Journal of Applied Sciences Research, 3(12): 1809-1818, 2007

Floristic Study on Benthic Diatoms of the Groundwater Seepages at Kobri El-kobba (Cairo, Egypt)

Ahmed A. El-Awamri, Abd El-Salam M. Shaaban and Amal I. Saleh

Botany Dept., Faculty of Science, Ain Shams Univ., Cairo, Egypt.

Abstract: The present investigation concerned with seasonal floristic study on benthic diatoms of the groundwater seepages at Kobri El-Kobba (Cairo, Egypt). Materials of this study were collected during the period from January 2000 to February 2001. Some physical and chemical parameters of waters were also studied, in an attempt to find out the relationships between these environmental factors and diatom growth and species composition. A total of ninety diatom taxa representing 27 genera were identified. The collected samples included epilithic, epipelic and epiphytic growths as well as submerged algal filaments. Physico-chemical analysis revealed that the seepages water is brackish, very hard and generally characterized by high ionic content. *Amphora coffeaeformis*, *Terpsinoe musica, Navicula confervacea* and *Nitzschia amphibia* were the most common and widespread species. High total dissolved salts recorded thought to play an important role in shaping its diatom community. This mainly appeared in the dominance of some mesohalobien taxa throughout the different seasons. According to the available literature on the diatom flora of Egypt, the present investigation added one new taxon to all previous records, this was; *Achnanthes marginulata*. In addition, two of the recorded taxa considered as new to the diatom flora of The Greater Cairo; these were *Nitzschia bilobata* and *N. communis*.

Keywords: Floristic Study, Diatoms, Ground water Seepages, Egypt

INTRODUCTION

Diatoms occur in waters as well as in soils and aerial habitats where the light, temperature and chemical conditions are suitable for their growth. They also occur in all latitudes and longitudes of the world[19,27]. In the area between kobri El-kobba and Manshiyet El-Bakri (Cairo, Egypt) and along the two sides of the metro open tunnel a ground water exists as separate seepages for a long distance. Aerial epilithic and epipelic green, greenish brown and brown masses of algae are grown on the surface of wet cemented walls which surround the railways. Filaments of green and brown colours of algae that grown under the surface of water enclosed between the rails were also present. Some mosses, *Adiantum* sp. and *Phragmites* sp. were observed associated and intermingled with these algae.

This characteristic community attracted us to study diatom flora grown in this benthic habitats. Therefore the objective of the present work has been undertaken to do seasonal study on the diatom flora grow in the groundwater seepages at Kobri El-kobba in relation to some physicochemical parameters of water.

MATERIALS AND METHODS

Materials: This study area located at latitude 30° 5` N and longitude 31° 17.3` E (measured using GPS). The groundwater exists as separate seepages along the two sides of the metro open tunnel in the area between Kobri El-Kobba and Manshiyet El-Bakri. The seeps are observed above the bed surface by about 20 cm depth. In spite of the presence of several water suction pumps along this area, the observations reflect continuous flow of groundwater under the pressure head differences between the surrounding aquifer and the tunnel that the water table level is 11.5 m and the ground level (These information supplied by Research Institute for Ground Water "RIGW"). Thirty two samples were collected throughout the study period (8 samples per season). These samples were found in the form of aerial, epilithic, epipelic, epiphytic and filamentous growths distributed through this study area (Fig.1).

Methods: Water samples were taken from the groundwater seepages to analyze and determine the concentrations of some chemical parameters. These parameters include field measurements of water temperature, pH, dissolved oxygen (DO) and some

Corresponding Author: Ahmed A. El-Awamri, Botany Dept., Faculty of Science, Ain Shams Univ., Cairo, Egypt.

Fig. 1: Algal growth on the wet cemented walls.

chemical parameters. Laboratory chemical analysis of major cations and anions was carried out according to Jackson[14].

Epilithic and scum samples were scraped using a sharp blade shovel, while attached algal filaments were collected by hand. Epiphytic samples were scraped from leaves, stems and rhizomes of higher plants. Rhizoids of mosses and roots of higher plants were cut, immersed in some water, shaken vigorously and rubbed gently to remove the attached algal film. After a rapid examination when fresh, all samples were fixed in 4% formalin solution. The collected samples where prepared for investigation by cleaning frustules using the method described by Jouse *et al.*[16] the material was mounted according to the method described by Proschkina-Laverenko *et al*[21].

Examination, identification and counting of diatoms were carried out using oil immersion lens (100 x) of a binocular microscope (MICRO Star® AO Scientific Instruments). Photomicrographs were taking for the majority of species.

The diatom taxa were identified according to Zabelina *et al.*[28], Patrick and Reimer[19,20], Jensen[15], Gasse[13], Krammer and Lang-Bertalot[17,18] and Round *et al.*[22].

The counting method described by Vilbaste[26] was applied that 500 valves were counted per sample while the other valves were also identified and recorded. The relative abundance of each taxon was then indicated with:

P = Predominant (50-20 %), f = frequent (20-5 %), c = common (5-1 %), r = rare (1- 0.2 %), + = noted and - = not noted. In cases where the diatom abundance was low, only 200 valves were counted.

RESULTS AND DISCUSSIONS

Results:

Physico-chemical Characteristics: Minimum water temperature was recorded in winter (21˚c), while the maximum was recorded in summer (29˚c).The recorded pH values were in the slightly alkaline side that ranged between 7.2 in winter and 7.7 in spring.Electrical conductivity values recorded throughout the different seasons were relatively high that ranged between 6.67 ds/m in autumn and 8.58 ds/m in summer. As calculating the total dissolved salts (T.D.S.), it was found that the water at this locality is brackish (T.D.S. values ranged between 4268.8 ppm in autumn and 5491.2 ppm in summer). Dissolved oxygen concentrations ranged between 8.2 ppm in spring and 11 ppm in autumn. As considering the cationic composition of water, it was found that sodium was the dominant cation that its concentration ranged between 824.37 ppm in autumn and 1448.28 ppm in spring. Maximum concentration of calcium was recorded in summer (501 ppm), while the minimum was recorded in autumn (206.41 ppm). Magnesium concentrations reached its maximum value in autumn (285.89 ppm) while its minimum value was recorded in winter (121.65 ppm).Maximum potassium concentration was recorded in summer (32.43 ppm) while the minimum was recorded in autumn (4.69 ppm). Regarding the anionic composition of water, chloride was the dominant anion that its concentration ranged between 1628.72 ppm in autumn and 2464.54 ppm in winter. The lowest value of bicarbonate concentrations recorded in spring (146.34 ppm) while the highest value was recorded in autumn (439.02 ppm). Carbonate concentration was under the detected level in all seasons. Minimum sulphate concentration was recorded in winter (299.04 ppm), while maximum was recorded in autumn (800.96 ppm). Nitrate concentrations were ranged between 0.2 ppm in summer and 0.5 ppm in autumn. Nitrite concentrations were constant in winter, spring and summer (0.1 ppm), while in autumn the concentration was 0.2 ppm. Phosphate concentrations ranged between 0.5 ppm in summer and 1 ppm in both spring and autumn. Silicate concentrations fluctuated between 10 ppm in both winter and summer and 12 ppm in autumn. As calculating the water hardness, it is apparent that water is very hard and hardness values ranged between 1126.21 ppm in winter and 2252.46 ppm in summer.

Diatom Flora: Through the examination of the fresh materials, it was noted that the surface of submerged filamentous algae, particularly *Cladophora* was coated by loosely attached long ribbons of *Achnanthes brevipes* var. *intermedia* and fan shaped colonies of *Synedra tabulata*. However, such observation was not consistent in all seasons. In addition, through the preliminary examination of samples, it was observed that some of the encountered species such as *Navicula confervacea*, *Biddulphia laevis*, *Terpsinoe musica* and *Achnanthes brevipes* var. *intermedia* were mostly present in the form of long chains (filaments).

Table 1: Mean seasonal frequencies of diatom taxa recorded at Kobri El-Kobba during 2000-2001.

Diatom taxa ↓ Season →	Winter	Spring	Summer	Autumn
Class:Centricae				
Genus:.*Cyclotella* Kützing				
Cyclotella Kützingiana Thwaites.	-	+	-	r
C.meneghiniana Kütz.	r	r	r	+
C.ocellata Pant.	r	r	r	r
Genus: *Melosira* Agardth				
Melosira granulata (Ehr.) Ralfs.	+	r	r	r
M.granulata var.*angustissima* O.Müll.	-	+	+	+
Genus:*Stephanodiscus* Ehrenberg				
Stephanodiscus hantzschii Grun.	+	+	+	r
Genus:*Thalassiosira* Cleve				
Thalassiosira fluviatilis Hust.	+	+	r	r
Genus:*Biddulphia* Gray				
Biddulphia laevis Ehr.	c	c	c	r
Genus: *Terpsinoe* Ehrenberg				
Terpsinoe musica Ehr.	p	f	f	f
Class: Pennatae				
Genus: *Fragilaria* Lyngbye				
Fragilaria construens (Ehr.) Grun.	-	-	-	+
F.construens var.*subsalina* Hust.	r	r	r	r
F.construens var. *venter* (Ehr.) Grun.	+	r	-	r
F.pinnata Ehr.	-	-	-	r
F.pinnata var. *lancettula* (Schumann) Hust.	+	-	r	-
Genus: *Synedra Ehrenberg*				
Synedra acus var. *radians* (Kütz.) Hust.	+	+	+	+
S.tabulata (Ag.) Kütz.	f	f	c	r
S.ulna (Nitzsch.) Ehr.	+	r	r	c
S.ulna var. *aequalis* (Kütz.) Hust.	r	+	r	c
S. ulna var. *danica* (Kütz.) Grun.	-	+	r	r
S. ulna var. *impressa* Hust.				
Genus: *Achnanthes* Bory				
Achnanthes brevipes var. *intermedia* (Kütz.) Cl.				
A. exigua Grun.	f	c	r	f
A. gibberula Grun.	r	r	c	c
A. hungarica Grun.	r	r	+	-
A. lanceolata (Bréb.) Grun.	+	-	-	-
A. marginulata Grun.	c	r	r	c
A. minutissima var.*cryptocephala* Grun.	r	-	-	-
A. orientalis Hust.	r	c	c	c
Genus:*Cocconeis* Ehrenberg	r	+	r	r
Cocconeis placentula var.*euglypta* (Ehr.) Cl.				
Genus: *Rhoicosphenia* Grunow	+	+	+	+
Rhoicosphenia curvata (Kütz.) Grun. ex. Rabh.	r	r	-	+
Genus: Amphiprora Ehrenberg				
Amphiprora alata Kütz.	+	r	r	r
Genus: *Amphora* Ehrenberg				
Amphora coffeaeformis (Ag.) Kütz	f	f	p	f
A. ovalis var. *pediculus* (Kütz.) V.H.ex Det	+	-	-	-
A.perpusilla Grun.	r	r	r	r
Genus: *Caloneis* Cleve				
Caloneis amphisbaena (Bory.) Cl..	-	-	-	+
C. budensis (Grun.) Krammer.	c	c	r	r
C. clevei (Lagst.) Cl.	c	r	+	+
C. silicula (Ehr.) Cl.	-	+	-	-
Genus: *Cymbella* Agardh				
Cymbella affinis Kütz.	c	c	f	c
C.pusilla Grun.	f	c	c	f
Genus: *Diploneis* Ehrenberg				
Diploneis ovalis (Hilse) Cl.	c	c	c	c
D. ovalis var. *oblongella* (Nag.) Cl.	r	+	+	+
Genus: *Gomphonema* Hustedt				

Table 2: Continued.

Gomphonema angustatum (Kütz) Rabh.	+	+	-	r
G. angustatum var. *productum* Grun.	+	-	-	+
G. gracile Ehr.	+	+	+	+
G. gracile var. *lanceolatum* kütz.	+	+	+	+
G. intricatum Kütz.	+	-	-	-
G. lanceolatum var.*insignis* (Greg.)Cl.	-	+	-	+
G. longiceps var. *subclavata* Grun.	+	+	+	r
G. parvulum (Kütz.) Grun.	r	r	r	r
G. parvulum var. lagenulum (Kütz.Grun.) Hust.	+	r	r	-
Genus: *Gyrosigma* Hassall				
Gyrosigma acuminatum (Kütz.) Rabh .	+	-	-	-
Genus: *Navicula* Bory				
Navicula confervacea (Kütz.)Grun.	r	f	f	f
N.cryptocephala Kütz.	-	+	+	r
N.cryptocephala var. *veneta* (Kütz.) Grun.	c	c	c	c
N.cuspidata (Kütz.) Cl.	+	-	-	-
N. cuspidata var. *ambigua* (Ehr.) Grun.	-	+	+	-
N.mutica kütz.	+	-	-	-
N.mutica var.*cohnii* (Hilse) Grun.	+	+	-	-
N.pupula Kütz.	-	-	-	+
N.pygmaea Kütz.	-	-	-	+
N.rhynchocephala Kütz.	-	+	-	-
N.symmetrica Patr.	-	+	+	+
Genus: *Pinnularia* Ehrenberg				
Pinnularia acrosphaeria W.Sm.	-	+	-	-
P. braunii var. *amphicephala* (A.Mayer) Hust.	+	-	-	-
Genus: *Pleurosigma* W. Sm.				
Pleurosigma elongatum W.Sm.	r	r	r	r
Genus: *Stauroneis* Ehrenberg				
Stauroneis sp.	+	-	-	-
Genus: *Rhopalodia* O.Müller				
Rhopalodia musculus (Kütz.) O.Müller.	r	+	+	r
Genus: *Bacillaria* Gmelin				
Bacillaria paradoxa Gmelin.	r	+	-	+
Genus: *Hantzschia* Grunow				
Hantzschia amphioxys (Ehr.) Grun.	+	-	-	-
H.amphioxys form *capitata* O.Müll.	+	-	-	-
Genus: *Nitzschia* Hassal				
Nitzschia amphibia Grun.	f	f	f	p
N. apiculata (Greg.) Grun.	r	+	-	-
N. bilobata W.Sm.	+	+	-	-
N. clausii Hantzsch.	r	r	+	r
N. communis Rabh.	+	+	-	+
N. dissipata (Kütz.) Grun.	+	-	+	+
N. fonticola Grun.	r	r	+	r
N. frustulum (Kütz.) Grun.	+	-	+	-
N. hungarica Grun.	+	+	+	+
N. linearis W.Sm.	+	+	-	-
N. microcephala Grun.	r	r	r	r
N. obtusa W.Sm.	+	-	+	-
N. obtusa var. *scalpelliformis* Grun.	c	c	r	c
N. palea (Kütz.) W.Sm.	c	c	c	r
N. sigma (Kütz.) W.Sm.	-	+	-	-
N. thermalis Kütz.	-	+	r	+
N. trybionella var. *debilis* (Arnott) A.Mayer.	-	-	+	+
N. vitrea Norman.	-	+	-	+
Genus:*Surirella* Turpin				
Surirella ovalis Bréb.	+	r	-	+
Total number of genera	27	24	20	23
Total number of taxa	70	68	56	65

P = predominant (50-20%), f = frequent (20-5%), c = common (5-1%), r = rare (1-0.2%),
+= noted, - = not noted.

As observing the diatom species hosted on mosses rhizoids, a slight increase in the frequency of *Diploneis ovalis*, *Nitzschia amphibia* and *Caloneis budensis* in many of the examined samples was observed. After cleaning, mounting, identifying and counting of each sample, the mean frequency of the recorded taxa in each season was calculated and summarized in (Table 1). A total of 90 diatom species representing 27 genera related to 8 families and 4 orders were identified from all the samples collected from Kobri El-Kobba. Class Pennatae was qualitatively and quantitatively dominant. It was represented by 81 taxa related to 21 genera while class Centricae was only represented by 9 taxa related to 6 genera. *Nitzschia*, *Navicula*, *Gomphonema* and *Achnanthes* were the richest genera in terms of species number that were represented by 18, 11, 9 and 8 species, respectively. The highest and the lowest numbers of both genera and taxa were recorded in winter (27 genera and 70 taxa) and summer (20 genera and 56 taxa) respectively .

Based on the present data, *Amphora coffeaeformis*, *Navicula confervacea* and *Nitzschia amphibia* were the most widespread species in this study area that were recorded in all the examined samples (32 samples). These species were also quantitatively significant all over the year. In addition, another 12 species (*Diploneis ovalis*, *Cymbella pusilla, C. affinis*, *Achnanthes minutissima* var. *cryptocephala*, *Terpsinoe musica*, *Nitzschia obtusa* var. *scalpelliformis*, *Achnanthes breviceps* var. *intermedia, Amphora perpusilla, Pleurosigma elongatum, Biddulphia laevis, Nitzschia microcephala and Synedra tabulata*) were recorded in more than 70% of the collected samples. Many of the latter species were also recorded in high frequencies throughout the different seasons.

Regarding the dominant species in the different studied seasons, it was found that *Terpsinoe musica* dominated the diatom flora in winter, whereas *Synedra tabulata*, *Amphora coffeaeformis*, *Nitzschia amphibia*, *Achnanthes brevipes* var. *intermedia* and *Cymbella pusilla* were the most frequent species during this season. However, *Synedra tabulata*, *Navicula confervacea*, *Nitzschia amphibia*, *Amphora coffeaeformis* and *Terpsinoe musica* were the most frequent species during spring. *Amphora coffeaeformis* was the most predominant species during summer, while *Nitzschia amphibia*, *Cymbella affinis, Navicula confervacea* and *Terpsinoe musica* were frequent during this season. Autumn flora was characterized by the quantitative dominance of *Nitzschia amphibia*, whereas *Amphora coffeaeformis*, *Navicula confervacea*, *Terpsinoe musica, Achnanthes brevipes* var. *intermedia* and *Cymbella pusilla* were the most frequent taxa during this season.

Discussion: The most common and widespread taxa were *Amphora coffeaeformis*, *Terpsinoe musica, Nitzschia amphibia* and *Navicula confervacea*. *Amphora coffeaeformis* was described by Gasse[13] as epipelic, epiphytic or aerophilous brackish water organism in stagnant or running water of medium to high conductivity. *Nitzschia amphibia* could be described as aerophytic, planktonic or benthic organism very common in electrolyte poor to very electrolyte-rich waters[5,6]. Additionally, the latter species was described by Silva-Benavides[25] as moderately tolerant species to organic pollution. *Navicula confervacea* was regarded by Caljon and Cocquyt[5] as aerophytic-benthic organism. In addition, this species was considered by Gasse[13]; Ziller and Economou-Amilli[29] and Round *et al*.[22] as indicator of intermittent pollution. Ecological characteristics of *Terpsinoe musica* were discussed in the work of El-Awamri *et al*.[9].

The growth of some diatom taxa such as *Navicula confervacea*, *Biddulphia laevis*, *Terpsinoe musica* and *Achnanthes brevipes* var. *intermedia*, which inhabit the water of study area, in the form of long filaments may help these taxa to resist the strong continuous flow of ground water and reduce the probability of washing these taxa away from the substrate.

Some of the physico-chemical characteristics of the groundwater seepages at Kobri El-Kobba, particularly the total dissolved salts thought to play an important role in shaping its diatom community. According to Davis and De Wiest[7], the water of this locality could be classified as brackish water. The reflection of this character on the diatom flora appeared in the dominance of some mesohalobien taxa such as *Amphora coffeaeformis*, *Cymbella pusilla*, *Synedra tabulata* and *Achnanthes brevipes* var. *intermedia* which were recorded in high frequencies throughout the different seasons. These taxa were considered to be most commonly associated with brackish and saline water habitats with relatively high ionic strength[19,20,15,2,3,4]. Elevated salinity and conductivity in such habitat may be due to high evaporation rate.

During the systematic study of the diatom flora, a total of 90 taxa related to 27 genera were identified. According to the main available literature on the diatom flora of Egypt[23,8,12,11,24,10,1], the present investigation added one taxon to all previous records of the Egyptian diatom flora; this was *Achnanthes marginulata*. In addition, two of the recorded taxa considered as new to the diatom flora of The Greater Cairo; these were *Nitzschia bilobata* and *N. communis*.

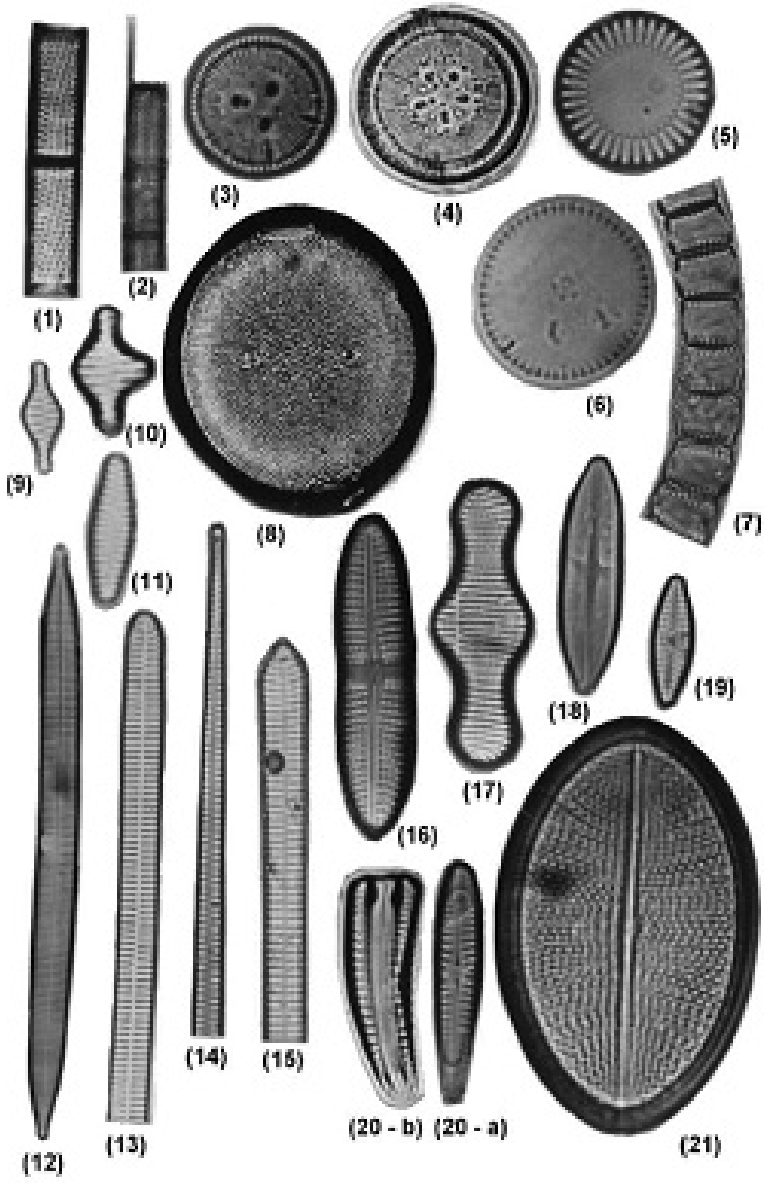

Plate I:

1- *Melosira granulata* (Ehr.) Ralfs. (x 1500).
2- *M. granulata* var.*angustissima* O. Mull. (x 1500).
3- *Cyclotella ocellata* Pant. (x 1500).
4- *C. Kützingiana* Thwaites. (x 1500).
5- *C. meneghiniana* Kütz. (x1500).
6- *Thalassiosira fluviatilis* Hust. (x 1500).
7- *Stephanodiscus hantzschii* Grun. (x 1500).
8- *Biddulphia laevis* Ehr. (x1000).
9- *Fragilaria pinnata* var. *lancettula* (Schumann) Hust. (x1500).
10- *F. construens* (Ehr.) Grun. (x 1500).
11- *F. construens* var. *subsalina* Hust. (x 1500).
12- *Synedra ulna* (Nitzsch.) Ehr. (x 800).
13- *S. ulna* var. *aequalis* (Kütz.) Hust. (x 1000).
14- *S. ulna* var. *danica* (Kütz.) Grun. (x 1000).
15- *S. ulna* var. *spathulifera* Grun. (x 1000).
16- *Achnanthes brevipes* var. *intermedia* (Kütz.) Cl. "valve view"(x1000).
17- *A. inflata* (Kütz.) Grun. "rapheless valve" (x 1500).
18- *A. hungarica* Grun. (x 1500).
19- *A. lanceolata* (Bréb.) Grun. (x 1500).
20- (a) *Rhoicosphenia curvata* (Kütz.) Grun. ex. Rabh. "valve view" (x 1500).
(b) *Rhoicosphenia curvata* (Kütz.) Grun. ex. Rabh. "girdle view" (x 1500).
21- *Cocconeis placentula* Ehr. "rapheless valve" (x 1500).

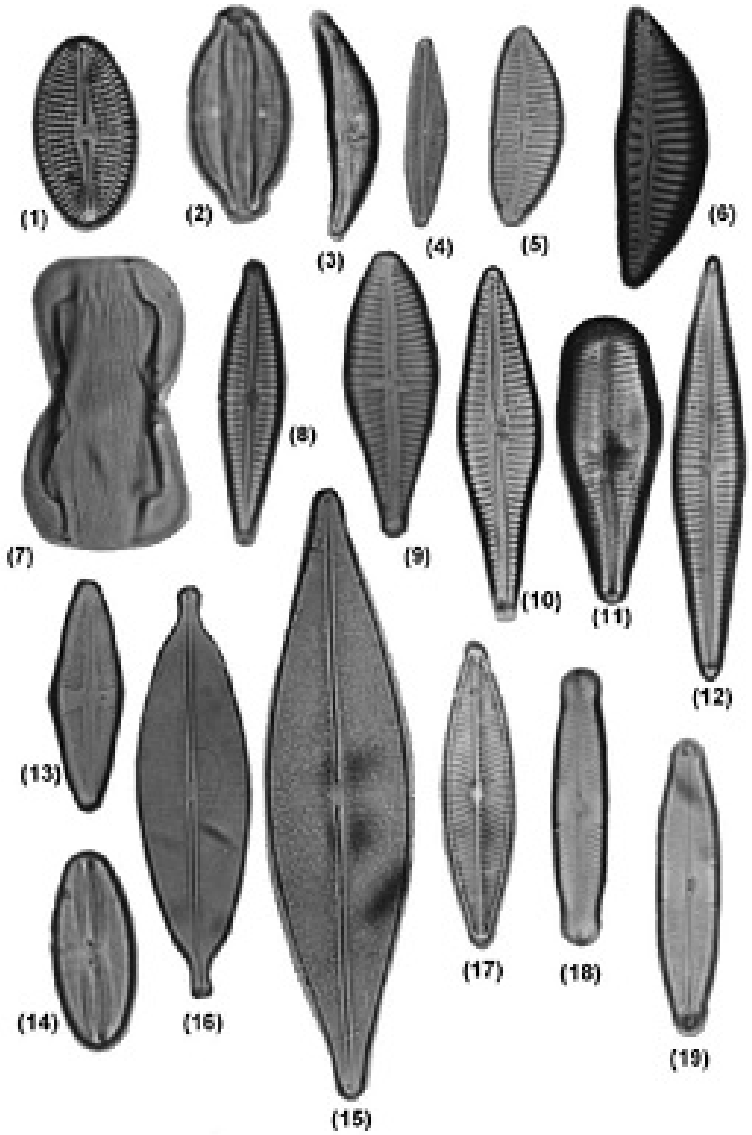

Plate II

1- *Diploneis ovalis* (Hilse) Cl. (x 1500).
2- *Amphora coffeaeformis* (Ag.) Kütz. (x 1500).
3- *A. ovalis* var. *pediculus* (kütz) V.H.ex Det. (x 1500).
4- *Cymbella pusilla* Grun. (x 1500).
5- *C. affinis* Kütz. (x 1500).
6- *C. ventricosa* Kütz. (x 1500).
7- *Amphiprora alata* Kütz. (x 1500).
8- *Gomphonema parvulum* (Kütz.) Grun. (x 1500).
9- *G. angustatum* var. *productum* Grun. (x 1500).
10- *G. lanceolatum* var.*insignis* (Greg.)Cl. (x 1500).
11- *G. constrictum* var. *capitatum* (Ehr.) Cl. (x 1500).
12- *G. gracile* Ehr. (x 1500).
13- *Navicula mutica* kütz. (x 1500).
14- *N. pygmaea* Kütz. (x 1500).
15- *N. cuspidata* (Kütz.) Cl. (x 1500).
16- *N. cuspidata* var.*ambigua* (Ehr.) Grun. (x 1500).
17- *Navicula rhynchocephala* Kütz. (x 1500).
18- *Caloneis budensis* (Grun.) Krammer. (x 1500).
19- *C. clevei* (Lagst.) Cl. (x 1500).

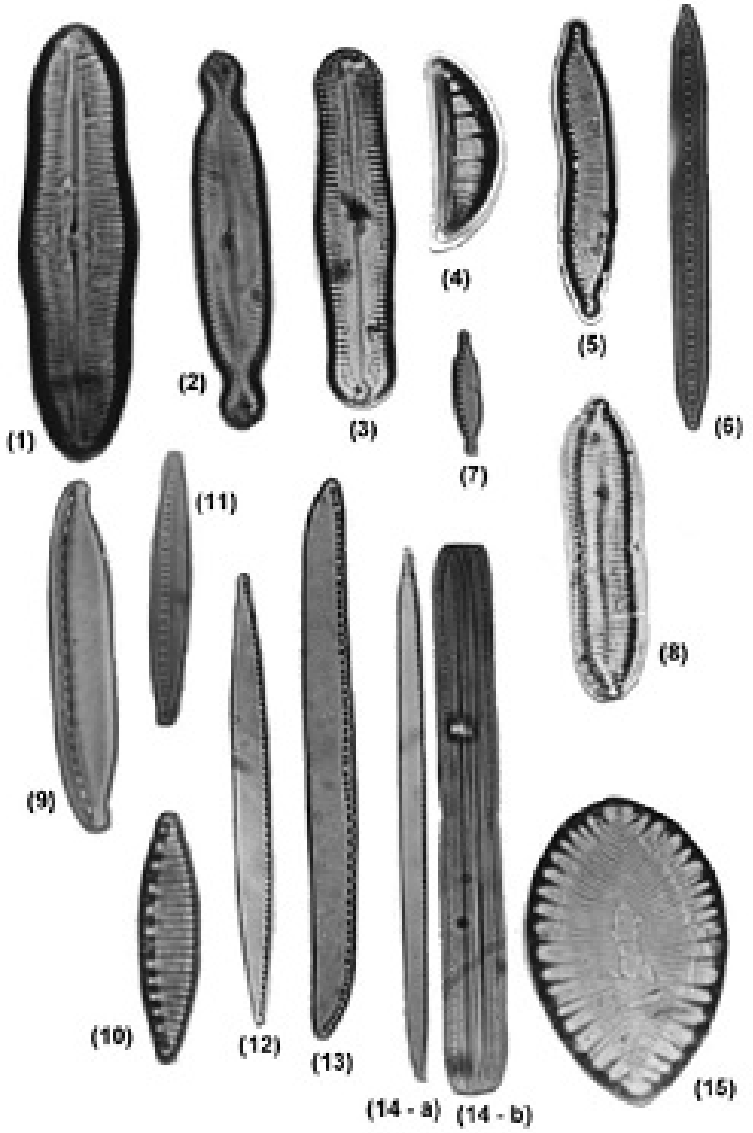

Plate III:

1- *Caloneis silicula* (Ehr.) Cl. (x 1000).
2- *Pinnularia braunii* var. *amphicephala* (A.Mayer) Hust. (x 1500).
3- *P. acrosphaeria* W.Sm. (x 1500).
4- *Rhopalodia musculus* (Kütz.) O.Müller. (x 1500).
5- *Hantzschia amphioxys* (Ehr.) Grun. (x 1500).
6- *Bacillaria paradoxa* Gmelin. (x 1000).
7- *Nitzschia microcephala* Grun. (x 1500).
8- *N. hungarica* Grun. (x 1500).
9- *N. vitrea* Norman. (x 1500).
10- *N. amphibia* Grun. (x 1500).
11- *N. dissipata* (Kütz.) Grun. (x 1500).
12- *N. palea* (Kütz.) W.Sm. (x 1500).
13- *N. obtusa* var. *scalpelliformis* Grun. (x 1000).
14- (a) *N. linearis* W.Sm. "valve view" (x 800).
(b) *N. linearis* W.Sm. "girde view" (x 800).
15- *Surirella ovalis* Bréb. (x 1500).

REFERENCES

1. Abd El-Fattah, H.M., 2007. A study on the geographical distribution of algae in Wadi El Natron region using the technologies of remote sensing and geographic information system. M.Sc. Ain Shams Univ., pp: 285.
2. Blinn, D.W., 1993. Diatom community structure along physico-chemical gradients in saline lakes. Ecology, 74: 1246-1263.
3. Blinn, D.W., 1995. Diatom community structure along salinity gradients in Australia saline lakes: biogeographic comparisons with other continents. In: A Century of Diatom Research in North America. Special symposium for Patrick and Reimer Festschrift. P. Kociolek and M. Sullivan (eds.). Koeltz Scientific Books, Koenigstein, pp: 163-174.
4. Blinn, D.W. and P.C.E. Bailey, 2001. Land-use influence on stream water quality and diatom communities in Victoria, Australia: a response to secondary salinization. Hydrobiologia, 466: 231-244.
5. Caljon, A.G. and C.Z. Cocquyt, 1992. Diatoms from surface sediments of the northern part of Lake Tanganyika. Hydrobiologia, 230: 135-156.
6. Cox, E.J., 1996. Identification of Freshwater Diatoms from Live Material. Chapman and Hall, London, pp: 158.
7. Davis, S.N. and R.J.M. De Wiest, 1966. Hydrogeology. John Wiely and Sons, New York, pp: 463.
8. El-Awamri, A.A., A.F. Hamed and A.A. Koussa, 2000. Some ecological aspects of Lake Mariut using phytoplankton as biological indicators. In: Proceedings of 1st Int. Conf. Biol. Sci. (ICBS). Fac. Sci., Tanta Univ., pp: 14-33.
9. El-Awamri, A.F, A.S. Shaaban and A.I. Saleh, 2003. Morphology and Ecology of the centric diatom *Terpsione musica* Ehrenberg based on material collected from, Cairo, Egypt. Egyptian J. Phyco., 4(2): 161-74.
10. El-Awamri, A.F, A.S. Shaaban and A.I. Saleh, 2005. Diatom flora from different Aquatic Habitats in the Greater Cairo (Egypt) Int. J. Argri. Bio., 7(2): 230-39.
11. El-Naghy M.A., A.M. El-Shahed, A.A. Fathi and G.G. Ahmed, 2004. Algal Flora of Rice fields at El-Kharga Oasis, Egypt Egyptian J. Phyco., 5: 51-69
12. Gab-Allah, M.M. and H.E. Touliabah, 2000. Diatom assemblages in superficial sediments from Nasser Lake, Egypt. In: proceedings of the 1st Int. Conf. Biol. Sci. (ICBS); Fac. Sci., Tanta Univ., pp: 89-103.
13. Gasse, F., 1986. East African Diatoms: taxonomy, ecological distribution. Bibliotheca Diatomologica. Band II. J.Cramer, Berlin, pp: 201.
14. Jackson, M.L., 1958. Soil Chemical Analysis. Constable and Co. Ltd., London, pp: 498.
15. Jensen, N.G., 1985. The Pennate Diatoms. A translation of Hustedt's "Die Kieselalgen, 2. Teil." Koeltz Scientific Books, Koenigstein, pp: 918.
16. Jouse, A.P., I.A. Kicelov, A.I. Proschkina-Laverenko and V.S. Sheshykova, 1949. Diatomical Analysis. Publ. "Geol. Liter". Leningrad, 2: 212-213.
17. Krammer, K. and H. Lange-Bertalot, 1986. Bacillariophyceae. 1. Teil: Naviculaceae. In: Süsswasserflora von Mitteleuropa. Band 2/1. H. Ettl; J. Gerloff; H. Heynig and D. Mollenhauer (eds.). Gustav Fisher Verlag, Stuttgart, pp: 876.
18. Krammer, K. and H. Lange-Bertalot, 1988. Bacillariophyceae. 2. Teil: Bacillariaceae, Epithemiaceae and Surirellaceae. In: Süsswasserflora von Mitteleuropa. Band 2/2. H. Ettl; J. Gerloff; H. Heynig and D.Mollenhauer (eds.). Gustav Fisher Verlag, Stuttgart, pp: 821.
19. Patrick, R. and C.W. Reimer, 1966. The diatoms of the United States (Exclucive of Alaska and Hawaii). Vol. 1: Fragilariaceae, Eunotiaceae, Achnanthaceae, and Naviculaceae. Monogrs. Acad. Sci. Philad., 13: 688.
20. Patrick, R. and C.W. Reimer, 1975. The diatoms of the United States (Exclucive of Alaska and Hawaii). Vol.2, Part 1: Entomoneidaceae, Cymbellaceae, Gomphonemaceae, and Epithemiaceae. Monogrs. Acad. Sci. Philad., 13: 213.
21. Proschkina-Laverenko, A.I., S.I. Gleser, A.P. Jouse, I.V. Makarova and V.S. Schesschykova-Poretzaja, 1974. The Diatoms of USSR. Fossil and Recent-Vol. I. Publ. House"Sov. Nauke.", Leningrad. Bronch., pp: 372.
22. Round, F.E., R.M. Crawford and D.G. Mann, 1990. The diatoms: biology and morphology of the genera. Cambridge University Press, Cambridge, pp: 747.
23. Shaaban, A.S., 1994. Freshwater Algae of Egypt. The United Nations Environment Programme, National Biodiversity Unit. Biological Diversity of Egypt. pp: GF/6105-92-02-2205,150.
24. Shaaban-Desouki S.A., M.A. Deyab, 2004. Phycological Assessment of water Quality of River Nile Delta-Egypt. Egyptian J. Phyco., 5: 19-34.
25. Silva-Benavides, AM., 1996. The use of water chemistry and benthic diatom communities for qualification of a polluted tropical river in Costa Rica. Rev. Biol. Trop., 44(2A): 395-416.

26. Vilbaste, S., 1994. The epiphytic and microphytobenthic diatoms in Estonian coastal waters (the Baltic Sea). In: Proceedings of the 13th International Diatom Symposium. D. Marino & M. Montresor (eds.). Biopress Limited, Bristol, pp: 259-269.
27. Willén, E., 1991. Planktonic diatoms- an ecological review. Algalogical Studies, 62: 69-106.
28. Zabelina, M.M., I.A. Kicelov, A.I. Proschkina-Laverenko and V.S. Scheshykova, 1951. The Freshwater Algaeof USSR. Vol.4. Bacillariophyta. Publ. “Sov. Nauk.” Moscow, pp: 619.
29. Ziller, S. and A. Economou-Amilli, 1988. Freshwater algae from lakes in the lower Niger Delta system (Nigeria). $Hydrobiologia, 368: 217-229.