L)	607.58±9.28	388.83±12.08	604.48±12.11	392.04±7.75
Silicate (mg/L)	3.61±0.76	3.65±0.78	3.65±0.77	3.44±1.32

- **n.r-not recorded**

The trend for alkalinity values were similar to those recorded for conductivity. Total alkalinity of lake water is mainly due to bicarbonates, although very small quantities of carbonates were also recorded at different sites during some months. These observations are in agreement with those of Zutshi *et al.*, (1980). The presence of carbonate alkalinity is due to aquatic plants chiefly phytoplanktons which removes half the bound CO_2 from the bicarbonates leaving a certain amount of carbonates in water. The total alkalinity of lake ranged from 97.36±11.72 mg/L to 142.18±37.44mg/L with greater concentration near drains. The high values of total alkalinity for all the basins were also reported by Trisal (1987). In general, chloride content of the lake water ranged from 25.27±4.48 to 40.29±6.55. High chloride content in the lake water is attributed to input of human and animal excretion (Bhat *et al.*, 2001). Among the various cations divalent cation components, Ca^{2+} and Mg^{2+} were more abundant in all the basins of Dal lake. Due to appreciable calcium and magnesium hardness Dal lake can be classified as calcium rich using the criteria of Ohle (1934). Phosphorus is one of the most important elements in an aquatic ecosystem for the growth of phytoplanktons. Phosphate seems to be limiting factor in nearly all fresh waters and its addition can increase the growth of algae particularly blue-green algae (*Oscillatoria* sp., *Lyngbya* sp.) and green algae (*Chaetophora* sp.). Both orthophosphate and total phosphate showed summer maxima and winter minima which can possibly be attributed to the excessive use of phosphate fertilizers in the paddy cultivations in the catchment area and in floating gardens etc. silicates play a major role in the growth and productivity of diatoms. Its values fluctuated from 3.44±1.32 to 4.83±1.39 mg/L. The biological importance of silicates in the lake waters is mainly due to the fact that it forms the constituent of cell wall in diatoms. The present investigation depicted an inverse correlation between silicates and diatoms (-0.31, -0.05) near drains and open water sites respectively, though the values were not significant. These observations are in consonance with earlier findings of Munawar (1974). According to Sarwar (1986) the silicate content in the lake water gets depleted as it is taken up by the abundance of diatoms. It again confirms the negative correlation of SiO_3 with profuse growth of diatoms. Though ammonical nitrogen was reported to be in low quantities as compared to nitrate nitrogen, yet appreciable quantities of ammonical nitrogen were reported to be found in lake waters that indicated the poillution status of lake in terms of ammonia concentration, being the end-product of amminification. During the present study, nitrate nitrogen showed positive correlation with Bacillariophyceae and Euglenophyceae near drains and open waters, which is in accordance with the view point held by Zutshi *et al.* (1984). In general, Cyanophyceae showed peak growth (2800 ind. L^{-1}) near drain at Site I during autumn whereas minimum population (100ind. L^{-1}) was obtained in summer at Site II, a fact also observed by Kant and Kachroo (1977). The maximum development of blue-greens was found to be associated with moderate to warm waters. Chlorophyceae being comprised of 63 species was more important in terms of species richness and its contribution to the total phytoplankton population was significant. It also showed single peak during summer, an observation also revealed by Kant and Kachroo (1977). Bacillariophyceae, being represented by 44 species, was the second dominant group after Chlorophyceae. Diatoms exhibited their peak population density of 2050 ind. L^{-1} during spring near drain at Site II which was followed by a fall till it reached the lowest of 260 ind.L^{-1} at open water of Site I during summer. Chrysophyceae was represented by only one taxon, *Dinobryon divergens*. The species was found all together absent during winter. Dinophyceae though in very small numbers and represented mainly by *Gymnodinium* sp. and *Peridinium* sp., showed its peak values during March and October. Euglenophyceae was represented by 5 species and showed peak growth and development during winter and minimum during autumn. It appears from the composition of phytoplanktons during different seasons, that the microscopic plant community depicted a definite seasonal succession, being dominated by diatoms during spring, green algae during summer, blue-green algae during autumn and diatoms again during winter (Table 3 and 4).

In conclusion, the lake environment showed signs of deterioration as a result of racing eutropication, being brought about by cultural activities. The large inputs of waste waters lead not only to the nutrient enrichment in regions experiencing sewerage outfalls but also lead to the formation of algal blooms even in deep basin of Dal lake, the Nagin.

Table 3. Seasonal variations in the density of various groups of phytoplankton at different selected sites

Winter

S.No.	Taxonomic Groups	Site I		Site II		Site III		Site IV	
		Drain	*Open*	*Drain*	*Open*	*Drain*	*Open*	*Drain*	*Open*
1	Cyanophyceae	1340	1043	1533	665	370	410	1300	560
2	Chlorophyceae	960	680	740	1060	920	700	530	440
3	Bacillariophyceae	1420	737	840	560	1320	840	1776	400
4	Chrysophyceae	0	0	0	0	0	0	0	0
5	Dinophyceae	0	0	0	0	0	0	0	0
6	Euglenophyceae	460	300	350	390	110	410	220	200
	Total	**4180**	**2760**	**3463**	**2675**	**2720**	**2360**	**3826**	**1600**

Spring

S.No.	Taxonomic Groups	Site I		Site II		Site III		Site IV	
		Drain	*Open*	*Drain*	*Open*	*Drain*	*Open*	*Drain*	*Open*
1	Cyanophyceae	680	500	320	370	260	330	370	280
2	Chlorophyceae	820	760	620	500	640	640	980	620
3	Bacillariophyceae	1370	630	2050	950	1690	500	1620	880
4	Chrysophyceae	0	0	0	0	0	0	0	0
5	Dinophyceae	110	40	20	130	50	80	50	40
6	Euglenophyceae	80	40	60	60	30	80	40	170
	Total	**3060**	**1970**	**3070**	**2010**	**2670**	**1630**	**3060**	**1990**

Summer

S.No.	Taxonomic Groups	Site I		Site II		Site III		Site IV	
		Drain	*Open*	*Drain*	*Open*	*Drain*	*Open*	*Drain*	*Open*
1	Cyanophyceae	540	530	570	100	350	360	170	310
2	Chlorophyceae	570	370	420	350	730	310	550	470
3	Bacillariophyceae	520	260	410	310	300	270	350	360
4	Chrysophyceae	10	0	0	0	0	10	10	0
5	Dinophyceae	10	50	0	30	0	10	20	40
6	Euglenophyceae	90	30	40	20	30	150	100	50
	Total	**1740**	**1240**	**1440**	**810**	**1410**	**1110**	**1200**	**1230**

Autumn

S.No.	Taxonomic Groups	Site I		Site II		Site III		Site IV	
		Drain	*Open*	*Drain*	*Open*	*Drain*	*Open*	*Drain*	*Open*
1	Cyanophyceae	2800	2540	1000	762	880	960	470	360
2	Chlorophyceae	350	690	530	906	630	1270	550	980
3	Bacillariophyceae	570	510	1000	930	890	780	850	950
4	Chrysophyceae	10	0	0	0	0	0	0	0
5	Dinophyceae	90	10	0	80	40	50	60	180
6	Euglenophyceae	60	50	40	30	0	70	10	60
	Total	**3880**	**3800**	**2570**	**2708**	**2440**	**3130**	**1940**	**2530**

Table 4. Correlations between physico-chemical parameters of water and phytoplankton at drains and open water sites

CORRELATION	Cyanophyceae		Chlorophyceae		Bacillariophyceae		Euglenophyceae	
	Drain	Open	Drain	Open	Drain	Open	Drain	Open
Temperature	-0.689	-0.418	-0.597	-0.600	-0.605	-0.590	-0.561	-0.728
Dissolved Oxygen (mgL^{-1})	0.283	-0.149	0.869	0.197	0.912	0.499	0.513	0.902
pH	-0.802	-0.194	-0.453	-0.389	-0.511	-0.430	-0.458	-0.868
Orthophosphate(OPP) ($mg\ L^{-1}$)	0.145	0.054	-0.950	-0.248	-0.963	-0.468	-0.439	-0.935
Total Phosphorus TPP ($mg\ L^{-1}$)	-0.316	-0.386	0.963	-0.591	0.670	-0.613	0.793	-0.748
Nitrate Nitrogen ($mg\ L^{-1}$)	-0.637	-0.530	0.778	-0.249	0.390	0.064	0.705	0.958
Ammonical Nitrogen ($mg\ L^{-1}$)	-0.415	-0.325	0.920	-0.157	0.583	-0.036	0.795	0.978
Silicates ($mg\ L^{-1}$)	-0.869	-0.774	-0.314	-0.519	-0.312	-0.050	-0.489	0.202

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