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Seasonal Diatom Variations with Reference to Physico-chemical Properties of Water of Mansagar Lake of Jaipur, Rajasthan

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ABSTRACT

The present investigation accounts for the seasonal studies of Mansagar Lake (Jalmahal), Jaipur on the diatom diversity, density and distribution in different seasons and their correlation with physico-chemical properties of water. The study reveals the presence of 35 diatom species. A limited number of these were recorded throughout the year, while others were distributed in different seasons mainly in winter and summer. These taxa belong to 22 genera viz *Stephanodiscus, Coscinodiscus, Cyclotella, Gomphonema, Melosira, Navicula, Cymbella, Epithemia, Amphora, Synedra, Diadesmis, Falcula, Rhopalopodia, Eunotia, Aulacoseira, Diatoma, Hantzschia, Tabularia, Surirella, Fragillaria, Anomoneis* and *Nitzschia*. The deposited sediment of lake was found to be rich in sand (66%), silt (16%), clay (18%) and other soil nutrients as compared to control soil. Total diatom density showed significant positive correlation with electrical conductivity and total dissolved solids ($p<0.01$) and significant positive correlation with chemical oxygen demand ($p<0.05$). Shannon-Weiner diversity index (H') value (1.372) and Evenness (J') value (0.903) were found to be highest during winter while Berger-Parker index of dominance (0.147) was highest in monsoon. This study reveals that the diatom species attain maximum growth in post monsoon and winter months and gradually declines in summer to reach its minimum during monsoon. These types of studies are prerequisites for evolving fish culture programmes and management of water resources.

Key words: Freshwater diatoms, Mansagar Lake, Physico-chemical properties, Rajasthan

Mansagar Lake (popularly known as Jalmahal) is located between 26° 56′ 45″ N latitude and 75° 51′ 45″ E longitude. It is approximately 130 hectares in its full spread and has a catchment area of 23.5 square kilometers of maximum depth 5.5 meters having water holding capacity of 54.12×10^4 cubic meters. This lake is an east westerly elongated shallow lake with irregular margins and has dense growth of algae and aquatic macrophytes.

Diatoms are photosynthetic algae with a distinct silica cell wall called frustules. They are either solitary or colonial (occurring in chains) with a cosmopolitan distribution. The physico-chemical parameters and nutrient status of water body plays an important role in governing the production of plankton which is the natural food of many species of fishes, especially diatoms constitutes important food source of many omnivorous and carnivorous fishes and also support the necessary amount of protein for the rapid growth of larval carps (Rahman and Hussain 2008). Diatoms are used extensively in environmental assessment and monitoring because they have ranges and tolerances for environmental variables like *p*H, nutrient concentrations, suspended sediment, flow regime, elevation and different types of human disturbances (Laskar and Gupta 2009). The use of density and diversity of phytoplankton and their association as biological indicators in the assessment of water quality or trophic status have been made by several workers (Chaturvedi *et al*. 1999, Sengar *et al*. 2009). Rajasthan is one of the driest states of the country, facing low rainfall coupled with erratic behavior of the monsoon. Due to lack of water resources it provides diverse habitats for algae, which are poorly investigated. The first investigation on diatoms in Rajasthan was made by Gandhi (1955). After a young gap, studies on diatoms were done by Jakher *et al.* (1990), Dadheech *et al.* (2000), Singh *et al.* (2006), Kumar *et al.* (2008, 2009). The present investigation deals with the seasonal fluctuations of the diatom abundance with reference to changes in physico-chemical parameters and to establish the correlations between them in an ecologically important semi arid region of Rajasthan.

MATERIALS AND METHODS

Fortnightly sampling was carried out from April 2009 to March 2010 at selected sampling sites of Mansagar Lake. Collections were made with the help of planktonic mesh net (pore size 40μm) and were preserved in Lugol's solution. The samples were preserved in the laboratory of the Botany Department, University of Rajasthan, Jaipur. Detailed diatom studies were done following hot HCl and $KMnO_4$ method (recommended technique of acid digestion) by Taylor *et al*. 2005. Photomicrographs were taken using a Nikon Labophot-II with H-III photographic attachment. Qualitative and quantitative estimation of the diatoms was carried out with the help of "Sedgwick-Rafter"

Fig 1 Illustrated map of Mansagar Lake, Jaipur, Rajasthan. Index: Sampling sites 1, 2, 3 and 4.

counting cell chamber and identified by consulting various standard literatures and monographs (Gandhi 1955, 1998, Husted 1959, Prescott 1975, Desikachary 1989, Round *et al*. 1990, Anand 1998). Rainfall and relative humidity data were collected from the State Meteorological Department, Jaipur.

Physico-chemical parameters of water such as dissolved oxygen, *p*H, total hardness, biological oxygen demand, chemical oxygen demand, total dissolved solids and electrical conductivity were analyzed by standard methods (Trivedi and Goel 1986, APHA 2000). During the course of the present investigation, five soil samples were collected from Mansagar lake bed, air dried at room temperature and analyzed for their basic soil properties like *p*H, percentage of sand, silt and clay, electrical conductivity, organic carbon, available nitrogen, potassium, phosphorus and their oxidized states (Tandon 1993). It is also compared with the normal soil so as to understand its nutrient status supporting diatom productivity. Diversity indices like Shannon-Weiner index of diversity (H′), Evenness index (J′) and Berger-Parker index of dominance (D_{BP}) were worked out by the software Biodiversity Professional version 2.0. The Pearson correlation coefficient was used to examine the relationships among the different environmental variables including diatom density using SPSS 14.0.

RESULTS AND DISCUSSION

A total of 35 species of diatoms were recorded in the Mansagar Lake of which the major genera in terms of frequency and abundance were *Navicula* (4), *Gomphonema* (4), *Synedra* (3), *Melosira* (2), *Nitzschia* (2), *Coscinodiscus* (2), *Cyclotella* (2) and single species of the following diatoms; *Aulocoseira, Stephanodiscus, Rhopalopodia, Epithemia, Falcula, Eunotia, Cymbella, Hantzschia, Fragillaria, Amphora, Surirella, Diatoma, Anomoneis, Tabularia and Diadesmis*. Majority of the forms were solitary and few colonial. Particularly, centric diatoms like *Coscinodiscus, Stephanodiscus, Melosira* and *Cyclotella* were most dominant during the monsoon whereas distinct numbers of dominant genera of pennate diatoms like *Nitzschia, Navicula, Gomphonema, Cymbella, Synedra* etc were dominant during winter season. Diatoms attain maximum density and size during winter months and these are also good indicators of water pollution (Fig 2). During the study period, the diatom density showed maximum peak during winter (January-February) and recorded least in monsoon season as previously studied by Nautiyal *et al*. (1996). During monsoon 2009, the total diatom density varied from 3750 to 7100 l-1 with the minimum value being recorded in July and the maximum in September. Subsequently, during post monsoon season, the diatom density revealed not much fluctuation i e from 7196 to 7362 l-1. The diatom density varied from 9500 to 13675 l-1 during winter, minimum number of frustules was recorded in the month of December and maximum in January, 2010. Variation in diatom density during summer season was from 6120 (June) to 12400 1-1 (March).

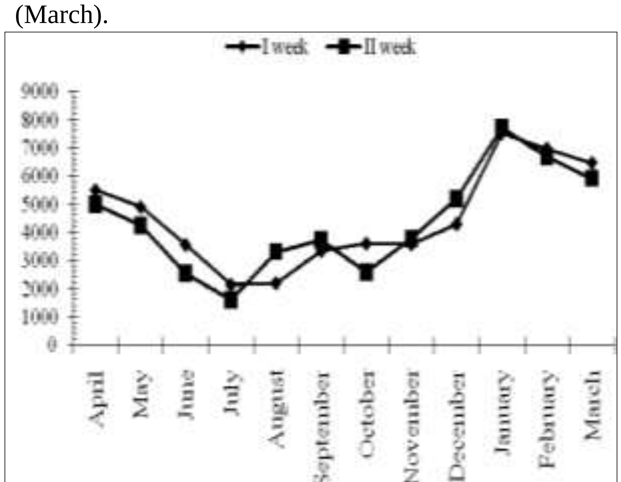

Fig 2 Quantitative studies of seasonal diatom cell abundance

The prominent seasonal variations in diatom diversity, clearly depicting highest number of diatoms in winter (34), followed by that in post monsoon (31), summer (26) and least was recorded in monsoon season (Table 1). Similar observations were made by Dubey and Boswal (2009). The Pearson correlation matrix of different physico-chemical variables including total diatom density (Table 2). The total diatom density showed significant positive correlation with *p*H ($r = 0.55$, $p<0.05$) and total dissolved solids ($r = 0.68$, $p<0.05$) and highly significant positive correlation with total hardness ($r = 0.69$, $p<0.01$) (Table 3). Temperature

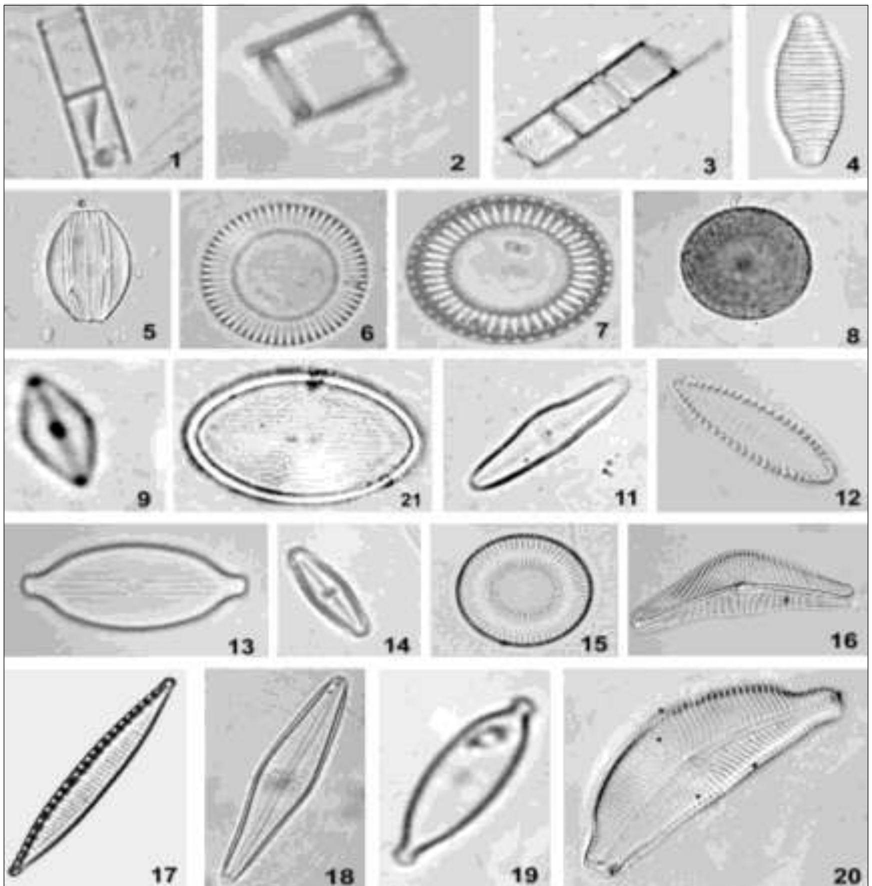

Fig 3 (1) *Melosira varians* Ag.
(2) *Aulacoseira crenulata* Ehr.
(3) *Melosira granulata* Ehr. Ralfs.
(4) *Diatoma vulgare* Bory
(5) *Amphora ovalis* Kuetz.
(6) *Cyclotella meneghiniana* Kuetz.
(7) *Coscinodiscus locustris* Grun.
(8) *Coscinodiscus centralis* Ehr.
(9) *Navicula frugalis* Hust.
(10) *Cocconeis placentula* Ehr. v. *euglypta* (Ehr.) Cl.
(11) *Diadesmis confervacea* Kuetz.
(12) *Surirella tenera* Greg. v. *ambigua* Gandhi
(13) *Anomoeoneis sphaerophora* Kuetz.
(14) *Navicula radiosa* Kuetz.
(15) *Stephanodiscus astrea* (Ehr.) Grun.
(16) *Cymbella turgida* (Greg.) Cl.
(17) *Nitzschia amphibia* Grun.
(18) *Gomphonema lanceolatum* Ehr.
(19) *Gomphonema parvulum* (Kuetz.) Grun.
(20) *Cymbella tumida* (Breb.) V. H.

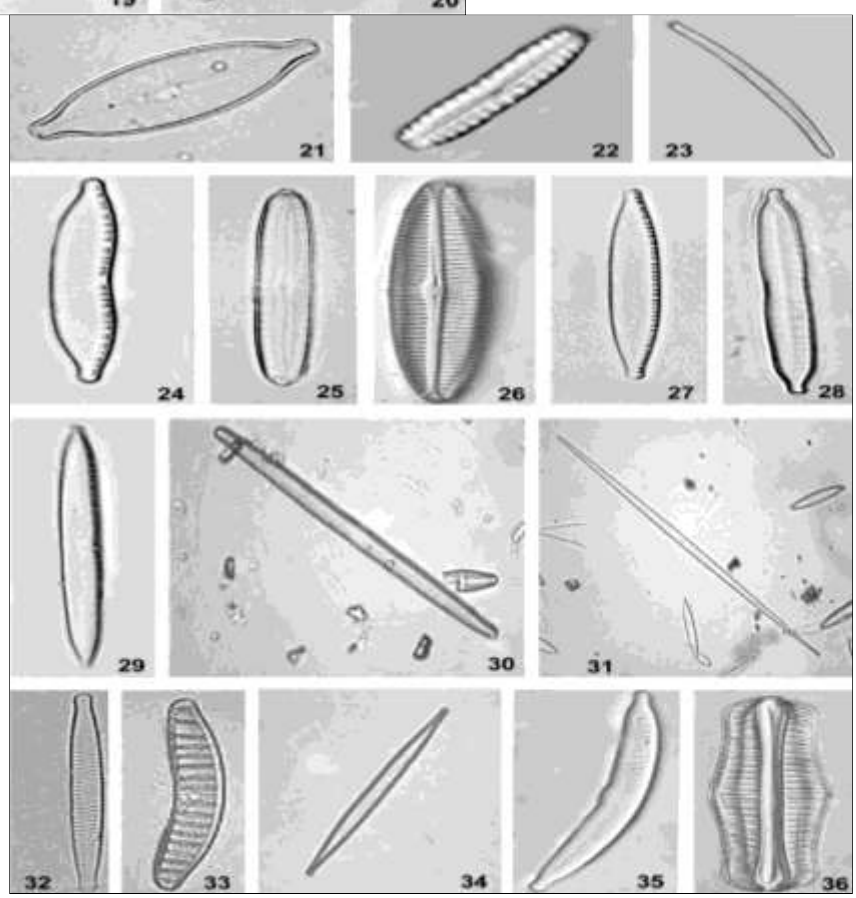

Fig 4 (21) *Navicula cuspidata* Kuetz. v. *ambigua* (Ehr.) Cl.
(22) *Pinnularia borealis* Ehr.
(23) *Eunotia lunaris* (Ehr.) Grun.
(24) *Hantzschia amphioxys* (Ehr.) Grun.
(25) *Pinnularia viridis* (Kuetz.) Ehr.
(26) *Navicula tripunctata* (O. F. Muller) Bory
(27) *Nitzschia palea* Kuetz. W. Sm.
(28) *Synedra rumpens* Kuetz. v. *familiaris* (Kuetz.) Grun.
(29) *Nitzschia linearis* Hust.
(30) *Synedra ulna* (Nitz.) Ehr.
(31) *Synedra acus* Kuetz.
(32) *Fragillaria intermedia* Grun.
(33) *Tabularia fasciculata* Ag.
(34) *Hannea arcus* (Ehr.) Kuetz.
(35) *Rhopalopodia gibba* (Ehr.) O. Mull. v. *ventricosa* (Ehr.) Grun.

Table 1 Seasonal variation of the diatoms in Mansagar Lake, Jaipur during the study year April 2009 to March 2010

Diatoms	Mean number × 10^2 l^{-1} ± SD			
	Summer (2009-10)	Monsoon (2009)	Post monsoon (2009)	Winter (2009)
Anomoeneis sphaerophora	0.66 ± 0.66	0	0	1.45± 0.44
Amphora ovalis	0.5 ± 0.2	0	1.2 ± 0.15	2.05 ± 0.8
Aulocoseira crenulata	1.2 ± 0.25	0	0	1.0 ± 0.5
Cocconeis placentula v. euglypta	1.5 ± 0.22	0	1.67 ± 0.45	2.1 ± 0.24
Coscinodiscus locustris	9.2 ± 5.4	6.65 ± 2.5	6.2 ± 0.55	7.8 ± 2.0
Coscinodiscus centralis	8.0 ± 4.82	7.35 ± 3.9	8.65 ± 2.6	8.9 ± 2.3
Cyclotella meneghenia na	3.5 ± 3.17	2.7 ± 1.48	5.5 ± 0.78	6.4 ± 3.5
Cymbella tumida	1.6 ± 1.5	1.0 ± 1.0	2.1 ± 0.5	2.8 ± 0.45
Cymbella turgida	0.5 ± 0.5	0	0.3 ± 0.3	0.9 ± 0.15
Diatoma vulgare	1.0 ± 0.92	0.84 ± 0.6	1.5 ± 0.92	3.2 ± 0.44
Diadesmis confervacea	0	0	0.8 ± 0.6	2.2 ± 1.25
Epithemia turgida	0	0	0.16 ± 0.16	1.3 ±1.6
Eunotia lunaris	0	0	0	1.1 ± 0.76
Fragillaria intermedia	1.8 ± 0.18	1.0 ± 0.05	1.5 ± 0.92	2.5 ± 0.34
Gomphonema parvulum	0.5 ± 0.5	0	0.7 ± 0.17	1.4 ± 1.25
Gomphonema lanceolatum	0.65 ± 0.65	0	0.83 ± 0.83	1.5 ± 1.25
Hannea arcus	0	0	0	0.8 ± 0.76
Hantzschia amphioxys	1.0 ± 0.5	0	0.9 ± 0.9	2.0 ± 0.6
Melosira granulata	2.5 ± 0.86	1.2 ± 0.12	5.9 ± 0.6	6.7 ± 0.28
Melosira varians	1.84 ± 0.92	0	0.34 ± 0.34	1.25 ± 1.25
Navicula cuspidata v. ambigua	9.5 ± 5.4	7.6 ± 4.0	10.1 ± 2.0	12.5 ± 2.5
Navicula frugalis	0	0	0.24 ± 0.04	0.5 ± 0.5
Navicula radiosa	8.6 ± 3.5	6.2 ± 0.35	11.75 ± 1.20	12.6 ± 1.5
Navicula tripunctata	0	0	0.5 ± 0.5	1.4 ± 0.67
Nitzschia amphibia	4.67 ± 3.87	1.5 ± 1.5	2.17 ± 0.92	3.67 ± 2.02
Nitzschia linearis	0.5 ± 0.5	0	0.6 ± 2.0	1.7 ± 0.16
Nitzschia palea	7.2 ± 4.2	4.5 ± 4.5	7.1 ± 3.17	10.5 ± 5.5
Pinnularia borealis	2.8 ± 0.18	0.7 ± 0.92	1.0 ± 0.05	1.5 ± 0.92
Pinnularia viridis	1.8 ± 0.99	0.4 ± 0.3	1.12 ± 0.82	2.5 ± 0.34
Rhopalopodia gibba v. ventricosa	0	0	0.5 ± 0.5	1.0 ± 0.5
Stephanodiscus astrea	6.1 ± 0.25	5.5 ± 0 .15	5.3 ± 1.6	7.5 ± 1.5
Surirella tenera v. ambigua	0	0	0	0.6 ± 1.20
Synedra acus	4.4 ± 1.44	2.5 ± 0.15	3.6 ± 0.5	4.6 ± 0.25
Synedra rumpens v. familiaris	0.4 ± 0.4	0.35 ± 0.35	0.8 ± 0.8	1.2 ± 0.25
Synedra ulna	4.5 ± 0.28	3.6 ± 0.92	6.2 ± 2.02	8.8 ± 3.8
Tabularia fasciculata	0	0	0	0.4 ± 0.67
Total Bacillariophyceae	86.42	53.59	89.23	128.32

Mean ± standard deviation (SD) of 3 samples

is an important factor, which regulates the biogeochemical activities in the aquatic environment. Air and water temperature have highly considerable positive correlation with each other (r = 0.91, p < 0.01). Maximum water temperature was recorded during May and June and minimum in December and January. The variation in water temperature may be due to different timing of collection and the influence of season (Jayaraman *et al.* 2003). *p*H is one of the most important factors that serves as an index of the pollution. The lake water was slightly alkaline to highly alkaline (*p*H = 7.3-9.1). The higher value of *p*H during summer may be due to increased photosynthetic activity by phytoplankton and macrophytes as they demand more CO_2 than quantities furnished by respiration and decomposition. *p*H showed significant positive relationship with biological oxygen demand (r = 0.53, p < 0.05) as similar observations were made by Satpathy *et al.* (2007).

The total rainfall recorded was 174.4mm with maximum in the month of August depicting less diatom count and diversity whereas the relative humidity of environment ranged between 17-82% during the study period. Both rainfall and relative humidity have important positive correlation among them (r = 0.74, p < 0.01). The level of oxygen concentration in aquatic ecosystem is dependent on temperature, photosynthetic activity, respiration of biotic communities and organic loading. The higher values of dissolved oxygen in winter (3.8-5.48) and monsoon (3.4-3.8) months may be due to higher solubility of oxygen at relatively lower temperature and churning i e circulation and mixing of water due to surface runoff. The lower values of dissolved oxygen during summer months (2.0-3.2) can be attributed to the fact that the rise in temperature leads to the warming of water and ultimately helps in an increase of mineralization of nonliving matter which demands oxygen and decrease in solubility of oxygen at higher temperature (Kumar *et al.* 2005). Dissolved oxygen showed significant positive correlation with COD (r = 0.86, p< 0.01).

BOD indicates the presence of microbial activities and dead organic matter on which microbes can feed. During monsoon, surface runoff carries waste and sewage from the surrounding areas into the low-lying beds of the lake thereby increasing the respiratory activity of the heterotrophic organisms (Singhal *et al.* 1986). This might be the reason for lowest DO and highest BOD values in monsoon (r = -0.94, p<0.01). BOD showed highly significant positive relationship with TDS (r =0.74, p< 0.01) as similar observations were made by Tiwari and Chauhan (2006).

The maximum electrical conductivity was observed in February (2820μmho/ cm^2) and minimum in July (1395μmho/ cm^2). Record of highest electrical conductivity in winter and lowest in monsoon as dilution of water during the rains causes a decrease in

Table 2 Seasonal variation of physic-chemical parameters of water at Mansagar Lake from April 2009-March 2010

Parameters	Summer (2009-10) (Mean ± SE)	Monsoon (2009) (Mean ± SE)	Post monsoon (2009) (Mean ± SE)	Winter (2009) (Mean ± SE)
Colour	Green	Dark brown	Pale green	Bright green
pH	8.98 ± 0.04	7.467±0.08	7.95±0.51	8.367±0.06
TDS (mg l^{-1})	3733±530.26	4356±574.81	2614±186.0	2073.33±60.41
EC (μS cm^{-1})	1499.5±237.91	1618.66±138.11	2100±50.0	2540±167.73
DO (mg l^{-1})	2.475±0.26	3.6±0.115	3.92±0.12	5.13±0.196
BOD_5 (mg l^{-1})	46.75±6.49	28.33±3.75	18.5±1.5	30.0±1.15
COD (mg l^{-1})	104.75±18.20	112.67±8.95	120.5±3.5	194.0±13.17
WT (^oC)	27.4±2.66	23.4±1.24	24.25±0.25	19.66±1.08
AT (^oC)	32.67±2.12	28.7±1.79	25.55±2.0	21.76±1.14
TH (mg l^{-1})	311.5±23.11	426.0±18.33	358±8.0	333.3±14.53
RH (%)	29.5±1.14	69.0±6.55	52.5±2	28.33±4.91
RF (mm)	0.15±0.15	47.83±24.01	0.25±0.25	0.83±0.833

Mean ± standard error of 3 samples

Table 3 Correlation matrix among the physico-chemical properties and diatom density (no. l^{-1}) of the water of Mansagar lake and rainfall and relative humidity data during April 2009 to March 2010

Parameters	*p*H	TDS	EC	DO	BOD	COD	WT	AT	TH	RH	RF	TDD
*p*H	-	-0.90	-.247	-.419	.531*	-.073	.378	.341	-.657*	-.811**	-.664*	.471
TDS		-	.886**	-.711**	.743**	-.801**	.638*	.755**	.647*	.550	.657*	.750**
EC			-	.656*	-.593**	.728**	-.540*	-.674**	-.718**	-.669**	-.676**	.868**
DO				-	-.943**	.866**	-.826**	-.931**	-.252	-.056	-.058	.454
BOD					-	-.775**	.813**	.925**	.197	-.051	.045	-.347
COD						-	-.838**	-.851**	-.459	-.356	-.294	.647*
WT							-	.910**	.245	.055	-.058	-.509**
AT								-	.320	.078	.107	-.516*
TH									-	.905**	.634*	-.792**
RH										-	.749**	-.816**
RF											-	-.628*
TDC												-

* = Correlation is significant at p<0.05 level (2-tailed), '-' indicate negative correlation, ** = Correlation is significant at p<0.01 level (2-tailed), DO = Dissolved oxygen, TH = Total hardness, EC = Electrical conductivity, TDS = Total dissolved solids, WT = Water temperature, AT = Air temperature, BOD = Biological oxygen demand, COD = Chemical oxygen demand, RF = Rainfall, RH = Relative humidity and TDD = Total diatom density.

electrical conductance. The highly significant positive relationships of electrical conductivity with COD ($r = 0.72$, $p<0.01$) and DO ($r = 0.65$, $p<0.05$) revealed that changes in conductivity were clearly associated with the addition of pollutants in the system (Tiwari *et al*. 2004).

The values of total dissolved solids in water varied from a minimum of 1976mg/ l (January) to a maximum of 5008mg/ l (July). The highest average value for total dissolved solid might be due to accumulation of the anthropogenic activity which hampered the quality of water (Senthilkumar and Sivakumar 2008). The diatoms growth is favored by low level of dissolved solids found during post rainy and winter season. It showed highly significant positive correlation with BOD ($r = 0.74$, $p<0.01$) and significant positive relationship with the rainfall ($r = 0.65$, $p<0.05$) and the total hardness ($r = 0.64$, $p<0.05$).

COD indicates the pollution level of water body as it is related to the organic matter present in the lake (WQM Report 1999). The present study found inverse relation of dissolved oxygen with BOD ($r = -0.77$, $p<0.01$) in agreement with observations of Rao (1994).

Variation in both biological oxygen demand (BOD) and chemical oxygen demand (COD) also indicated deterioration of water quality during summer. As expected, COD values (67 - 216mg/ l) of lake water were higher than those obtained for BOD (10-59mg/ l) as the latter deals only with the oxidation of biodegradable organic matter. High COD values during rainy (97-128mg/ l)) and winter season (117-216mg/ l) were due to rise in input of surface run off and raw domestic sewage of Jaipur city.

Total hardness of water is mainly governed by the content of calcium and magnesium which largely combine with bicarbonates and carbonates (temporary hardness) and with sulphate, chlorides and other anions of minerals (permanent hardness). Mansagar lake water is nutrient rich as its total hardness value ranged from 270-450mg/ l supporting the study of Kaur *et al*. (1996) that reported high values of hardness are probably due to the regular addition of large quantities of sewage and detergents in the water body from the nearby residential localities. It showed highly positive relationship with the relative humidity ($r = .90$, $p<0.01$) and rainfall ($r = 0.63$, $p<0.05$).

Table 4 Seasonal variation of diversity indices of different diatom species in Mansagar Lake during April 2009 to March 2010

Diversity indices	Summer(2009-10)	Monsoon(2009)	Post monsoon(2009)	Winter(2009)
Shannon-Weiner diversity index (H')	1.195±0.15	1.077±0.004	1.312±0.05	1.372±0.09
Evenness Index (J')	0.844±0.05	0.895±0.005	0.872±0.01	0.903±0.02
Berger-Parker index of Dominance (D_{BP})	0.115±0.01	0.147±0.015	0.136±0.012	0.087±0.09

Table 5 Mansagar Lake bed samples of soil compared with normal soil (control) for basic properties

Soil analysis	Units	Control soil	Mansagar lake (mean values)
Sand	(%)	81	66
Silt	(%)	11	16
Clay	(%)	8	18
pH	(1:2)	6.50 -7.50	8.15
EC	milli mhos/cm	0.5 - 0.75	0.3
OC	(%)	1.25 - 3.00	1.5
Avail. 'N'	kg/ha	200-500 to 224-560	1390.19
Avail. 'K'	kg/ha	-	1021.44
Avail. 'K_2O'	kg/ha	125-250 to 169.40-380.80	1235.94
Avail. 'P'	kg/ha	-	202.16
Avail. 'P_2O_5'	kg/ha	20-50 to 27.10-67.76	462.95

Analysis of community structure revealed that Shannon-Weiner diversity index and evenness were highest in winter whereas Berger-Parker index of dominance was found maximum in monsoon (Table 4). The percentage composition of sand, silt and clay, *p*H, electrical conductivity, organic carbon, nitrogen, available phosphorus and potassium and their oxidized states (Table 5). The average readings obtained were compared with the normal soil range and the results obtained emphasized that Mansagar Lake bed have highly good quality nutrient rich soil. Hence, attribute to stimulate the growth of diatoms especially pennate ones which profusely found attached to sediments, pebbles and mud.

CONCLUSION

This study revealed that diatom densities exhibited the positive relationship with TDS, EC and COD. Hence, these variables were the important factors governing the abundance of diatoms in Mansagar Lake. Since, lake retaining their connection for a reasonably long period of time and is relatively occupied with aquatic macrophytes, weeds, phytoplankton's, zooplanktons and fishes; thus supporting diatom community either directly or indirectly. Therefore, this study necessitates that some drastic regulations be made and warrants remedial measures to save this lake as it supports a vast variety of diatoms acting as bio-indicators.

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