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ORIGINAL PAPER

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Eutrophication in Lake Mariut, Egypt

Abstract: Eutrophication is the most serious problem in Lake Mariut. Lake Mariut is one of the North Nile Delta lakes. It is closed and unconnected directly with the sea. Its waters are discharged into the sea via El-Mex pumping station. Its area has been reduced due to land reclamation and the construction of some fish farms. Hydrographical and nutrient salts studies covering five seasons from January 1996 (winter) to April 1997 (spring) showed increasing quantities of inorganic and organic nutrients, which led to pronounced change in the quantitative and qualitative structure of Lake Mariut. Originally, Lake Mariut had a basin of quite different biological properties, one part mostly covered by *Potamogeton pectinatus* (macrophytes), while another part that received discharge from Alexandria city was plankton dominated and of extremely high productivity. Primary production measured as chlorophyll-a ranged between 0.78 and 1.91 g m^{-3}. As a result of the extensive input of nutrients from Alexandria city, the enclosed nature of the lake and the shallowness of the water, heavy algal blooms and domination of plankton existed. The lake receives heavy industrial, domestic and agricultural waste waters from different sources. The chlorosity values showed a narrow range of variation between 1.139 and 2.009 g l^{-1}. The most affected part of the lake is its north-western sector (lake proper). The state of deterioration of this basin is so bad that the intensive production led to remarkable reduction of dissolved oxygen ($\simeq$1 mg l^{-1}) and the appearance of hydrogen sulphide up to 14.4 mg l^{-1}. The study of hydrochemical variables was supported by hydrographical data (temperatures, pH, E_h and transparency). Very high values of phosphate 18.3 (mol l^{-1}, polyphosphate 11 (mol l^{-1} , ammonia 41 (mol l^{-1} , nitrite 2.4 (mol l^{-1} , nitrate 36 (mol l^{-1} and silicates 157 (mol l^{-1} were recorded.

Keywords: eutrophication; nutrients; chlorophyll-a; dissolved oxygen; Hydrogen sulphide.

الإثراء السالب للأملاح المغذية في بحيرة مريوط، مصر

وفيقة محمد أبو النجاه

المستخلص : يعتبر التحلل الناتج عن الزيادة المفاجئة في الأملاح المعدنية والتي تؤدي إلى تعفن البيئة من أخطر المشاكل التي تواجه بحيرة مريوط . وبحيرة مريوط بحيرة مغلقة من البحيرات الشمالية بدلتا النيل ولاتتصل مباشراً بالبحر المتوسط ومياهها نتتقل مباشراً إلى البحر من خلال محطة طلمبات المكس . وقد قلت مساحتها للتجفيف والإستغلال في المزارع السمكية .

دُرست الظواهر الطبيعية والأملاح المعدنية خلال خمسة فصول من يناير 1996 (شتاء) إلى إبريل 1997 (ربيع) والتي قدرت بتركيزات عالية في الكم والنوع من المواد العضوية وغير العضوية بالمياه والتي أدت إلى التغير الكبير في شكل بحيرة مريوط .

وتنقسم بحيرة مريوط بيولوجيا إلى ثلاث وجدات مائية ، الأولى تتميز بأنها مغطاه بالهيش والجزء الأخر يصرف فيه الصرف الصحي لمدينة الأسكندرية ويتميز بالإحتواء الكامل على الهوائم المائية والجزء الثالث ويتميز بالخصوية العالية وتراوحت الخصوبة الأولية للبحيرة بين 0,78 %1.9 _ جرام/متر3 ونتيجة للصرف الصحي والصناعي من مدينة الأسكندرية والمحتوي على كميات كبيرة من الأملاح المعدنية وكذلك إنغلاق البحيرة وقلة مياهها مما أدى إلى زيادة الطحالب المائية وإنتشار الهوائم المائية بصورة مطردة . وتستقبل البحيرة كميات كبيرة من الصرف الصحي والصناعي والزراعي من مناطق كثيرة من محافظتي الأسكندرية والبحيرة . ودرجة تركيز أيون الكلوريد محسوباً باللتر كانت متقاربة ومتراوحة بين 1,139 . 2,009 جرام/لتر . والجزء الأساسي في البحيرة والموجود في الشمال الغربي من البحيرة والأكثر تأثراً بالصرف مما أدى إلى إنحلاله ونقص في الأكسجين إلى أقل من 1 مجم/لتر وظهور كبريتيد الهيدروجين والذي وصل 14,4 مجم/لتر . وتم قياس الحرارة وتركيز أيون الهيدروجين ومعامل الإختزال والشفافية والفوسفات 18,3 ملي مول/لتر والفوسفات المتعدد 11 ملي مول/لتر والأمونيا 41 ملي مول/لتر والنتريت 2,4 ملي مول/لتر والنيترات 36 ملي مول/لتر والسليكات 157 ملي مول/لتر .

كلمات مدخليه : التحلل ، الأملاح المغذية . كبريتيد الهيدروجين . تغيرات هايدروكيميائية .

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Introduction

Eutrophication is a major problem which increasingly touches coastal seas and semi-closed basins. This process is mainly caused by land-based and airborne inputs of nutrients of anthropogenic origin, whereas natural sources are of low significance in this respect. Eutrophication also depends on the water exchange with adjacent seas.

Lake Mariut is a well studied closed basin. It is shallow with an average depth of 80 cm. It is situated along the Mediterranean coast of Egypt, south of Alexandria city. It receives a considerable amount of drainage containing fertilizers, domestic water and industrial water. The inflow of water to the lake is estimated as 6.1×10^6 m^3 day^{-1}. One of the most important features of the lake is the prevailing stagnant condition of the water which causes microbial oxygen consumption and the formation of hydrogen sulphide (Youssef, 1999).

Study Area

Lake Mariut is located south of Alexandria city, approximately between 31° 03` and 31° 11` N and 29k 50` and 29° 57` E (Fig.1). It is shallow, with a depth ranging from 60 to 120 cm with an average of 80 cm. In the last three decades, it has been subdivided artificially into four basins, the main lake proper (~29 km^2), the southwest basin including Mallahat Mariut (~25 km^2), the southeast basin (~13 km^2) and a fish farm (~4 km^2). The main lake basin, or lake proper, from which nine samples were collected, is heavily polluted (El-Rayis *et al.* 1998). It is an extremely fertile, highly productive body of water and eutrophication is well advanced. The lake proper receives heavy industrial, domestic and agricultural waste water from different sources as follows. (1) The main source is El-Umum drain which receives its water from secondary drains located in the northeastern part of Beheira Province. (2) El-Qalaa drain discharges polluted water into the southeast part of the lake proper. Its water, agricultural and drainage is pumped by El-Qalaa pumping station, in addition to different types of wastes including raw sewage, treated sewage and industrial and trade waste. Anaerobic conditions prevail along the whole path of El-Qalaa drain from the point of sewage discharge into the lake. These conditions are manifested by the bad smell of

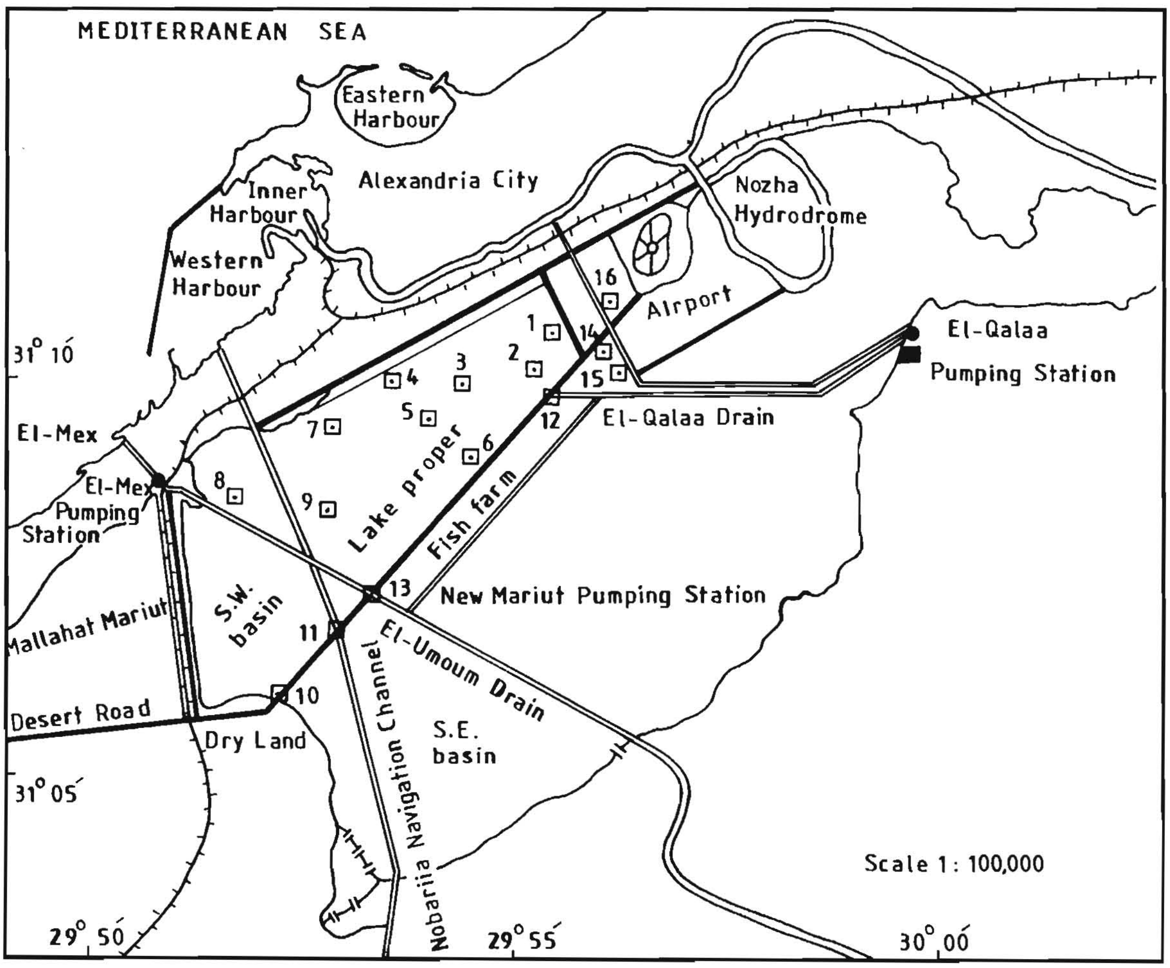

Fig. 1 lake Mariut and position of sampling stations hydrogen sulphide and the dark colour of water near the drain. The flow through the outfall is ~650,000 m^3 day^{-1}, of which 150,000 m3 are sewage waste water pumped out by El-Qalaa pumping station. The disposal waste increased to ~920,000 m^3 day^{-1} after 1993 (Mitwally *et al.* 1996). (3) Industrial outfall from the different factories in the Moharrem Bey region, which discharge about 55,000 m^3 day^{-1} of waste in the northeast corner of the main lake proper. The wastes of the different factories differ in quantity and content of dissolved and suspended solids and organic load. (4) Gheit El-Enab outfall; the flow of this drain is about 30,000 m^3 day^{-1}. It receives the sewage together with the liquid waste of some factories and the waste from cattle sheds and milk farms. (5) Kabbary outfall discharges untreated sewage with various amounts of industrial waste (about 25,000 m^3 day^{-1} flow). Recently, Moharrem Bey, Gheit El-Enab and Kabbary drain were redirected to be primarily treated through a water treatment plant (WTP) at El-Metrass and then discharged into the main lake proper. According to Mitwally *et al.* (1996), the water treatment plant disposes about 170,000 m^3 day^{-1}. (6) Drainage water from cultivated lands is discharged into the northeast side of the lake. (7) Fresh water of Mahmoudiah Canal.

The southeast and southwest basins are totally separated from the lake by a dyke bordering El-Umum drain. These two basins are constantly supplied by El-Umum drain water and are relatively non-polluted in comparison with the main lake proper which is probably the most heavily polluted.

The types of pollution in the lake result in a decrease of the fish production in the lake, environmental pollution, health problems and economic complications. Lake Mariut has economic importance for thousands of fishermen and for the public consumption of fish in the market. It long had a high natural productivity of international scale. The fish production of the lake was once about 360 kg per feddan, but since the late fifties, the fish catch has drastically decreased to about 1% of the previous total fish catch.

The chemical components of this basin were studied by Mahlis *et al.* (1970), Abdelmoneim (1977), Samman and Abdelmoneim (1986), Abdelmoneim *et al.* (1987), and Samman *et al.* (1988). In addition, the trace metal content in Tilapia spp. from Lake Mariut was studied by Aboul-Naga and Allam (1996) and the behaviour of some heavy metals in sulphidic aquatic conditions by Youssef (1999).

Therefore, the present work was undertaken to evaluate the dangerous effects on the Lake Mariut ecosystem arising from the long-term pollution loading and eutrophication resulting from the high nutrient input of municipal sewage and industrial waste in comparison with high photosynthetic activity.

Sample collection

Sixteen water samples were collected seasonally in January (winter), April (spring), August (summer), November (autumn), 1996 and March (winter), 1997 from Lake Mariut. Both surface and bottom waters were sampled, in spite of the shallowness of the lake, from nine stations selected in the heavily polluted main lake proper (Fig.1).

The water samples were kept frozen in polyethylene bottles at -4°C to determine nutrients (nitrate, nitrite, ammonia, total inorganic nitrogen, phosphorus and polyphosphate and silicate). The sampling was supported by hydrographical data (temperature, transparency, chlorosity, dissolved oxygen, hydrogen sulphide, pH and Eh). The phytoplankton biomass was evaluated by measuring chlorophyll a.

Materials and Methods

The hydrographical data were measured using a pocket thermometer for water temperature, a white enameled Secchi disc (30 cm in diameter) for transparency, a portable digital pH meter of 0.01 unit accuracy (model 3410 Jenway) for pH, a platinum electrode and silver chloride reference electrode for Eh, American Public Health Association (APHA, 1985) silver nitratre titration method for chlorosity (Mohr's method), conventional Winkler's method for dissolved oxygen and hydrogen sulphide and Strickland and Parons (1968) for chlorophyll a.

Nutrient salts in water, including reactive phosphate, polyphosphate, silicate, ammonia, nitrite and nitrate were determined following the procedures of Grasshoff (1976).

Results and Discussion

Hydrographical and hydrochemical characteristics

The results of the present investigation, as mean values of each parameter in the lake water during the investigation, are shown in Table (1). Temperatures varied between 30.05°C in summer and 17.17°C in winter. Surface water temperature was always higher than that of the bottom temperature. An increase of temperature leads to a decrease in the solubility of oxygen in water, which leads to an increase of the metabolic activities of microflora and fauna, which in turn results in higher BOD (Biological Oxygen Demand) and local hypereutrophication (El-Nagaar, 1993). Water was stratified, consisting of a dilute surface water with a mean value of 1.14 g $Cl^- l^{-1}$, arising from the mixed runoff of Lake Mariut drain system and a more saline bottom water with a mean value of 2.01 g $Cl^- l^{-1}$. On the other hand, the chlorosity of El-Umum drain (1.27 g l^{-1}) and El-Nubariya canal (2.30 g l^{-1}) were higher than in the lake due to the lake-sea connection through Mex pumping station. An abrupt decrease of chlorosity was noticed in El-Qalaa drain inflow (0.654 g l^{-1}) and WTP (0.776 g l^{-1}) (Table 2). The pH value of Lake Mariut water lies in the slightly alkaline range, between 7.51 and 8.72 (Table 2), which reflects the oxidation/ reduction reactions. In front of El-Qalaa drain (station 2), where the depth does not exceed 80 cm, Eh recorded a value of -59 m V and -78 m V, indicating the extreme pollution of the water of this drain. Lower redox potentials are related to the presence of hydrogen sulphide. As shown in Table (1), the surface water is characterized by high average values of temperature (21.49°C), pH (7.97), dissolved oxygen (1.0 mg l^{-1}), hydrogen sulphide (14.4 mg l^{-1}) and high phytoplankton biomass, as indicated from the high value of chlorophyll-a (1.91 g m^{-3}) (Table 3).

It is worthwhile noticing that the state of eutrophication which prevailed in the lake led to a drastic difficiency of oxygen. This was observed also in Lake Mariut, not only in the decreasing dissolved oxygen concentration (10% saturation in the surface water) but also in the increasing hydrogen sulphide concentration (14.4 mg l^{-1}) and the spreading of the anoxia zone in the water. The present high values of hydrogen sulphide, up to 17.8 mg l^{-1} in El-Qalaa drain water, may be due to high consumption of oxygen by the biological and nonbiological oxidation of organic matter in the water, not only in bottom water but also at the surface. Recently, Youssef (1999) found higher levels of H_2S, particularly in winter and spring, when the concentration of H_2S exceeds 1 mmol l^{-1}. The decrease in dissolved oxygen content in the lake water confirms an organic matter degradation and anoxic condition of the lake. Stagnant conditions prevail mainly in the lake proper and in front of El-Qalaa drain, causing microbial oxygen consumption and formation of high hydrogen sulphide, as shown in Table (2). Skei *et al.* (1988) refer to super anoxic environments as those containing greater than 1 mmol l^{-1} H_2S. The present data are in agreement with those of El-Rayis *et al.*(1998), who found that the water quality of Lake Mariut drain system (El-Qalaa, West Treatment Plant [WTP]) was contaminated with sewage effluents containing high values of BOD, COD, NH_4, PO_4, total P and fecal and total coliform bacteria with a remarkable depletion in dissolved oxygen, while the waters from El-Nubariya canal and El-Umum drain were less contaminated with sewage. Youssef (1999) found a concentration of 7.16 (mol l^{-1} hydrogen sulphide in El-Qalaa drain water. According to Dunnette *et al.*(1985), H_2S greatly influences the biological, chemical and physical characteristics of the aquatic environment. In the anoxic zone of the Hall Lake, concentration of H_2S reaches a peak of 10 (mol l^{-1} at 12 m depth (Balistrieri *et al.*, 1994).

Nutrient salts

The seasonal values of nutrient salts in the surface and bottom water detected during this work are shown in Figure (2). The influence of continuous discharge of different kinds of pollutants led to an increase of the values of NO_3-N (36 µmol l^{-1}), NO_2-N (2.4 µmol l^{-1}), NH_4-N (41 µmol l^{-1}), PO_4-P (18.3 µmol l^{-1}), polyphosphate (11µmol l^{-1}) and SiO_4-Si (157 µmol l^{-1}). Thus, it is postulated that the load of nutrient inputs exceeds the capacity of the lake; moreover, the shallowness of the lake (ranging between 45 cm and 150 cm depth) and the restriction of the water exchange between the lake and the sea are also factors in the pollution problem occurring in Lake Mariut. Generally, the levels of different nutrient salts in the surface and bottom water of the lake proper (Fig.2) and in the surface and bottom water of the different drains (Fig.3) relative to the fish farm showed a considerable increase, reflecting the intensive effect of pollution on the lake. This can also be justified due to the anoxic conditions prevailing in the lake.

Dissolved Inorganic Nitrogen

Ammonia (NH_4-N)

Ammonia is the major nitrogenous product of the bacterial decomposition of organic matter and is an important excretory product of invertebrates and vertebrates. In addition, ammonia is released during organic decomposition via sulphate reduction (Richards, 1965).

The absolute concentration of ammonia during the five seasons in Lake Mariut fluctuated between 39 and 43.3 µmol l^{-1} with an annual mean value of 41.0 µmol l^{-1}, which is about 53% of that of the total inorganic nitrogen in the water of the lake proper (Table 4). The lake proper exhibited higher values of ammonia, representing from 36% to 68% of the dissolved inorganic nitrogen (DIN). This may be attributed to the heterotrophic activity in this basin (Table 4). This is in agreement with Youssef (1999), who found levels of ammonia exceeding 1000 µmol l^{-1} in El-Qalaa drain of Lake Mariut. According to Fahmy *et al.* (1997), the range of ammonia of 67-189 µmol l^{-1} suggests the eutrophied condition prevailing in Lake Manzalah, Egypt. In general, ammonia can be used as a good indicator of sewage pollution (Thomas and Carsola, 1980).

In Lake Mariut, the concentration of ammonia decreased in the lake proper from surface to bottom (Fig.2). The high ammonia concentration in the surface water reflects the effect of discharged water through El-Qalaa drain and west treatment plant (WTP) to the lake proper (85.7 µmol l^{-1}) (Table 3 and Figure 3).

Nitrite (NO_2-N)

Nitrite content was frequently low, forming a minor part of the total organic nitrogen (~2%). Surface water concentration ranged between an average of 4.2 µmol l^{-1} and 2.3 µmol l^{-1} with a remarkable trend of decrease with depth to 3.1 µmol l^{-1} and 2.1 µml l^{-1} near the bottom water (Fig.2). The high content of nitrite recorded in El-Umum drain (Fig.3), indicated the allochtonous input of nitrite brought about through the water of El-Umum (average water chlorosity 1.274 g l^{-1}) into the lake. In addition, the excretion of nitrite by phytoplankton during assimilation increased the concentrations of nitrite especially in the most polluted water (main lake proper) (Ward *et al.*, 1984 and Wafar *et al.*, 1986). Therefore, the presence of nitrite in a considerable quantity in Lake Mariut may be due to the eutrophied condition as a result of the low dissolved oxygen (~1 mg l^{-1}), and the presence of H_2S (~14 mg l^{-1}) which permits the occurrence of nitrite in high values and prevents the oxidation of nitrite to nitrate. It consists of 3.2% of the total inorganic nitrogen (Table 4). The presence of nitrite at high concentrations observed in the oceanic environment at a limit of the eutrophic zone was confirmed by Vaccaro and Ryther (1960) and Kiefer *et al.*(1976). Nitrification also contributes to the formation of nitrite maximum (Miyazaki *et al.* 1973). On the other hand, the principal process responsible for the presence of nitrite maximum is its excretion by phytoplankton stressed by the absence of sufficient light in a nitrate rich environment (El-Sayed *et al.* 1994).

Nitrate (NO_3-N)

The absolute concentration of nitrate in the lake was 36 mmol l^{-1}, while in the main lake proper it was ~28 µmol l^{-1} (Table 3). It represents ~43% of total inorganic nitrogen (Table 4). The seasonal mean concentration is remarkably high in autumn, while it was low during spring (Fig.2). The nitrate content is very high in El-Umum drain water as for nitrite (Fig.3). According to El-Wakeel and Wahby (1970), the nitrate content in Manzalah water is 19 µg atom l^{-1} on average. According to Franco (1983), lake water is highly eutrophied when ammonia exceeds 2 µmol l^{-1} and nitrate 4µmol l^{-1}. This evidence is also in agreement with Wetzel (1975), who found that lake water transparency <245 cm, chl a >14.3 mg m^{-3} and PO_4-P >2.72 µmol l^{-1}. On view of the above bases, Lake Mariut water has shown 52 cm transparency and chl-a >780 mg m^{-3}, which is more elevated than that recorded by Wetzel (1975) for lake water.

Dissolved inorganic phosphate

The main pollution sources of phosphate in an aquatic environment are manufactured fertilizers, domestic and industrial waste waters and, to a lesser extent, decomposition of organic phosphorus compounds during the biological processes.

Reactive phosphate (PO_4-P)

The mean concentration of reactive phosphate in Lake Mariut during the five seasons was ~18 µmol l^{-1}, while the mean concentration in the main lake proper was ~29 µmol l^{-1} (Table 3). The surface water was higher in concentration than the bottom (Fig.2). The phosphate concentration in the lake proper showed a narrow range of variation between the different seasons. High concentrations of phosphate were detected in El-Qalaa drain water followed by WTP and El-Umum drain (Fig.3). During the period of heavy phytoplankton bloom (spring and autumn), chlorophyll-a reached its maximum and phosphate content was reduced to 20 µmol l^{-1} (Fig.2). Youssef (1999) found a range of reactive phosphate from 3.38 and 99.3 µmol l^{-1} in El-Qalaa drain, while it is 29.8 µmol l^{-1} in El-Nubariya canal water. According to Stirn (1972), the average phosphate was around 0.3 µg at. l^{-1} in the euphotic layer of the productive temperature coastal water. Therefore, Lake Mariut is considered as a highly eutrophic water mass. Cociasu and Popa (1976) and Popa *et al.*(1985) found phosphates of nearly 200 μg l^{-1} and nitrates 100 μg l^{-1} in the waters along the Romanian shore which was strongly affected by the increasing load of the Danube. According to Nehring (1987), in the stagnation of water, the continuous decrease in water and salt concentrations led to an increase in the phosphate concentration mainly due to phosphate remobilization from the sediments in the presence of hydrogen sulphide.

As shown in Table (4), the ratio of N:P lies in the range of 3-8 with an average of 4.8. These values are quite comparable with those previously found in Lake Edku (2:1) by Kenawi (1973) and Lake Manzalah by Fahmy *et al.* (1997). The low ratio of N:P reflects the enrichment of the discharged effluents through El-Qalaa drain and WTP with inorganic nitrogen and phosphorus (Table 3 and Fig.3) as well as increasing DIN consumption more than PO_4. In addition, this ratio indicated that nitrogen is the most limiting factor for phytoplankton growth in Lake Mariut. This result is in agreement with that of Elster and Vollenweider (1961), who found low N:P ratios indicating nitrogen limitation.

Polyphosphates

The condensed phosphoric acids, viz. diphosphoric acid, $H_2P_2O_7$, and all polyphosphoric acids with P-O-P-linkage have been known to occur in coastal waters as a result of pollution with detergents (Koroleff, 1968). However, determination of polyphosphate may be of interest in Lake Mariut which may be contaminated with traces of polyphosphates liberated from detergents through the drain. As shown in Figure (2), the surface water had a higher concentration than the bottom water with a high mean value of 14.9 μmol l^{-1} recorded in the main lake proper. It showed wide variations, reflecting higher mean values for El-Qalaa drain (up to 40 μmol l^{-1}) compared with El-Umum drain (<1 μmol l^{-1}). Therefore, it is directly affected by the major outfall of the lake (El-Qalaa drain and WTP), and the lowest at El-Umum drain, which is influenced by the open sea water. Polyphosphates were very high in lake water especially during spring and summer seasons, suggesting continuous anthropogenic inputs of nutrients into the lake.

Silicates (SiO_4-Si)

Silicates showed a very wide range of fluctuations in the water varying between ~40 μmol l^{-1} in winter and ~240 μmol l^{-1} in summer (Fig.2). Silicates in lake water are controlled with uptake by heavy diatom blooms and the input of drainage water. The very high content of silicates in the drains, as shown in Figure (3), permits the bloom of phytoplankton to take it up and the presence of a very high concentration of silicates in lake water. Thus, one can say that normal seasonal cycles of nutrients are not disturbed in the lake. Silicon, probably existing as hydrated silica, is a major constituent of diatoms, which form a large proportion of marine phytoplankton. The diatoms and radiolaria can also excrete silica in the form of opal and amorphous silica ($SiO_2.nH_2O$). When silicous organisms die, silica is rapidly liberated into the water and the element probably passes through the life cycle several times in one season (Koroleff, 1968). The concentration of silicate is too high as compared with that of the Western Harbour (23.6 μg at. l^{-1}) (Nessim and Tadros, 1986) and that of eutrophication in Iskenderun Bay, northeastern Mediterranean (8.0-11.0 μg at. l^{-1}) (Yilmaz *et al.* 1992).

Table 1: Mean and seasonal values of hydrographical characteristics of surface (S) and bottom (B) water samples during the present investigation in Lake Mariut proper.

Determinant	Winter		Spring		Summer		Autumn		Winter		Annual	
	S	B	S	B	S	B	S	B	S	B	S	B
Temperature°C	17.17	17.3	18.8	18.75	30.05	28.94	23.21	22.79	18.20	18.63	21.49	21.25
Cl^- g l^{-1}	1.266	1.278	1.090	2.006	0.965	2.165	1.153	1.794	1.221	2.801	1.139	2.009
Transparency cm	60		45		40		55		60		52	
pH	7.6	7.6	8.4	8.4	8.32	8.16	7.88	7.79	7.64	7.61	7.97	7.91
E_h mV	158	328	196	188			174	193	335	322	216	258
DO mg l^{-1}	0.97	0.81	0.68	0.74	2.6	1.8	0.31	0.23	0.38	0.38	1.0	0.8
H_2S mg l^{-1}	12.1	2.8	9.1	16.3	7.7	3.8	26.9	10.6	16.4	24.7	14.4	11.7

Table 2: Mean values of hydrographical characteristics of surface water samples of El-Qalaa drain, waste treatment plant (WTP), El-Umum drain, El-Nubariya canal, fish farm and El-Nassr canal.

Determinant	Station					
	El-Qalaa	WTP	El-Umum drain	El-Nubariya canal	Fish farm	El-Nassr canal
	12	7	13	11	14-15	16
Temperature°C	24.04	22.2	20.46	20.34	21.23	-
Cl^- gl^{-1}	0.654	0.776	1.274	2.297	1.069	1.179
Transparency cm	20	-	50	115	45	105
pH	7.51	7.75	7.77	7.81	8.72	7.59
E_h mV	21	208	191	266	223	314
DO mg l^{-1}	-	0.4	0.79	1.02	1.6	0.55
H_2S mg l^{-1}	17.8	3.3	-	-	-	-

Table 3: Mean values of nutrient salts in water samples of main lake proper basin and Lake Mariut during the period of investigation.

Determinant		Main Lake proper	Lake Mariut
Ammonia	μmol l^{-1}	85.70	41.00
Nitrite	μmol l^{-1}	3.00	2.40
Nitrate	μmol l^{-1}	28.30	36.00
Inorganic nitrogen	μmol l^{-1}	118.00	79.40
Reactive phosphate	μmol l^{-1}	29.30	18.30
Polyphosphate	μmol l^{-1}	14.90	11.00
Silicate	μmol l^{-1}	146.50	157.10
Chlorophyll a	g m^{-3}	1.91	0.78

Table 4: Percentage of inorganic nitrogen and N:P ratios in Lake Mariut proper waters during the period of investigation in the different seasons.

Determinant	Winter	Spring	Summer	August	Winter	Annual
NH_4 : DIN %	44.0	68.5	66.5	36.9	51.6	53.5
NO_2 : DIN %	3.1	5.6	2.4	2.9	1.9	3.2
NO_3 : DIN %	52.9	25.9	31.1	60.2	46.5	43.3
DIN : PO_4 ratio	4.1	3.5	3.0	5.3	8.0	4.8

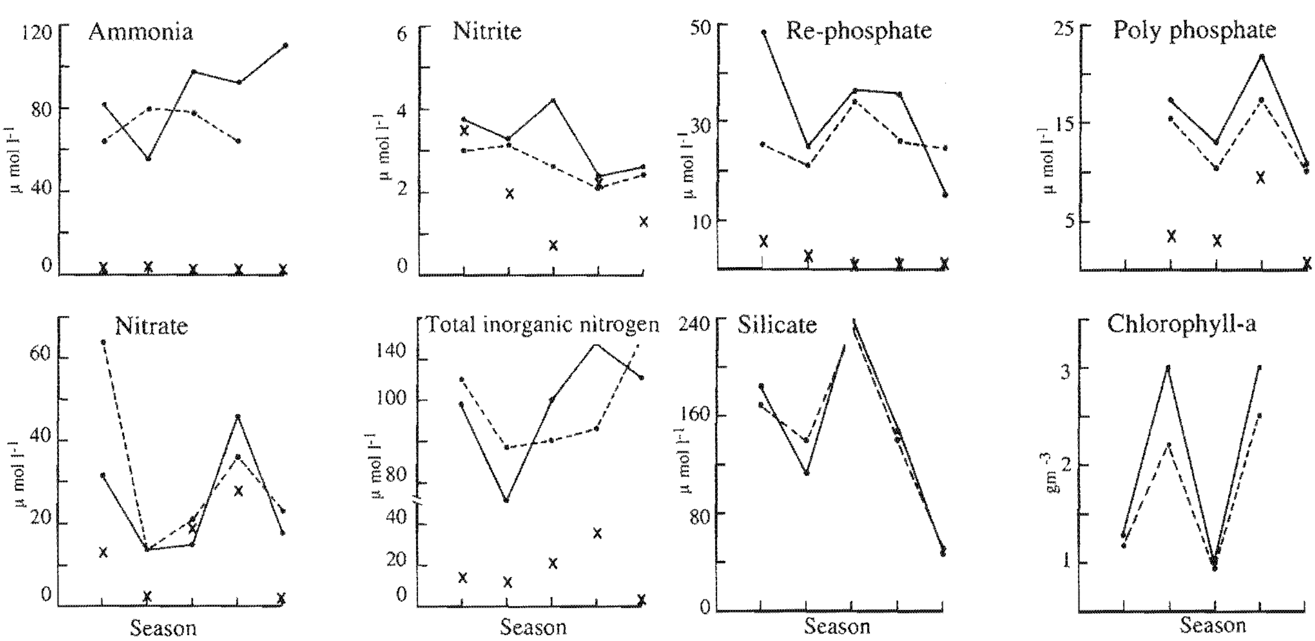

Fig. 2 Average seasonal variation of nutrient salts at the surface and bottom waters of Lake Mariut proper
——— WTP, ------- Bottom water, x x x Fish farm

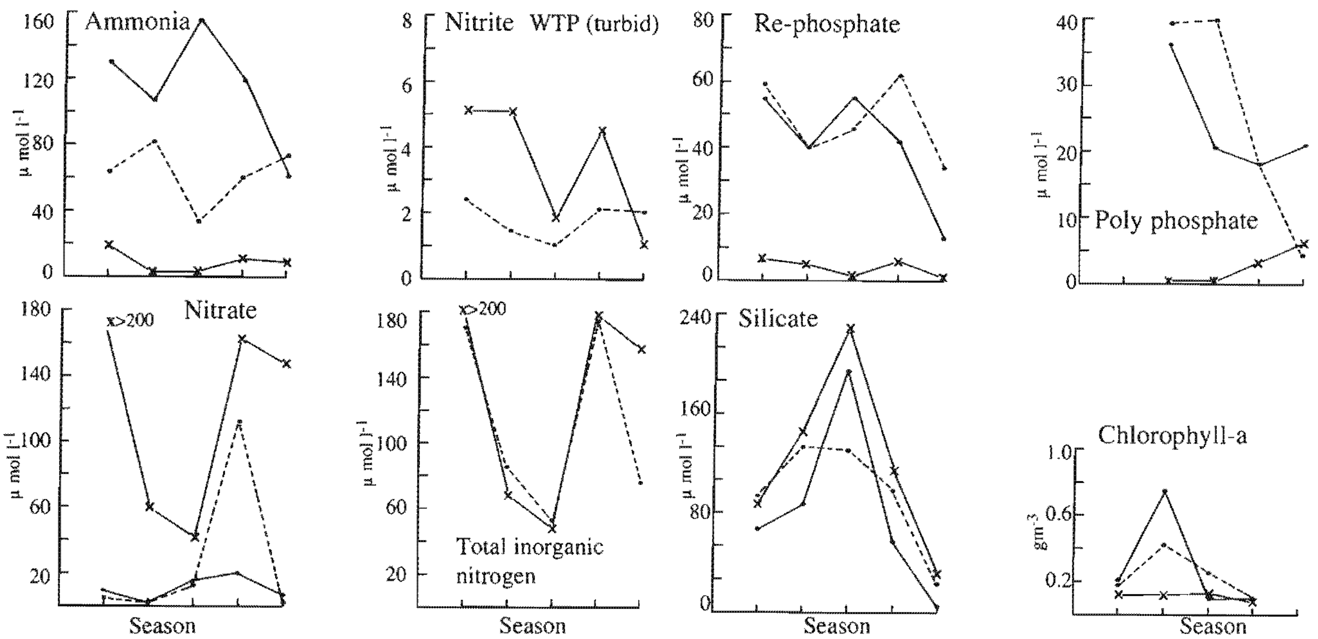

Fig. 3 Fig. 3 Average seasonal variation of nutrient salts in the water of treatment plant (WTP), El-Qalaa drain and El-Umum drain
——— Surface water, -------- El-Qalaa drain, x—x—x El-Umum drain

Conclusion

From the results of the study which were deducted from the high chlorophyll and nutrient salts coming from the drainage water, it is concluded that Lake Mariut could be considered as an eutrophic lake. The solution for making the lake productive comes through controlling the water supply feeding the lake by treatment programs.

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