Bot. Bull. Academia Sinica 28: 13-24 (1987)

BACILLARIOPHYCEAE OF TWO TROPICAL SOUTH INDIAN LAKES OF HYDERABAD

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(Received January 18, 1985; Accepted October 27. 1986)

Abstract

Two lakes of Hyderabad—Osman Sagar and Mir Alam, which serve as drinking water reservoirs are studied for their biology for two years (1977–78). Mir Alam, the older of the two, harboured denser diatoms. Diatoms formed the second largest group (2–36%) of algae after bluegreens. The shallower stations of both the lakes had more diatoms than the deep-water stations. 55 diatom species were identified in these lakes, forming the largest group (44%) to be represented qualitatively. 9–10 diatoms occurred perennially in either of the lakes. The distribution and periodicity of diatoms is discussed in detail with reference to the physico-chemical parameters.

Diatom-biomass relation shows that the correlations were poor indicating little contribution of this group to the biomass in these lakes. Osman Sagar, with greater percentage of diatoms, projected a better correlation. It is concluded that pigment content per unit volume of biomass was more for diatoms in Osman Sagar and bluegreens in Mir Alam. Assessment of the water quality based on diatom species indicates a deterioration as both the lakes showed presence or dominance of 10 to 12 pollution-tolerant species.

Key Words: Osman Sagar; Mir Alam; distribution; periodicity; water quality.

Introduction

The classical works of Pearsall (1923) and Hustedt (1938), and the pioneering works of Singh (1960), Zafar (1964, 1967), Munawar (1970, 1974) and Rao (1977) in the Indian waters paved the way for a better understanding of the ecology of diatoms. In this study an attempt is made to identify the conditions which helped the diatom growth and also a diatom-biomass relationship in two drinking water lakes of Hyderabad, India. The study was considered essential as diatoms were known to help in the eutrophication of water bodies (Duthie and Srnivasa, 1971).

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Materials and Methods

Two drinking water lakes of Hyderabad—Osman Sagar and Mir Alam, were studied for two years (1977-78) for their chemistry, biology and biomass. Osman Sagar, the younger of the two, with a surface area of 22.12 km^2 had 136.41 Mm^3 of water. Mir Alam with a surface area of 1.69 km^2 accommodated 8.12 Mm^3 of water. Three sites were selected from each lake, of which two represent offshore (designated as stations 1 and 2 of either lake in the text) and one nearshore (designated as station 3) regions.

Surface waters were analysed for their chemical parameters as per APHA (1971). Samples for phytoplankton were sedimented in 1000 cc measuring cylinders after fixing with Lugol's solution for a fortnight. Enumeration was done in the concentrate using a Sedwigrafter Counting Cell, and the results are reported as 'organisms per liter of lake water' (Welch, 1948). Biomass was studied in the second year as per the procedures given by Zafar (1966). Pigments were extracted in 90% acetone following the Procedures of Parsons and Strickland (1963). Statistical methods were calculated after Panse and Sukhatme, revised by Sukhatme and Amble (1978).

Results and Discussion

Osman Sagar and Mir Alam, are both of alkaline-bicarbonate type with pH always above 7.6. Mir Alam lake, the older of the two, generally showed higher

Table 1. *Stationwise averages of selected chemical parameters in Osman Sagar and Mir Alam*

Values except pH are in mg/l.

	Osman Sagar			Mir Alam		
	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3
pH	8.07	8.06	8.10	8.18	8.17	8.08
Inorganic C	40.68	39.97	38.10	61.87	52.74	65.53
Cl	28.92	30.89	32.39	50.77	52.01	49.87
Organic matter	1.76	1.55	1.65	5.65	6.08	5.29
O_2	7.16	7.50	7.71	6.68	6.43	4.61
Total N	3.71	3.97	3.50	1.79	2.52	2.69
Total P	0.24	0.24	0.26	0.49	0.49	0.41
Ca	67.27	68.28	75.99	88.94	90.37	99.07
Mg	69.05	66.07	57.39	51.60	48.19	49.86
Na	48.38	49.39	48.76	52.64	58.18	58.87
K	3.06	2.84	4.20	1.61	1.41	1.88
Total solids	500.92	468.46	476.46	671.24	675.67	772.45

concentrations of several chemical parameters (Table 1), except N, Mg and K, which were more in Osman Sagar. The cationic composition of Mir Alam (Ca>Na>Mg>K) differed from the freshwater composition (Rodhe, 1949), which was evident in Osman Sagar (Ca>Mg>Na>K).

Mir Alam harboured denser phytoplankton than Osman Sagar (Table 2). Bluegreens formed the most dominant group followed by diatoms in these lakes. Greens, euglenoid and dinoflagellates formed meagre composition. Shallower stations of both the lakes (stations 3) recorded denser diatoms qualitatively and quantitatively (Table 3). Barring stations 1 and 2 of Mir Alam, diatoms formed a major composition of phytoplankton. Fifty five species of diatoms were encountered during the present study, which formed approximately 44% of the total algal species recorded, forming thus the largest group to be represented qualitatively in these lakes.

Table 2. *Percentwise distribution of algal groups in Osman Sagar and Mir Alam*

	Osman Sagar			Mir Alam		
	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3
Chlorophyceae	4.01	4.17	3.65	2.25	2.03	6.22
Euglenophyceae	1.11	1.02	0.90	0.08	0.06	3.95
Bacillariophyceae	25.79	26.97	34.26	2.77	3.17	36.57
Dinophyceae	2.40	1.71	1.94	0.91	0.98	0.99
Cyanophyceae	66.69	66.13	59.33	94.01	93.77	52.29
Total algae ($\times 10^3$ org. No./1)	15.56	14.73	10.49	358.06	370.30	79.21

Table 3. *Stationwise distribution of diatoms in Osman Sagar and Mir Alam*

	Osman Sagar			Mir Alam		
	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3
No. of species	21	32	38	28	23	41
Organism No./1	3145	3052	3866	8237	8981	17528
% Composition of total algae	25.7	26.9	34.2	2.7	3.1	36.5

Spatial distribution of diatoms is listed in table 4. It was observed that *Melosira granulata, Cyclotella meneghiniana, Synedra ulna, Navicula cryptocephala, Cymbella affinis, C. cymbiformis, Amphora* sp., *Rhopalodia gibba, Nitzschia amphibia* and *N. palea* were recorded from both the lakes. *Achnanthes exigua, Navicula viridula, Mastogloia smithii, Diploneis ovalis* and *Cymbella* sp. were observed only in Osman Sagar lake, which had more oxygen, N, Mg and K. *Cyclotella glomerata, C. stelligera, N. cuspidata* var. *ambigua, N. halophila* and *Pinnularia interrupta* were confined only

Table 4. *Qualitative distribution of diatom species in Osman Sagar and Mir Alam lakes*

	Osman Sagar			Mir Alam		
	Stn 1	Stn 2	Stn 3	Stn 1	Stn 2	Stn 3
Melosira granulata (Ehr.) Ralfs	+++	+++	++	+	+	+
Cyclotella glomerata Bach.					+	+
C. ***meneghiniana*** Kuetz.	+++	+++	+++	+++	+++	+++
C. ***stelligera*** Cl. et Grun.				+	+	+
Synedra ulna (Nitzsch.) Ehr.	++	++	++	+	++	+++
Eunotia pectinalis (Kuetz.) Rabenh.			+			+
Achnanthes exigua Grun.		+				
A. ***lanceolata*** (Breb.) Grun.	+		+	+	+	++
A. ***lanceolata*** var. ***rostrata*** (Ostr.) Hust.			+			+
A. ***minutissima*** Kuetz.			+			++
A. ***minutissima*** var. ***cryptocephala*** Grun.					+	+
Cocconeis sp.	++	++	++	+		+
Navicula cryptocephala Kuetz.	+++	+++	+++	+++	+++	+++
N. ***cuspidata*** var. ***ambigua*** (Ehr.) Cl.				+	+	
N. ***gothlandica*** Grun.	++			+		
N. ***halophila*** (Grun.) Cl.				+		+
N. ***lanceolata*** (Ag.) Kuetz.		++		+		
N. ***mutica*** Kuetz.		++	+	+	+	+
N. ***pupula*** Kuetz.	++	+	++		+	+
N. ***pupula*** var. ***capitata*** Hust.			+			+
N. ***rhynchocephala*** Kuetz.	++	+	++			+++
N. ***rostellata*** Kuetz.			+	+		
N. ***subtilissima*** Cl.			+			+
N. ***viridula*** Kuetz.			+			
Pinnularia braunii (Grun.) Cl.		+	+	+		+
P. ***gibba*** Ehr.		+		+		+
P. ***interrupta*** W. Sm.				+		+
P. ***interrupta*** var. ***minor*** Boye P.			+	+	+	
Caloneis bacillum (Grun.) Mer.		+	+		+	+
Anomoeoneis exilis (Kuetz.) Cl.		+	+	+	+	+
A. ***serians*** (Breb.) Cl.			+			+
A. ***sphaerophora*** (Kuetz.) Pfitz.			+			+
Diploneis elliptica (Kuetz.) Cl.		+		+		
D. ***ovalis*** (Hilse) Cl.	+	+				
Stauroneis phoenicenteron Ehr.			+	+	+	+
Gryosigma distortum var. ***Parkerii*** Harr.	+	+	+			++
Pleurosigma angulatum (Queck.) W. Sm.		+		+		
P. sp.		+			+	

	Osman Sagar			Mir Alam		
	Stn 1	Stn 2	Stn 3	Stn 1	Stn 2	Stn 3
Mastogloia smithii Thwaites	+					
Gomphonema gracile Ehr.	++	++			+	
G. parvulum (Kuetz.) Grun.			++	+		++
G. sphaerophorum Ehr.			++			+++
Cymbella affinis Kuetz.	+	++	+++	+	+++	+++
C. cymbiformis (Ag? Kuetz.) V. H.	+	+	++	+	+	++
C. species	+	+	+			
Amphora sp.	+	+	+	+	+	++
Rhopalodia gibba (Ehr.) O. Mull.	+	+	+	+	+	++
Nitzschia acicularis var. *closterioides* Grun.		+	+			++
N. amphibia Grun.	++	++	++	++	+++	+++
N. obtusa var. *scalpelliformis* Grun.		+				+
N. palea (Kuetz.) W. Sm.	++	+++	+++	++	++	++
N. sigmoidea (Ehr.) W. Sm.		+	+			+
N. tryblionella Hantz.		+	+			+
Hantzschia amphioxys (Ehr.) Grun.			+			+
Surirella sp.	+	+	+			+

\+ Rare ++ Common +++ Dominant

to Mir Alam, which had more organic matter, P, Ca, Na and total solids. *Achnanthes exigua, Navicula cuspidata* var. *ambigua, N. gothlandica, N. lanceolata, Diploneis elliptica, D. ovalis, Pleurosigma angularis, P.* sp. and *Gomphonema gracile* were recorded from deep-water zones where NH_3, Ca and K was low and particulate organic matter and percent composition of dissolved iron were high. *Eunotia pectinalis, Achnanthes lanceolata* var. *rostrata, A. minutissima* var. *cryptocephala, Navicula subtilissima, N. viridula, Anamoeoneis serians, A. sphaerophora, Gomphonema sphaerophorum* and *Hantzschia amphioxys* showed up in shallow water regions where NH_3, Ca, K and particulate iron were more.

Cholnoky (1968) emphasised the higher requirement of oxygen by diatom species while Schoemann (1973) proved that diatoms can successfully form fairly in low amounts of oxygen. Station 3 of Mir Alam with lowest average of dissolved oxygen recorded not only the highest average of diatom population but also the greatest number of species (41). *Navicula cryptocephala, N. pupula, Nitzschia amphibia* and *N. palea* persisted there even when oxygen was as low as 0.8 mg/1. In the background of high organic matter content of this lake (5.3-6.1 mg/1) these species looked like 'meso-oxybionts', which according to Patrick (1948) thrive in oxygen deficient and organically rich situations.

In the present data, the stationwise averages of diatom populations changed in almost the same order as the averages of total cations, anions and their sums (Table 5). This obviously indicated the density of diatom populations increased with the concentrations of cations and anions. *Gomphonema parvulum* and *Anomoeoneis sphaerophora* developed where water was highly concentrated and *Cyclotella meneghiniana* where it was least.

Table 5. *Changes in the diatom populations (org. no./1) shown with selected chemical paramaters (mg/1)*

	Osman Sagar			Mir Alam		
	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3
Diatoms	3145	3052	3866	8237	8981	17528
Silicates	7.9	7.9	7.6	17.9	18.2	19.4
Cations	187.8	186.6	186.4	194.8	198.2	209.7
Anions	242.9	241.4	233.1	382.1	388.2	401.7
Total ions	430.7	428.0	419.5	576.9	586.4	611.4

Pearsall (1923), Rosenberg (1939) and Lund (1955) considered the importance of silica on the development of diatoms. Kilham (1971) while proposing his hypothesis concerning silica and the freshwater planktonic diatoms based on a survey of available literature, suggested a strong correlation between dominance of specific diatoms and the silica content of water. He further conceived that some measure of 'silica demand' could be used as an index of increasing environmental enrichment or eutrophication. The growth of diatoms in these lakes was probably not restricted for want of silica since it was plenty in both. Instead, diatoms contributed to the silicate content of water which was highest at the station where they were abundant. Singh (1960) and Zafar (1967) also made similar observations.

Periodicity

Osman Sagar experienced only one peak of diatoms in winter when water temperature was around 26°C (Fig. 1). It was dominated by *Cyclotella meneghiniana* and *Melosira granulata*. However Mir Alam showed two peaks—once in winter which persisted for about four months and the other in early summer (Fig. 2). *Cyclotella meneghiniana*, *Navicula cryptocephala*, *N. pupula*, *Cymbella affinis* and *Nitzschia acicularis* var. *closterioides* formed the winter peak. *Melosira granulata*, *Navicula* sp., *Gyrosigma distortum* var. *Parkerii*, *Anamoeoneis sphaerophora*, *Cymbella cymbiformis* and *Nitzschia palea* formed the summer peak. *Nitzschia amphibia* and *Rhopalodia gibba* were indifferent to the temperature variation. Rodhe (1948), Hustedt (1956), Round (1968), Patrick (1971), Munawar (1974) and Rao (1977) have all emphasised the importance of temperature on the periodicity of diatoms.

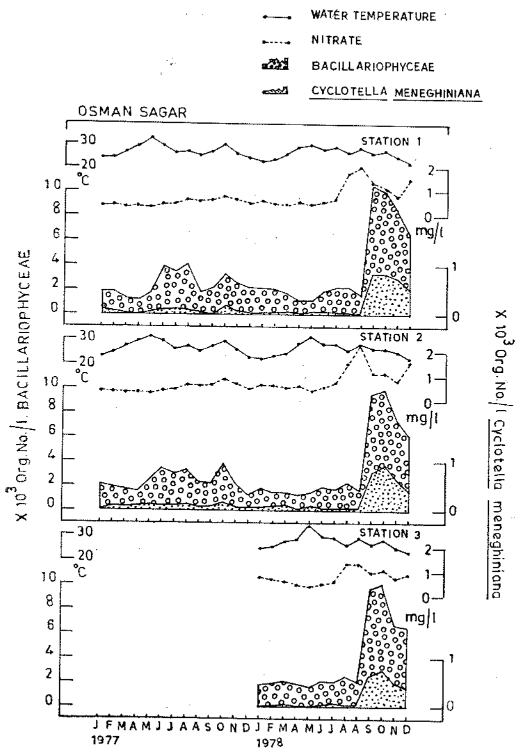

Fig. 1. Periodicity of Bacillariophyceae.

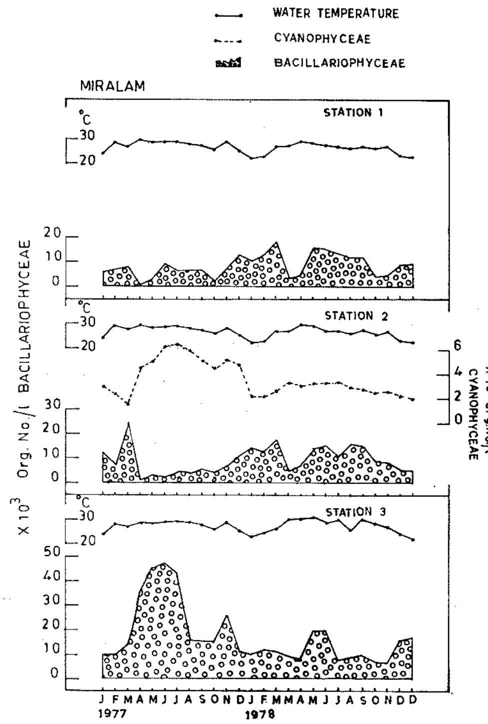

Fig . 2. Periodicity of Bacillariophyceae.

Table 6 enlists the seasonal distribution of diatoms in these lakes. Few species showed seasonal specificity occurring in a particular season. Some species, viz., *Rhopalodia gibba* was recorded in more than one season. The study further showed that a species found in one season in a lake, showed up in another season in the other, and vice versa, thus indicating that seasonal specificity of a species is confined to a particular ecosystem and is influenced by various chemical complexes confining to that region. Secondly, seasonal cycling could have delayed the appearance or disappearance of a particular species in a habitat. Ten species in Osman Sagar and nine in Mir Alam occurred perennially.

In the opinion of Whipple and Parker (1902), Pearsall (1923) and many others nitrate is the main factor that controls the periodicity of diatoms. From amongst the Indian workers no such relationship was found by Singh (1960), Zafar (1967) and Munawar (1974). Komarovsky (1953) and Prowse and Talling (1958) observed nitrate to vary inversely with diatom populations. Patrick (1977) inferred that diatoms utilised ammonia. In the present study *Cyclotella meneghiniana* tolerated nitrite concentration as high as 0.03 mg/1 in Osman Sagar. Its optimum development was reached only when nitrate content was high (Fig. 1). Similarly *Nitzschia*

Table. 6. *Lakewise seasonal distribution of diatom species*

	Osman Sagar	Mir Alam
Summer forms	*Fragilaria* sp.	*Melosira granulata*
	Eunotia pectinalis	*Navicula pupula*
	Diploneis ovalis	*N. rhynchocephala*
		Gomphonema gracile
		Amphora sp.
		Rhopalodia gibba
Monsoon forms	*Navicula gothlandica*	*Cocconeis* sp.
	N. halophila	*Rhopalodia gibba*
	Mastogloia smithii	*Nitzschia obtusa* var. *scalpelliformis*
	Nitzschia acicularis var. *closterioides*	*Hantzschia amphioxys*
	Surirella sp.	
Winter forms	*Achnanthes minutissima* var. *cryptocephala*	*Eunotia pectinalis*
		Nitzschia obtusa var. *scalpelliformis*
	Diploneis elliptica	
	Gyrosigma distortum var. *parkerii*	
Perennials	*Melosira granulata*	*Cyclotella meneghiniana*
	Cyclotella meneghiniana	*Synedra ulna*
	Synedra ulna	*Navicula cryptocephala*
	Cocconeis sp.	*Pinnularia braunii*
	Navicula cryptocephala	*Anomoeoneis sphaerophora*
	N. cuspidata var. *ambigua*	*Cymbella cymbiformis*
	Gomphonema parvulum	*Rhopalodia gibba*
	Cymbella affinis	*Nitzschia amphibia*
	Nitzschia amphibia	*N. palea*
	N. palea	

amphibia apparently utilised both inorganic and organic fractions of nitrogen as it attained its optimum only when inorganic to organic nitrogen was around unity.

Melosira granulata apparently released into water quite large quantities of nitrogenous materials which were converted to ammonia after a short while. This increased the ratio of inorganic to organic nitrogen to 28 (optimum) in the following months (July-August, 1977) at station 1 of Osman Sagar.

Periodicity of diatoms was also affected by the proportions of cations. Higher concentrations of calcium (75-125 mg/1) favored the development of *Cyclotella meneghiniana*, *Navicula cryptocephala* and *Nitzschia amphibia*. It was only once (in August 1978) that magnesium accumulated in large quantities (~260 mg/1) at all the stations of Osman Sagar. The active multiplication of *Cyclotella meneghiniana* was observed soon after this phase of water chemistry. May be, magnesium was the cause of multiplication of that diatom. *Cymbella cymbiformis* multiplied profusely at station 3 of Mir Alam which had high salinity (Na+Cl). Contrastingly *Nitzschia amphibia* multiplied only when Na+Cl was as low as 53 mg/1 in July 1977. This suggests the existing difference in the osmotic pressures of the diatoms. Again, it was only once (in July, 1977) that station 3 of Mir Alam exhibited potassium concentration as high as 8.12 mg/1 and specifically at that time *Cymbella cymbiformis* multiplised profusely.

Station 3 of Mir Alam was the richest of all in the suspended solide and consequently the turbidiest. It harboured and developed thick populations of *Navicula cryptocephala* and *Nitzschia amphibia*. Probably high turbidity accompanied by the reduction in light intensity stimulated the growth of these diatoms (Chandler, 1942). However this point cannot be stretched too much as the density of population itself would have been the cause of the increased values of suspended solids at that station.

The interactions of certain diatom species with Cyanophyceae was quite interesting. *Melosira granulata* was completely compatible to the growth of various bluegreen forms and looked like their associate. On the other hand, *Cyclotella meneghiniana* and *Navicula cryptocephala* were adversely affected when bluegreens were abundant. Such interactions are possibly explained on the basis of extracellular substance which could be toxic to one and stimulant to the other.

Diatoms and Biomass

Diatoms showed little impact on the contribution to biomass in these lakes. It can be generalised that biomass was more in Mir Alam as also the diatoms, which however was not reflected when stationwise averages were considered (Table 7). The shallower stations harbouring more diatoms had lesser biomass. Correlation studies were attempted to interpret their relationship. Generally the diatom-biomass correlations were poor in these lakes indication a negligible contribution of diatoms to biomass. Osman Sagar harbouring greater percentage of diatoms (around 30%) in its phytoplankton population projected a better correlation of the two lakes, significantly, the diatom-chlorophyll relationship (Table 8). One of the reasons could be the easier extraction of pigments from diatoms (Wetzel, 1975). On the other hand, diatoms forming a lesser proportion in

Table 7. *Stationwise averages of diatoms (org. no./1) shown with biomass parameters (g/m³)*

	Osman Sagar			Mir Alam		
	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3
Diatoms	3145	3052	3866	8237	8981	17528
Oven-dry biomass	5.68	6.56	5.22	17.02	20.24	6.73
Chlorophyll	0.15	0.14	0.12	1.78	1.93	0.86

Table 8. *Correlation (r) matrix showing diatoms with biomass parameters in Osman Sagar and Mir Alam lakes*

	Osman Sagar	Mir Alam
Diatoms vs chlorophyll	0.6524***	-0.1429
Diatoms vs oven-dry biomass	-0.1557	0.1239
Diatoms vs residual ash	-0.1653	-0.1395
Diatoms vs primary production	0.3638	0.0109

*** Significant at 1% level

Mir Alam, could not reflect such a correlation, which was overshadowed by the bluegreen-chlorophyll (r=0.6061, significant at 5% level). It can thus be concluded that the pigment content per unit volume of biomass was more for diatoms in Osman Sagar and bluegreens in Mir Alam.

Diatoms as an Index of Water Quality

An attempt was made to assess the water quality of these lakes based on diatoms. As already mentioned, both the lakes had denser diatom populations. However, on qualitative analysis of species, pollution-tolerant organisms like *Melosira granulata, Cyclotella meneghiniana, Navicula cryptocephala, Gomphonema parvulum, Nitzschia acicularis* var. *closterioides, N. palea, N. tryblionella* and *Hantzschia amphioxys* occurred in both the lakes. In addition, Osman Sagar recorded *Achnanthes exigua*, and Mir Alam had *Navicula halophila, N. pupula* var. *capitata* and *Gomphonema sphaerophorum*. The presence or dominance of these species indicates the deterioration of water quality in these lakes.

Acknowledgements

The author is grateful to Prof A R Zafar, Department of Botany, Osmania University, Hyderabad, India, for hig supervision, guidance and criticism during the present work. He is thankful to the Osmania University for providing laboratory facilities and to the Department of Science and Technology, Government of India, for financial assistance. Thanks are also due to Prof M R Suxena, Prof Jafar Nizam and Dr K P Rao for their encouragement.

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南印度 Hyderabad 二個熱帶湖的 Bacillariophyceae

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調查 Hyderabad 地方的二個當作飲用水源的湖—Osman Sagar 和 Mir Alam 的生物狀態兩年 (1977-78)，較老的一個湖 Mir Alam 生長有較密的矽藻，此矽藻構成湖中僅次於藍綠藻的第二大藻類族羣 (2-36%)，二湖中較淺的水域均比較深者生有較多的矽藻。已鑑定的55種矽藻佔矽藻族羣的 44%，並加以性質上的說明，9-10 種矽藻長期出現在二個湖中。矽藻的分佈與週期依性理化變數加以討論。

矽藻與生物量的相關很弱，顯示這族羣對湖的貢獻不大。但是，Osman Sagar 湖含有較高百分比的矽藻，反應出有較佳的相關。依此而論，在 Osman Sagar 中的矽藻和在 Mir Alam 中的藍綠藻其單位容積的生物量中所含之色素含量較高。

二湖中水質的評估是基於10-12種忍耐污染的矽藻的出現，作爲水質惡化的指標。