Arab Gulf Journal of Scientific Research, 22 (4): 206-216 (2004)

Original Paper Ref. No 2289

Water Quality Observations in the Dekhaila Harbour, Alexandria, Egypt

مراقبة خصائص المياه فى ميناء الدخيلة، الأسكندرية، مصر

ممدوح أحمد فهمى، نجوى السيد عبد العزيز، و محمد موسى درغام*

M.A.Fahmy, N.E.Abdel-Aziz1 and M.M.Dorgham*

**Oceanography Department, Faculty of Science, Alexandria University, Egypt*

*قسم علوم البحار، كلية العلوم، جامعة الأسكندرية، مصر

Abstract: The Dekhaila Harbour, which was recently constructed in Alexandria, has become a highly eutrophied areas due to intensive maritime activities, and the effect of a mixture of nutrients and different pollutants reaching the harbour through land-based effluent. Environmental observations which were carried out monthly from April 1998 to March 1999 demonstrated extremely high nutrient level and productive phytoplankton, showing wide temporal and spatial variations. The variability of surface salinity was one of the characteristic features of the harbour, falling within the range of 17.3 - 39.2 ppt. Nutrients sustained pronouncedly high values, with annual average of 19.22 µM for nitrate, 4.16µM for nitrite, 38.69µM for ammonia, 6.44µM for phosphate and 49.52µM for silicate. Chlorophyll a was exceptionally high (up to 1323.7 µg/l), having an annual average of 107.5 µg/l. The harbour water was relatively turbid most of the year. The concentrations of dissolved oxygen revealed the alternation of good (5-10 ml/l) and relatively bad (1.9- 4 ml/l) aeration conditions. Consequently, low zooplankton abundance was found in the Dekhaila Harbour (annual average: 22,640 ind./m^3). Statistical analysis showed that the environmental factors controlling both phytoplankton and zooplankton biomass had different seasonal patterns.

Keywords: Eutrophication- nutrients- water quality- plankton biomass - Hydrography- Egypt - Dekhaila Harbour.

المستخلص: يهدف البحث إلى دراسة الخواص البيئية والبيولوجية لميناء الدخيلة الذى أنشئ فى الجانب الغربى من خليج المكس، والذى أصبح يعانى من خصوبة زائدة (شاذة) نتيجة للأنشطة البحرية ولتأثره بمياه صرف متنوعة، كما يهدف البحث إلى التعرف على مدى ما وصلت إليه الحالة البيئية للميناء بعد فترة قصيرة نسبيا من إنشائه. تعتمد الدراسة على قياسات شهرية عند خمسة مواقع للعديد من الخصائص الهيدروجرافية (درجة الحرارة، الملوحة، الأكسجين الذائب، شفافية الماء،)، الأملاح المغذية (أمونيا، نترات، نيتريت، فوسفات، سليكات) والكتلة الحية للهائمات النباتية بالإضافة إلى الكثافة العددية للهائمات الحيوانية. وقد أظهرت النتائج مايلى:

– سايرت درجة حرارة الماء السطحية التغيرات الموسمية المعتادة فى المياه الساحلية المصرية، حيث تراوحت بين 13°م كحد أدنى فى الشتاء و30°م كحد أقصى خلال الصيف.

– تباينت قيم ملوحة المياه السطحية بدرجات كبيرة بين 17.39 - 39.18 جزء فى الألف، عند مواقع الرصد فى فصول العام المختلفة نتيجة لتغير حجم مياه الصرف فى تلك الفصول، وكذلك تبعا لقرب أو بعد كل موقع من مصب مياه الصرف.

– تأرجح تركيز الأكسجين الذائب بصورة واضحة مابين المستوى الحرج للكائنات الحية (2.4 - 3.3 ملجرام/لتر) والمستوى المناسب لها (4.9 - 7.2 ملجرام/لتر)، وقد عزى هذا التأرجح إلى كثرة المواد العضوية فى الميناء.

– تميزت مياه الميناء بانخفاض واضح فى شفافيتها معظم أوقات العام (45 - 105 سم)، وذلك نتيجة لكثرة الهائمات النباتية والتقليب المستمر للماء الذى تسببه الحركة الكثيفة للمراكب والاندفاع القوى لمياه الصرف داخل خليج المكس.

– شهد الميناء ارتفاعا حادا فى تركيزات الأملاح المغذية، حيث بلغ المتوسط السنوى 38.69 ميكرومول للأمونيا، 19.22 ميكرومول للنترات، 4.16 ميكرومول للنيتريت، 6.44 ميكرومول للفوسفات، 49.52 ميكرومول للسليكات. وهذه المتوسطات تمثل أضعاف عديدة لما يوجد عادة فى المياه العادية البعيدة عن مصادر صرف أرضية.

– أدى غنى الميناء بالأملاح المغذية إلى ازدهار قوى للهائمات النباتية حيث بلغت كتلتها الحية متوسطا سنويا قدره 107.5 ميكروجرام/ لتر، الأمر الذى انعكس سلبا على نمو الهائمات الحيوانية والتى انخفض المتوسط السنوى لكثافتها العددية إلى 22460 كائنا فى المتر المكعب.

– من خلال المعالجات الإحصائية للنتائج أمكن تحديد أكثر العوامل البيئية تأثيرا على نمو كل من الهائمات النباتية والحيوانية فى الفصول المختلفة وتكوين معادلات رياضية يمكن استخدامها فى حساب تواجدها الكمى فى أى فصل من الفصول.

كلمات مدخلية: مصر، ميناء الدخيلة، هيدروغرافيا، خصائص، خصوبة

Introduction

Since its establishment in 1986 on the southwestern part of the Mex Bay, west of Alexandria, the Dekhaila Harbour (4-20 m depth) was and is still exposed to marked ecological variations, due to the collective effects of heavy maritime traffic, export and import related activities, ship services, as well as the effect of the different types of waste waters discharged to the Mex Bay bordering the eastern side of the Dekhaila Harbour. As the infrastructure and development of the harbour is still going on, this will consequently leads to increase of the maritime and development activities in the future. Furthermore, the untreated sewage of Alexandria City which was previously discharged to the sea has completely come to an end, and directed at present to Lake Mariut, reaching Mex Bay through Umoum Drain. All these conditions have created more stress on the harbour ecosystem, and undoubtedly cause significant variations in its water quality and biotic components. Several studies have been conducted on the hydrography and plankton of the Dekhaila Harbour, the most recent were those of Fahmy *et al.*, (1997), Abdalla *et al.*, (1995), Zaghloul *et al.*, (1995), Tayel *et al.*, (1996) and Abdel-Aziz (2000). However, due to the increase in the maritime activities and the discharged wastes, it is assumed that water quality and plankton abundance will be subject to permanent ecological stress, that will require long-term monitoring. Therefore, this work assesses the water quality and plankton biomass and their temporal and spatial variations in Dekhaila Harbour under the stress of the conditions mentioned above.

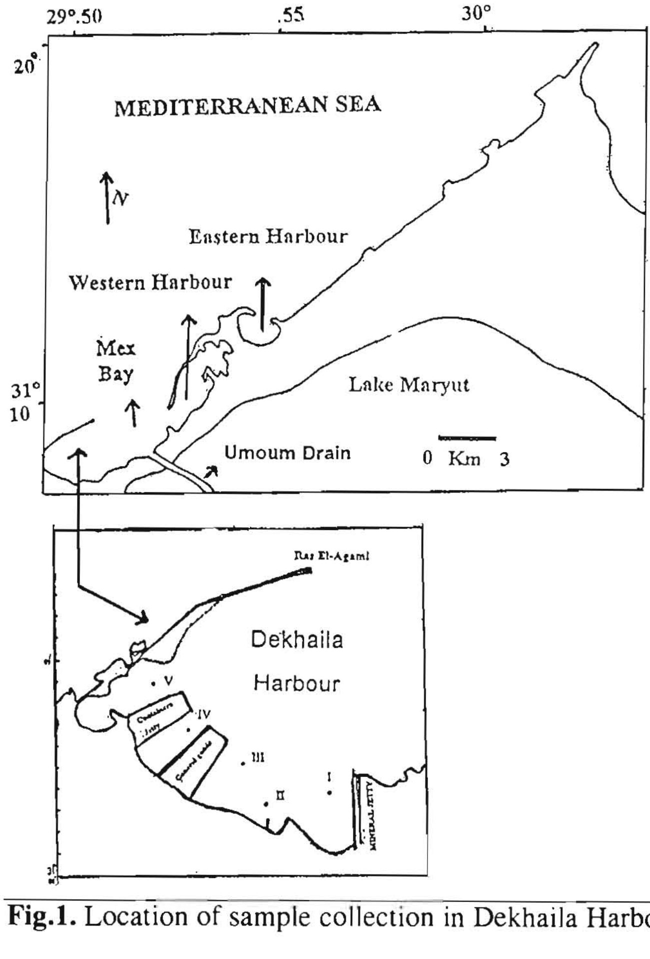

Fig.1. Location of sample collection in Dekhaila Harbour

Material and Methods

The main basin of the Dekhaila Harbour occupies an area of 32.2 km^2 with depth range of 4 - 20 m. It is subdivided into three parts by ship quays, which are opened directly to the Mex Bay. For physico-chemical analysis, surface water samples were collected monthly from April 1998 to March 1999 at five stations (Fig 1), representing different parts of the harbour. Water temperature, transparency, salinity, dissolved oxygen, nutrients (ammonia, nitrite, nitrate, reactive phosphate and silicate) and chlorophyll a and phaeopigments were determined according to Strickland and Parsons (1972) and APHA,AWWA,WPCP (1980).

Quantitative zooplankton samples were collected from the upper 10 m through vertical hauls, using a plankton net of 30cm mouth diameter, 55µm mesh size and 130 cm length. The standing stock of zooplankton was calculated from average three counts of 5 ml each of concentrated preserved samples.

The relationship between both phytoplankton biomass and zooplankton abundance and the physico-chemical parameters were correlated using correlation coefficient and multiple regression analysis applying a SPSS program.

Results and Discussion

Hydrography:

The temporal variations of maritime activities as well as those of discharged waste waters appeared to impact distinctly the water quality in the harbour. The water temperature experienced clear seasonal variations, falling between 13 - 18°C in Winter, 19-21 °C in Spring, 26-30 °C in Summer and 22.5-28 °C in Autumn. Homogenous horizontal distribution of water temperature was recorded throughout the harbour every month, attributed to the limited area of the harbour and strong stirring caused by intense ships traffic, comprising 11 Cargo per day and many small motorized boats for maritime services.

Despite being constructed at the Southwestern extreme of Mex Bay, at a relatively distant place from the outlet of Umoum Drain, the Dekhaila Harbour appeared to be impacted by discharged wastes as well as by the maritime activities. Similar observations were also reported by El-Saraf (1991) and Fahmy *et al* (1997). The construction of the Dekhaila Harbour made the Mex Bay an environmentally unstable area (Gurguess, 1999) as it causes crucial changes in the circulation pattern inside the Mex Bay. The surface salinity showed wide variations (17.34-39.18 ppt) during the whole period of study, but it two water types were reported over the year (Fig. 2), one with high salinity (31.86-38.33 ppt) from February to May, and another of low salinity (22.2-24.5 ppt) from June to January, except the deviated values in November (19.14 ppt) and December (28.39 ppt). The annual amplitudes of salinity variations showed approximately similar values (20.0-20.9 ppt) at stations 1-3, but were narrower at station 4 (18.6 ppt) and station 5 µ17.1 ppt), which were less affected by Umoum Drain discharge. The spatial effect of discharged wastes demonstrated monthly variations, whereas salinity differences between stations were sometimes relatively small (Autumn and Winter) and in other times large (Spring and Summer). Such changes are related to the seasonal variations in the volume (6.6x106 m^3/day) and distribution of the discharged waters in the harbour. The proximity of stations to the entrance of Umoum Drain was reflected in the salinity variations at each station. Since station 1 is the nearest to Umoum Drain it is continuous to be sustained the lowest salinity (Table 1),

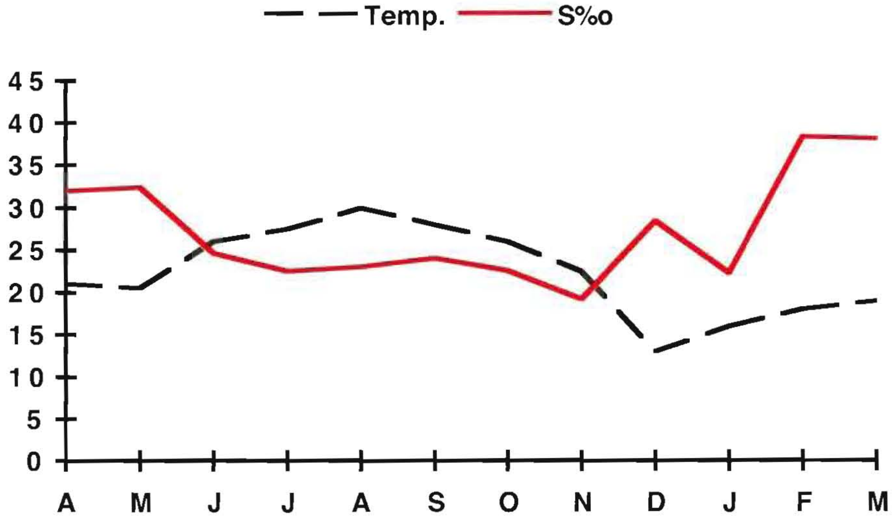

Fig.2. Monthly average temperature and salinity in the Dekhaila Harbour from April 1998 to March 1999)

Table 1- The annual average values of different parameters measured at the sampled stations in the Dekhaila Harbour (April 1998-March 1999)

Stations	1	2	3	4	5
Secchi disc (cm)	100	103	120	111	98
Salinity (ppt)	24.4	26.6	26.5	28.4	27.4
D O (ml/l)	4.5	4.6	4.3	4.6	4.9
Ammonia (µM)	32.95	36.00	37.00	36.45	50.55
Nitrite (µM)	4.99	4.00	4.74	4.39	2.65
Nitrate (µM)	19.91	17.75	20.91	19.14	18.4
Phosphate (µM)	5.48	6.05	5.82	5.62	9.22
Silicate (µM)	48.92	48.39	53.11	47.73	49.27
N/P	5	3.9	4	6.4	5.5
Si/P	11.3	8.8	9.5	9.9	10.6
Chl-a (µg/l)	76.3	69.00	55.00	79.3	257.6
Zoopl. (ind./m^3)	12900	23800	11000	29300	36300

As station 4 was closed to the open sea, it was less affected by these wastes and hence showed high salinity. The long-term observations of hydrographic conditions in Dekhaila Harbour revealed a continuous variability in the range of salinity variation year by year (Table 2).The wide fluctuation of dissolved oxygen in the Dekhaila Harbour reflected the changes of its water quality on a monthly bases, as the monthly distribution of dissolved oxygen indicated two aeration levels, one moderately high (4.9-7.2 ml/l) intermittently during six months (April, June-August, October and March) and a significantly low one (2.4-3.3 ml/l) during the rest of the year (May, September, November, December-February) (Fig. 3).

Table 2- Hydrographic and eutrophication parameters recorded in the Dekhaila Harbour

		Abdalla *et al.*,1995	Tayel *et al.*, 1996	Present study
Sampling date→ Parameter↓		1990-1991	1993-1994	1998-1999
Temp (°C)	Range	18.3 – 29.9	16.2-29.8	13-30
Secchi depth (cm)	Range Average	42 -300 170	------	30-300 106
Salinity (ppt)	Range Average	19.5 -36.5 29.1	13.4 – 36 26.3	17.3 – 39.2 26.7
DO (ml/l)	Range Average	0.7 – 4.8 2.9	4.3 – 10.1 7.5	1.9 -11.8 4.6
NO_3-N (μM)	Range Average	0.52 – 8.28 2.46	ND -2.04 0.89	0.3 -45.29 19.22
NO_2-N (μM)	Range Average	1.23 – 2.1 1.52	0.02- 0.35 0.09	0.21 – 14.98 4.16
NH_4-N (μM)	Range Average	4.38 – 14.2 8.12	1.21 – 29.7 9.85	2.15- 166.25 38.69
PO_4-P (μM)	Range Average	0.3 – 0.6 0.4	0.1 – 5.29 1.13	0.54 – 56.46 6.44

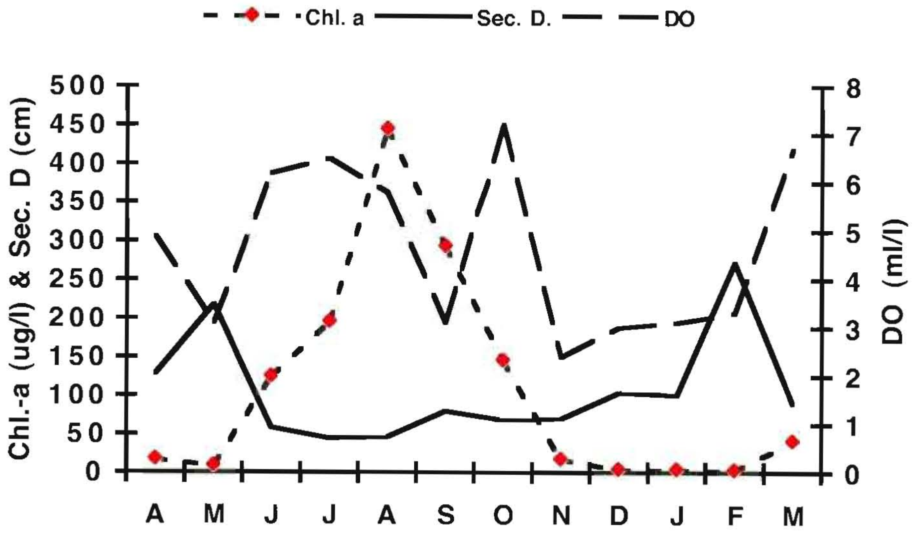

Fig.3. Monthly records of chlorophyll-a, Secch disc and dissolved oxygen in the Dekhaila Harbour from April 1998 to March 1999.

According to the criteria of hypoxia (<1.4ml/l) conditions (Stachowitsch & Avcin, 1988) and threshold level (< 2.8ml/l) of well aerated waters (Huet, 1973), it was clear that oxygen contents in the Dekhaila Harbour during a significant period of the year fall within a range (2.4-3.3 ml/l), closed to the threshold level and slightly higher than that of hypoxia. Such levels are unfavourable for healthy populations of numerous aquatic organisms (Grundy, 1971; Arin, 1974). Although this situation contradicts the high amount of oxygen which was supposed to be photosynthesized by abnormal phytoplankton bloom in the area over the year, it may corresponds to the intensive consumption of oxygen in oxidation of high load of organic matter (3.63-10.07 mg/l), recorded by Tayel *et al.*, (1996) and oil spills released frequently from ships and small motorized boats. Relative to these factors oxygen levels in the Dekhaila Harbour was subject to marked variations during the past decade (Table 2), reflecting deterioration of water quality and brought it near to the critical aeration conditions.

The turbid water dominated in the harbour most of the year, with Secchi depth records varying between 45 cm to 105 cm. Slight clear water (130-270cm) was observed during late Winter and Spring. High turbidity in the harbour is caused by several factors such as the abnormal phytoplankton bloom (Chlorophyll a up to 1323 μg/l), the active mixing, and frequent blown dust of scrap iron, coke which are stored as great heaps on the neighboring land and flour flying from grains milling inside the harbour. Low transparency (170cm) was also reported by Abdalla *et al.*, (1995) in the harbour. Lorentze (1980) and Cruzado (1988) admitted that changes in water transparency have been used to asses the rate of eutrophication.

Nutrients:

The nutritional situation and phytoplankton biomass in the Dekhaila Harbour indicated high fertility that created an acute eutrophication most of the year. The eutrophication parameters fluctuated within abnormally wide ranges on both monthly and spatial scales, demonstrating each different patterns of variation.

Ammonia was the major component of DIN, forming 62.3 % and showing pronounced monthly variations with distinctive peaks in June (52.71μM NH_4-N), August-September (72.74-73.83μM NH_4-N), November (61.08μM NH_4-N) and January (64.19μM NH_4-N). In addition, relatively high concentrations (11.31-35.53μM NH_4-N) were recorded in the other months (Fig. 4).

The ammonia peaks in the harbour coincided with the lowest salinity, particularly in Summer and Autumn, demonstrating a direct relationship between the discharged wastes and the concentration of ammonia in the Dekhaila Harbour. However, negative significant correlation (at p =0.01) was found between ammonia and salinity in Spring (r = - 0.6684) and Winter (r = - 0.9387). This may be related to the decrease of the discharged wastes and consequently their content of ammonia during Winter and Spring as indicated from the relatively high salinity. The spatial distribution revealed little variations between stations 1-4 which contained annual averages of 32.95 - 37.00μM NH_4-N, as compared to markedly higher value (50.55μM NH_4-N) at station 5. This station is exposed to the stress of excess sewage discharged from ships anchoring for relatively long time for fueling and other maritime survices. On the other hand, the high level of ammonia in the harbour may reflect the high

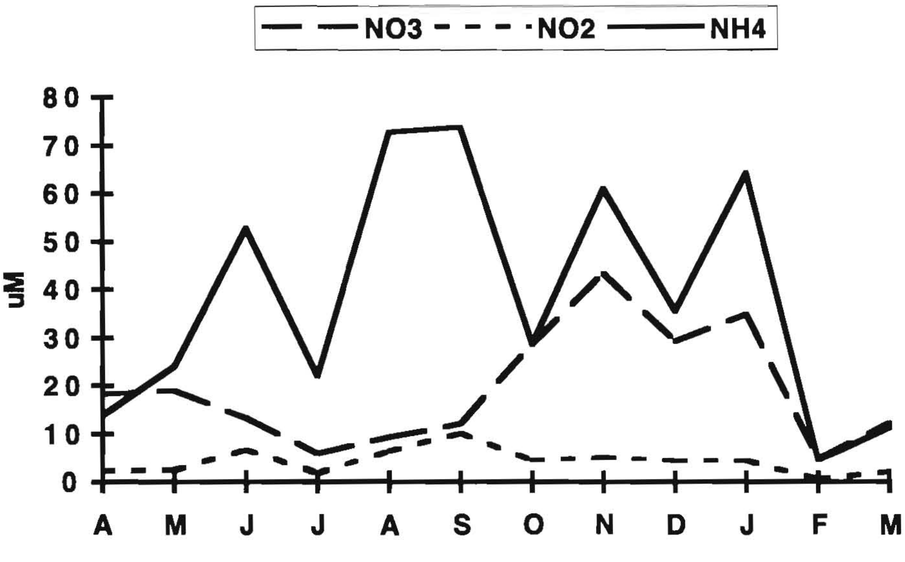

Fig. 4. Monthly records of the dissolved inorganic nitrogen in the Dekhaila Harbour from April 1998 to March 1999.

content of organic matter, resulting from the decay of great numbers of phytoplankton cells, as indicated from high Phaeopigment concentration (annual average: 26 μg/l) measured during the present study, and increasing load of untreated domestic wastes, entering the Mex Bay from Lake Mariut after the complete direction of the sewage of Alexandria City to the lake in 1987. The concentration of ammonia showed significant correlation with Phaeopigment most of the year, whereas r = 0.625 for Summer, 0.819 for Autumn, and - 0.665 in Winter at p = 01 and n = 15. This means a direct relationship between ammonia and decayed phytoplankton during the warm period and reversed in the cold season. Such statement coincided with a progressive increase of ammonia in the harbour during the past decade (Table 2). Furthermore, the concentration of ammonia in the harbour exceeded about 20 times the values that (2μM NH$_4$-N) defined as a low limit of eutrophication by Franco (1983), meaning that the problem of eutrophication is maximizing with time in the Dekhaila Harbour.

Nitrate constituted 31 % of DIN, but it showed different seasonal distribution from that of ammonia (Fig. 4), attaining the highest concentrations (28.79-43.31(MNO$_3$-N) from October to January and relatively high ones (18.31-18.91μMNO$_3$-N) in late spring. Such pattern was associated with negative significant correlation (at p= 0.01) between salinity and nitrate in autumn, winter and spring (r = - 0.7607, - 0.9045 & - 0.6737 respectively). It is worth noticed that in addition to the role of discharged wastes in nitrate supply, indicated by low salinity, the abnormally high nitrate during October- January may be caused also by additive amount brought through the blown flour of milled grains by strong northwest winds frequently reported during this period. In such context, the highest nitrate in the harbour was recorded at station 3 (Table, 1), that is directly affected by the blown flour as the nearest station to the flow-mill. Similar to ammonia, progressive increase of nitrate was detected in the harbour during the past 10 years, representing about 22 times those found in 1993-1994 (Table 2) and 5 folds (4μMNO$_3$-N) of eutrophication level suggested by Franco (1983).

Although nitrite is an intermediate component between ammonia and nitrate, usually found in low amount even in polluted coastal waters, it sustained high concentrations in the study area, reaching a maximum of 14.98μM NO$_2$-N. Figure 4 shows low values of nitrite in winter and spring months and high ones during Summer and autumn, demonstrating the effect of land-based effluent, as indicated from the negative significant correlation of nitrite with salinity in winter (r = - 0.8983 at p=0.001) and Spring (r =- 0.6002 at p = 0.01), where n =15 for both seasons and insignificant correlation in Summer and Autumn. Riley and Chester (1971) found that during the earlier part of regeneration, the nitrite increased progressively to a maximum in Autumn and then fell to lower values in winter. On spatial scale, stations 1-4 measure continuous higher amounts of nitrite than station 5 (Table 1), which may be explained by higher rate of denitrification at station 5. This may be confirmed by the high content of ammonia and relatively low nitrate at station 5. Similar to nitrate and ammonia, the present value of nitrite (Table 2) was 46 times greater than those reported by Fahmy *et al.* (1995), but higher values (up to 21.6 μM NO2-N) were recorded in Mex Bay (Emara *et al.*, 1992).

The reactive phosphate was recorded in markedly high concentrations (up to 56.46μM PO$_4$-P), having peaks in August-September (13.32-17.84μM PO$_4$-P), June (7.62μM PO$_4$-P), November, (7.75(M PO$_4$-P) and January (8.74μM PO$_4$-P) (Fig. 5).

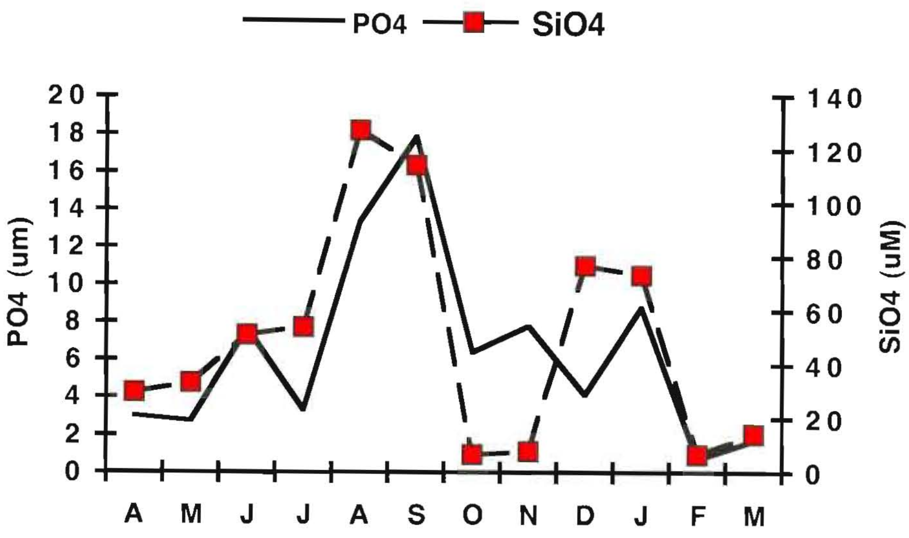

Fig. 5. Monthly Records of reactive Silicate in the Dekhaila Harbour from April 1998 to March 1999.

Similar to DIN components, phosphate showed significant negative correlation with salinity in winter (r = - 0.9268 at p= 0.001) and Spring (r = - 0.7293 at p= 0.01), with n=15 for both seasons, and insignificant one in Summer and Autumn. Such pattern revealed that the role of discharged wastes in phosphate enrichment decreased during winter and Spring with increasing salinity in the harbour. Station 5 was the richest in phosphate (Table 1), while the other stations contained lower approximately closed concentrations (5.48-6.05(M PO_4-P). The high phosphate at station 5 may be related to high organic matter produced from the death and decay of great number of phytoplankton cells (Phaeopigment: 69.4 µg./l), which was exceptionally higher than at the other stations (12.8 - 19.2 (g /l), and the domestic wastes discharged from ships anchoring long time at this station. Comparing with other eutrophied areas on the Egyptian Mediterranean coast, phosphate content in the Dekhaila Harbour (6.44 µM PO_4-P) was pronouncedly greater than those (1.17 µM PO_4-P) measured in the Western Harbour of Alexandria (Dorgham, *et al.*, 2001) and (1.42 µM PO_4-P) in the hot spot of Abu Qir Bay (Abdel-Aziz *et al.*, 2001). Further, the phosphate content in the harbour represents around 6 folds the previously recorded values (Table 2). This may be due to the additive source of phosphate brought to the harbour through the precipitating flour of the milled grains, which are usually rich in phosphate and also to those released from the bottom sediments, amounting to 2.98 µM PO_4-P /m²/day (EL-Samra *et al.*, 1984). In general, the level of phosphate in the harbour reflects an abnormally acute degree of eutrophication, since it is 22 times greater than the level (0.3 µM PO_4-P) assigned by Marchetti (1984) and Stirn (1988) for eutrophic waters.

The relationship between nitrate and phosphate (N/P) showed remarkably lower monthly values (0.7-9.5, Fig. 6) than that (16:1) given by Redfield (c.f. Riley & Chester, 1971). This case was reported in different locations along the Egyptian Mediterranean coast, particularly those receiving discharged wastes (Nessim and Tadros, 1986; Nessim and Zaghloul, 1991; Fahmy *et al.*, 1995; Zaghloul, 1996; Abdel-Aziz *et al.*, 2001; Dorgham *et al.*, 2001). In Dekhaila Harbour, N/P ratio (5) was markedly lower than those recorded in other eutrophied areas, like the hot spot of Abu Qir Bay (8.2, Abdel-Aziz *et al.*, 2001) and the Western Harbour of Alexandria (11.8, Dorgham *et al.*, 2001). This corresponds to the relatively higher phosphate in the Dekhaila Harbour, as shown from coincidence of lowest N/P ratio with the highest phosphate content during the period from June to September. These conditions are in agreement with Welch (1980), who reported that the N/P ratio varies with trophic state and decreases with increased eutrophication. On the other hand, Chiaudani & Vighi (1978) presumed that N/P ratio of 4.5-6 represents suitable range for optimal proportion of assimilation of nitrogen and phosphorous, and the lower or higher ratio indicates nitrogen or phosphorous as limiting element for the algal growth. This statement contradicts with the actual situation of both elements in the environment, since N/P ratio depends upon the relative abundance of both nitrate and phosphate, which means that variations in the absolute values of both elements by the same ratio will give the same N/P ratio, i.e. one N/P ratio can be obtained from several absolute values of nitrate and phosphate, regardless of their magnitudes.

Remarkably high silicate (ann. av.: 49.52µM SiO_4-Si) was found in the harbour, reflecting a great external supply through the Umoum Drain with clear seasonal variations (Fig. 5). Different correlation were reported seasonally between silicate and salinity; they shpwed negative significant in winter and Spring (r = - 0.8897 at p = 0.001 and - 0.9171 at p = 0.01 respectively, n=15), positive significant in Autumn (r = 0.628 at p = 0.02, n=15) and insignificant in Summer. Such pattern demonstrates the major role of discharged waters in silicate enrichment in the harbour water. The spatial distribution of silicate showed negligible variations, whereas closed annual averages were found at all stations (47.73-49.27µM SiO_4-Si), except of higher value (53.11µM SiO_4-Si) at station 3. During the present study, similar to the inorganic nitrogen and phosphorous compounds, silicate sustained markedly higher concentration (Table 2) than those measured previously by Fahmy *et al.*, (1995) and Abdalla *et al.*, (1995). This finding indicates the increasing impact of agricultural wastes in silicate supply to the Dekhaila Harbour through the Umoum Drain.

The silicate-phosphate ratio (Si/P) had greater monthly values (1-19.4) than those of N/P ratio (0.7-9.5), except in October and November, during which N/P was higher (Fig. 6). Both ratios showed similar pattern of monthly variations, differing only in few months (Fig. 6).

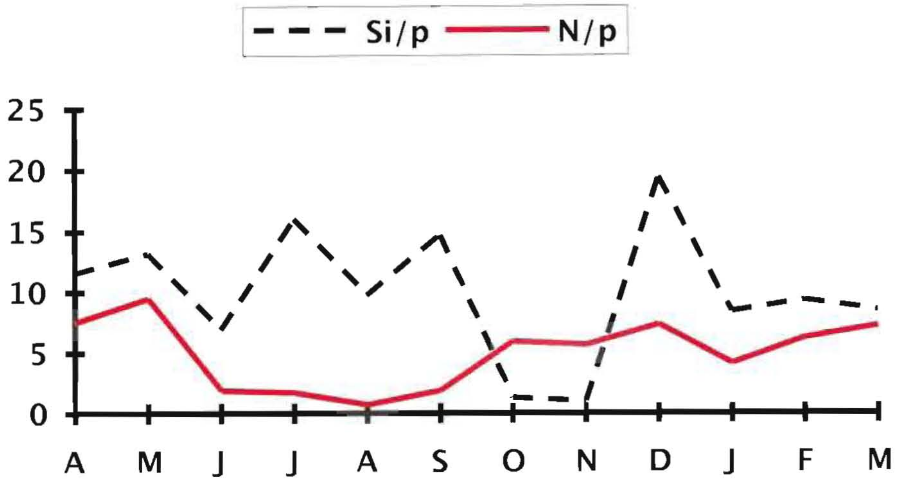

Fig. 6. Monthly values of N/P and Si/P ratios in the Dekhaila Harbour from April 1998 to March 1999

Compared with the past records (14.3 & 19.6) by Abdalla *et al.*, (1995) and Fahmy *et al.*, (1995) respectively, the present study reported markedly lower Si/P ratio (10), which was mainly attributed to the increase of phosphate content in the harbour than the previous records. It is worth mention that significant correlation between salinity and all nutrients in Winter and Spring was converted into significant correlation between N/P and Si/P ratios during the two seasons, with correlation coefficient r = 0.6535 & 0.719 respectively at p = 0.01.

The phytoplankton biomass (chlorophyll a) in the Dekhaila Harbour demonstrated extremely high primary production, with different growth rates all year. High production of phytoplankton (chlorophyll a: 123.8µg/l - 444µg/l) was found during the period from June to October, and another comparatively low production appeared in Winter (2.5-3.4µg/l) and Spring 8.2-40.7 µg/l). The exceptionally high chlorophyll a during the warm period (June-October) has resulted mainly from a great amount of planktonic cyanobacteria and green algae associating the discharged agricultural waste waters, which reached their maximum volume during this period as indicated from the low salinity values. This agrees with previous observations of Ismael and Dorgham (2002), who reported the dominance of diatoms in winter and Spring, and fresh water cyanobacteria and green algae in Summer and Autumn. Throughout the harbour, the phytoplankton biomass exhibited pronouncedly different values (ann. av.: 55.0 - 257.6 µg/l), reflecting the variation of productivity rate due to ecological differences in different parts of the harbour. Although chlorophyll a concentrations had significant correlation with silicate content (r = 0.3826 at p: 95 and n = 60), the two parameters showed different patterns of monthly distribution, may be related to the abnormal amount of fresh water algae, which do not need silicate for their growth, transferred to the area most of the year. Comparing to the measurements of Abdalla *et al.*, (1995) and Fahmy *et al.*, (1995), the present phytoplankton biomass appeared to be higher (Table 2).

The zooplankton population appeared in moderately low density, with annual average of 22600 ind./m^3. In spite of two clear peaks in September 1998 (93900 ind./m^3) and March (85900 ind./m^3), the monthly average was generally low over the year, falling within the range of 3300-16300 ind./m^3. Wide spatial fluctuation was observed in the zooplankton abundance (11000-36300 ind./m^3), indicating the difference in water quality between the sampled stations.

The abundance of zooplankton revealed significant correlation with the phytoplankton biomass in Autumn and Winter (r = 0.7995 and 0.665 respectively, at p=0.01and n=15), insignificant one during Spring and Summer. Such different seasonal relationships seem to be related not only to the seasonal ecological variations, but also to changes in community structure of both phyto- and zooplankton and to the feeding selectivity of different zooplankton species. This is in agreement with the seasonal structure of phytoplankton in the Dekhaila Harbour (Ismael & Dorgham, 2002) and zooplankton (Abdel-Aziz, 2000), whereas the significant relation between zooplankton and phytoplankton in winter coincided with the dominance of diatoms in this season, which are a preferable food item for many zooplankton species as well as the dominance of tintinnids in Autumn, the zooplankton group that feed on pico- and nano-phytoplankton species. This also agrees with the high content (4-26.3 %) of chlorophyll-a extracted from pico-phytoplankton in the Dekhaila Harbour during the present study. In the meantime, insignificant correlation in Spring and Summer was associated with the dominance of cyanobacteria and green algae, known to be inedible by marine zooplankton.

The multiple regression analysis on a seasonal basis revealed significant correlation (at confidence level = 95%) between each of phytoplankton biomass and zooplankton abundance and physico-chemical characteristics. The stepwise regression analyses determine the factors limiting the growth of both phytoplankton and zooplankton in different seasons. For chlorophyll-a, the results showed that dissolved oxygen was the limiting factor in Spring, nitrate and temperature in Summer, dissolved oxygen, salinity and ammonia in Autumn and silicate in winter. Accordingly, the predicted values of chlorophyll a are calculated seasonally from the following equations:

Spring:
Chl. a = - 24.6 (± 4.51) + 9.4 DO (±0.823),
Standard Error (SE) = 7.24, n=15, R=0.957.

Summer:
Chl. a = - 228.5 (±129.0) - 4.93 NO_3 (±0.96) + 16.21 Temp. (±4.65),
SE= 25.5, n=13, R= 0.895.

Autumn:
Chl. a = - 203.8(±36.3) + 17.7 DO (±2.8) + 7.7 S‰ (±1.4) + 0.5 NH_4 (±0.3),
SE=10.7, n=12, R=0.97.

Winter:
Chl. a = 2.46 (±0.3) + 0.01 SiO_4 (±0.005), SE= 0.63, n=15, R=0.5016.

Regarding zooplankton abundance, temperature and chlorophyll a were the most effective factors in Spring, phosphate in Summer, and phosphate and nitrate in Autumn, while several factors were considered in Winter, namely temperature, ammonium (NH_4-N), nitrate (NO_3-N), chlorophyll a and dissolved oxygen. The predicted seasonal abundance of zooplankton in Dekhaila Harbour can be calculated from the following equations:

Spring:
Zoopl.= 402206 (±105384) - 19129 Temp. (±5034) + 647 Chl. a (±164),
SE= 8990, n=14, R=0.963

Summer:
Zoopl. = 13893(±1895) - 876 PO_4 (±205.5),
SE=3534.7, n= 15, R=0.763.

Autumn:
Zoopl. = 11486(±5215) - 1197 PO_4 (±574) +2091 NO_2 (±441),
SE= 5277, n=13, R=0.859.

Winter:
Zoopl. = 42961(±7407) - 1085 Temp. (±244.8) - 167.5 NH4 (±29.2) +167 NO3 (±65.4) -1151.2 Chl. a (±535.8) - 4629.4 DO (±22.5),
SE= 1192, n=15, R= 0.965.

Conclusion

The present study revealed that the ecosystem of the Dekhaila Harbour is exposed to continuous stress of a land-based effluent, containing mixed wastes of domestic, agricultural and industrial origins, beside the intensive impact of the maritime activities. This stress was reflected on the water quality and plankton biomass, appearing in form of abnormally high nutrients, extremely intensive phytoplankton production and relatively low zooplankton abundance. These conditions showed pronouncedly wide spatial as well as temporal variations, but when compared to the previous records, they indicate the aggravation of the eutrophication problem with time in the Dekhaila Harbour, that becoming at present an acute chronic case. Therefore, we recommend that the milling of grains must be done in a closed system in order to reduce the flying flour, an interference should be made to change the water circulation system in the harbour to give more chance the exchange between the harbour and the open sea, and finally the heaps of scrapped iron and coke must be covered to minimize the turbidity and pollution of the harbour water.

Acknowledgement

The authors are deeply grateful to Dr. A.A.El-Gindy, Professor of Physical Oceanography, Department of Oceanography, Faculty of Science, Alexandria University, for his valuable advise in the statistical treatment of the data of this paper.

References

Abdalla, R.R., Zaghloul, F.A., Hassan, Y.A. and Moustafa, H.M. (1995) Some water quality characteristics of El-Dekhaila Harbour, Alexandria, Egypt, Bull. Inst. Oceanogr. & Fisher., **21**(1): 85-103.

Abdel-Aziz, N.E. (2000) Zooplankton dynamics and ecology of an eutrophic area, Egypt, Arab Gulf Jour. Sci. Res., **18**(2): 110-121.

Abdel-Aziz, N.E., Fahmy, M.A. and Dorgham, M.M. (2001) Hydrography, nutrients and plankton abundance in the hot spot of Abu Qir Bay, Alexandria, Egypt, Mediterranean Marine Science, Athene, Greece.

APHA-AWWA WPCF (1980) Standard Methods for the examination of water and wastewater, 15th ed., .

Arin, M.L. (1974) Monitoring with the carbon analyzers, Environmental Science and Technology, **8**(10): 898-902.

Chiaudani, G. and Vighi, M. (1987) Metodologia standard disaggio algare per 10 studio delle aque marine-Quaderni delli, Inst. Di Ricerca sulle aque No. 39: 120.

Cruzado, A. (1988) Eutrophication in the pelagic environment and its assessment, Bologna, Italy, 2-6 March,1987, MAP. Tech. Rep. Ser., No.21: 57-66.

Dorgham, M.M., Abdel-Aziz, N.E., EL-Deeb, K.Z. and Okbah, M.A. (2001) Eutrophication problem in the Western Harbour, Alexandria, Egypt, Oceanologia (unpublished).

El-Samra, M.I., Halim, Y.and Moustafa, Th. (1984) Environmental conditions in Mex Bay, VI- Role of the sediment-water interface in the nitrogen and phosphorous dynamics, VIIes Journees etud. Pollutions, Lucerne, C.I.E.S.M.: 141-150.

El-Sarraf, W.M. (1991) Water quality of the Mediterranean coastal marine environment in front of Alexandria, Egypt. Bull. Nat. Inst. Oceanogr. & Fisher., **17**: 18-25.

Emara, H.I. Sheriadah, M.A., Moustafa, Th.H. and EL-Deek, M.S. (1992) Effects of sewage and industrial wastes on the chemical characteristics of the Eastern Harbour and El-Mex Bay waters of Alexandria, Egypt, Proceedings of Intern. Conf. "Marine coastal eutrophication", Bolognu, Italy, 21-24 March 1990:773-784pp.

Fahmy, M.A., Tayel, F.T. and Sheriadah, M.M. (1997) Spatial and seasonal variations of dissolved trace metals in two contaminated basins of the coastal Mediterranean Sea, Alexandria, Egypt, Bull. Fac. Sci. , Alex. Univ., **37**:(2): 187-198.

Franco, P. (1983) Fattori influenti sulla productivita primaria dell Adriatico settentrionale, Proc. Intern. Conf. "Problems of Adriatic Sea, Trieste, Italy: 155-174 pp.

Grundy, R.D. (1971) Strategies for control of man-made eutrophication, Environmental Science and Technology, **5**(12):1184-1190.

Guergues, M.S.K. (1999) Monitoring and assessing the water quality after the construction of El-Dekhela new harbour using remote sensing techniques. M.Sc. Thesis, Institute of Graduate Studies and Research, Alexandria Univ., 150 pp.

Huet, M. (1973) Text book of fish culture, breeding and cultivation of fish, Fishing News Books, LTD, 436 pp.

Ismael, A.A. and Dorgham, M.M. (2003) Ecological indices as a tool for assessing pollution in Dekhaila Harbour (Alexandria, Egypt), Oceanologia 45:1:121-131.

Lorentz, M.W. (1980) Use of Chlorophyll Secchi disc relationships, Limnol. Oceanogr., **25**:(2): 371-372.

Marchetti, R. (1984) Quadro analitico compllessivo dei resultati delle inadagini condatte degli anni 1977-1980, Sul problema dell Eutrofizzazione nelle aque costiere dell Emilia Romagna Situazione Ipotesi Dunteruneto, Bologna Regione Emilla Romagna, 308 pp.

Nessim, R.B. and Tadros, A.B. (1986) Distribution of nutrient salts in the water and pore water of the Western harbour of Alexandria, Egypt, Bull. Inst. Oceanogr. & Fisher., **12**: 165-174.

Nessim, R.B. and Zaghloul, F.A. (1991) Nutrient and chlorophyll at Kayet Bey region, Alexandria, Proc. Symp. Mar. Chem. In the Arab region, Suez, Egypt, April: 71-80 pp.

Riley, J.P. and Chester, R. (1971) Introduction to Marine Chemistry, Academic Press, London and New York, 465pp.

Stachowitsch, M. and Avcin, A. (1988) Eutrophication induced modifications of benthic communities, UNE˜SCO Report Mar. Sci., **49**:67-80.

Stirn, J. (1988) Eutrophication in the Mediterranean Sea, MAP Tech. Rep. Series., No.**21**:161-187.

Strickland, J.D.H. and Parsons, T.R. (1972) A practical handbook of seawater analysis, Bull. Fish. Res. Bd. Canada, 167:(2nd ed.) 310 pp.

Tayel, F.T., Fahmy, M.A. and Sheriadah, M.A. (1996) Studies on the physico-chemical characteristics of Mex and new Dekhaila Harbour waters of Alexandria, Egypt, Bull. Inst. Oceanogr. & Fish. , **22**:1-19.

Welch, E.B. (1980) Ecological effects of wastewater. Cambridge Univ. Press. Wetzel, R.G. (1983). Limnology 2nd ed. Sounders College Publishing, Philadelphia: pp.66-98.

Zaghloul, F.A., Abdalla, R.R., Moustafa, H.M. and Badr, A. (1995) Phytoplankton community structure in EL-Dekhaila Harbour of Alexandria, Egypt, Bull. Inst. Oceanogr.& Fish., **21**(1):103-125.

Zaghloul, F.A. (1996) Further studies on the assessment of eutrophication in Alexandria Harbours, Egypt, Bull. Fac. Sci., Alex. Univ., **36**:281-294.

Received, 15th Dec.2003; in revised form;30th Marcc 2004