1st Int. Symp. Phycol. (ISP).
(21-22) Oct. 2000.

Egypt. J. Phycol. Vol. 1, 2000

PHYTOPLANKTON AS INDICATORS OF WATER QUALITY IN THE IRRIGATION AND DRAINAGE CANALS IN WESTERN DAMIETTA-EGYPT

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Abstract

The monthly variation of phytoplankton composition as well as physico-chemical characteristic of irrigation and drainage canals water in Western Damietta were recorded over the year 1998, from January to December. The presence of agrochemicals has differential effects on water quality and phytoplankton population. There were 126 species of algae identified at the irrigation canal, Omm Dongol (81 Bacillariophyta, 14 Euglenophyta, 13 Chlorophyta, 11 Cyanophyta, 6 Dinophyta, and 1 Cryptophyta). The number of species at the three drainage canals, El Senania, Marssok and Gamassa, was 28, 68 and 56 species, respectively. The species at El Senania, Marssok and Gamassa were respectively identified as 14, 41, 33 Bacillariophyta, 3, 10, 5 Cyanophyta, 7, 5, 6 Euglenophyta, 3, 7, 8 Chlorophyta, 1, 4, 2 Dinophyta, 0, 1, 1 Cryptophyta and 0, 0, 1 Chrysophyta. Phytoplankton standing crop would come from the contribution of Chlorophyta, Cyanophyta and Bacillariophyta representing 74, 23 and 2.5%, respectively in irrigation water and of Cyanophyta in drainage water. The number of species was dependent on Bacillariophyta. Total phytoplankton biomass resulted from the considerable growth of Euglenophyta, Chlorophyta and Bacillariophyta in irrigation canal and from Cyanophyta and Bacillariophyta at drainage canals. Diversity index indicated that pollution level for irrigation water was slight and heavy to moderate for drainage water. Moreover, saprobic index revealed the presence of ß`-mesosaprobic in irrigation water and α` to α`` -mesosaprobic forms of algae in drain water. In addition, compound eutrophication indicated that the nature of irrigation water was mesotrophic while drain water was eutrophic.

Key words: drainage canals, irrigation canals, phytoplankton, pollution, water quality, Damietta.

Introduction

Agricultural discharges usually contain metals as well as organic contaminants e.g. herbicides, fungicides, insecticides or fertilizers. Moreover, turbid water contains large amounts of fine suspended solids. Agricultural intensification led to chemical changes of fresh water. Agricultural run off influences fresh water chemistry by increasing nutrient loading and ionic strengths due to mineral weathering or salinization (Jenkins *et al.* 1995). Biological monitoring has several advantages over chemical monitoring in integrating responses to range of pollutants occurring in water stream over different times (Calow and Petts 1994). Algae are an ecologically important group in most aquatic ecosystems but are often ignored as indicators of aquatic ecosystem change (McCormick and Cairns 1994). Monitoring of algae is done with the assumption that increasing in eutrophication will be reflected in the species composition of the phytoplankton, thus giving an early indication of the effectiveness of management strategies. The sensitivity or tolerance of algae to eutrophication and other forms of pollution has led the creation of many indicators systems and indices to assess water quality.

Therefore, this work was aimed to evaluate the use of phytoplankton for monitoring water quality of four canals representing the Western part of Damietta. One of

(ISSN: 1110-8649)

these canals (Omm Dongol) is irrigation bay whereas the others (El Senania, Marssok and Gamassa) are drainage canals

Materials and Methods

Study area

This investigation was conducted on four canals, one represents irrigation canal and the other three represent drainage canals at Western Damietta-North Egypt (Fig. 1). These stations are:
1-Omm Dongel station, a standard irrigation canal and is considered as the vital irrigation source of water in western Damietta, 2- El Senania station, a drainage canal receiving domestic sewage pollutants, 3- Marssok station, a drainage canal receiving agricultural and domestic discharges, and 4- Gamassa station, a drainage canal receiving agricultural, domestic and industrial discharges.

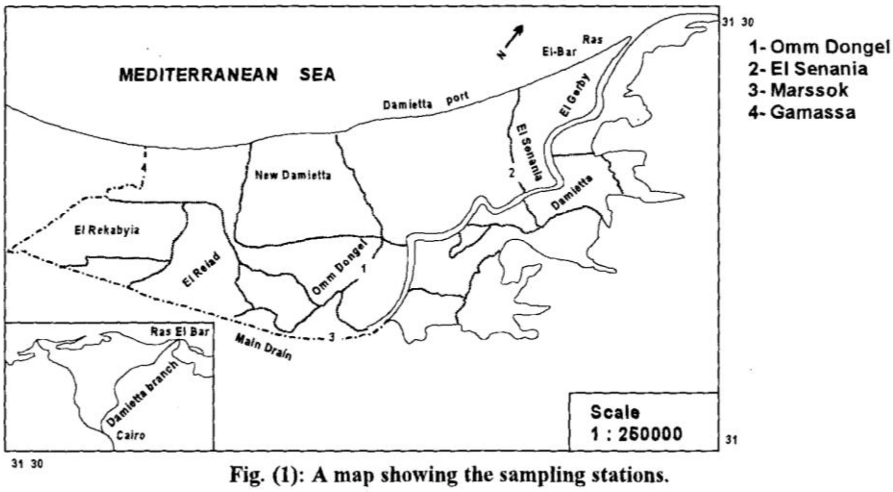

Fig. (1): A map showing the sampling stations.

Sampling and Chemical analyses: Surface water samples were collected from each of the different stations for the biological and chemical analyses from January to December 1998. Chemical analyses for determination of Cl^-, salinity, temperature, ph.ph alkalinity, total alkalinity, pH, total hardness, turbidity, oxygen, ammonia, NO_2^-, NO_3^-, PO_4^{--}, total PO_4^{--}, Si, SO_4^{--}, Na, K, Fe, Mn, Zn and Cu were conducted according to Golterman (1969).

Phytoplankton quantitative analysis and identification: After the standard preparation, the modified technique developed by Utermohle (1936) was adopted for quantitative analysis of phytoplankton. Identification and nomenclature were based on the procedures of Jarvornicky and Popovsky (1971), Cyrus and Sladecek (1973). The diversity index, saprobic index and compound eutrophication were performed according to Shannon and Weaver (1963), Sladecek (1973) and Round (1981), respectively.

Result and Discussion

Chemical Analyses:

The results depicted in table 1 reveal that the changes in temperature during the different months of the year were more or less similar at the different four stations. Temperature was relatively low in winter months (11-22 °C), slightly warm in summer months (27-29 °C) and moderate in autumn and spring (20-26 °C). This temperature appeared suitable for algal growth. In this respect, Kebede and Ahlgren (1996) reported that the optimum temperature for phytoplankton growth is 30°C. Generally temperature could strongly regulate algal growth and metabolism (Tang *et al.* 1997) as well as algal community and composition (Lefebvre *et al.* 1996). This may be attributed to that temperature is considered as key in the optimization of solar bioreactor (Tang *et al.* 1997).

Table (1): Monthly variations of temperature, total soluble salt, chloride and total hardness of water at some of Western Damietta canals during the year 1998.

	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	S.E
A . Temperature (	°	C	)											
1- Omm Dongel	11	12	21	20	24	26	28	29	26	27	24	21	22.4	1.762
2- El-Senania	11	13	19	20	24	26	26	26	27	27	23	20	21.8	1.628
3-Marssok	12	12	22	21	25	26	29	29	27	27	24	20	22.8	1.744
4- Gamassa	11	13	21	21	24	26	27	28	27	27	26	21	22.67	1.692
B. Total soluble salts (g/l)														
1- Omm Dongel	1.40	2.00	2.00	0.60	0.60	0.50	0.60	0.30	0.50	0.50	0.40	0.50	0.83	0.18
2- El-Senania	1.80	2.70	2.80	2.60	1.70	1.50	1.20	2.00	1.80	1.60	0.60	0.70	1.75	0.21
3-Marssok	3.50	4.15	4.20	2.00	2.00	2.00	2.20	1.00	2.10	1.80	1.95	1.90	2.40	0.29
4- Gamassa	4.00	5.50	4.20	4.40	4.20	3.20	3.20	4.50	3.20	4.75	4.60	3.20	4.08	0.22
C. Chloride (ppm)														
1- Omm Dongel	285	470	480	130	125	120	140	93	115	124	104	115	191.8	45.74
2- El-Senania	432	672	672	624	408	360	240	480	432	384	244	268	434.7	51.46
3-Marssok	890	1068	1081	450	450	452.5	555	445	486	432	468	456	586.1	78.16
4- Gamassa	960	395	1480	960	980	980	880	895	680	920	884	780	532.8	58.68
D. Total Hardness (meq/l)														
1- Omm Dongel	15.30	9.60	17.40	6.80	8.30	6.40	5.20	2.60	5.60	4.80	5.00	4.60	7.63	1.29
2- El-Senania	12.60	15.40	19.60	18.20	11.90	10.50	8.20	14.65	12.60	11.20	4.20	4.90	12.00	1.36
3-Marssok	23.00	26.88	27.20	13.00	15.30	14.80	12.65	8.00	15.30	12.00	14.20	13.30	16.30	1.75
4- Gamassa	28.65	30.50	33.40	24.00	33.75	34.00	34.00	30.50	34.30	22.25	21.40	24.60	29.28	1.43

In addition, the table clearly indicates that the pattern of change in salinity, chloride and total hardness was more or less alike throughout the different months. However, there was an increase in the values of these parameters at the drainage relative to irrigation canal. At irrigation canal, salinity, chloride and total hardness fluctuated between 0.3 to 2 g/l, 93-480 mg/l and 2.6-17.4 meq/l, respectively. On the other hand, the values determined at drainage canals varied between 0.6-5.5 g/l, 240-1081 mg/l and 4.2-34.3 meq/l, respectively. The relative increase of salinity, chloride and total hardness detected at drainage canals may be attributed to the washing of the relative saline agricultural soil. Kebede *et al.* (1994) indicated that chloride concentration increased with increasing salinity and alkalinity.

Table 2 shows that total alkalinity varied between 2.3-6.9 meq/l in irrigation canal and 4.1-14.94 meq/l in drainage canal. Whilst ph.ph alkalinity values varied between 0.2 - 0.77 meq/l in irrigation canal and from 0-1.9 meq/l in drainage canals. Alkalinity is an important factor for fish and other aquatic life in fresh-water systems (Heath *et al.* 1995).

In this context, total alkalinity of River Nile water was found to be about 2.4 at Assiut, 2.75 at Cairo, 2.9 at Faraskour and 3.72 meq/l at Edfina (Hammer 1976). It could be concluded that total alkalinity increases by increasing the different pollutant doses especially sewage discharges.

Table (2): Monthly variations of total alkalinity, ph.ph alkalinity, turbidity, dissolved oxygen and pH of water at some of Western Damietta canals during the year 1998

	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	S.E
A. Total Alkalinity (meq/l)														
1- Omm Dongel	4.81	6.90	7.40	3.30	4.60	2.30	4.20	4.40	3.80	4.40	6.40	5.40	4.83	1.39
2- El-Senania	6.20	6.80	6.71	5.40	4.40	4.63	4.76	6.78	6.32	5.80	12.00	4.10	6.16	1.78
3-Marssok	6.40	9.96	9.12	4.20	5.71	4.10	6.11	5.94	4.60	5.62	8.40	5.66	6.32	1.82
4- Gamassa	7.71	12.30	14.94	6.15	6.13	5.10	6.60	6.52	4.66	5.77	9.70	6.70	7.69	2.22
B. ph.ph alkalinity (meq/l)														
1- Omm Dongel	0.23	0.45	0.77	0.36	0.20	0.43	0.56	0.50	0.54	0.35	0.22	0.20	0.40	0.04
2- El-Senania	0.31	0.00	0.60	0.16	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.16	0.13	0.05
3-Marssok	0.50	0.00	0.49	0.00	0.48	0.00	0.60	0.22	0.20	0.00	0.00	0.08	0.21	0.07
4- Gamassa	0.31	0.00	0.37	1.90	0.13	0.10	0.46	0.14	0.19	0.10	0.00	0.00	0.31	0.15
C. Turbidity (NTU)														
1- Omm Dongel	1.10	1.80	1.70	1.90	1.60	3.45	4.50	4.55	4.40	4.40	3.69	4.10	3.10	0.39
2- El-Senania	3.30	6.30	4.60	3.10	3.60	5.60	11.80	7.20	10.20	6.40	4.80	5.10	6.00	0.77
3-Marssok	19.10	24.08	8.35	7.80	10.60	33.50	18.65	12.35	14.90	13.20	13.10	13.20	15.74	2.10
4- Gamassa	4.60	6.85	4.40	9.50	6.90	18.60	13.30	8.25	11.25	6.35	5.50	6.80	8.53	1.19
D. Dissolved Oxygen (ppm)														
1- Omm Dongel	11.20	12.00	12.80	13.60	11.11	10.60	6.80	11.90	5.50	6.50	8.40	9.20	9.90	0.77
2- El-Senania	1.60	1.00	1.60	1.60	1.40	0.80	zero	1.60	1.40	1.20	1.20	0.40	1.25	0.11
3-Marssok	4.60	4.60	4.60	4.50	4.50	4.00	zero	3.00	3.90	4.80	4.50	4.80	4.50	0.53
4- Gamassa	4.60	4.00	4.50	4.00	4.80	4.52	2.40	4.50	3.75	2.50	4.80	4.40	4.30	0.24
E. pH														
1- Omm Dongel	7.10	7.20	7.50	7.30	8.10	7.60	7.10	7.60	8.10	7.40	7.30	7.70	7.50	0.10
2- El-Senania	7.80	7.40	7.60	7.50	7.20	7.40	7.20	7.20	7.60	7.50	7.15	8.10	7.47	0.08
3-Marssok	7.90	8.10	7.90	7.60	8.10	7.40	7.30	7.60	7.50	7.65	7.90	7.80	7.72	0.08
4- Gamassa	8.10	7.60	7.50	8.10	8.40	8.20	8.30	7.90	7.60	7.95	8.00	7.70	7.94	0.08

Turbidity in irrigation canal was slightly detected;, being 1.1 to 4.55 NTU in Omm Dongel. This may be attributed to a low level of water pollution. At drainage canals (El-Senania, Marssok and Gamassa stations), turbidity fluctuated between 3.3-33.5 NTU according to type and degree of pollution. However, the high turbidity due to resuspension and shallow depth of the canal, may control the species composition of phytoplankton (De Seve 1993). High turbidity promotes photosynthetic adaptation in shallow water among the appropriate algae but it also provides a good defense against photoinhibition of the population as a whole (Reynolds *et al.* 1994).

The concentration of dissolved oxygen reached minute levels at some stations, it varied between zero–4.8 mg/l at drainage canals. This may be attributed to many quantities of pollutants input to these canals. In contrast, water of the irrigation canal (Omm Dongel) had relatively high values of dissolved O_2 (5.5-13.6 mg/l) probably because of photosynthesis activities of phytoplankton liberates significant amounts of oxygen into water (Deyab 1987).

The pH value of water of the different stations tends towards the alkaline side (7.1-8.4). These values appeared suitable for phytoplankton growth. In this context, Qijun *et al.* (1994) found that the maximum growth of phytoplankton was observed at pH 7.5-8.

In table 3, the concentration of ammonia was very low at the irrigation canal (0.001 mg/l-0.003 mg/l). This low level may be attributed to low pollution and/or to the biological consumption of ammonia at surface water. These low levels greatly increased in drainage canals varying from 0.003 to 2.1 mg/l especially at Marssok station. It is well known that optimal concentration of ammonia is 0.02 mg/l (as unionized ammonia) for freshwater aquatic life (NAS 1974). However, ammonia could be increased because CO_2 can be depleted during photosynthesis, thereby, increasing pH and enhancing NH_3 volatilization (Bartlett and Harris 1993).

Table (3): Monthly variations of ammonia, nitrate, nitrite, orthophosphate, total phosphorus, silica and sulphate of water at some of Western Damietta canals during the year 1998.

	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	S.E
A. Ammonia (ppm)														
1- Omm Dongel	0.02	0.02	0.03	0.01	0.02	0.02	0.08	0.01	0.01	0.02	0.04	0.03	0.03	0.01
2- El-Senania	0.06	0.08	0.07	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.05	0.00
3-Marssok	0.80	2.10	1.80	1.75	1.40	1.20	0.80	0.30	0.36	0.30	0.04	0.03	0.91	0.21
4- Gamassa	0.07	0.06	0.18	0.09	0.01	0.05	0.06	0.07	0.09	0.08	0.07	0.02	0.07	0.01
B. Nitrite (ppm)														
1- Omm Dongel	0.00	0.00	0.00	0.00	0.00	0.02	0.10	0.09	0.01	0.00	0.01	0.03	0.02	0.01
2- El-Senania	0.02	0.01	0.01	0.01	0.01	0.03	0.04	0.02	0.01	0.07	0.04	0.17	0.04	0.01
3-Marssok	0.09	0.02	0.02	0.05	0.08	0.15	0.04	0.01	0.22	0.30	0.20	0.33	0.13	0.03
4- Gamasa	0.20	0.11	0.05	0.08	0.11	0.17	0.08	0.01	0.02	0.01	0.31	0.32	0.12	0.03
C. Nitrate (ppm)														
1- Omm Dongel	0.01	0.15	0.24	0.20	0.15	0.05	0.17	0.14	0.01	0.00	0.00	0.01	0.09	0.03
2- El-Senania	0.01	0.14	0.09	0.02	0.01	0.01	0.03	0.02	0.01	0.10	0.02	0.31	0.06	0.03
3-Marssok	0.28	0.07	0.03	0.13	0.65	0.93	0.03	0.03	1.13	1.30	0.93	0.51	0.50	0.14
4- Gamassa	0.58	0.50	0.25	0.31	0.74	0.85	0.20	0.05	2.10	1.57	1.53	0.68	0.78	0.18
D. Phosphate (ppm)														
1- Omm Dongel	0.10	0.13	0.17	0.15	0.12	0.44	0.43	0.45	0.15	0.11	0.08	0.07	0.20	0.04
2- El-Senania	0.52	1.24	0.24	0.32	1.12	0.30	0.49	0.92	0.95	0.87	0.24	0.41	0.64	0.10
3-Marssok	0.49	0.70	0.59	0.31	0.31	0.24	0.32	0.22	0.20	0.55	0.28	0.35	0.38	0.05
4- Gamassa	0.48	0.49	0.32	0.97	0.31	0.26	0.25	0.47	0.30	0.22	0.25	0.34	0.39	0.06
E. Phosphorus (ppm)														
1- Omm Dongel	12.40	15.20	16.60	13.10	8.40	4.33	16.20	15.20	18.40	16.30	2.90	2.80	11.82	3.41
2- El-Senania	11.00	22.97	3.34	30.88	4.46	11.79	12.60	33.83	25.20	10.54	5.95	5.12	14.81	4.27
3-Marssok	12.56	14.46	18.37	9.69	6.60	13.60	18.40	14.30	16.40	9.97	6.84	8.76	12.50	3.61
4- Gamassa	11.51	26.94	20.41	11.59	7.89	1.84	8.60	10.34	9.20	3.55	7.31	4.51	10.31	2.98
F. Silica (ppm)														
1- Omm Dongel	2.70	3.10	2.50	2.47	2.45	2.00	2.92	2.20	3.62	2.60	1.32	2.59	2.54	0.73
2- El-Senania	2.60	3.20	1.90	1.74	2.89	3.58	2.66	1.96	2.22	1.53	2.41	1.76	2.37	2.37
3-Marssok	2.39	2.90	2.35	2.50	2.32	2.90	2.80	2.03	2.61	1.85	2.69	2.08	2.45	0.71
4- Gamassa	2.38	2.73	2.20	2.30	2.58	2.98	2.96	1.93	2.53	2.06	2.69	2.03	2.45	0.71
G. Sulphate (ppm)														
1- Omm Dongel	126.0	180.0	180.0	54.0	54.0	45.0	54.0	27.0	45.0	45.0	36.0	45.0	74.3	21.4
2- El-Senania	162.0	243.0	252.0	153.0	243.0	135.0	108.0	180.0	162.0	144.0	154.0	113.0	170.8	49.3
3-Marssok	315.0	373.5	378.0	180.0	180.0	180.0	198.0	190.0	189.0	162.0	175.5	171.0	224.3	64.8
4- Gamassa	360.0	335.0	480.0	360.0	380.0	380.0	280.0	235.0	380.0	257.5	244.0	280.0	331.0	95.5

The concentrations of nitrite were very low (0.02 mg/ 0.1 mg/l) at the irrigation canal and increased considerably (0.01 mg /l to 0.33 mg/l) at drainage canals. Such increases could be caused by the action of nitrifying bacteria in this canal that receive agricultural and sewage pollution. Supporting these findings, the nitrite-N of the River Nile (segment from Mansoura city to Faraskour dam) varied between 0.0 and 0.22 mg/l with northward increase (Shaaban Dessouki and Baka 1985). Similarly nitrate, values were very low (0.0-0.24 mg/l) at irrigation canal and considerable at drainage canals particularly during autumn months (0.01 mg/l-2.1 mg /l). This may be mainly due to the agricultural runoff to the latter canals. The decrease in nitrate contents during summer might be due to its utilization by phytoplankton (Hutchinson 1967).

As apparent also from table 3, the values of orthophosphate recorded at the irrigation canal appeared lower in relation to those recorded at drainage canals. These values ranged from 0.07-0.44 mg/l for the irrigation canal and from 0.2 mg/l to 1.24 mg/l for drainage canals. In addition, the value of total phosphorus fluctuated between 2.8

mg/l-18.4 mg/l at irrigation canal and between 3.55-33.83 mg/L at drainage canals. These findings could be explained on the basis of PO_4^{--}-P consumption by high phytoplankton density at surface water (Brown and Austin 1973). Moreover, Deyab (1987) indicated that the Damietta estuary water has very high values of total phosphorus (6.98-24.89 mg/l). Heavy polluted water by domestic and agricultural sewage and the total dissolved phosphorus is normally present in high quantity in such polluted water (Raymont 1980).

Phytoplankton prefer essentially to utilize phosphorus as inorganic forms, whilst in phosphorus deficiency conditions, some phytoplankton has the ability to produce alkaline phosphatase for enzymatic hydrolysis of organically bound phosphates to inorganic phosphorus (Vrba *et al.* 1995). The available phosphorus limits the maximum biomass of the phytoplankton in freshwater systems (Gibson *et al.* 1996). Phosphorus increases by erosion of sediments and by using fertilizer (Carpenter *et al.* 1998). Competition for phosphate leads to a replacement of green algae by large diatoms, which are only partly available to zooplankton as food (Sommer *et al.* 1986).

Silica values appeared alike for the different stations ranged between 1.533-3.58 mg /l. These results seemed most likely to those obtained by Shaaban Dessouki and Baka (1985) who recorded 0.16-3.9 mg silica/l in Damietta branch of the River Nile. Diatoms took up all the dissolved Si, which disappeared from the water column (Tallberg 1999). Silica depletion may lead to a replacement of the large diatoms by large dinoflagellates and/or Cyanophyta (Sommer *et al.* 1986). The concentration of $SO4^{--}$ was low at irrigation canal varied between 27-180 mg/l and high at drainage canals ranged from 108-480 mg/l). These results are in consistence with the changes in salinity. In accordance with these observations, Kebede *et al.* (1994) found that the concentration of SO_4^{--} increased with increasing salinity and alkalinity.

In table 4, the trend of change in sodium concentration was more or less similar to that of salinity. The values of sodium ranged between 108-400 mg/l at irrigation canal and between 120-900 mg/l) at drainage canals. In confirmation, there was a strong positive correlation between increasing salinity and the concentration of Na^+, alkalinity and Cl^- (Kebede *et al.* 1994). Sodium is an important requirement for photosynthesis and transport transport of several components (Garcia-Gonzales *et al.* 1987; Maeso *et al.* 1987; Lara *et al.* 1993). Potassium values were varied between varied between 12.5-37.5 mg/l at irrigation canal and between 10-75 mg/l at drainage canals. Potassium is used as a cofactor for a variety of enzymes required for algal growth and photosynthesis (O'Kelley 1974). However, Na^+ and K^+ could be considered as indicators of sewage effluents (Abdel-Hamid *et al.* 1992). Nevertheless, Na^+ exceeds K^+ depending on the different sampling locations and different seasons (Ahmed *et al.* 1983).

Iron recorded at irrigation canal varied from 0.83-0.98 ppm but varied from 1.2-2.8 ppm at drainage canals. Quantitatively, iron is the most important trace metal for phytoplankton. It is believed to assume an even greater role as an algal growth limiting nutrient. It is required in numerous redox reactions and in the synthesis of chlorophyll (O'Kelley 1974). The concentration of copper in the present study ranged between 0.07-0.17 ppm in the irrigation canal and from 0.11-0.48 ppm at drainage canals. Copper, even though is an essential micronutrient, it is very toxic to algae; copper sulphate and other copper-containing compounds have been used to control algal blooms in freshwaters by inhibiting growth as well as photosynthesis of algae (Fujita *et al.* 1977).

Table (4): Monthly variations of sodium, potassium, iron, copper, zinc and manganese of water at some of Western Damietta canals during the year 1998.

	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	S.E
A. Sodium (ppm)														
1- Omm Dongel	280.0	400.0	400.0	120.0	120.0	108.0	120.0	160.0	108.0	118.0	180.0	110.0	185.3	53.5
2- El-Senania	360.0	540.0	560.0	520.0	340.0	300.0	240.0	400.0	360.0	320.0	120.0	140.0	350.0	101.0
3-Marssok	700.0	830.0	840.0	400.0	400.0	400.0	440.0	200.0	420.0	360.0	390.0	380.0	480.0	138.6
4- Gamassa	800.0	860.0	900.0	800.0	400.0	600.0	500.0	600.0	400.0	550.0	320.0	500.0	602.5	173.9
B. Potassium (ppm)														
1- Omm Dongel	14.0	26.0	18.0	21.0	30.0	37.5	25.0	30.0	35.0	16.0	12.5	35.0	25.0	7.2
2- El-Senania	16.5	28.0	20.0	26.5	75.0	37.5	28.5	36.0	48.5	18.5	18.5	45.0	33.2	9.6
3-Marssok	50.0	25.0	20.0	10.0	37.5	52.0	22.5	25.0	50.0	18.8	50.0	50.0	34.2	9.9
4- Gamassa	50.0	26.5	26.0	50.0	50.0	75.0	50.0	30.0	62.5	36.5	60.0	50.0	47.2	13.6
C. Iron (ppm)														
1- Omm Dongel	0.95	0.96	0.98	0.91	0.91	0.92	0.83	0.93	0.92	0.92	0.91	0.98	0.93	0.01
2- El-Senania	1.20	1.30	1.38	1.43	1.56	1.61	1.70	1.80	1.71	1.65	1.50	1.40	1.52	0.05
3-Marssok	1.50	1.65	1.80	1.90	2.00	2.20	2.25	2.30	2.26	2.10	1.90	1.70	1.96	0.08
4- Gamassa	1.38	1.40	1.45	1.50	1.60	2.20	2.60	2.80	2.70	2.56	2.40	1.60	2.01	0.57
D. Copper (ppm)														
1- Omm Dongel	0.07	0.09	0.09	0.08	0.09	0.09	0.10	0.12	0.17	0.16	0.14	0.11	0.11	0.01
2- El-Senania	0.18	0.14	0.11	0.16	0.15	0.18	0.21	0.24	0.28	0.26	0.22	0.21	0.20	0.01
3-Marssok	0.16	0.28	0.40	0.31	0.38	0.41	0.48	0.36	0.41	0.32	0.28	0.26	0.34	0.09
4- Gamassa	0.14	0.24	0.34	0.21	0.36	0.41	0.46	0.34	0.36	0.31	0.26	0.24	0.31	0.09
E. Znic (ppm)														
1- Omm Dongel	0.86	0.89	0.62	0.66	0.78	0.79	0.91	0.92	0.95	0.97	0.93	0.88	0.85	0.03
2- El-Senania	1.94	1.96	1.99	1.30	1.20	1.25	1.23	1.37	1.26	1.22	1.10	1.96	1.48	0.10
3-Marssok	11.81	25.70	41.98	43.10	41.00	12.60	4.60	4.97	2.10	2.90	3.50	8.90	16.93	4.74
4- Gamassa	8.60	10.70	12.20	15.80	11.35	9.60	7.70	6.50	4.30	3.80	12.40	5.65	9.05	1.05
F. Manganse (ppm)														
1- Omm Dongel	0.00	0.00	0.01	0.08	0.16	0.17	0.12	0.12	0.11	0.11	0.18	0.02	0.09	0.02
2- El-Senania	0.01	0.01	0.02	0.08	0.16	0.18	0.21	0.23	0.22	0.20	0.19	0.03	0.13	0.03
3-Marssok	0.34	0.32	0.34	0.32	0.30	0.28	0.26	0.23	0.24	0.27	0.29	0.30	0.29	0.01
4- Gamassa	0.32	0.31	0.33	0.30	0.28	0.27	0.25	0.23	0.22	0.20	0.11	0.28	0.26	0.02

The concentration of Zn varied from 0.62-9.7 ppm the at irrigation canal and from 1.1-43.1 ppm at drainage canals. The later stations, however, receive great amount of the agricultural discharges, in addition to usual doses of industrial wastes. Nevertheless, there was a sharp variation in zinc content correlated with the type of water sources as well as the degree and / or the amount of pollution during a specific time. Zinc metal was considered as the first heavy metal pollutant. Although zinc is a micronutrient it is very often found in high concentrations in algal biomass due to accumulation (Vymazal 1995). Manganese concentration varied between zero to 0.17 ppm at the irrigation canal and from 0.01- 0.342 mg/l at drainage canals. The concentration of Mn may be attributed to the content of Mn in the pollutants discharged to different drainage canals. Manganese is known to activate and constituent several enzymes thereby it is considered -at the sublethal doses- to be of a great importance to many vital processes (Vymazal 1995).

Biological analysis

Irrigation canal: As can be seen from figure 2, there was a gradual increase in the total phytoplankton growth at Omm Dongel by increasing temperature from 880 x 10^3 cell /l in January, 18439 x10^3 cell/l in February to 140039 x10^3 cell/l in March. This might be resulted from a sharp decrease in the nutrient pool of meso to eutrophic water (Fig. 3A). The minimum growth of phytoplankton was recorded in April (237 x 10^3 cell/l). Again by increasing nutrients concentration in irrigation water, the phytoplankton growth could be increased from May (1370 x 10^3 cell/l) to June (35996 x 10^3 cell/l) which might consume more nutrients resulting in a decrease in the phytoplankton growth in July (1338 x 10^3 cell/l).

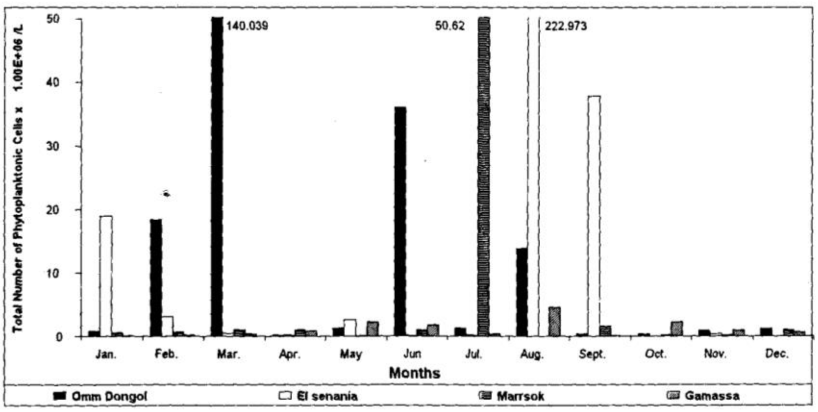

Figure (2): Monthly variations of total number of phytoplanktonic cells identified in water at some of Western Damietta canals during the year 1998.

A high rate of phytoplankton growth was detected in August probably because of a considerable increased nutrients and temperature. The reverse pattern was also detected during autumn months. The predominant group at this station was Cyanophyta mainly as *Merismopedia punctata* in January (73%) and in December (49%) and also as *Microcystis pulverea* in May (83%) and *spirulina laxa* in June (89%). Moreover, Cyanophyta predominated in July (74%), August (91%) and September (88%) and November (69.3%) mainly by a considerable growth of *Oscillatoria coerutescens, O. rupicola, Merismopedia punctata* respectively. Chlorophyta, flourished by *Chlorella vulgaris, Crucigenia tetrapedia* and *Actinastrum hantzschii* constituting 89% and 98% of total phytoplankton in February and March, respectively. Bacillariophyta predominated in October (71%) and in December (53%), this mainly due to flourish of *Naviculla cnicta, Nitzschia sublinearis* and *Bacillaria paradoxa.* The sharp fluctuation of Bacillariophyta growth in autumn may be due to the sharp fluctuation of silicon. In this respect, Kebede *et al.* (1994) reported that the decline in silica concentration combines with an increase in algal production. Moreover, Bacillariophyta substituted the dominance of Chlorophyta during other months. Competition for phosphate leads to a replacement of green algae by large diatoms, which are only partly available to zooplankton as food (Sommer *et al.* 1986). Dinophyta especially *Peridinium orbiculare* and *Gymnodinium eurytopium* mostly represented the growth of phytoplankton in April and low growth in March. Silica depletion leads to a replacement of the large diatoms by large dinoflagellates and/or Cyanophyta (Sommer *et al.* 1986). Euglenophyta was observed by appearing few species as *Euglena acus* and *Phacus caudatus.*

The composition of phytoplankton may be attributed to the relative high temperature in summer and the slight pollution of water concomitant with considerable amounts of phosphorus and nitrogen that would promote growth of Cyanophyta. In agreement with this explanation, some researchers confirmed that the seasonal development of phytoplankton is subjected to variety of controlling factors including water temperature, turbidity and nutrients (Sabater and Munoz 1990).

Drainage canals: At El-Senania station, there was an intense growth of Cyanophyta which predominated the other groups during March (57.8%), May (48%), June (79%), July (53%), August (99%), September (99.7%) and December (98%) (Fig, 3B). The intensive growth was mainly due to flourishing of *Oscillatoria putrida* Schmidle, *O. limosa* Ag. *Gloeocapsa magma* (Breb.) Kutz. Emend Hollerb. Chlorophyta predominated in January (70.4%) mainly due to the growth of *Pandorina morum* (O. Mul.) (Bory). Bacillariophyta predominated in October (75%) by considerable growth of *Cyclotella* sps and *Nitzschia* sps. Chlorophyta and Bacillariophyta alternated the second position of dominance in most months. The fluctuation of Bacillariophyta was attributed to different source of pollutants and reactive silica (Gibson *et al.* 1996). Dinophyta predominated during April (52.8%) represented by the considerable growth of *Peridinium volzii* Lemmermann. This maybe appeared to be due to increased sewage pollution and to the depletion of the reactive silica in water. The maximum growth of Euglenophyta was recorded in April (21.6%) mainly represented by *Euglena polymorpha* Dang.

At Marssok station, there was a gradual increase in phytoplankton growth during winter months. Cyanophyta predominated in most months forming 54% in January, 63% in March, 73.3% in April, 76% in July, 91% in September and 63% in October mainly as *Oscillatoria quadripunctulata, O. rupicola, O. putrida, O. Agardhii* (Fig, 3C). This may be attributed to Sewage input and agricultural runoff, which influence fresh water chemistry by increasing nutrient loading and ionic content (Jenkins *et al.* 1995). Chlorophyta predominated during February (72%), June (44%) due to the considerable growth of *Pandorina morum* and *Dictyocha navicula* Ehr. On the other hand, Bacillariophyta dominated during May (94%), August (99%), November (57%) and December (60%). This was mainly due to the relative growth of *Navicula perpusilla, N. tuscula, N. cincta, Cyclotella menghiniana, Nitzschia sublinearis, Bacillaria paradoxa* and *surirella delicatissima.* Meanwhile, Dinophyta, mainly as *Gymnodinium mitratum* and *Peridinium volzii*, represented in January, February and April 10%, 4.5% and 8.5% of the total phytoplanktonic growth, respectively. Euglenophyta, mainly represented by *Euglena oxyruis, E. polymorpha* and *Phacus caudatus,*was of heavy growth in May. The composition of phytoplankton community at Gamassa station was detected as Cyanophyta which predominated during August (50%), September (98%) October, November and December forming respectively 50%, 98%, 70%, 47% and 74% of the total phytoplanktonic growth (Fig, 3D). It was represented mainly by *Oscillatoria planctonica, O. amphibia, Spirulina trolleri* and *O. rupicola.*

The present results are in accordance with those of Reynolds (1984) who reported that Cyanophyta extend their dominance from summer to other seasons in later year. Bacillariophyta predominated during winter months, January, February and March as well in July forming 91%, 54%, 73% and 53% of total growth, respectively. This group was represented mainly as *Navicula tuscula, Nitzschia sublinearis, N. obtusa, Cyclotella menighiniana* and *Fragilaria construens*. As revealed in the literatures, the abundance growth of Bacillariophyta during winter may be favored by the low temperature and light (Reynolds 1984; Descy 1987). Chlorophyta predominated during April (64%) and May (45%) but became the second group during autumn months, October, November and December constituting 24%, 8% and 12% respectively. The growth of Chlorophyta was mainly due to the high growth of *Pandorina morum, Chlorella vulgaris* and *Protococcus viridis.* Dinophyta predominated during June forming 50% of phytoplankton growth and represented the second group in February (40%) and March (17%) and the third group in

April (3%) and May (2%). This mainly due to the high growth *of Exuviaella comperssa, Peridinium volzii* may be due to the changes in the hydrographic conditions as reported by Reynolds (1973). Some growth of Euglenophyta was recorded during March (4%), July

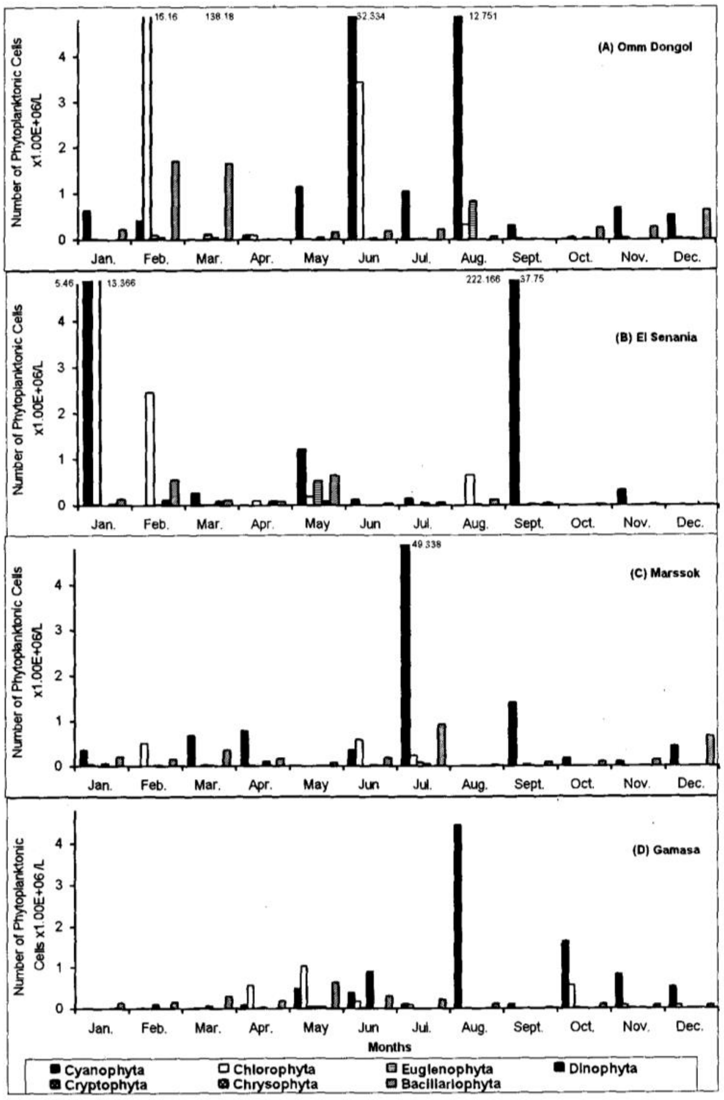

Figure (3): Monthly variations of number of the various phytoplanktonic groups identified in water at some of Western Damietta canals during the year 1998.

(5%) and September (6%) as *Astasia dangeardii, Euglena acus, Euglena viridis* and *Tracheomonas bulla* may be due to organic enrichment in this station. In accordance, Hutchenson (1967) recorded great growth of *Euglena* in organically polluted bodies of water. Cyanophyta alternated Bacillariophyta for the second position of dominance during most months. The high growth of diatoms and Cyanophyta may be attributed to sewage pollutants and relatively high silicon concentration. Chrysophyta detected only as *Mallomonas globosa,* was the second dominant group (8.4%) during January.

These findings clearly indicate that the variations of phytoplankton growth depend mainly on the type and quantity of pollutant discharges. Consequently, a fluctuation in the growth of phytoplankton could be recorded in the same month for the different drainage canals. Indeed during August, the maximum growth (222973 x 10^3 cell/l) was recorded at El Senania while the minimum (14 x 10^3 cell/l) being at Marssok. Similarly, in July, the maximum growth (50620 x 10 ^{3} cell/l) was recorded at Marssok and the minimum growth (274 x 10^3 cell/l) was recorded at El Senania. As a result of such system of phytoplankton growth in drainage canals low growth of phytoplankton was also recorded in April, May, November and December. A plausible explanation is that the irrigation canal, El Senania is receiving low amounts of domestic and agricultural discharges. On the contrary, Marssok canal accepting much amounts of agricultural discharges containing fertilizers, herbicides and insecticides frequently used during these months for crops as rice and cotton.

As a whole, Bacillariophyta was detected in the different water canals throughout the entire period of investigation, although with different degrees of dominance. Nevertheless Chlorophyta seemed to alternatedominance with Bacillariophyta. In this context, Guasch *et al.* (1998) reported that Bacillariophyta predominant communities were more tolerant than Chlorophyta. However, the present results clearly indicate that silica did not seem to be a limiting factor for Bacillariophyta growth because it was found by enough concentration for diatom growth. In this respect, Kebede *et al.* (1994) reported that the decline in silica concentration combines with an increase in algal production.

Generally, the change of the water chemistry may affect the individual and species number as well as composition of phytoplankton at the different stations. It is documented that salinity is an important factor in increasing the tolerance of algae to toxicants such as heavy metals (Haglund *et al.* 1996). The present results clearly indicate that the chemical characteristics of water were generally coincided with the biological constituents of phytoplankton. In fact, as shown in table 5, the species diversity of phytoplankton indicate that Omm Dongel station attained the highest number of species indicating that this indicate that Omm Dongel station attained the highest number of species indicating that this canal is slightly polluted. In contrast, the saprobic index values were lowest to clarify a slight contamination and hence water could be considered to be located in ß``- mesosaprobic zone.

Moreover, compound eutrophication indicated that the irrigation water was mesotrophic (1.05–1.99). However, the chemical analyses proved that water was sufficiently or slightly contaminated; considerable values of dissolved O_2 were record at irrigation canal. These findings coincided with the nature of this bay, which is considered as the main sources of water along the area of investigation. On the other hand, low phytoplankton diversity at El Senania station was coincided with a decreased oxygen concentration. This might point to claim that water at this station was heavily polluted. In support, the saprobic index indicates that water at this station is heavily contaminated and located in α``-mesosaprobic. Moreover compound eutrophication was highest at El Senania station indicating that water of this canal is eutrophic (3.2–4.21). This probably due to that this station is receiving large amount of domestic sewage as organic pollutants beside agricultural discharges.

Table (5): Changes in diversity index, saprobic index and compound eutrophication of water at some of Western Damietta canals during the year 1998.

	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
A. Diversiy Index													
1- Omm Dongel	2.00	2.00	2.00	1.18	2.30	2.30	2.10	2.34	2.60	2.30	2.20	2.00	**2.11**
2- El-Senania	1.11	1.19	1.25	0.89	1.03	0.66	0.80	1.37	1.26	0.50	0.45	0.00	**0.88**
3-Marssok	1.11	0.81	0.91	0.94	0.96	1.22	1.22	1.04	1.56	0.86	1.20	0.85	**1.06**
4- Gamassa	0.58	1.30	0.70	0.97	1.26	1.29	0.96	0.98	1.10	1.20	1.40	1.60	**1.11**
B. Saprobic Index													
1- Omm Dongel	2.20	2.00	2.00	2.10	1.90	2.10	2.10	2.20	2.00	2.20	1.80	2.00	**2.05**
2- El-Senania	2.05	2.00	2.80	3.72	3.01	3.68	3.00	3.80	2.96	3.60	2.96	3.70	**3.10**
3-Marssok	2.90	2.98	2.40	2.30	3.10	2.30	2.50	3.10	2.10	2.80	2.05	3.10	**2.60**
4- Gamassa	2.40	2.97	2.70	2.70	2.20	2.50	3.00	2.30	2.50	2.50	2.40	3.40	**2.60**
C. Compoud Eutrophication													
1- Omm Dongel	1.90	1.88	1.69	2.00	2.00	1.99	1.05	1.20	1.20	2.00	2.00	1.80	**1.73**
2- El-Senania	3.20	3.20	3.99	3.20	3.20	3.99	4.20	3.20	3.08	3.10	3.30	4.00	**3.47**
3-Marssok	3.00	2.60	2.99	2.99	2.00	2.99	3.16	3.20	3.10	3.20	3.20	2.99	**2.95**
4- Gamassa	2.10	3.09	3.01	2.10	3.16	2.60	2.60	2.50	2.40	2.99	2.40	2.00	**2.58**

In contradistinction, there was a considerable diversity of species at Gamasa and Marssok stations. This may indicate that both stations are moderately polluted. Saprobic index, however, indicated that water at these stations was moderately contaminated and located in $\alpha\alpha$`-mesosaprobic zone. Moreover compound eutrophication evidenced that the drainage canals water was meso- to eutrophic (2.1–3.2). This could be attributable to the much amounts of agriculture discharge and low amount of domestic sewage. Therefore, it could be concluded that an increase in the degree of pollution would subsequently result in a decrease in the diversity of phytoplanktonic species with a concomitant increase in the saprobity index.

Microalgal diversity of species is an intrinsic part of biodiversity of aquatic communities (Ibelings *et al.* 1998). Pollution toxicity was indicated by low number of species occurring in the communities (Bokn *et al.* 1996). Eutrophication, however, would result an oxygen deficiency and consequently mass mortality of aquatic organisms have alarmed the public to emerge from the enhanced oxygen consumption required to mineralize the increasing amounts of organic matter produced within the ecosystem (Borum and Sand- Jensen 1996).

Phytoplankton Biomass

Figure 4 reveals that there was a sharp variation of total phytoplankton biomass. The high phytoplankton biomass was recorded during February, August and December. In the first, Bacillariophyta predominated followed by Chlorophyta and Euglenophyta forming respectively 8.8 mg/l, 4.2 mg/l and 3.5 mg/l. In August, phytoplankton biomass was 24.55 mg/l mainly due to the growth of Euglenophyta which formed about 60% of this biomass while the biomass of Chlorophyta and Cyanophyta was 8.9 mg/l and 1.5

mg/l, respectively. In December phytoplankton biomass being 18.4 mg/l from which Euglenophyta constituted 9.6 mg/l followed by Bacillariophyta as 8.24 mg/l.

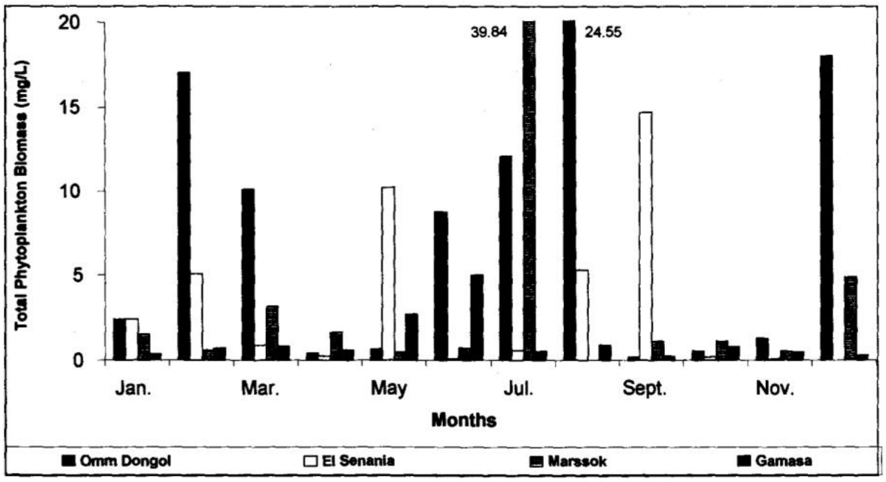

Figure (4): Monthly variations of total biomass of phytoplanktonic identified in water at some of Western Damietta canals during the year 1998.

On the other hand, moderate values of phytoplankton biomass were recorded during July (12 mg/l), March (10.1 mg/l) and June (9.2 mg/l), mainly due to the growth of Euglenophyta and Bacillariophyta then followed by Chlorophyta and Cyanophyta. A low value of total biomass was recorded at irrigation canal during January (2.39 mg/l), May (0.65 mg/l) and October (0.52 mg/l) due to some growth of Bacillariophyta as well as in April (0.065 mg/l) and November (0.127 mg/l) due to Cyanophyta and Euglenophyta (Fig. 5A). Therefore, more than one group of phytoplankton participated in total biomass pointing out to a lower level of pollution, which would lead to high species diversity of phytoplankton in the irrigation canal, Omm Dongal station.

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In the drainage canals, Cyanophyta contributed most the phytoplanktonic biomass. In fact, 36.5 and 1.1 mg/l were recorded at Marssok station in July and April, respectively (Fig. 5B). Most likely at El Senania station, 3.8 and 11.05 mg/l were similarly recorded in August and September, respectively. This may be attributed to the

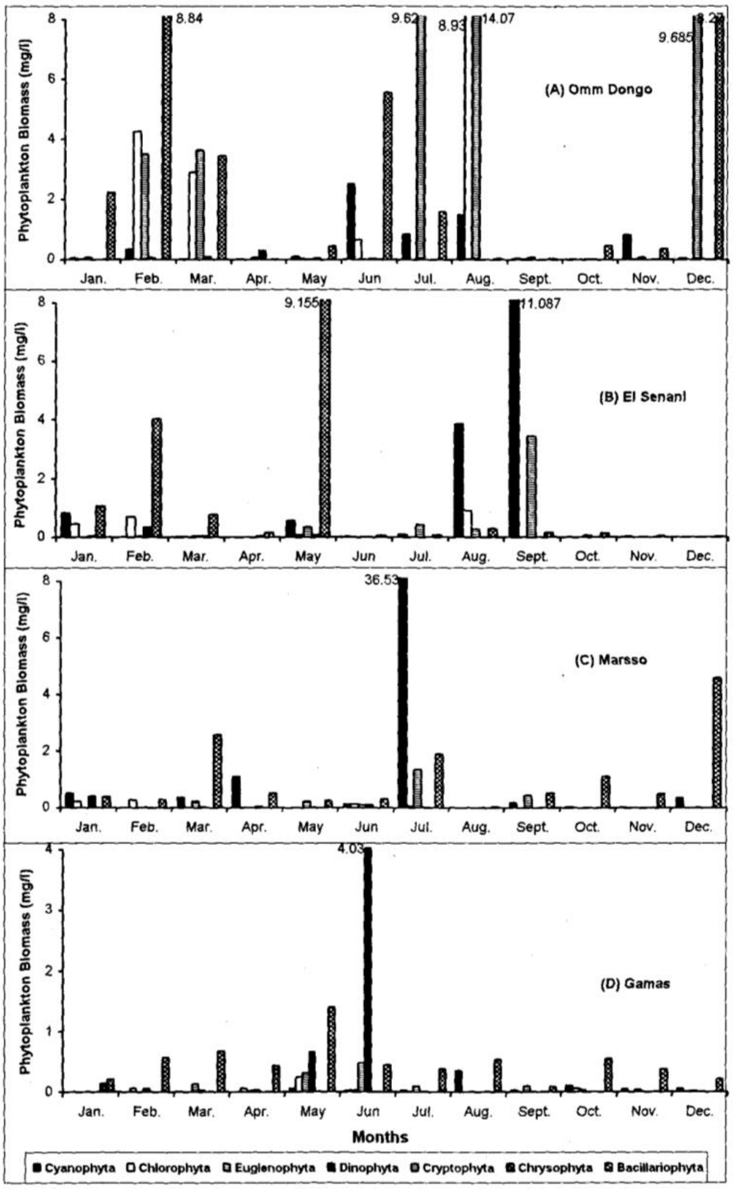

Figure (5): Monthly variations of total biomass of the various phytoplanktonic groups identified in water at some of Western Damietta canals during the year 1998.

discharge of considerable amounts of domestic sewage. Bacillariophyta predominated at El Senania in May and February forming 9.15 mg/l and 4.3 mg/l, respectively. Also 4.5

and 2.57 mg/l were recorded at Marssok station in December and March, respectively (Fig. 5C). These results are in coincidence with the observations of Schelske *et al.* (1978) who reported that the high growth of diatoms may be attributed to sewage pollutants and relatively high silicon concentration.

The lowest values of phytoplankton biomass were recorded at Gamassa station during the entire period of investigation (Fig. 5D). This could be attributable to the relative high salinity levels (3.2-5.5‰) of water at Gamassa drainage which would limit the growth and size of phytoplankton. Therefore, high salinity would tend to decrease the phytoplankton standing crop. On the other hand, the highest values of phytoplankton biomass was obtained in June (5.02 mg/l) due to the considerable growth of Dinophyta (4.04 mg/l). A low growth of Bacillariophyta was evident during other months from 0.09-1.4 mg/l. As a whole, the only phytoplanktonic group predominated in total phytoplanktonic biomass at drainage canals was Bacillariophyta. This could be explained on the basis of the high amounts of pollution, which might encourage growth and/or lead to a predominance of only one phytoplanktonic group.

Phytoplankton growth succession and composition over the year indicate that the irrigation water was slightly polluted and mesotrophic. Meanwhile the water of drainage canals was eutrophic and moderate or heavy polluted. The multiple and/or misusing of agrochemicals in the agriculture would reduce or inhibit the phytoplankton growth in the drainage water. These results might point out that the low quality of some crops such as rice, which is irrigated by drainage water, may be attributed to its uptake of high amounts of agrochemicals and consequently, further research should be carried out to resolve this problem.

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الهائمات الطحلبية كدلائل لجودة المياه في مجارى الري والصرف في المنطقة الشمالية الشرقية لدمياط - مصر

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تم في هذا البحث تقدير التغيرات الشهرية للهائمات الطحلبية وكذلك الخواص الفيزيائية والكيميائية لمياه مجارى الري والصرف في منطقة شمال شرق دمياط علي مدار عام ١٩٩٨ كدليل علي جودة المياه. وأثرت المخصبات أو المبيدات الزراعية المستخدمة في الزراعة علي تنوع الهائمات الطحلبية كماً ونوعاً في المواقع المختلفة الذي كان دليلا على تفاوت درجة جودة المياه في المواقع المختلفة. وتم تعريف ١٢٦ نوعا من الطحالب في مياه الري لترعة آم دنجل منها ٨١ للطحالب الذهبية، ١٤ لليوجلينية،١٣ للخضراء،١١ للخضراء المزرقة، ٦ للدينوفيتية ونوعا واحدا فقط من الكربتوفيتية بينما تم تعريف ٢٨، ٦٨، ٥٦ نوعاً في مياه المصارف الثلاثة السنانية، مرزوق وجمصة علي التوالي، وكان عدد الطحالب الذهبية في المواقع الثلاثة ١٤، ٤١، ٣٣ أما الخضراء المزرقة فكانت ٣، ١٠، ٥ واليوجلنية ٧، ٥، ٦ والخضراء ٣، ٧، ٨ والدينوفيتية ١، ٤، ٢. ومن حيث عدد الخلايا وجد إن الهائمات الطحلبية كانت ممثلة في مياه الصرف بالطحالب الخضراء المزرقة أما فى مياه الري فقد مثلت الطحالب الخضراء ٧٤٪ والخضراء المزرقة ٢٣٪ والذهبية (الدياتومات) ٢,٥ ٪. ونتجت الكتلة الحية أساسا عن النموات الهائلة للطحالب اليوجلنية والخضراء والذهبية في مياه الري وعن النموات الكثيفة للطحالب الخضراء المزرقة في مياه الصرف. وأوضحت دلائل التنوع والتعفن والتركيب أن مياه الري كانت متعددة العشائر وانها كانت اقل عفونة وان تركيبها الطحلبي كان وسطياً، أما مياه الصرف فكانت الأقل في عدد الأنواع والأعلى عفونة مما قد يؤثر على جودة الإنتاج الزراعي بالمناطق التي تستخدم هذه المياه.