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STUDIES ON DIATOM DIVERSITY IN RESPONSE TO ABIOTIC FACTORS IN MAWATHA LAKE OF JAIPUR, RAJASTHAN

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ABSTRACT

The present investigation accounts on the diatom diversity, density and distribution in different seasons and their correlation with physico-chemical properties of water. The study period of 12 months duration from April 2009 to March 2010 revealed the presence of 30 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 19 genera viz. *Stephanodiscus, Coscinodiscus, Cyclotella, Gomphonema, Melosira, Navicula, Hantzschia, Eunotia, Rhopalopodia, Cocconeis, Amphora, Synedra, Diatoma, Surirella, Fragillaria, Anomoeneis*, *Nitzschia, Diadesmis and Pinnularia*. The deposited sediment samples of lake were found to be rich in sand (60%), silt (15%), clay (22%) 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 concludes that the diatom species attain maximum growth in post monsoon and winter months and gradually declines in summer to reach its minimum during monsoon.

Key words: Diatoms, Physico-chemical parameters, Mawatha Lake, Rajasthan.

INTRODUCTION

The Mawatha Lake is one of the oldest, well noted for its sophisticated design and grand architecture as well spiritually very significant Lake in Rajasthan being flanked by the Aravalli hills on the north and the east. This region falls under the semi-arid region of climatic zones and experiences a continental type of climate. It is generally classified into four seasons; Summer from March to June, Monsoon from July to September, Post-monsoon from October to November and Winter from December to February. Diatoms are an extremely important and diverse portion of the Great Lakes phytoplankton community. Diversity, distribution, abundance and variation in the biotic factors provide information of energy turnover in the aquatic systems (Forsberg, 1982). The diatom bloom provides the first pulse of photosynthesis in the lakes for the year kicking the food web into gear. The fall diatom bloom is also important to the organisms in the lake providing a pulse of food that will carry them through the winter. In India, particularly Rajasthan state the use of density and diversity of diatoms and their association as biological indicators in the assessment of water quality or trophic status have been made by several workers (Gandhi, 1955; Jakher et al 1990; Gupta and Sharma, 1993; Nautiyal et al, 1998; Chaturvedi et al, 1999; Singh et al 2006; Kumar et al, 2008, 2009 and Sengar et al, 2009).But still there are many such aquatic ecosystems that remain unexplored. The Mawatha Lake is one among them which has not received due attention. Hence, the present work is an attempt to study the seasonal influence of physico-chemical parameters of water on the diatom population, species composition and community organization.

History and Morphometric of Mawatha Lake

Lake Mawatha is a freshwater reserve located at an elevation of about 462 meters above sea level with apparently no outlet between Latitude 27°56'45" N and Longitude 75°51'45" E. It is situated adjacent to the Amber Fort built by Raja Jai Singh in the 15^{th} century and as on date its age is 612 years. The mirrors in the fort reflect the waters lake thereby creating a wonderful sight. The lake is being used for multipurpose utility such as irrigation, fish catching, drinking, washing and bathing. The Lake covers on water spread area of 14.2 square kilometers having water storing capacity of 39.76 x 10^4 cubic meters and its depth varies between 1.5 to 7.2 meters. This traditional lake exists as 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 Mawatha Lake. Collections were made with the help of planktonic mesh net (pore size 40 µm) 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" 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 and Anand, 1998). Rainfall and relative humidity data were collected from the State Meteorological Department, Jaipur.

Physico-chemical parameters of water such as dissolved oxygen, pH, total hardness, biological oxygen demand, chemical oxygen demand, total dissolved solids and electrical conductivity were analyzed by standard methods (APHA, 2000). During the course of the present investigation, five soil samples were collected from Mawatha lake sediments, air dried at room temperature and analyzed for their basic soil properties like pH, 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 diatom community of Mawatha Lake comprised of 30 species representing 8 centric and 22 pennate forms. Of which the major genera in terms of frequency and abundance were *Navicula* (4), *Gomphonema* (3), *Nitzschia* (3), *Synedra* (2), *Melosira* (2), *Coscinodiscus* (2), *Fragillaria*(2) and single species of the following diatoms; *Stephanodiscus, Pinnularia, Hantzschia, Cocconeis, Eunotia, Diadesmis, Cyclotella, Amphora, Surirella, Diatoma, Rhopalopodia* and *Anomoeneis.* The presence of these typical eutrophic species is characteristically indicative of the organically rich water. Majority of the forms were solitary and few colonial. Particularly, centric diatoms like *Amphora*, *Coscinodiscus, Stephanodiscus, Melosira* and *Cyclotella* were most dominant during the monsoon whereas distinct numbers of dominant genera of pennate diatoms like *Nitzschia, Navicula, Gomphonema, Pinnularia, Synedra, Fragillaria, Surirella, Diatoma* and *Anomoeneis* were dominant during winter season.

Table 1 represents the prominent seasonal variations in diatom diversity, clearly depicting highest number of diatoms in winter (30), followed by that in post monsoon (26), summer (23) and least was recorded in monsoon season. Similar observations were made by Dubey and Boswal (2009).

Table 1: *Seasonal variation of the diatoms in Mawatha Lake, Jaipur during the study year April 2009 to March 2010.*

	Mean number x 10^4 l^{-1} ± SD			
Diatoms	**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
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 meneghениana	3.5 ± 3.17	2.7 ± 1.48	5.5 ± 0.78	6.4 ± 3.5
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
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
Fragillaria pectinalis	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
Gomphonema parvulum	0	0	0	0.8 ± 0.76
Gomphonema olivaceum	1.0 ± 0.5	0	0.9 ± 0.9	2.0 ± 0.6
Hantzschia amphioxys	2.5 ± 0.86	1.2 ± 0.12	5.9 ± 0.6	6.7 ± 0.28
Melosira granulata	1.84 ± 0.92	0	0.34 ± 0.34	1.25 ± 1.25
Melosira varians	9.5 ± 5.4	7.6 ± 4.0	10.1 ± 2.0	12.5 ± 2.5
Navicula cuspidata v. ambigua	0	0	0.24 ± 0.04	0.5 ± 0.5
Navicula frugalis	8.6 ± 3.5	6.2 ± 0.35	11.75 ± 1.20	12.6 ± 1.5
Navicula radiosa	0	0	0.5 ± 0.5	1.4 ± 0.67
Navicula tripunctata	4.67 ± 3.87	1.5 ± 1.5	2.17 ± 0.92	3.67 ± 2.02
Nitzschia amphibia	0.5 ± 0.5	0	0.6 ± 2.0	1.7 ± 0.16
Nitzschia linearis	7.2 ± 4.2	4.5 ± 4.5	7.1 ± 3.17	10.5 ± 5.5
Nitzschia palea	2.8 ± 0.18	0.7 ± 0.92	1.0 ± 0.05	1.5 ± 0.92
Pinnularia borealis	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 ulna	4.5 ± 0.28	3.6 ± 0.92	6.2 ± 2.02	8.8 ± 3.8
Total Bacillariophyceae	**82.72**	**52.24**	**85.87**	**120.72**

Mean ± standard deviation (SD) of 3 samples

Fig. 1 showed that diatoms attain maximum density and size during winter months and these are also good indicators of water pollution. During the study period, the diatom count 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 count with the minimum value being recorded in July and the maximum in September. Subsequently, during post monsoon season, the diatom count revealed not much fluctuation.

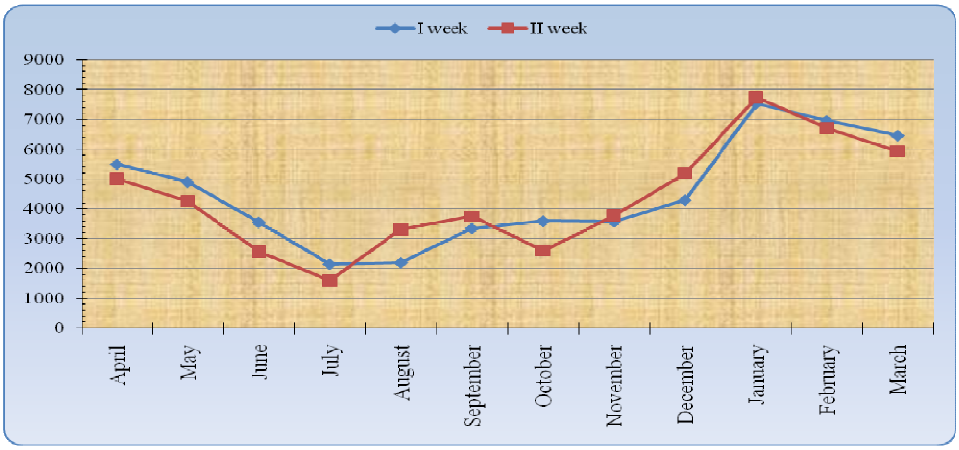

Figure 1: ***Quantitative studies of seasonal diatom cell abundance.***

Table 2 depicts the physico-chemical properties of water and Table 3, the Pearson co-relation matrix of different physico-chemical variables including total diatom count. The total diatom count showed significant positive co-relation with pH ($r = 0.55$, $p<0.05$) and total dissolved solids ($r = 0.68$, $p<0.05$) and highly significant positive co-relation with total hardness ($r = 0.69$, $p<0.01$).

Table 2: ***Seasonal variation of physic-chemical parameters of water at Mawatha 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	7.9 ± 0.3	7.5±0.5	7.2±0.5	7.8±0.6
WT (^{o}C)	28.4±2.6	23.4±1.4	24.0±1.2	18.6±1.8
AT (^{o}C)	34.6±2.2	28.7±1.6	28.5±2.5	21.7±1.4
DO (mg l^{-1})	2.8±0.5	4.6±0.35	5.9±0.25	6.4±0.20
BOD_5 (mg l^{-1})	45.5±5.6	30.2±3.5	28.5±1.5	32.0±1.5
COD (mg l^{-1})	106.75±25.0	122.67±9.5	142.5±13.5	64.0±23.2
TDS (mg l^{-1})	2208±230.2	2525±245.8	2266±120.0	2034±160.5
EC (µS cm^{-1})	405.5±123.5	554.4±138.12	389.2±150.0	158.0±165.5
TH (mg l^{-1})	308.0±12.2	226.0±8.5	268.0±8.0	312.0±10.5
Chloride (mg l^{-1})	65.5±2.0	32.4±1.2	46.5±1.5	54.5±3.5
NH_4Nitrogen(mg l^{-1})	1.2±0.5	0.5±0.5	0.8±0.2	1.0±0.2

P (mg l^{-1})	0.5±0.5	1.3±0.2	1.8±0.3	2.0±0.5
NO_3Nitrogen(mg l^{-1})	15.5±2.3	20.2±1.2	22.5±0.5	24.5±0.8
RH (%)	29.5±1.2	69.0±6.5	52.5±2.5	28.33±5.0
RF (mm)	0.15±0.2	47.83±24.0	0.25±0.2	0.83±0.8

Mean ± standard error of 3 samples

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

Parameters	pH	TDS	EC	DO	BOD	COD	WT	AT	TH	RH	RF	TDC
pH	-	-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 TDC = Total diatom count.***

Temperature is an important factor, which regulates the biogeochemical activities in the aquatic environment. Air and water temperature have highly considerable positive co-relation 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).

pH is one of the most important factors that serves as an index of the pollution. The lake water was slightly alkaline to alkaline (pH = 7.2 – 7.9). The higher value of pH 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. pH showed significant positive relationship with biological oxygen demand ($r = 0.53$, $p < 0.05$) as similar observations were made by Satpathy (2007).

The total rainfall recorded was 174.4 mm with maximum in the month of August depicting less diatom count & diversity whereas the relative humidity of environment ranged between 17- 82 % during the study period. Both rainfall and relative humidity have important positive co-relation 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 co-relation 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 (2820 μmho/cm^2) and minimum in July (1395 μmho/cm^2). Record of highest electrical conductivity in winter and lowest in monsoon as dilution of water during the rains causes a decrease in 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 1976 mg/l (January) to a maximum of 5008 mg/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 co-relation 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 - 216 mg/l) of lake water were higher than those obtained for BOD (10 – 59 mg/l) as the latter deals only with the oxidation of biodegradable organic matter. High COD values during rainy (97 - 128 mg/l)) and winter season (117 - 216 mg/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 & carbonates (temporary hardness) and with sulphate, chlorides and other anions of minerals (permanent hardness). Mawatha lake water is nutrient rich as its total hardness value ranged from 270 – 450 mg/l supporting the study of Kaur (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 ($r = 0.63$, $p < 0.05$).

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).

Table 4: ***Seasonal variation of diversity indices of different diatom species in Mawatha 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 depicts the percentage composition of sand, silt & clay, pH, Electrical Conductivity, Organic Carbon, Nitrogen, available Phosphorus and Potassium and their oxidized states. The average readings obtained were compared with the normal soil range and the results obtained emphasized that Mawatha Lake sediment samples have highly good quality nutrient rich soil. Hence, attribute to stimulate the growth of diatoms especially pennate ones which were profusely found attached to sediments, pebbles and mud.

Table 5: ***Mawatha Lake sediment samples of soil compared with normal soil (control) for basic properties.***

SOIL ANALYSIS	UNITS	CONTROL SOIL	MAWATHA LAKE (mean values)
Sand	(%)	81	60
Silt	(%)	11	15
Clay	(%)	8	22
pH	(1:2)	6.50 -7.50	7.5
EC	milli mhos/cm	0.5 - 0.75	0.32
OC	(%)	1.25 - 3.00	3.0
Avail. 'N'	kg/ha	200 - 500 to 224 - 560	1302.64
Avail. 'K'	kg/ha	-	1908.48
Avail. 'K_2O'	kg/ha	125 - 250 to 169.40 - 380.80	2309.26
Avail. 'P'	kg/ha	-	96.32
Avail. 'P_2O_5'	kg/ha	20 - 50 to 27.10 - 67.76	220.57

CONCLUSION

This study revealed that diatom densities exhibited the positive relationship with TDS, EC and COD. These variables were the important factors governing the abundance of mixed group of diatom species which indicated its nutritionally enriched status in Mawatha Lake. Considering various physicochemical parameters it can be concluded that the present environment of the lake is quite congenial for the well-being of aquatic flora and diatoms in particular and exhibit potentiality of high aquatic productivity.

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