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PHYTOPLANKTON COMPOSITIONS AS A RESPONSE OF WATER QUALITY IN EL SALAM CANAL HADOUS DRAIN AND DAMIETTA BRANCH OF RIVER NILE EGYPT

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Abstract

Considerable variation in water quality was found in El Salam canal; Hadous drain and Damietta branch of River Nile, Egypt. These resulted in variation of phytoplankton flora at the study area. Sixty seven species of phytoplankton were recorded at River Nile (site I) with maximum mean individual numbers (4810.6×10^5 cell/l), Bacillariophyta predominant group followed by Cyanophyta, Chlorophyta, Euglenophyta and Dinophyta. Hadous Drain recorded maximum mean species number 72 species but with low mean individual number (195×10^5 cell/l) mean while, El Salam canal have local variation in phytoplankton standing crop (32-65 species). Cyanophyta or Chlorophyta were the predominant groups followed by Bacillariophyta and Euglenophyta in both El Salam and Hadous water. Phycological monitors (Diversity, Saprobic indices and Saprobic quotient) indicated that Hadous Drain has relatively high polluted water and El Salam canal water more polluted than River Nile water. The matrix of biological (phytoplankton number and biomass standing crops) parameters and environmental variables of 36 samples were subjected to Canonical correspond analysis and cluster analysis.

Introduction

El Salam Canal project initiated in 1987 to irrigate 650000 hectares of the newly reclaimed areas in the west and east Suez Canal by mixed water from River Nile and Hadous Drain (1:1). Hadous Drain has been constructed in 1965 and receiving principally agriculture drainage water from 420000 hectares, moreover some domestic and industrial wastes are also discharged. The end part of Damietta branch of River Nile is significantly polluted than the other parts because of the presence of fish boxes and other discharges. Changes in water quality exert a selective action on flora and fauna which constitute the living population of water and can be used to establish biologic indices of water quality (Palmer, 1980). Therefore, an intensive spatial sampling program is needed to determine variability in phytoplankton distribution, abundance and community structure throughout El Salam canal, in relation to the physico-chemical properties and pollution status of water.

Study area: Six sites were chosen according to the nature and direction of water from River Nile at (site I) and Hadous Drain (site III) through El Salam canal at (site II, IV, V and VI). Bimonthly surface water samples were collected over one year. pH and temperature of water were determined in the field by the pH meter and thermometer, respectively. Other physico-chemical parameters of water were determined according to APHA (Anon., 1996). Algal species were identified according to Skuja (1948**)** and Hindak *et al*., (1975) and counted using an inverted microscope, following sedimentation according to Utermohle (1936). The phytoplankton biomass was calculated according to Edler (1979). Diversity index, Saprobic index and Saprobic equation were respectively performed according to Shannon & Weaver (1963); Sladecek (1973); Drescher & Mark (1976).

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Table 1. Average of annual values of physico-chemical parameters in River Nile (site I), Hadous Drain (site III) and El Salam canal water (site II, IV, V and VI).

Parameters \ Sites	I R.N	II S.C	III B.H	IV J.C	V J.C	VI S.C
Temp.^{o}C	27.83	23.33	24.71	23.01	23.24	23.48
NTU	4.09	19.30	44.78	35.71	29.98	23.47
E.C.(µs/cm)	1988.33	2183.33	5616.67	4141.67	3616.67	3808.33
TDS mgL-1	2104.67	4315.33	10636.17	8371.33	7685.83	6607.17
Salinity %	2.64	4.23	10.53	8.29	7.63	6.64
Cl gL^{-1}	1.22	1.36	5.09	3.93	3.34	2.38
pH	7.21	7.45	7.43	7.48	7.54	7.65
ph. Alk ($meqL^{-1}$)	0.08	0.12	0.18	0.14	0.11	0.14
T. Alk ($meqL^{-1}$)	1.77	2.25	3.45	2.78	2.79	2.87
CO_2 (mgL^{-1})	3.06	3.78	6.16	4.53	4.82	4.92
T.CO_2 (mgL^{-1})	8.95	10.92	17.83	12.82	13.85	14.10
O_2 mgL^{-1}	5.97	5.23	2.15	4.19	5.36	5.64
BOD mgL^{-1}	11.63	12.13	18.23	15.77	13.81	13.37
photo.mg/l/h	0.06	0.10	0.15	0.12	0.15	0.05
NH_4 mgL^{-1}	0.25	0.28	0.97	0.60	0.55	0.50
NO_2 mgL^{-1}	0.05	0.06	0.18	0.11	0.09	0.07
NO_3 mgL^{-1}	0.28	0.30	0.73	0.70	0.57	0.58
ON mg L^{-1}	0.35	0.37	0.51	0.40	0.31	0.29
PO_4 mgL^{-1}	0.01	0.01	0.05	0.02	0.02	0.02
Org. PO_4 mgL^{-1}	0.62	0.66	0.89	0.76	0.78	0.77
T. PO_4 mgL^{-1}	0.63	0.67	0.90	0.78	0.80	0.84
Si mgL^{-1}	3.15	3.16	5.42	4.84	4.39	4.22
SO_4 mgL^{-1}	339.27	327.24	562.08	424.55	461.58	458.09
Mg mgL^{-1}	277.51	270.86	249.87	222.44	189.12	112.66
Ca mgL^{-1}	658.73	680.37	1038.67	936.17	866.47	882.50
Na mgL^{-1}	194.88	293.96	608.33	572.75	489.71	457.50
K mg L^{-1}	114.78	148.23	187.28	163.08	163.90	166.38
Cu mgL^{-1}	0.11	0.13	0.17	0.15	0.12	0.11
pb mgL^{-1}	0.22	0.20	0.35	0.29	0.27	0.25
Zn mgL^{-1}	2.41	2.81	13.18	9.50	5.83	3.90
Fe mgL^{-1}	2.09	2.20	3.89	2.89	2.79	2.68

Results and Discussion

Physico-chemical analysis: The annual mean values of temperature at different sites were more or less similar relatively warm during summer and relatively cold during winter (Table 1). Moreover, temperature was correlated positively with Cyanophyta standing crop (r = 0.27). Variations affect the periodicity and succession of different groups of the algal communities (Behrndt, 1990). The minimum annual mean values of turbidity were recorded at River Nile (4.09 NTU); meanwhile the maximum were recorded at Hadous Drain (44.7 NTU). At El Salam canal the annual mean values of turbidity have a high local variation (9.3 - 35.71 NTU). The high turbidity may be due to re-suspension of sediment and high organic pollution of water. Turbidity levels control the species composition of phytoplankton (De Seve, 1993).

There were similar trend of annual mean values of electric conductivity, TDS, salinity and chloride were maximum (5616.67 µs/cm, 10636.17 mg l^{-1}, 10.53 % and 5.09 g l^{-1} respectively) at Hadous Drain (site III), whereas minimum values (1933.33 µs/cm 2104.67 mg l^{-1}, 2.64‰ and 1.22 g l^{-1} respectively) were recorded at River Nile

(site I). These variations may be due to agriculture drainage water from relatively saline soil received by Hadous Drain. While water at El Salam sites is mixture of 50% River Nile water and 50% Hadous Drainage water. Salinity may be an important factor in increasing the tolerance of algae to toxicants eg., heavy metals (Haglund *et al*., 1996). All sites occur in alkaline side where the annual mean pH values ranged between 7.21 at site I and 7.65 at site VI. However in shallow water, an increase of photosynthetic activity of algal population results in increasing pH value (Deyab, 1987). The annual mean values of Ph.ph alkalinity, total alkalinity, CO_2 and $T.CO_2$ were low at site I and high at site III (Hadous Draine). This difference might be related to water quality. In fact, total alkalinity depends upon the type of discharged wastes (Abdel-Baky, 2001). Also total alkalinity value was greater than 1.4 meq/l indicate eutrophic conditions (Moss, 1973).

Table 1 shows also that the maximum annual mean value of D.O (5.97 mg O_2/l) was recorded at River Nile site (I) with a minimum defected (2.15 mg /l) at Hadous Drain (site III) and moderate at El Salam canal. Data showed higher annual mean values of both BOD (18.23 mg O_2/l) and photosynthesis (0.15 mg-C/l/h) at Hadous Drain (site III), whereas the lower values (11.63 mg/l and 0.06 mg/l/h respectively) were recorded at River Nile (site I).

Ammonia, nitrite, nitrate and organic nitrogen were high (0.97, 0.18 and 0.51 mg/l respectively) at Hadous Drain (site III) and the low (0.25, 0.05 and 0.35 mg/l respectively) at River Nile (site I). It has been reported that, industrial and urbane sewage water carried high amount of ammonia (Soria *et al*., 1987), whereas, NO_2 in the surface water increased with temperature as nitrifying bacteria became active (Hu *et al*., 2001). Water with total soluble inorganic nitrogen greater than 0.3 mg/l was concerned to be eutrophic (Vollenweider, 1971). From the present results, it may be conclude that, total soluble inorganic nitrogen in the study area reach the eutrophic level.

Low PO_4 values were detected at River Nile (site I) and upstream (site II), however a high value (0.05 mg/l) was detected at Hadous Drain (site III). On the other hand, there was a local variation of organic– P, with high value (0.89 mg/l) at Hadous Drain (site III), and low value (0.62 mg/l) at River Nile (site I). In this account, Soria *et al*., (1987) reported that industrial and urbane sewage water carried high amount of phosphorus.

Silica content ranged from 3.15 mg/l at River Nile (site I) to 5.42 mg/l at Hadous Drain (site III). The increase in silicate may be attributed to the agricultural activities (Juttner *et al*., 1996). El-Khatib (1991) reported that Na^+ predominate K^+ in River Nile water. Sulphate content recorded high value (562.08 mg/l) at Hadous Drain (site III) and low value (339.27 mg/l) at River Nile (site I). This seemed to be in relation with the higher salinity level at Hadous Drain than that at River Nile. The minimum silicate level at which diatom growth can occur is between 0.03 and 0.04 mg/l (Serra *et al*., 1984). The concentration of SO_4 was found to be increased with increasing salinity and alkalinity (Kebede *et al*., 1994). This may be due to oxidation of sulphide, sulphite and sulphur to sulphate (Awadallah *et al*., 1994).

Contents of Mg, Ca, Na and K seemed most high at Hadous Drain (site III) but low at River Nile (site I). The same was also detected for copper, lead, zinc and iron. These variations appeared to depend on water pollution and salinity variation. Many domestic water supplies exceed the level of 270 mg/l of sodium which reprehensive of mineralized waters and treatment for removal of sodium in water supplies is costly (Anon., 1974). From the above discussed physico-chemical results, it is evident that the area attained to be polluted especially that of Hadous Drain and the down-stream water. Meanwhile, site II (up-stream) seems to be slightly polluted. It is worth mentioning here, that, this site (II) is rich in hydrophytes.

Table 2. Annual variations in cell number (x 10^5) of total phytoplankton standing crop at six sites.

Site / Division	Site I		Site II		Site III		Site IV		Site V		Site VI	
	Number cell	Species number	Number cell	Species number	Number cell	Species number	Number cell	Species number	Number cell	Species number	Number cell	Species number
Cyanophyta	1608	15	50	3	583.75	16	745	8	105.5	5	258.75	4
Chlorophyta	1427	18	7	5	205	19	128.5	18	49.6	16	72.5	12
Euglenophyta	48	2	2	1	49.75	12	8.75	9	3.5	6	3.5	4
Dinophyta	32.5	3	2	2	12.85	3	6.75	3	2.5	2	3	3
Bacillariophyta	1695	29	134.75	17	68.7	22	88	28	65	20	31.75	15
Total	4810.5	68	195.75	28	920.05	72	977	66	226.1	49	369.5	38
Diversity	2.78		2.07		1.46		1.49		2.01		1.64	
Saprobity	1.79		2.04		2.96		2.06		1.74		2.63	

Site I (Inanyia), site II (Up-stream), site III (Drain), site IV (Mixed), site V (Down stream) and site VI (up-sahara).

Biological analysis: A maximum number of phytoplankton species (72) was recorded at Hadous Drain, mainly due to the nutrient rich and slightly brackish stagnant water (10 %) of Hadous Drain is favorable for several species of phytoplankton. The number of total phytoplankton standing crop was greatly higher at site I relative to the other sites (Table 2). However sites II, V and VI showed the least number with relative to numbers at sites III and IV. The phytoplankton composed mainly of Cyanophyta, Chlorophyta, Bacillariophyta and Euglenophyta. Although River Nile water (site I) had the maximum individual number of phytoplankton (4810.5×10^5 cell/l) it attained a relatively low species (68 species). These may be related to relative high movement of water and nutrient content less than that at Hadous Drain (site III) which had a relatively low individual number (920.05×10^5 cell/l). This might be due to the relative high pollution state of drainage water which reserved agriculture and domestic discharges. Physico-chemical analysis and biological indices of water quality indicated that the water of Hadous Drain (site III) is more polluted site through the investigated area. A high content of the agricultural containing organic pollutants in Hadous Drainage water beside the domestic sewage discharges could alter water quality. Abdel Baky (2001) concluded that, organic matter within domestic sewage discharge give a suitable medium for the growth of Euglenophyta. Hutchinson (1967) recorded great growth of *Euglena* in organically polluted bodies of water. The predominance of Cyanophyta was due to the high N and P content of Hadous Drain water, but Cyanophyta and Chlorophyta predominated with high nitrogen content of water (Deyab *et al*., 2002).

Bacillariophyta dominated at site I may be because of industrial wastes of furniture factory which increase the silicon content of water. Phytoplankton standing crop was least at El-salam canal (site II); a record of 28 species and 195.7×10^5 cell/l was defected, mainly due to sharp decrease of Cyanophyta species, individual destruction during pumping water from River Nile to El Salam canal and high mobility of water. On the other hand, a relatively high phytoplankton species number (66 species) and individual number (977×10^5 cell/l) was recorded at site IV (down stream), a mixed site which affected by Hadous Drain water. Whereas, the phytoplankton standing crop decreased to

49 species and 226.1×10^5 cell/l at site V and to 38 species and 369.5×10^5 cell/l at site VI. This decrement seemed mainly due to high loss of Cyanophyta, Euglenophyta and Dinophyta species and individual at mixing station as a result of vigorous pumping of water. The variations of temperature are found to affect the periodicity diversity and succession of the phytoplankton group (Behrndt, 1990; Deyab 2003). Deyab *et al*., (2003) reported that the vigorous growth of Cyanophyta is correlated with the increase of phosphorus of surface water, whereas, silica depletion leads to a replacement of the large diatoms by large Cyanophyta.

According to the frequency of abundance (Table 3) of Cyanophyta, *Merismopedia trolieri, Anabaena constricta, Anabaena variabilis*, *Oscillatoria woronichinii, Chrococcus dispersus, Chroococcus limneticus* var. *distans. Phormidium autumnale* and *Microcystis aeruginosa were* the common species within site I. Meanwhile, *Oscillatoria putrida, O. brevis, O. lemnetica O. nitida* and *Merismopedia tenuissima* were the dominant species at site IV.

According to the relative of abundance, there are some species which participate in the dominance of Chlorophyta standing crop such as *Chlorella vulgaris* var. *vulgaris, Nodularia spumigena* f. *litorea, Pandorina morum, Ankistrodesmus acicularis, Scenedesmus quadricauda* var. *quadricauda, Crucigenia quadrata, Ankistrodesmus hantzschi* var. *gracile* and *Scenedesmus bijugatus* var. *bijugatus*. *Vulgaris, Nodularia spumigena* f. *litorea, Pandorina morum, Ankistrodesmus acicularis, Scenedesmus quadricauda* var. *quadricauda, Crucigenia quadrata, Ankistrodesmus hantzschi* var. *gracile* and *Scenedesmus bijugatus* var. *bijugatus*. The increase of Chlorophyta standing crop of cell number may be attributed to high nutrient content especially nitrogen (Deyab *et al.,* 2001). The most frequent species of diatoms which recorded within the different sites were *Cyclotella meneghiniana, Navicula cincta, Synedra acus, Melosira varians, Nitzschia sublinearis, Gyrosigma macrum, Nitzschia denticula, Nitzschia acicularis, Nitzschia frustulum* var. *astatica, Melosira islandica* and *Nitzschia tibetana*.

The most abundante Euglenophyta was at Hadous Drain (site III). *(Phacus caudatus, Euglena acus, Euglena velata, Euglena caudata, Euglena variabilis* and *Euglena viridis).* Dinophyta represented mainly by *Exuviaella compressa, Peridinum volzii, Katodinium vorticella, Glenodinum kulezynskii* and *Glenodinium pulvisculus* were the most frequently abundance Dinophyta at different sites. *Exuviaella compressa* prefer to inhabit in polluted water (El-Adl, 2000). In Table 4, the average of total phytoplankton standing crop biomass was ranged between 168 and 2512.2 mgL^{-1} at site II and III (Hadous Drain), phytoplankton standing crop biomass as follows: III> V> IV> VI> I > II. The data showed that the total biomass standing crop was higher during summer and spring (especially July and March) than autumn and winter months.

Chlorophyta predominated forming 58.9% of total biomass standing crop and represented the first group from March to September (68%, 71%, 73 and 58% respectively), this may be due to increase water temperature and nitrogen from agricultural discharge. Kebede & Ahlgren (1996**)** reported that the increase in water temperature and nitrogen often accompany with Chlorophyta, Bacillariophyta formed 18.3 % of total biomass standing crop and representing the second group, followed by Euglenophyta forming 14.6 % of total biomass standing crop. The fluctuation of Bacillariophyta may be attributed to different source of pollutants and reactive silica (Gibson, 1981) and sewage pollutants (Schelske *et al***.,** 1978). Cyanophyta and Dinophyta formed only 7.6 % of total biomass standing crop, respectively.

Table 3. Annual variations in frequency of different taxa at different sites at the studied area.

Species	I	II	III	IV	V	VI	T.F
Cyanophyta							
Anabaena constricta (Szaf.) Geitl	3	0	0	0	0	1	4
Anabaena variabilis Kutz	3	0	3	0	0	0	6
Calothrix stagnale var. *angustatum* G.M. Smith	3	0	0	0	0	0	3
C. parietana (Nag.) Thuret	3	0	0	0	0	0	3
Chroococcus dispersus (Keissl.) Lemm.	0	0	2	2	2	2	8
Chroococcus limneticus var. *distans* G.M. Smith	3	0	0	0	0	0	3
Chroococcus limneticus var. *carneus* (Chod.) Lemm.	0	0	1	0	0	0	1
Chroococcus minutus (Kutz.) Naegeli	0	0	0	1	0	0	1
Coelosphaerium dubium Grun.	3	0	0	0	0	0	3
Cylindrospermum majus Kutz	4	0	0	0	0	0	4
*Gloeocapsa aeruginosa (*Garm.)	3	0	0	0	0	0	3
Gloeocapsa alpina f. *ambigna (*Kirchn.) Hollerb,	0	0	0	0	1	0	1
Gloeocapsa rupestris (Breb.) Kutz.	0	0	0	1	0	0	1
Gomphosphaeria lacustris var. *compacta* Lemm.	3	0	0	0	0	0	3
Merismopedia elegans A. Braun.	3	0	0	0	0	0	3
Merismopedia tenuissima Lemm	0	0	1	1	0	0	2
Merismopedia trolieri Bachm.	3	0	0	0	0	0	3
Microcystis aeruginosa Kutz.	5	0	0	0	0	0	5
Oscillatoria woronichinii Kutz.	4	0	0	0	0	0	4
Oscillatoria brevis (Kutz.) Gom.	0	0	0	2	0	0	2
Oscillatoria chalybea f. *conoidea* V. Poljansk	0	0	0	1	0	0	1
Oscillatoria lemnetica Lemm.	0	0	3	0	0	0	3
Oscillatoria nitida Kutz	0	0	0	1	0	2	3
Oscillatoria putrida Schmidle	0	0	0	6	2	3	11
Oscillatoria rupicola (Hansg.)	0	1	3	0	1	0	5
Oscillatoria simplicissima Kutz.	0	0	0	0	2	0	2
Phormidium autumnale (C.A.Ag.) Gomont	4	0	0	0	0	0	4
	14	**1**	**6**	**8**	**5**	**4**	**38**
Chlorophyta							
Actinastrum gracilimum G.M. Smith	3	0	0	0	0	0	3
Actinastrum hantzschii var. *gracile* Roll	3	0	4	1	3	0	11
Ankistrodesmus convolutes Corda G.M. Smith	3	0	0	0	0	0	3
Ankistrodesmus acicularis (A. Br.)	0	0	2	4	4	5	15
Ankistrodesmus angustus (Bern.) Korschik.	3	0	2	0	1	1	7
Ankistrodesmus fusiformis Chodat	0	0	0	1	0	0	1
Ankistrodesmus minutissima Korschik	0	0	3	0	0	0	3
Ankistrodesmus tatrae (Turn.) Lemm.	0	0	0	1	0	0	1
Botryococcus braunii Kutz.	3	0	0	0	0	0	3
Characium gracilipes Lambert	2	0	0	0	0	0	2
Characium limneticum Lemm.	1	0	0	0	0	0	1
Chlorella vulgaris var. *vulgaris* f. *vulgaris* Beij.	4	0	0	0	0	0	4
Chlorellidiopsis separalibis Pascher	0	0	1	0	0	0	1
Chlorococcum humicola (Naeg.)	3	0	0	0	0	0	3
Chlorococcum wimmeri Lemm.	0	0	0	1	0	0	1

Table 3. (Cont'd.).

Species	I	II	III	IV	V	VI	T.F
Coccomyxa lacustris Kutz.	0	0	0	0	0	2	2
Coelastrum microporum Naeg.	4	0	0	0	0	0	4
Crucigenia apiculata (Lemm.) Schmidle	0	0	2	1	0	0	3
Crucigenia irregularis Wille	0	0	0	0	0	1	1
Crucigenia quadrata Morren	4	3	2	1	0	2	12
Crucigenia tetrapedia (Kirch.)W. et W.	0	0	0	0	1	0	1
Dictyosphaerium chrenbergianum Nag.	3	0	0	0	0	0	3
Eudorina illinoisensis O. Mul.	0	0	0	2	0	0	2
Gonium pectorale (Turp.)	0	0	2	0	0	0	2
Kirchneriella obes Korsh.	0	0	1	0	0	0	1
Kirchneriella subsolitaria G.S. West	2	0	0	0	0	0	2
Meringosphaera spinosa Prescott	2	0	0	0	0	0	2
Oocystis crassa Wittrock	0	0	0	0	1	1	2
Oocystis elliptica var. *elliptica* W. West	0	0	0	0	0	1	1
Pandorina morum (O.Mul.) (Bory)	4	0	6	4	3	6	23
Pediastrum simplex var. *duodenarium* (Bailey) Raben-horst	3	0	0	0	0	0	3
Protoccoccus viridis Kutz.	0	0	0	1	0	0	1
Scenedesmus arcuatus var. *arcuatus*	0	0	1	0	0	0	1
Scenedesmus bicaudatus var. *intermedius* (Chod.)	0	0	1	0	0	0	1
Scenedesmus obliquus var. *obliquus* (Trup.)Kuetz	0	0	0	0	1	0	1
Scenedesmus acuminatus var. *bernardii* (Smith) Dedus	0	0	0	0	1	1	2
Scenedesmus acuminatus (Turp.)	0	0	0	0	2	0	2
Scenedesmus acuminatus var. *acuminatus* (Lagerh.) Chod.	0	0	4	5	0	0	9
Scenedesmus acuminatus var. *biseriatus* Reinsch	0	0	1	1	1	0	3
Scenedesmus bijugatus (Turp.) Kuet var. *bijugatus*	0	0	2	1	2	1	6
Scenedesmus bijugatus (Turp.) Lagerheim	0	0	0	0	1	0	1
Scenedesmus bijugatus var. *alternans* Reinsch	0	0	0	1	0	0	1
Scenedesmus quadricauda Hansg.	0	0	4	1	0	0	5
Scenedesmus quadricauda var. *danubialis* (Hortob.)	0	0	0	0	2	0	2
Scenedesmus quadricauda var. *granulata (Hortob.)*	0	0	2	0	1	1	4
Scenedesmus quadricauda var. *quadricauda* (Trup.) Brebis	2	0	0	1	2	3	8
Schizochlamys gelatinosa Reinsch	0	0	1	1	0	0	2
Staurastrum gracile Lemm	0	0	0	0	1	0	1
*Tetraedron triangulare (*Turp.)	0	0	0	1	0	0	1
Tetraedron trigonum (Naeg.) Hansg.	1	0	1	0	0	0	2
	18	**1**	**19**	**18**	**16**	**12**	
Euglenophyta							
Euglena acus Ehr.	0	2	2	3	1	0	8
E. caudata Hubner	0	0	4	0	0	0	4
E. elastica Prescott	0	0	0	1	0	0	1
E. elegans Ehr.	0	0	1	0	0	0	1
E. geniculata (Duj.) em. Schmidle	0	0	1	0	0	0	1
E. mutabilis Schmitz	0	0	0	1	0	0	1
E. physeter Fott	0	0	0	0	0	1	1
E. variabilis Klebs	0	0	1	1	0	0	2

Table 3. (Cont'd.).

Species	I	II	III	IV	V	VI	T.F
E. velata KLEBS	0	0	5	0	0	0	5
E. viridis Ehr.	0	0	2	1	0	0	3
Lepocinclis fusiformis var. *major* Fritsch& Rich	0	0	0	0	1	0	1
L. ovum (Ehr.)	0	0	0	1	1	0	2
L. playfairiana Deflandre	0	0	0	0	0	4	4
Phacus agilis Skuja	0	0	0	0	1	1	2
Ph. brachykentron Pochm	0	0	1	0	0	0	1
Ph. brevicaudatus (Klebs)	0	0	3	0	0	0	3
Ph. caudatus Hubner	0	0	6	3	0	1	10
Ph. chloroplastes far. *Incisa* Prescott	2	0	0	0	0	0	2
Ph. curvicauda SWIR	0	0	0	0	1	0	1
Ph. pleuronectes (Muller)	0	0	0	0	1	0	1
Ph. pusillus Lemm.	0	0	0	1	0	0	1
Strombomonas fluviatilis Lemm. Defl.	0	0	2	1	0	0	3
Trachelomonas labiata TELING	1	0	2	0	0	0	3
	2	**1**	**12**	**9**	**6**	**4**	
Dinophyta							
Exuviaella compressa Ostenfeld	3	0	5	3	0	2	13
Glenodinium kulezynskii (Wolosz) Schiller	2	1	0	2	0	0	5
Glenodinium pulvisculus FOTT	0	0	1	1	1	2	5
Katodinium vorticella (STEIN) FOTT	3	0	0	0	0	0	3
Peridinium cinctum var. *tuberosum* (Meunier) Lindeman	0	0	1	0	0	0	1
Peridinium volzii Lemm.	0	2	0	0	2	1	5
	3	**2**	**3**	**3**	**2**	**3**	
Xanthophyta							
Ophiocytium capitatum var. *longispinum* (Moebius) L.	2	0	0	0	0	0	2
Bacillariophyta							
Achnanthes conspicua A. Mayer	0	0	3	0	0	0	3
Achnanthes Jentzschii (Grun.)	0	1	0	0	0	0	1
Achnanthes linearis var. *pusilla* Grun.	0	0	0	1	0	0	1
Amphiprora alata Lemm.	0	0	1	0	0	0	1
Amphiprora paludosa var. *subsalina* Cl.	0	0	2	0	0	0	2
Amphora monoglica var. *cornuta*	0	0	0	1	0	0	1
Bacillaria paradoxa Ehr.	0	0	0	1	0	0	1
Caloneis amphisbaena (Bory) Cl.	0	0	1	1	0	0	2
Cocconeis scutellum Ehr.	0	0	0	0	1	0	1
Cocconeis pediculus Ehr.	0	2	1	1	0	0	4
Cocconeis placentula Ehr.	0	0	0	0	1	0	1
Cyclotella bodanica var. *lemanensis* Kutz.	0	0	1	0	0	0	1
Cyclotella meneghiniana Kutz.	4	4	6	6	6	6	32
Cymatopleura solea var. *regula* Lemm.	0	0	0	0	1	0	1
Gomphonema angustatum Ehr.	1	0	0	0	0	0	1
Gomphonema longiceps var. *subclavatum* Grun	0	1	1	2	0	0	4
Gomphonema olivaceum Kutz.	0	0	0	0	0	3	3

Table 3. (Cont'd.).

Species	I	II	III	IV	V	VI	T.F
Gomphonema parvulum var. *lagenulum* Kutz.	0	0	1	0	0	0	1
Gyrosigma attenuatum (Kutz.) Rabenh.	0	1	2	1	0	0	4
Gyrosigma acuminatum (Kutz.) Rabenh.	0	0	1	0	0	0	1
Gyrosigma macrum W. Sm.	0	0	1	2	1	2	6
Melosira islandica O. Mull	4	1	0	3	3	0	11
Melosira varians Lemm.	2	2	3	5	3	3	18
Navicula cincta (Ehr.) Kutz.	0	0	3	4	2	5	14
Navicula diluviana Kutz.	1	0	0	0	0	0	1
Navicula fossalis Krasske	0	0	0	2	0	0	2
Navicula graciloides Grun.	0	1	1	0	0	0	2
Navicula placentula (Ehr.) Grun.	0	0	0	0	0	1	1
Navicula placentula f. *lanceolata* Ehr.	0	1	0	0	0	0	1
Navicula pygmaea Ehr.	0	0	0	1	0	0	1
Navicula tuscula (Her.) Grun.	0	1	1	0	0	0	2
Neidium productum (W.Sm)	0	0	0	2	0	0	2
Nitzschia acicularis W. Sm.	0	0	4	0	1	0	5
Nitzschia filiformis (W. Sm.)Hust.	0	0	0	0	0	2	2
Nitzschia bremensis Hust.	0	0	0	0	1	0	1
Nitzschia denticula Grun.	1	2	2	1	1	3	10
Nitzschia frustulum var. *asiatica*	0	0	3	4	0	2	9
Nitzschia hungarica (Greg.) Grun	0	0	2	1	1	0	4
Nitzschia longissima f. *parva*	0	0	1	1	0	0	2
Nitzschia longissima f. *parva* var. *reversa*	0	0	4	2	0	0	6
Nitzschia paleacea Grun.	0	0	2	3	0	3	8
Nitzschia stagnorum Rabenh	0	0	2	1	3	0	6
Nitzschia sublinearis Hust.	0	4	6	3	1	1	15
Nitzschia thermalis Hust.	0	0	2	0	0	0	2
Nitzschia tibetana Hust.	0	0	1	3	1	1	6
Nitzschia tryblionella var. *levidensis* (W. Sm.) Grun.	1	1	1	0	0	0	3
Pleurosigma subsalsum Grun.	0	0	0	1	0	0	1
Stauroneis baicalensis Grun.	0	2	0	0	1	0	3
Stauroneis montana Krassake	0	1	0	1	0	0	2
Stephanodiscus dubius Grun.	0	0	0	0	1	1	2
Surirella didyma var. *minor* Kutz.	0	1	0	0	0	0	1
Surirella ovata var. *crumena* Ag.	0	0	1	0	0	0	1
Synedra acus Kutz.	3	3	3	5	3	4	21
Synedra tabulata (Ag.) Kutz	0	0	0	0	1	0	1
Synedra ulna (Nitzsch) Ehr.	0	0	0	1	3	0	4
Synedra ulna var. *aequalis* Ehr.	1	0	0	0	0	0	1
Synedra ulna var. *contracta* Kutz.	0	1	0	0	0	0	1
	9	**18**	**30**	**28**	**20**	**15**	
No of Taxa	**47**	**22**	**70**	**67**	**48**	**37**	

Table 4. Total Biomass (mg/l) of different groups and total phytoplankton standing crop at the six sites. Site I (Inanyia), site II (Up-stream), site III (Drain), site IV (Mixed), site V (Down stream) and site VI (Up-sahara).

Site \ Phylum	Cyanophyta	Chlorophyta	Euglenophyta	Dinophyta	Bacillariophyta	Total
I	14	57	0.3	0.2	121.2	198.7
II	10	1	50	0.8	107	168.8
III	75	1530	564	22	321	2512
IV	235	443	135	8	239	1060
V	48	1265	44	0.9	173	1530.9
VI	54	125	29	4	73	285
Total	427	3420	822	36	914	5619
%	7.6	58.9	14.6	0.6	18.3	100

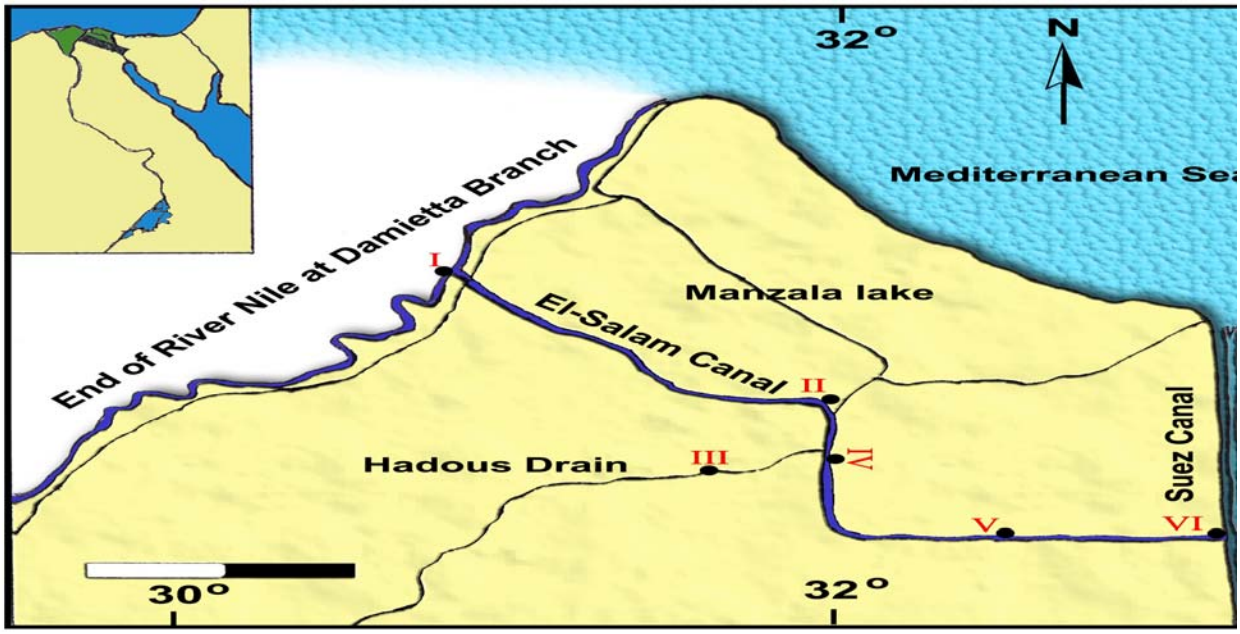

Fig. 1. A map showing the sampling sites: River Nile (I); Up-Stream (II); Hadous Drain (III); Mixed (IV); Down- stream(V); Up-Sahara (VI).

Table 5. The mean value of phycological monitors for water quality .

Bioindices \ Stations	I	II	III	IV	V	VI
Diversity index	2.78	1.46	2.07	1.49	2.01	1.64
Saprobic index	2.37	1.9	2.06	2.96	1.74	2.63
Saprobic quotient	0.82	0.95	0.59	0.80	0.96	0.87

Biological assessment of water quality: The mean value of diversity index among the different sites ranged from 2.78 at site I to 1.46 at site II. This range indicates that, this area is moderately polluted (Table 5). Similarity, the values of Saprobic index fluctuated between 1.74 at site V and 2.96 at site IV, indicating a range of clean to heavily contaminated area. The lower values were recorded at site II and site V may be due to the presence of some hydrophytes (*Ceratophyluum demersum* and *Potamogeton pectinatus*) which could make biological filtration for water (Serag & Khedr, 2001). The saprobic quotient indicating β – mesosaprobic condition of the study area with slight pollution, the

saprobic quotient varied between 0.46 at site V and 0.59 at site II. Biological parameters (number and biomass) were used in the multivariate cluster analysis (Fig. 2) to find out the similarity between different sites using Bray–Curtis index. It is worth mentioning that biological characteristics of polluted water at site (III) tended to be more similar to those in mixed water at site (IV) with relative similarity coefficient (62 %) and they clustered in one sub-group, both of them were clustered with site (V) in one large group. Site (II) and site (I) were different from other groups and each other. This may be due to different in the type and quantity of pollutants, which are received by each site.

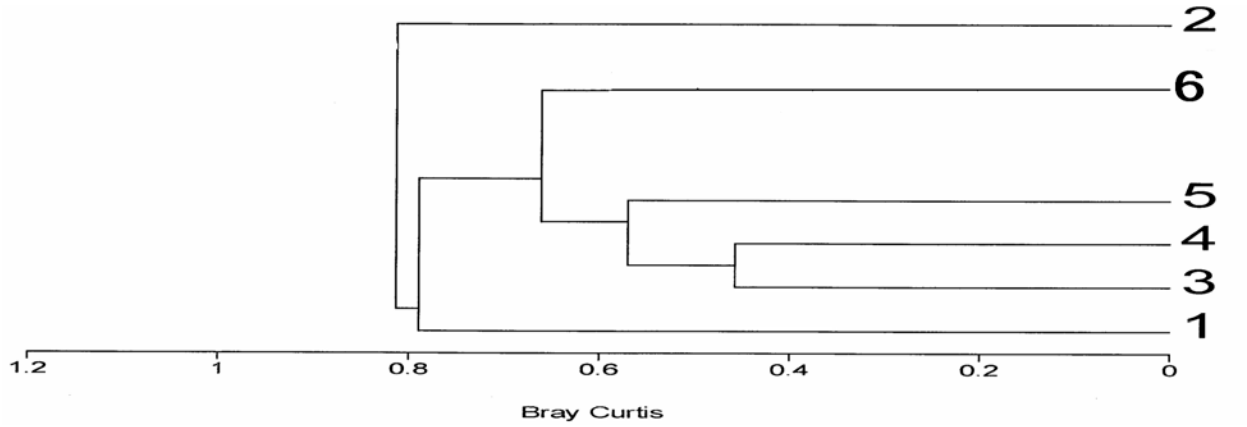

Fig. 2. Similarity Dendrogram between six sites [Site I (Inanyia), site II (Up-stream), site III (Drain), site IV (Mixed), site V (Down stream) and site VI (Up-sahara)]. during the investigation period according to the abundance of the phytoplankton groups using Bray – Curtis measure.

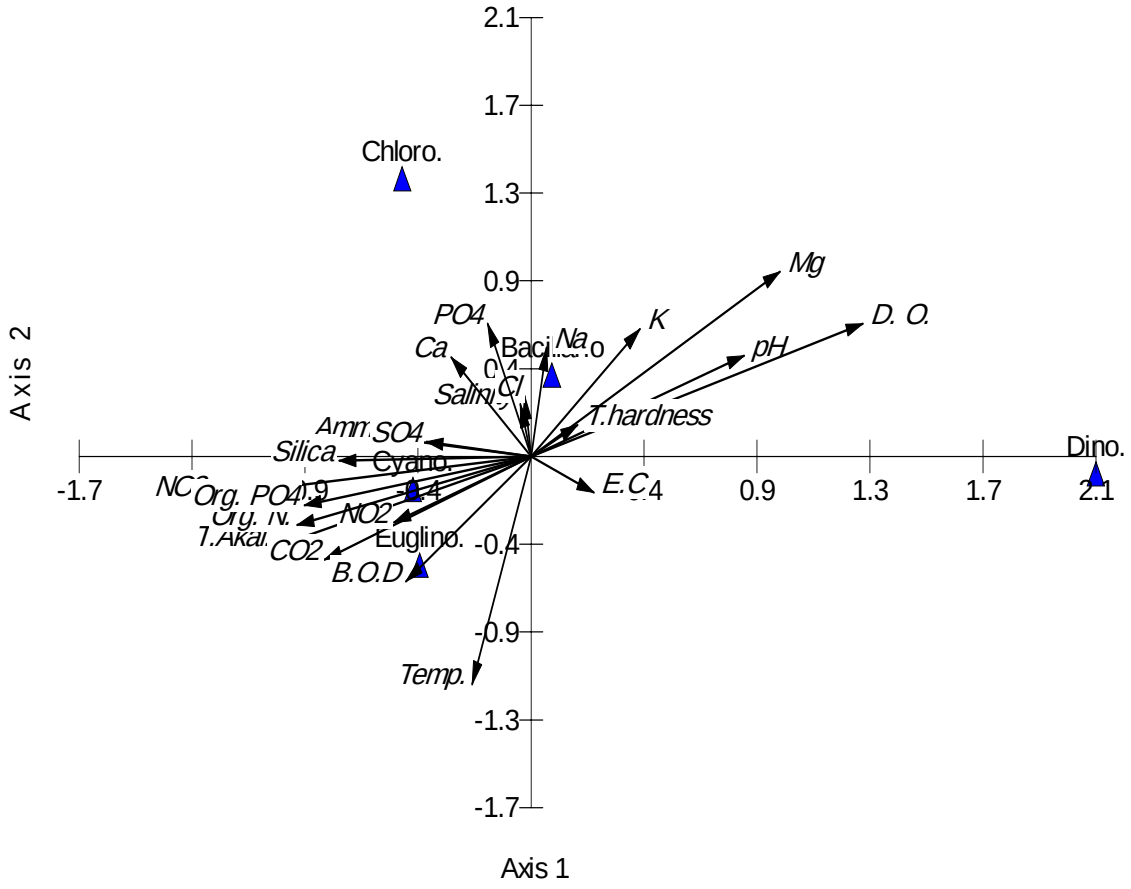

Fig. 3. Canoco analysis plot of physico-chemical and biological parameters.

By using the canocal corresponding analysis (CCA) various the physico-chemical parameters and phytoplankton groups Could be recognized (Fig. 3). The correlations between the abundance of different phytoplankton groups and the environmental variables are followed. A positive correlation is expressed by relatively long vector roughly pointed into the same direction, whereas arrow pointing into the opposite direction indicates a negative correlation. Thus Cyanophyta and Euglenophyta were positively correlated with ammonia, BOD, total CO_2, organic nitrogen, organic phosphorus, temperature, nitrite and nitrate. In contrast, to Cyanophyta and Euglenophyta, Chlorophyta, Bacillariophyta, Dinophyta were negatively correlated with the above–mentioned parameters. However, they were positively correlated with dissolved oxygen, pH and PO_4, Mg, K and Na, salinity and Chloride. Pollution level or quality of natural water and of wastewater is determined by physical/chemical, saprobiological, radiological and recently also by cytogenetic and genotoxic analyses (De- Serres, 1992; Gong *et al*., 2001).

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