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Physical and Chemical Characteristics of Lake Edku Water, Egypt

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Abstract

The objective of this work is to evaluate the quality of Lake Edku water. Regional and seasonal variations of some physico-chemical parameters (nutrient salts, total nitrogen, total phosphorous and silicate, in addition to pH, total alkalinity, chlorosity, dissolved oxygen, biological oxygen demand and oxidizable organic matter) that were determined during the period from January to December 2000.

Important variations have occurred in the investigated area as a result of human activity and the discharge of wastewater to the lake. The relatively low pH values reflect the decreased productivity of the Lake as a result of the polluted water discharged into the lake. Total alkalinity varied between 2.25 ± 0.35 to 8.38 ± 0.9 meq/l. In comparison with previous decades chlorosity content (586-1562 mg/l) showed the general decreasing trend. Dissolved oxygen varied (2.37 ± 0.72 - 4.47 ± 0.94 mg/l). The ratios of BOD/ OOM values indicate that the lake water has a biodegradable nature. There was a noticeable variation in ammonia levels; a lower ammonia content was recorded in summer and spring. Nitrite and nitrate concentrations in Lake Edku water showed values ranging from 3.7±1.4 to 7.8±1.9 μM and from 15.2±2.9 to 45.9±11.8 μM, respectively. The total nitrogen of the lake exhibited higher levels (53.1±12.2 – 164.2±30.7 μM). The ratio of NH_4/TIN (0.09-0.45) seems to be highly representative of the microbial nitrification rate as well as of the varying agricultural inflows. It is interesting to note that increasing values of reactive phosphate (11.6±1.8 – 14.7±2.5 μM) were determined in autumn and winter respectively. The higher concentrations of reactive silicate were directly proportional to drainage water discharged into the Lake. It is clear from the mean ratio of N/P (2.4-8.8) nitrogen is the limiting factor. The lower values of N/P ratio could be related to an allochthonous condition.

Keywords: Lake Edku, Nutrient salt, N/P ratio, Total nitrogen, Total phosphorus.

Introduction

Lake Edku lies in the north of the Nile Delta, west of the Rosetta branch between Long. 30- 8\30\\ & 30- 23\00\\ E and Lat. 31- 10\ & 31- 18\ N. It is one of four coastal deltaic lakes that are connected to the Mediterranean Sea. Its area has decreased from 28.5x 10^3 to about 12x10^3 Feddans (is an area unit equals 4200sq. meters) as a result of agricultural reclamation. The lake can be divided into three ill-defined basins; eastern, central and western.

Lake Edku receives huge amounts of drainage water from three main drains, namely Berzik, Edku and El-Boussili, which open into the eastern basin of the lake. The maximum inflow from all drains is recorded during summer, while the minimum is in winter. An amount of 3.3 x 106 m3 per day of brackish water is introduced into Abu Qir Bay from Lake Edku through Boughaz El-Maadiya (NESSIM & EL-DEEK, 1995).

Many investigators (e.g. KINAWY, 1974; SOLIMAN, 1983; SAAD, 1988; MOUSSA & EL-SAYED, 1990; SHRIDAH, 1992; ABDEL-MOATI & EL-SAMMAK 1996; SHAKWEER et. al. (1998) and NOUR EL-DIN (2000) have studied the hydrographic and chemical characteristics of Lake Edku water and sediments. SHATA & OKBAH (2001) studied the geochemical behavior of some trace elements of deep subsurface sediments of Lake Edku. SHATA (2000) observed the transport of carbonate granules to the subsurface sediments of Lake Edku from Abu Qir headline.

The present investigation aims to study the changes in the hydrographic features of lake Edku.

Materials and Methods

Seven surface water samples were collected seasonally during the period from January to December 2000. Sample collection was carried out covering both western and central basins (Fig.1). The eastern basin was omitted owing to its heavy vegetation. Station VII was collected near Boughaz El-Maadiya to illustrate the influence of the mixed water of sea and lake. Three stations I, II and III were collected from the central basin. Stations IV, V and VI represented the western basin.

Samples were taken at the 30-cm below the surface using a plastic Ruttner water sampler. Nutrient salts (nitrite, nitrate, ammonia, reactive phosphate and silicate) were determined according to STRICKLAND & PARSONS (1972). The determination of total nitrogen and total phosphorous was carried

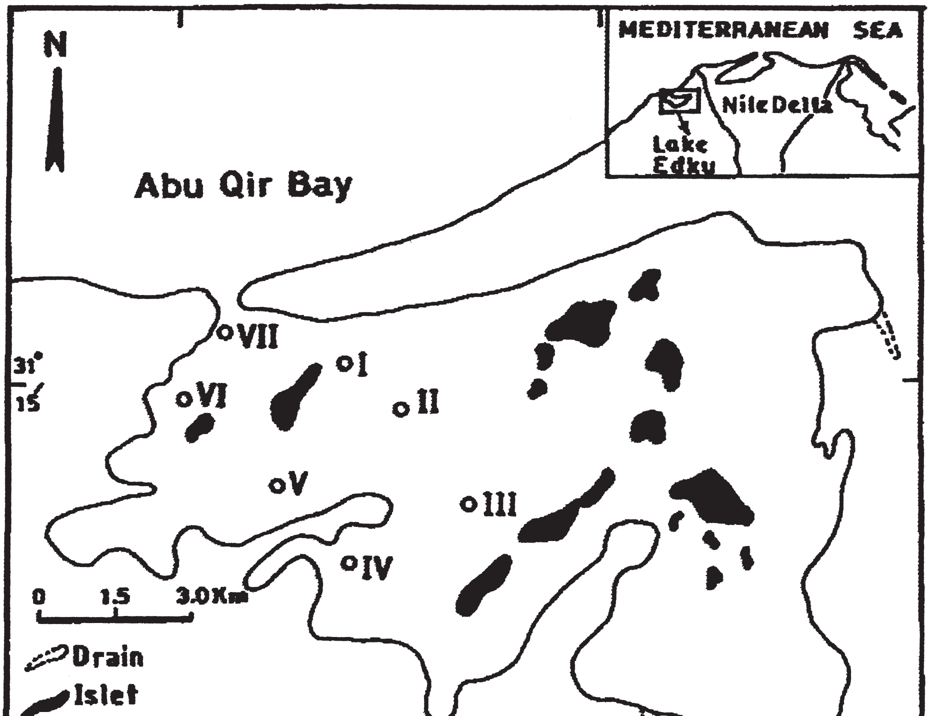

Fig.1: Map showing sites of sampling (Lake Edku).

out according to VALDERRAMA (1981). These parameters were measured using a Shimadzu double beam spectrophotometer UV- 150-02. Determination of total alkalinity was worked out according to RILEY & SKIRROW (1961). Dissolved oxygen determination was performed according to the Winkler method. The oxidizable organic matter was determined by the permanganate oxidation method (FAO, 1975). Determination of biological oxygen demand (BOD) was carried out by APHA (1985). The chlorosity of the samples were determined using Mohr's titration method. The pH of the water samples was determined using a portable pH meter.

Results

Hydrogen ion concentration (pH)

The regional and seasonal variations of pH values in Lake Edku water during 2000 are presented graphically in Figure 2. The pH of the investigated lake water fluctuated between 7.70 in autumn and 8.52 in winter in Table 1.

Total alkalinity

The absolute values of total alkalinity fluctuated between 2.0. meq/l at station V in spring and 9.78 meq/l at station II in summer (Table 1 & Fig. 2). The seasonal average varied between 2.25 ± 0.35 meq/l in spring and 8.38±

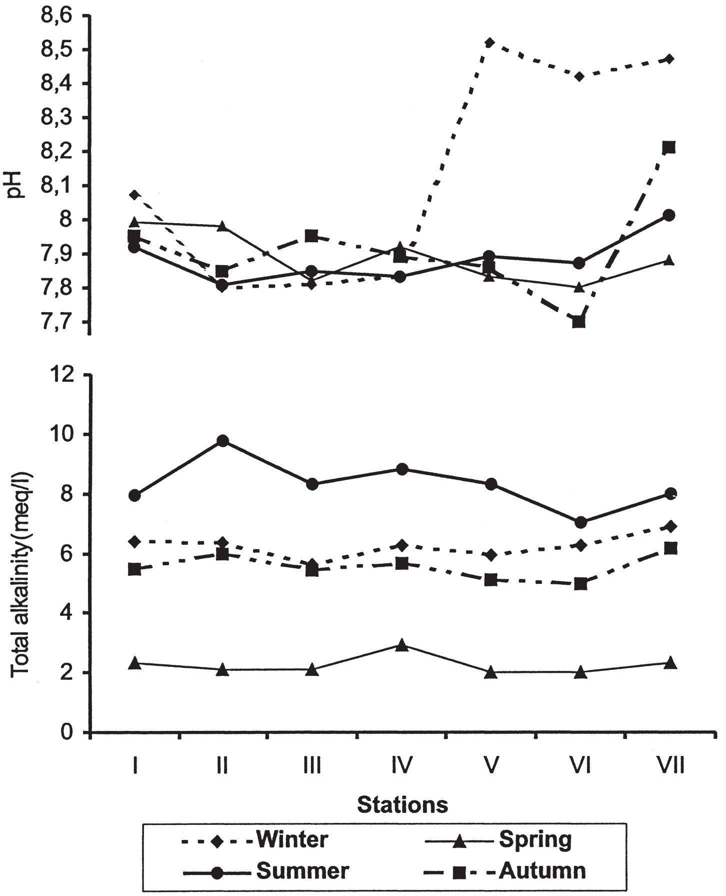

Fig. 2: Regional and seasonal variations of pH and total alkalinity values in Lake Edku water during 2000.

Table 1
Range and Mean ± S. D. of some parameters of Lake Edku water (Jan. -Dec. 2000).

Season	PH	T.Alk. mg/l	Chlorosity mg/l	DO mg/l	BOD mg/l	OOM mg/l
Winter	7.8-8.52	5.60-6.88	709-1562	1.76-6.98	0.13-6.23	3.50- 4.86
	8.13± .0.33	6.23± 0.40	1175± 344	3.44± 1.94	1.92± 2.21	4.23± 0.50
Spring	7.8-7.98	2.0-2.92	568-997	3.16-5.63	0.23-2.48	6.40- 19.48
	7.87±0.07	2.24± 0.35	687±154	4.47± 0.94	1.32± 0.95	10.53± 4.96
Summer	7.81-8.01	7.04-9.78	710-1136	1.58-3.48	0.49-3.48	2.40-4.0
	7.88±0.07	8.38± 0.90	923± 149	2.37± 0.72	1.98± 1.22	3.20± 0.66
Autumn	7.70-8.21	4.96-6.16	994-1560	2.73-5.46	0.12- 0.24	2.55-5.19
	7.91± 0.17	5.56± 0.48	1230±193	4.01± 1.03	0.17± 0.05	3.64± 1.12
Annual average		5.6 ± 0.53	1003.8±210	3.75±1.16	1.35±1.11	5.4±1.81

0.9 meq/l in summer with an annual average of 5.6 ± 0.53 meq/l.

Chlorosity

The distribution pattern of cholorsity during the period of investigation was presented in Figure 3. It varied between a minimum of 568 mg/l (stations I & V) in spring to 1562 mg/l (station VII) in winter. The seasonal average variations of chlorosity reach its minimum of 687 ± 154 mg/l in spring and its maximum of 1230 ± 193 mg/l in autumn, with an annual average of 1004 ± 210 mg/l (Table 1).

Dissolved Oxygen (DO)

Dissolved oxygen in Lake Edku water fluctuated between a minimum of 1.58 mg/l in summer at station V and a maximum of 6.98 mg/l in winter at station VII (Fig. 3). The seasonal average values ranging between 2.37 ± 0.72 mg/l in summer and 4.47 ± 0.94 mg/l in spring, with an annual average of 3.56 ± 1.16 mg/l (Table 1).

Biological oxygen demand (BOD)

The regional distribution of biological oxygen demand in Lake Edku varied between 0.12 and 6.23 mg/ l at stations III and IV in autumn and station VII in winter respectively, (Fig. 3). The seasonal variations of BOD fluctuated between 0.17 ± 0.05 and 1.98 ± 1.22 mg/l in autumn and summer respectively, with an annual mean value of 1.36 ± 1.11 mg/l.

Oxidizable organic matter (OOM)

The concentrations of the oxidizable organic matter in Lake Edku showed seasonal variations. It ranged between a minimum of 3.2 ± 0.66 and a maximum of 10.53 ± 4.96 mg O2/l in summer and spring respectively, Table 1. The regional distribution of OOM values fluctuated between 2.4 and 19.48 mg O_2/l (station VII) in summer and spring respectively (Fig. 3). The annual average value was 5.4 ± 1.81 mg O_2/l.

Nutrient salts: Nitrogenous compounds (NH_4-N, NO_2-N, NO_3-N and TN)

The regional and seasonal distributions of the different nitrogenous components are presented in Figure 4 and Table 2. The regional distribution of ammonia content in the investigated waters of Lake Edku varied between 3.2 and 30.96 μM in autumn and winter at stations VII and II respectively. The seasonal average concentrations of ammonia fluctuated between 7.2 ± 1.8 and 17.88 ± 7.6 μM in summer and winter its annual average is 12.77 ± 4.67 μM.

The seasonal average of nitrite ranged between 3.7± 1.4 and 7.8 ± 1.9 μM in winter and autumn respectively (Table 2 & Fig.4). The annual average was 4.95 ± 1.2 μM. It is clear from the data that nitrite and ammonia

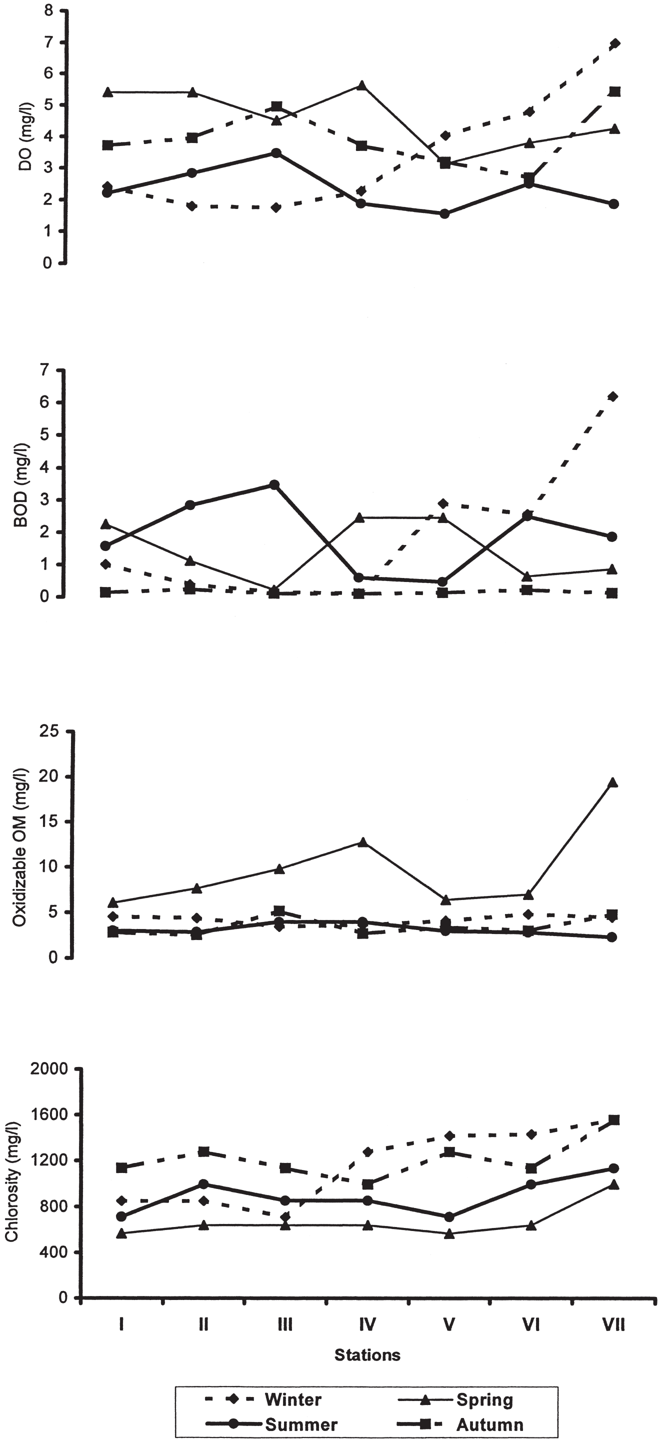

Fig.3: Regional and seasonal variations of chlorosity oxidizable organic matter, BOD and dissolved oxygen values in Lake Edku water during 2000.

Table 2
Range, Mean ± S. D of nutrient salts in Lake Edku water (Jan. -Dec.2000).

Season	NO_3-N µM	NO_2-N µM	NH_4-N µM	TN µM	PO_4-P µM	TP µM	SiO_2 µM	N/P µM	NH_4-N/DIN µM
Winter	18.5-44.1	1.2-5.1	7.7-31.0	127.5-216	11.2-18.3	32.9-54.5	19.4-54.2	2.4-4.8	0.18-0.45
	30.7±9.7	3.7±1.4	17.9±7.6	160±32	14.7±2.5	44.8±8.6	39.8±12.4		
Spring	11.0-20.0	3.8-5.8	5.6-15.5	117-188	6.8-9.4	30.3-36.2	78-147.6	2.8-4.4	0.20-0.39
	15.2±2.9	4.6±0.83	9.1±3.2	148±27.7	7.9±1.1	33.6±2.05	108± 24.2		
Summer	16.4-44.6	2.6-4.8	3.7-9.2	29.4-76.3	7.0-8.6	19.5-22.4	51-76	3.3-6.5	0.12-0.32
	25.1±9.9	3.7±0.68	7.2±1.8	53.1±12.2	7.9±0.57	20.9±1.06	66.8±9.6		
Autumn	27.3-62.3	3.9-9.7	3.2-21.0	100-193	9.1-13.7	24.8-34.3	108-206	3.6-8.8	0.09-0.31
	45.9±11.8	7.8±1.9	16.9±6.1	164±30.7	11.6±1.8	32.2±3.3	150±30.7		
Annual average	29.22±8.6	4.95±1.2	12.8±4.7	131.3±25.6	10±1.5	32.9±3.75	91.1±19.2	4.5	0.27

clear from the data that nitrite and ammonia follow the same trend during autumn.

Nitrate content in Lake Edku reached its minimum value (13.17 µM) during spring at station IV and its maximum (62.3 µM) in autumn at station I1 (Fig.4). The seasonal average of nitrate fluctuated between 15.2 ± 2.9 and 45.9± 11.8 µM during spring and autumn respectively. Its annual average was 29.22 ± 8.6 m M.

Total nitrogen (TN) fluctuated between 39.4 µM in summer at station VI and 215.9 µM at station II in winter. The seasonal average ranged from 53.10 ± 12.2 to 164.14 ± 30.7 µM in summer and autumn respectively. With some exceptions, the seasonal distribution of total nitrogen resembles that of ammonia and nitrate contents (Fig. 4).

Phosphorous compounds

Regional distribution of reactive phosphate (PO_4-P) in Lake Edku ranging between 6.82 and 18.29 µM, was recorded in spring and winter at stations I and 1V respectively (Fig.5 & Table 2). The mean seasonal variations of PO_4-P ranged between 7.9 ± 1.1 and 14.73 ± 2.5 µM in spring and winter respectively, with an annual average of 10.54 ± 1.5 µM. The total phosphorous content varied between 19.5 and 54.5 µM in summer and winter at stations V and II, respectively (Fig.5). The results revealed a wide variation in the seasonal distribution of total phosphorous, it ranged from 20.9 ± 1.06 µM in summer to 44.8 ± 8.6 µM in winter.

Silicate

It is an important factor as a major nutrient for diatoms, and brought from the rivers or sewage outfall. The regional distribution of the reactive silicate in Lake Edku is presented in Table 2 and Figure 5. Reactive silicate content fluctuated between 19.38 and 206.4 µM in winter and autumn at stations I and I11 respectively. The seasonal average varied between a minimum of 39.8 ± 12.4 µM in winter and a maximum of 150 ± 30.7 µM in autumn, with an annual average of 91.15 ± 19.23 µM. It attained its maximum contribution in autumn with mean value reached to 150 ± 30.7 µM.

Discussion

Hydrogen ion concentration, pH

Hydrogen ion concentration plays an important role in the biological processes of almost all aquatic organisms (WELCH, 1952). Relatively low the pH values may reflect the decreased productivity of the lake as a result of the polluted water discharged into the Lake. KINAWY (1974) found that the average of the western basin of Lake Edku varied between 9.04 in summer and 8.26 in winter. The difference between the data of the previously

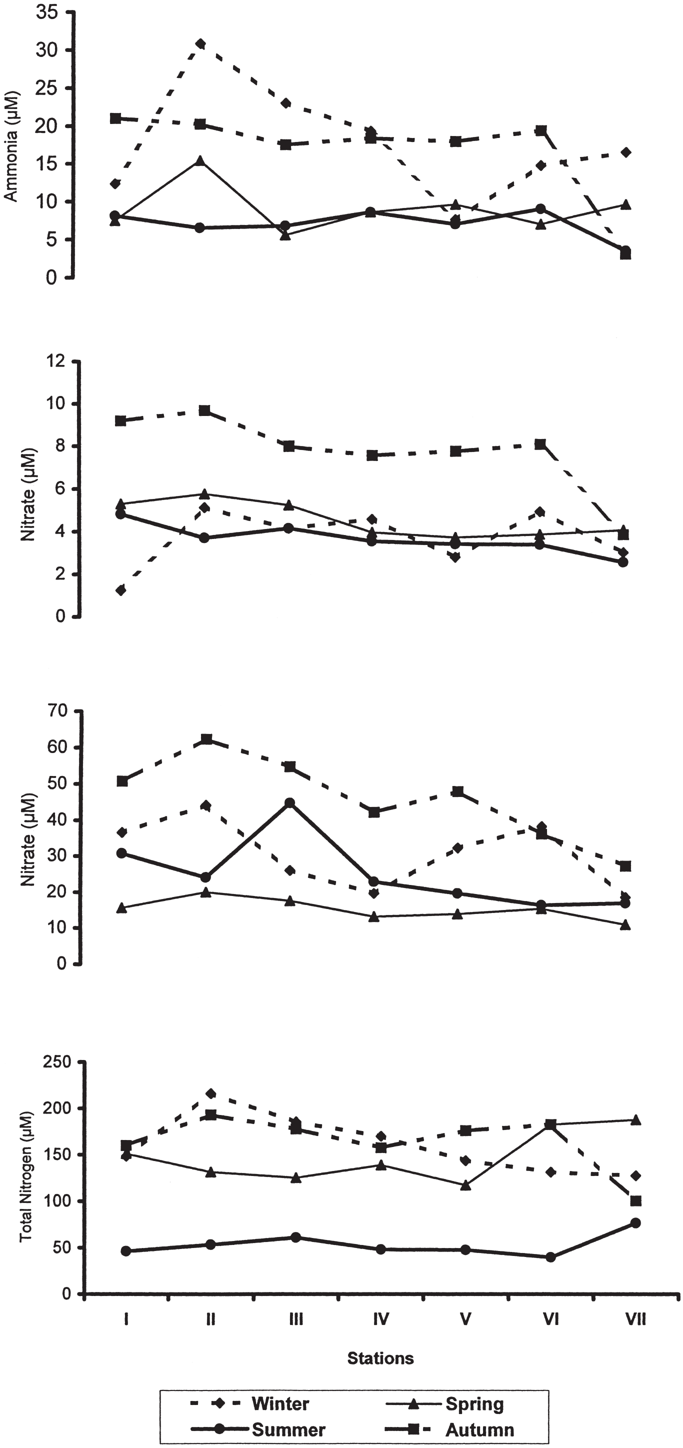

Fig. 4: Regional and seasonal variations of total nitrogen, nitrate, nitrite and ammonia values in Lake Edku water during 2000.

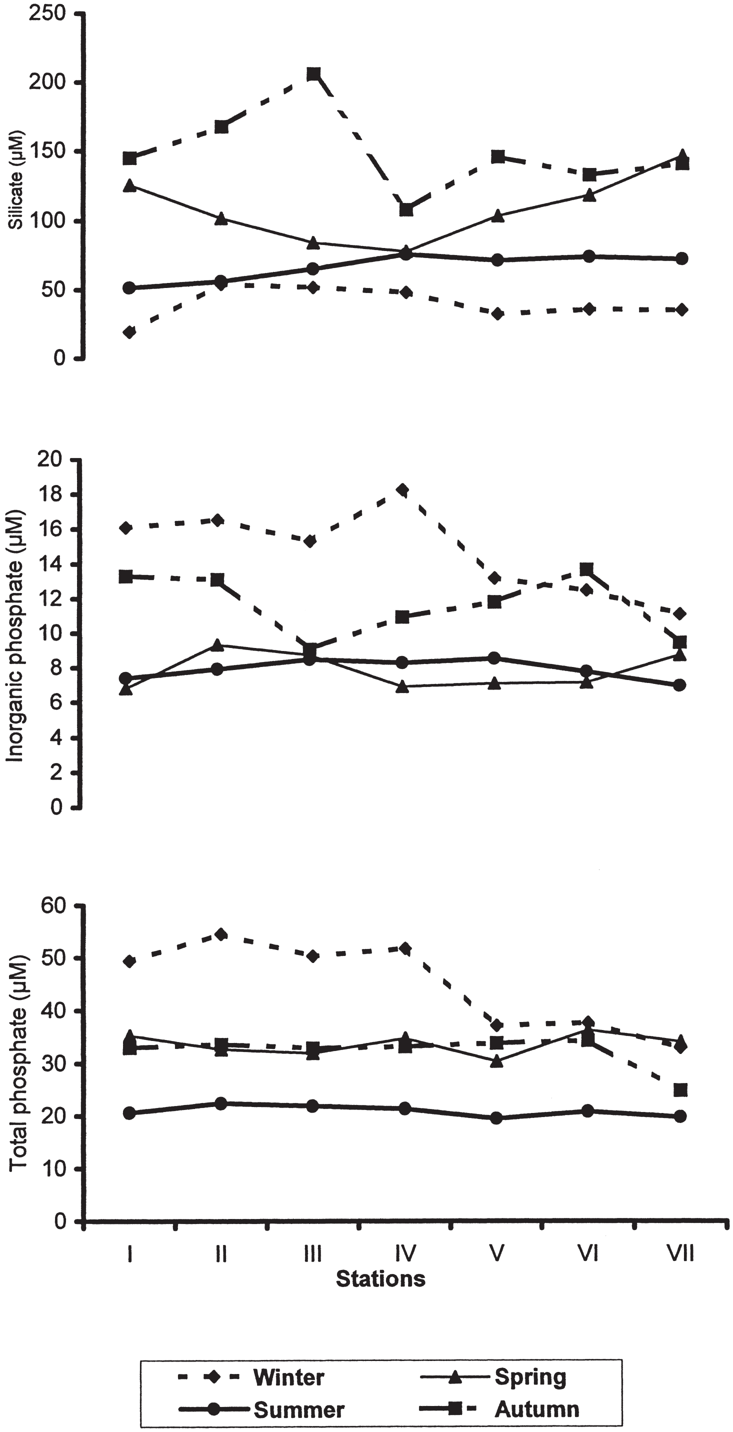

Fig.5: Regional and seasonal variations of total phosphorus, PO4 and SiO2 values in Lake Edku water during 2000.

mentioned study and that of the present one reflects the increase in the pollution in Lake Edku during the last three decades. With some exceptions, the results of pH values revealed slight variation in its values (Fig. 2). The slight increase of pH values at station V, VI and VII may reflect the conditions of inflowing marine water invading the lake during the winter season. The pH values considered as a controlling factor affected some other parameters, such as dissolved oxygen and total alkalinity.

The result of stepwise regression analysis revealed that 97% of pH variability could be related to dissolved oxygen, oxidizable organic matter and total alkalinity

$$pH = 4.55 + 0.499\ D.O. + 0.452\ O.O.M + + 0.998\ T.\ alk. \qquad r=0.97\ p \leq 0.001$$

Total Alkalinity

The seasonal distribution of total alkalinity during the period of investigation showed a general decrease in spring. On the other hand, a significant increase was recorded in the summer season. The higher values of total alkalinity in Lake Edku during summer may be attributed to the higher CO_2 content produced as a result of algal degeneration, as well as the important role of temperature in increasing photosynthetic activity (ABOUL KASSIM, 1987). In contrast, the lower values of total alkalinity during spring may be due to the utilization of CO_2 during phytoplankton growth as well as the effect of drainage water discharged into the lake. In general the total alkalinity has increased during the last few years. Regression analysis indicates that 98% of total alkalinity variability is affected by the variation of DO, BOD, OOM and pH.

$$T.\ alk. = 1.757 + 0.245\ D.O. + 0.265\ B.O.D. + + 0.194\ O.O.M. + 0.267\ pH \qquad r = 0.98\ p < 0.65$$

Chlorosity

It is interesting to note that the chlorosity of Lake Edku showed a general decreasing trend compared with the last decades (KINAWY, 1974). This is related to the increase in the amount of drainage water entering the lake through Edku and Berzik drains. There are hydrotrophic variations occurring in the lake, including decreased lake area and an increase in submerged water plants, which cover the whole eastern basin of the lake and most of the northern and southern parts of the central basin. Moreover, the increase in the level of the to about 16-cmabove sea-level (personal communications) has led to water flow from the lake to the sea in most seasons (except in the winter) due to the tidal effect of the sea and the action of prevailing winds. KINAWY (1974) found that the annual average chlorosity of the western basin reached 1440 mg/l with a maximum of 1840 mg/l, in winter and a minimum of 1110 mg /l in autumn. The comparisons between these values and the present study are significant, and explain the changes which have occurred in the hydrotrophic features of the lake water.

Dissolved oxygen (DO)

The lowest dissolved oxygen values were recorded in the central part of the lake. In summer dissolved oxygen showed lower values than the other seasons, this may be due to several factors, the rise in temperature, increased biological activity, respiration of organisms and the increased rate of decomposition of organic matter.

Biological oxygen demand (BOD)

Low values of BOD were recorded in Lake Edku water. Significant positive correlations were found between BOD and the other parameters. This can be confirmed by stepwise regression analysis that revealed that 97% of biological oxygen demand variation depending on the variables of dissolved oxygen and oxidizable organic matter

$$BOD. = -2.2813 + 0.501\ D.O. + 0.450\ OOM \qquad r=0.97 \quad p < 0.1$$

Oxidizable organic matter

The organic supply introduced into the lake and the slow rate of self purification processes led to the relative increase of organic matter content. The regional distribution of organic matter revealed higher values recorded in spring ranging from 6.04 to 19.48 mg O_2/l.

The type of wastewater discharge can be determined according to BOD/ OOM (ECPH, 1975). 1: 1 ratio reveals well-purified water; the biodegradable matter has a ratio ≤ 2: 1. Finally the ratio that ranged between 2:1 and 4:1 is specific to crude domestic sewage. The ratio of BOD/ OOM in the investigated area is less than one during the period of study, as follows: 0.6: 1 (summer), 0.1: 1(autumn), 0.5: 1 (winter) and 0.2: 1 (spring), its annual mean value of BOD/ OOM is 0.3:1. The previous BOD/ OOM values indicate that the water of Lake Edku has a biodegradable nature.

Nutrient salts: Nitrogenous compounds (NH_4-N, NO_2-N, NO_3-N and TN)

The relatively high concentrations of NH_4-N may be due to the relatively lower content of dissolved oxygen that inhibits the rate of chemical oxidation of ammonia. RILEY & CHESTER (1971) showed that under anaerobic conditions the decomposition of organic matter stopped at the ammonia stage. There was a noticeable variation in ammonia levels; the lowest ammonia content was recorded in summer and spring seasons. This is probably due to the utilization of NH_4-N by phytoplankton. On the other hand, the increase in ammonia may be due to the reduction of NO_3 to NH_4-N via a denitrification process (SEITZNIGER, 1988).

The nitrite content revealed a higher value in autumn than in the other seasons, probably due to the effect of the huge amounts of drainage water discharged into the lake, as well as the decrease in the uptake by phytoplankton. The result showed a correlation between nitrite and oxidizing organic matter (r=0.4). This indicates that the increase in organic matter decomposition processes is an important source of nitrite; it also indicates the allochthonous origin of nitrite. Narrow variations in nitrite values were observed in the other seasons, perhaps as a result of NO2-N reduction to ammonia under anaerobic conditions. This can be explained by the fact that the lower nitrite values were accompanied by an increase in NH_4.

The higher values of NO_3 –N could be interpreted on the basis of the the decomposition of the organic matter as well as the large amounts of drainage water. On the other hand, the lower values during spring are mostly due to its assimilation by phytoplankton and aquatic plants during the spring bloom. This leads to a rapid removal of the dissolved inorganic nitrogen compound from the eutrophic zone. The high values of total nitrogen exhibited in winter (160 ± 32 μM), in autumn (164± 30.7 μM) and spring (148± 27.7 μM) may be due to the huge amounts of organic nitrogen (its content reached to 87% of the total nitrogen). In contrast, the lowest value of total nitrogen was detected in the summer period (53.1± 12.2 μM). Comparing the levels of the total nitrogen with that in the polluted area of Abu-Qir (OKBAH & TAYEL, 1999) atwo-three fold increase could be observed in the present study area. This is due to the fact that the organic nitrogen seems to be assimilated by the aquatic organisms at a much slower rate than that of the inorganic species (FAHMY *et.al.* 1996). Some organic matter containing nitrogen usually resists bacterial change and remains in the water or sinks to the sediments as bottom humus (RILEY & CHESTER, 1971). Generally, Lake Edku showed higher a concentration of organic nitrogen form in comparison with the values of dissolved inorganic nitrogen.

NH_4/TIN Ratio

The rate of microbial nitrification is usually expressed by the NH_4/TIN ratio (KOUIMTZIS *et.al.,* 1994). The present data showed that the ratio of NH_4/TIN ranged between 0.09 in autumn at station VII and 0.45 in winter at IV. (Table 2). Nitrite content did not show remarkable spatial variation. On the other hand, the results of nitrogen and ammonia revealed spatial variation in its content; the variations in NH_4/TIN ratio values are mainly due to nitrate and ammonia fluctuations. However, nitrate and ammonia fluctuations throughout the year may be due to microbial utilization as well as varying agricultural inflows. This ratio seems to be highly representative of the microbial nitrification rate.

Phosphorous compounds

Phosphorous is an important element which controls the reproduction and growth of aquatic organisms. Many organisms utilize both organic and inorganic forms of phosphorous, however inorganic phosphorous seems to be more appreciated by plants than organic phosphorous is (RILEY & CHESTER, 1971). It is interesting to note that the increasing values of reactive phosphate were determined in the autumn and winter seasons. The higher concentrations of reactive phosphate are mostly due to the effect of drainage water enriched with phosphorous compounds.

In contrast, the mentioned parameter reveals a significant decrease during the summer and spring seasons on the basis of the increasing uptake by phytoplankton.

The lower content of total phosphorous in summer could be due to the decomposition of organic remains. Comparing the present data of reactive phosphate in Lake Edku with those recorded by KINAWY in 1974, it appears that Lake Edku was subjected to direct wastewater outfall. Comparing the results of total phosphorous and reactive phosphate, it is found that the most abundant fractions of total phosphorous are presented in the organic form; it constitutes about 56-70% of total phosphorous.

N/P ratio

To evaluate the influence from urban, agricultural and industrial activities upon the physicochemical characteristics of Lake Edku water, the ratio of N/P was estimated.

The data of the N/P ratio is lower than those recorded by RICHARDS (1958) in the North Atlantic (16:1). The results of the N/P ratio showed that the ratio decreased to 2.4 in winter at station IV and reached 8.8 in autumn at station III. (Table 2) This may be related to the higher rate of consumption of inorganic nitrogen than reactive phosphate, also the low values of the N/P ratio may be as a result of an allochthonous condition from wastewater drainage. The annual mean N/P was 4.5. This could suggest that nitrogen is the most limiting factor for the growth of phytoplankton.

Silicates

The lowest silicate values were recorded in the winter season for all stations. This may be due to the uptake of silicate by phytoplankton as well as to the slow rate of regeneration of silicate from the sediments. The higher concentrations of reactive silicate were directly proportional to drainage water discharged into the Lake. Decomposition and death of diatom, in addition to the increase of generation rate from underlying sediments, are factors influencing silicate variability. It is interesting to observe that in autumn the higher concentrations of reactive silicate are controlled by the content of dissolved oxygen (Tables 1&2). This can be explained by the fact that in very badly oxygenated area the decomposition of siliceous compounds increases under the effect of aerobic bacteria (KINAWY, 1974).

Conclusions

Lake Edku has received domestic, industrial and agricultural wastewater from the its surrounding area. In order to study the effect of anthropogenic influence on the ecosystem several water samples have been analyzed for physico-chemical characteristics. The present data show more significant variations in the eutrophication parameter levels.

The present study throws light on the following:

1. The difference between the data of the previous studies and that of the present one reflects an increase in the pollution status of Lake Edku during the last three decades.

2. There was a noticeable variation in ammonia levels. This is probably due to the utilization of NH_4-N by phytoplankton, in addition to the reduction of NO_3 to NH_4-N via a denitrification process.

3. Nitrate and ammonia fluctuations may be due to microbial utilization as well as to the varying agricultural inflows.

4. The higher concentrations of reactive phosphate are mostly due to the effect of drainage water enriched with phosphorous compounds.

5. The low values of N/P ratio may be a result of an allochthonous condition from the drainage of wastewater. This could suggest that nitrogen is the most limiting factor for the growth of phytoplankton.

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