EGYPTIAN JOURNAL OF AQUATIC RESEARCH **1687-4285**
VOL. 32 NO. 1, 2006: 264-282.

IMPACTS OF DRAINAGE WATER DISCHARGE ON THE WATER CHEMISTRY OF LAKE EDKU

LAILA SHAKWEER

National Institute of Oceanography And Fisheries

Keywords: Lake Edku – water chemistry – drainage water – Ecology of lakes.

ABSTRACT

Lake Edku which is considered as important fishing area in Egypt receives its water from two sources. The main source is the drainage water of Kom Belag and Bersik drains where it is annually supplied with 1836.55×10^6 m^3 of water. The sea water of Abu Qir Bay enters the lake sometimes through the lake sea connection as subsurface water current under the action of wind specially in winter. The present study pointed out that the water temperature of the lake (22.38°C) was slightly higher than that of the drains average (21.70°C). The average values of total dissolved solids were 1.88 and 1.44 g/L in the lake and drainage water respectively. pH values indicated that both the lake and drainage water were always on the alkaline side where the average values 8.04 and 7.89 in both respectively. The study showed that the lake and drainage water were mostly well oxygenated therefore nitrate compounds dominated the nitrogen species in the water of both. The annual supply of inorganic nitrogen and phosphorus compounds to the lake through drainage water were estimated as 1065.62 metric tons of nitrogen and 646.61 metric tons of phosphorus.

1. INTRODUCTION

The shallow brackish water north delta lakes of Egypt are considered as important fishing grounds. These lakes contributed with about 135606 tons in the fish production of the country during 2003 (according to the available fishery statistics of Egypt).

Lake Edku, the smallest in area comparing with lake Manzalah or lake Borollus is connected to the Mediterranean through the lake-sea connection Bughaz El-Meadia.

The water chemistry and productivity of this lake is generally controlled by the drainage water reaching it through the two main drains namely Kom Belag and Bersik.
The present investigation deals with the following points:

1- The hydrographic parameters of both the lake and drainage water with special reference to the impacts of the inflow of drainage water on these parameters.
2- The spatial and seasonal distribution of nutrient salts in the lake and the factors affecting their distribution.
3- The possibility of the inflow of the Mediterranean water to the lake during the low tide periods.

Evaluation of these parameters is an essential pre-requisite for understanding the dynamics of the lake fishery and to predict fishery responses to further natural and man induced environmental changes.

1.1. Area of investigation

Lake Edku is a brackish lake which lies to the west of Rosetta Nile branch. Its maximum depth rarely reaches 125 cm. The area of this lake is about 17.000 feddans. A number of small islands exist in the lake as shown in Fig. (1). These islands divide the lake into a smaller western district and a larger one comprising the central and eastern parts where the outlets of Kom Belag drain at the east and Bersik at the south central part of this lake. Therefore the eastern and southern

areas are heavily populated with aquatic vegitations specially *Potamogaton a*nd *Eichormia crassipes* which renders navigation difficulties.

Exchange of water between the lake and the sea takes place through the opening lied at the west of the lake. Through this opening the water level of the lake is maintained more or less as that of the sea.

However it is believed that two water currents exist at the lake-sea connection where the surface water flows from the lake to Abu Qir Bay and the subsurface water of the Bay enters the lake in the opposite direction (El – Samra, 1973).

Two main drains discharge their water into the lake. The first drain namely Kom Belag receives its water from three subdrains; Bosily, Edku and El-Khairy where they are connected at about 3 km to the east of the lake. The drainage water of kom Belag drain is discharged at the eastern part of the lake.

The second main drain connected to Lake Edku is Bersik drain which outlets its water at the southern central part of this lake.

2. MATERIAL AND METHODS

Twenty sampling stations were selected to cover the area of investigation. Ten of these stations, were selected at Lake Edku as shown in Fig. (1) Stations from (1) to (5) and station (10) at lake sea connection were chosen to represent the western area while stations from (6) to (9) to represent the eastern area of the lake. Another 6 stations were selected at Kom Belag drain and 4 stations at Bersik drain. Samples were collected from the upper 30 cm surface water during 2004. These samples were kept in well stoppered polyethylene bottles.

Temperature, total dissolved solids, pH and Secchi depth were determined in situ at time of sampling using a portable microprocessor based pH, Conductivity and temperature meter model M 90. Dissolved Oxygen was determined following Winkler's method (Harvey, 1974).

Nutrient salts, nitrates, nitrites, ammonia, dissolved inorganic phosphorus and silicate were determined spectrophotometrically according to Grasshof (1976).

Inorganic phosphorus: as indicated in the phosphate in water is allowed to react with ammonium molybdate forming a complex heteropoly acid. This acid is reduced by ascorbic acid, to a blue colored complex the light absorption of which is measured in a photometer by adding a catalyst antimomyl tartrate the reduction proceeds swiftly.

Ammonia (FAO Fish. Tech. pap. 1975). In a weekly alkaline solution ammonia reacts with hypochlorite to form monochloramine, which in the present of phenol, chatalytic amounts of nitroprusside ions and an excess of hypochloride yields indophenol blue.

Determination of nitrite is based on the classical Griess's reaction as mentioned in Strickland (1968).

Nitrate is reduced to nitrite by amalgamated cadmium. Then nitrite is determined as the method mentioned before.

Shimadzue double beam spectrophotometer UV-150-02 was used for measurements.

3. RESULTS AND DISCUSSION

Lake Edku is one of the four northern delta lagoons of Egypt permenantly connected to the sea through lake sea connection. The lake receive on the other hand significant amount of drainage water from Kom Belag and Bersik drains. The amount of drain water reaching the lake is subjected to seasonal variations with a maximum in autumn and minimum in spring. The volume of water discharged to the lake through 2003 (in 10^6 m^3) was as follows:

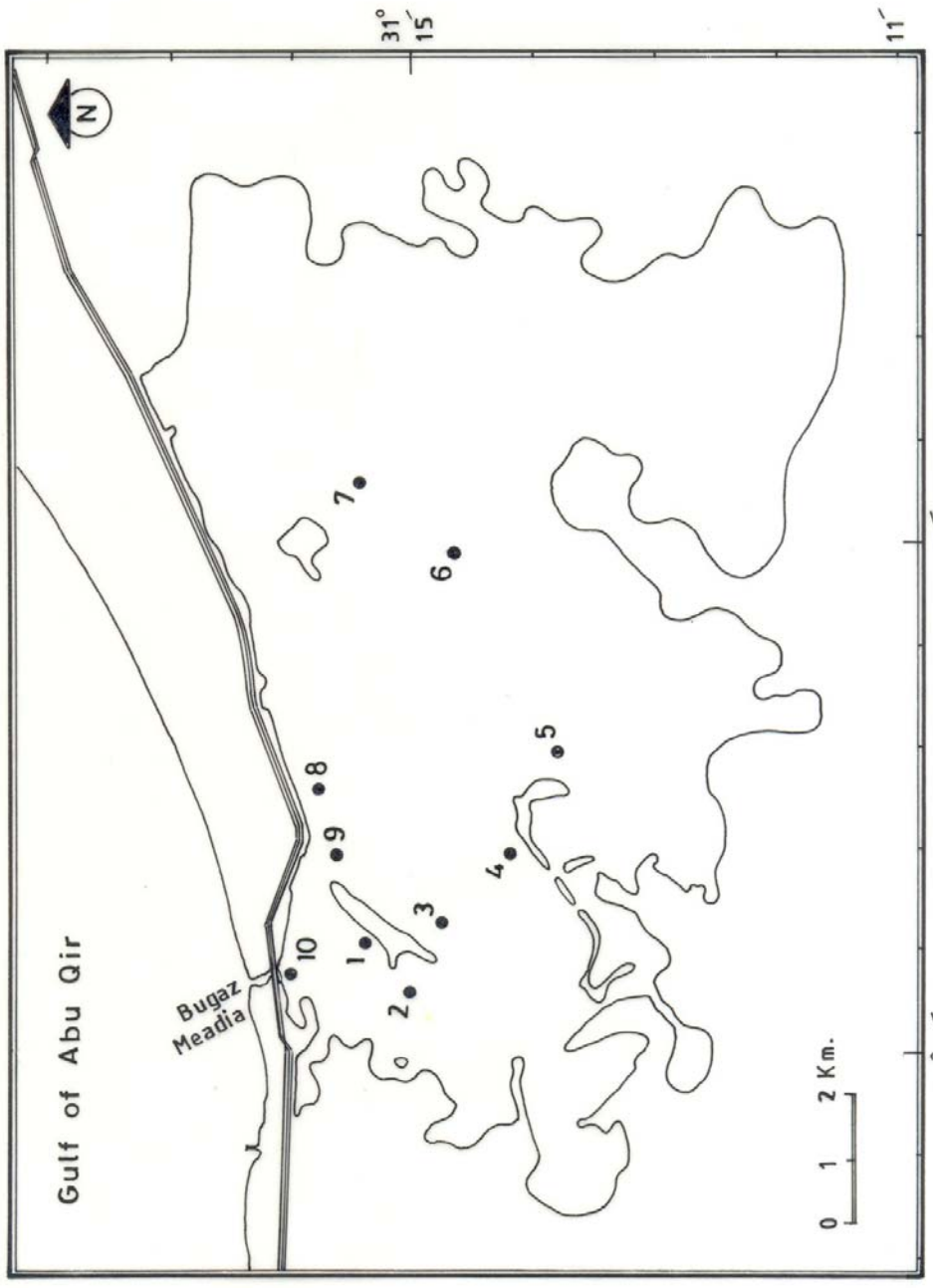

Fig. (1): The location map of sampling stations in Lake Edku.

	Kom Belag	Bersik
Spring	47.73	259.91
Summer	64.79	386.12
Autumn	88.49	558.00
Winter	51.01	380.50
Total	252.02	1584.53

As a result of the permanent connection of the lake with the sea, the water of the lake is kept about 70 cm above the sea level. The invasion of sea water to the lake through the lake sea connection is believed to exist during winter season where stormy winds may contribute in transporting Abu Qir water to the lake.

However the movement of sea water to the lake is undertaken as subsurface water current specially in winter. It is a matter of fact therefore that the main source of water to the lake is the drainage water. Consequently the chemical aspects of the lake water is greatly dependant on the quantitative and qualitative characters of the drainage water reaching the lake.

It will be attempted therefore to deal with the hydrographic and chemical properties of both the lake and drainage water to show to what extent may the drainage water affect the conditions prevailing at lake Edku.

3.1. Transparency

Due to the shallowness of lake Edku the seasonal variation of wind directions and duration affects greatly the transparency of this lake. The inflow of the less turbid drainage water may on the other hand contribute in increasing the sechi depth at the lake water. Flourishment of phytoplankton can be considered also as an important factor in decreasing the transparency of the lake.

The average values of recorded depth and sechi depths at the eastern and western basins of Edku Lake are given in Tables (1) and (2) respectively. It can be noticed that both the depths and sechi depths were slights higher at the western basin in comparison with the eastern one.

It can be observed also that the sechi depth a tarried its minimum value during spring. This can be attributed to the maximum flourishment of phytoplankton which plays an effective role in decreasing the visibility in the shallow lake water. The stagnancy of the water during summer and autumn decrease the turbidity in the whole area of the lake. Therefore higher sechi depths were recorded during these two seasons in comparison with winter where the wind actions in increasing the turbidity of the water especially in the shallower water of the eastern basin.

3.2. Water temperature

The shallow water lagoons as it is the case of Lake Edku follow water temperature variations parallel to those of air temperature. On the other hand the shallowness of these lake as well as the effect of blowing winds contribute in mixing the whole water body. Therefore variations in water temperature between surface and bottom water lie in a narrow range.

The average recorded water temperatures at the eastern and western areas of Lake Edku are given in Table (3). The average water temperatures of the drainage water of Kom Belag and Bersik drains are shown also in Table (4).

It can be observed from the data given that the shallow water of the lake seems to gain heat from the overlying air, more rapidly than the slightly deeper running water of the drains, as it was found that the average surface water temperature for the lake water as 22.38^{o}C while it was 21.70^{o}C for the drainage water.

In this concern welch, (1952) indicated that the shallower the water body the more quickly it reaches to the changes in the atmospheric temperature. It can be observed also that the average water temperature in the western area was slightly higher than that at the eastern one where these averages were 22.06 and 22.58^{o}C in the eastern and western areas respectively. In agreement with that Kenawy (1974) indicated that the western basin of the lake showed slightly higher water temperature in comparison with eastern basin.

Table (1): Average water depths in (cm) at the eastern and western basins of Edku Lake.

Area / Season	Eastern area			Western area			Whole lake		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	60.00	80.00	66.25±9.46	60.00	80.00	68±10.95	60.00	80.00	67.22±9.72
Summer	80.00	105.00	97.5±11.90	85.00	100.00	96±12.94	80.00	105.00	96.7±11.73
Autumn	60.00	100.00	85±19.15	50.00	140.00	105±51.72	50.00	140.00	96.11±39.83
Winter	85.00	100.00	93.75±7.5	60.00	100.00	79±15.17	60.00	100.00	85.56±14.02
Whole year	60.00	105.00	85.63±16.92	50.00	140.00	87±29.84	50.00	140.00	86.39±24.63

Table (2): Average recorded sechi depths in (cm) at the eastern and western basins of Edku Lake.

Area / Season	Eastern area			Western area			Whole lake		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	20.00	25.00	21.25±2.50	20.00	25.00	22.5±2.74	20.00	25.00	21.88±2.58
Summer	30.00	40.00	35±4.08	30.00	45.00	36.67±5.16	30.00	45.00	35.84±4.59
Autumn	25.00	40.00	33.75±7.5	20.00	50.00	33.33±10.80	20.00	50.00	33.5±9.14
Winter	20.00	30.00	26.25±4.79	20.00	60.00	34.17±15.30	20.00	60.00	31±12.43
Whole year	20.00	40.00	29.06±7.36	20.00	60.00	31.67±10.70	20.00	60.00	30.63±9.49

Table (3): Average water temperature ^{o}C at the eastern and western areas of Edku Lake.

Area / Season	Eastern area			Western area			Whole lake		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	20.50	22.00	21.13±0.629	21.00	22.00	21.83±0.408	20.50	22.00	21.55±0.599
Summer	26.50	27.00	26.63±0.250	26.00	27.00	26.75±0.418	26.00	27.00	26.7±0.349
Autumn	22.50	23.50	23±0.408	23.50	25.00	24.08±0.585	22.50	25.00	33.65±0.747
Winter	14.40	17.60	17.5±0.105	17.00	18.00	17.67±0.408	17.00	18.00	17.6±0.316
Whole year	17.40	27.00	22.06±3.420	17.00	27.00	22.58±3.428	17.00	27.00	22.38±3.391

Table (4): Average water temperature °C at Kom Belag and Bersik drains.

Area / Season	Kom Belag			Bersik			Whole drains		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	15.50	20.00	18±1.612	16.50	20.00	18.38±1.493	15.50	20.00	18.15±1.492
Summer	26.00	26.50	26.25±0.274	26.00	26.50	26.38±0.250	26.00	26.50	26.25±0.274
Autumn	24.00	25.60	25±0.632	24.00	26.00	24.65±0.789	24.00	26.00	25±0.632
Winter	17.30	17.60	17.5±0.253	16.50	17.90	17.25±0.624	16.50	17.90	17.4±0.392
Whole year	15.50	26.50	21.69±4.133	16.50	26.50	21.66±4.121	15.50	26.00	21.7±4.058

3.3. Water salinity

Lake Edku has traditionally been considered as a brackish water lake because of its connection to the sea. Annual mean salinity levels in Lake Edku decreased obviously through the past three decades. The water salinity at the area near the lake sea connection was 14.89 ‰ 100 during the early 70's (El-Samra, 1973). This value decreased to 2.9 ‰ 100 in 2000, (Abbas *et al.*, 1971). This decrease is attributed to the restriction of water flow from the sea to the lake through the lake sea connection due to the increase of the rate of drainage water discharge to the lake from one year to the next. Expansion of agricultural, industrial and fish farming activities contributed in increasing the volume drainage water. Decrease of the lake area may have also played an important role in decreasing the evaporation rates of the total volume of lake water. This lead to the decrease of sea water inflow to the lake, therefore decreasing its salinity.

a-Total dissolved solids in the lake water:

It is a matter of fact that the shallowness of Lake Edku contributes in an effective vertical mixing of the water at the whole area of the lake. Kenawy, (1974) reported that there was no significant difference between the chlorosiry of both the surface and bottom water.

The total dissolved solids (TDS) recorded at the various sampling station of the lake are given in Table (5) as minimum, maximum and average values at the eastern and western parts of this lake. It can be pointed out from the data given in table (5) that:

1-The average values of TDS were higher at the western part of the lake in comparison with its values at the eastern part. The decreased values of TDS at the eastern part can be attributed to the discharge of drain water with high rates from Kom Belag drain in this part. On other hand the inflow of Abu Qir Bay water during the low tide periods can be considered as a main reason for increasing the TDS values of the western part.

In agreement with that Kenawy (1974) indicated that the water salinity of Lake Edku showed a gradual increase toward the west of the lake, and attributed this attributed this increase to the effect of Abu Qir Bay water inflowing into the lake as a subsurface mixed water through the lake – sea connection she also indicated that the magnitude and extension of this saline water into the lake was however limited on account of the increased amount of drainage water discharged into the lake.

2-The highest values of TDS were found during winter – where the average values were found as 1.71, 1.85, 1.69 and 2.28 g/L during spring, summer, autumn and winter respectively.

However it is believed that two main factors have played important role in increasing the inflow of sea water to the lake during winter. The first of these factors is the marked decrease in the rate drainage

water discharge to the lake which is closely related and dependant on the variations in agriculture activities. This with no doubt assiss in decreasing the water level in the lake, therefore helps the inflow of Abu Qir Bay saline water. The second factor is the action of the prevailing winds during winter where their direction and speed assiss in transplanting the sea water to the lake.

3- Higher values of TDS were mostly recorded at station (1) which locates at the southern side opposite to the lake - sea connection. This may represent a sort of trapped water at this area probably caused by the varying direction and speed of prevailing wind.

b- Total dissolved solids in the drains water:

The total dissolved solids were determined in the water collected from both Kom Belag and Bersik drains as given in Table (6). It is abvious that the average values of TDS were lower at Kom Belag drain than that at Bersik drain during the four seasons. The increased values of TDS at Bersik drain can be attributed to the discharge of agricultural wastes in various parts of this drain before it reaches the lake. These wastes are supposed to contain more soluble salts used mainly as fertilizers.

On the other hand the wastes discharging in Kom Belage drain is composed to a large extent from industrial and domestic wastes as well less percentage of agricultural ones. It can be observed also that the average values recorded at the drains were generally less than those recorded at the lake water. This means that the drainage water decrease the water salinity of the lake specially its southern areas.

3.4. Hydrogen ion concentrations (pH)

Hydrogen ion concentration (pH) of water is one of the important chemical parameters changes in the ionic strength and pH play important role in the solubility and precipitation of metals. Mixing of drainage water (slightly alkaline) with sea water (more alkaline) in the lake cause changes in phase distribution of some metals and organic matter.

Average values for pH measurements at the eastern and western parts of Lake Edku are given in Table (7). On the other hand the average values of pH for drain water are indicated in Table (8).

The data given show that the water of either the lake or the drains was slightly alkaline. The pH values through out the whole period of study ranged between 7.50 and 8.71 at the lake while its range lied between 7.35 and 8.51 in the drains water. The average values of pH were therefore 8.04 and 7.89 in the lake and drains water respectively.

It can be observed also that the pH values of the lake water was slightly higher than that of the drainage water at either Kom Belag or Bersik drains specially during spring and summer seasons. The average pH values of the lake water were 8.22 and 8.24 during spring and summer respectively while the corresponding values were 7.93 and 7.72 at the drains water.

The increased pH values of the lake water can be attributed to the consumption of CO_2 with high rates through the process of photosynthesis undertaken by the intensive masses of macrophytes in the lake. This process is activated during spring and summer seasons due to high light intensity and water temperature during these two seasons.

This may lead to the conclusion that the discharge of drainage water to the lake contributes in decreasing the pH of the lake water as a result of mixing specially at the area of the lake near to the outlet of Kom Belag drain where high rates of drainage water discharge.

Table (5): Total dissolved solids (gm/L) in the water of Edku lake.

Area / Season	Eastern area			Western area			Whole lake		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	1.35	1.58	1.47 ±0.094	1.69	2.14	1.87±0.156	1.35	2.14	1.71±0.247
Summer	1.46	1.85	1.66±0.16	1.68	2.85	1.97±0.443	1.46	2.85	1.85±0.377
Autumn	0.66	2.60	1.35±0.865	0.87	4.78	1.92±1.428	0.66	4.78	1.69±1.213
Winter	1.64	2.18	1.96±0.261	1.97	3.49	2.49±0.545	1.64	3.49	2.28±0.514
Whole year	0.66	2.60	1.61±0.477	0.78	4.78	2.04±0.711	0.66	4.78	1.88±0.71

Table (6): Total dissolved solids (gm/L) in the water of drains connected to Edku Lake.

Area / Season	Kom Belage			Bersik			Total drains		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	0.94	2.36	1.35±0.534	1.38	2.93	2.45±0.732	0.94	2.93	1.79±0.809
Summer	0.60	1.20	0.78±0.214	1.60	2.30	1.82±0.324	0.60	2.30	1.20.2001±0.589
Autumn	0.43	1.31	0.89±0.316	1.08	3.51	1.95±1.094	0.43	3.51	1.31±0.867
Winter	0.83	1.54	1.02±0.265	1.96	2.35	2.16±0.206	0.83	2.35	1.48±0.631
Whole year	0.43	2.36	1.01±0.393	1.08	3.51	2.09±0.661	0.43	3.51	1.45±0.74

Table (7): pH values of lake water recorded at different parts of Edku Lake.

Area / Season	Eastern area			Western area			Whole lake		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	8.02	8.22	8.23±0.135	8.2	8.5	8.12±0.077	8.02	8.5	8.22±0.16
Summer	8.1	8.71	7.93±0.368	7.5	8.3	8.43±0.269	7.5	8.71	8.24±0.385
Autumn	7.68	7.94	7.77±0.177	7.6	7.81	7.76±0.113	7.6	7.94	7.77
Winter	7.77	8.16	7.93±0.082	7.85	8.01	7.94±0.162	7.77	8.16	7.94±0.13
Whole year	7.68	8.71	8.01±0.298	7.5	8.5	8.07±0.3	7.5	8.71	8.04±0.297

Table (8): pH values of drain water recorded at different parts of drains.

Area / Season	Kom Belage			Bersik			Total Drains		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	7.4	8.3	7.75±0.398	7.8	8.4	8.2±0.271	7.4	8.4	7.93±0.408
Summer	7.53	7.95	7.67±0.149	7.35	8.3	7.8±0.316	7.35	8.03	7.72±0.225
Autumn	7.54	8.27	7.94±0.312	7.67	8	7.83±0.137	7.54	8.27	7.89±0.253
Winter	7.41	8.35	7.94±0.37	7.65	8.51	8.08±0.466	7.41	8.51	8±0.392
Whole year	7.4	8.35	7.83±0.325	7.35	8.51	7.98±0.336	7.35	8.51	7.89±0.334

3.5. Dissolved Oxygen:

It is a matter of fact that in shallow water bodies the dissolved oxygen is greatly affected by air and water temperatures, wind mixing and photosynthetic activity. The oxidation processes in water and sediments can be also considered as an important factor controlling the dissolved oxygen in water.

The importance of dissolved oxygen for aquatic plants and animals is directly related to the respiration process or indirectly with the oxidation of organic matter in water and sediments. Dissolved oxygen of Lake Edku water during the period of the present investigation is indicated in Table (9).

On the other hand the values of dissolved oxygen at the drains connected to the lake are given in Table (10).

The data given indicate that:

1- The water of Lake Edku is well oxygenated throughout the whole period of the year. The annual average of dissolved Oxygen in this water was found to be 8.34 mg/L ± 1.717.

2- The highest concentrations of dissolved Oxygen were found winter while the lowest were existing during summer. Such highly recorded concentration during winter can be attributed to some environmental factors. The most effective of these factors are low water temperature, effect of wind in increasing the aeration of water, decreased rate of Oxygen consumption by living marine organisms at the lake specially zooplankton and aerobic bacteria due to the decreased water temperature, therefore a pronounced decrease in their activities.

In agreement with that, Ruttner (1968), and Kenawy (1974) pointed out that there was an inverse relationship between dissolved Oxygen and water temperature. Welch (1952) pointed out that the rise of water temperature diminishes the solubility of Oxygen.

3- Comparing the recorded values of dissolved oxygen at the drains with those at the lake it can be pointed out that in all cases the concentrations of dissolved Oxygen at the drain were lower than those at the lake. The decreased concentrations of dissolved oxygen in the drains water can be attributed to the exhaustion of oxygen in decomposing the organic matter which exists in the drains with higher concentrations.

This means that the drainage water is oxygenated when it is mixed with the lake water as soon as it is discharged to the lake. The presence of intensive aquatic vegetations in the areas of the lake adjacent to the outlets of the drains contribute in Oxygenating the discharged water with high rates as a result of photosynthesis process undertaken by these vegetations.

3.6. Nutrient salts

a- Inorganic Nitrogen species:

Inorganic nitrogen compounds ammonium, nitrite and nitrate can be absorbed by phytoplankton living in the aquatic habitat or at least by some species. There is a very marked preferential absorption of ammonium. When the organisms become nitrogen deficient and are supplied by nitrogen source, they absorb ammonium and nitrate in the dark converting them into organic compounds including chlorophyll. Nitrite can not be utilized in the dark. (Ketchum, 1939; Harvey 1974).

The proportion of nitrogen to phosphorus in phytoplankton is not a fixed ratio. Cells can be deficient in either and the ratio varies with the relative concentration of each in the medium. (Harvey, 1974). When phytoplankton or animal tissue is voided by animals, the soluble and particulate nitrogen compounds are broken down by bacteria yielding ammonia.

Table (9): Dissolved Oxygen mg/L in the water of different parts at Edku Lake.

Area / Season	Eastern area			Western area			Whole lake		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	6.4	8.64	7.36±1.012	6.72	8.96	7.57±0.851	6.4	8.96	7.49±0.869
Summer	5.44	8	6.88±1.093	7.04	8	7.2±0.803	5.44	8	7.07±0.585
Autumn	6.08	9.91	8.63±1.728	6.72	14.07	9.06±1.102	6.08	14.07	8.89±2.167
Winter	8.93	10.79	9.82±0.789	9.16	11.17	9.96±1.109	8.93	11.17	9.91±0.947
Whole year	5.44	10.79	8.17±1.602	6.72	14.7	8.45±1.815	5.44	14.07	8.34±1.717

Table (10): Dissolved Oxygen (m/L) in the water of different parts of Edku drains.

Area / Season	Kom Belag			Bersik			Total Drains		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	5.88	7.26	6.34±0.512	5.06	7.49	6.14±1.211	5.06	7.43	6.26±0.802
Summer	4.29	6.87	5.56±1.032	4.45	7.16	6.27±1.278	4.29	7.16	5.94±1.127
Autumn	5.41	9.6	7.28±1.682	5.44	8.64	7.04±1.407	5.44	9.6	7.14±1.507
Winter	5.44	9.59	7.47±1.467	7.04	8.32	7.68±0.523	5.44	9.59	7.55±1.14
Whole year	4.29	9.6	6.66±1.406	4.45	8.64	6.78±1.218	4.29	9.6	6.7±1.313

The average concentrations of ammonia, Nitrite and Nitrate at the eastern and western parts of Lake Edku are given in Table (11). On the other hand the average concentrations of these compounds at Kom Belag and Bersik drains are shown in Table (12). It can be pointed out from the data given that:

1- The highest concentrations of ammonia were found at either the eastern or western areas of the lake during winter in comparison with the other seasons of the year. These concentrations decreased gradually to reach the lowest values during summer. These decreased concentrations during summer may be due to the consumption and assimilation of ammonia by aquatic plants. Hutchinson (1957) found that the sudden fall of ammonia is accompanied by great increase of aquatic plants. In Lake Edku the maximum flourishment of aquatic vegetations is in summer. (Samman 1974).

On the other hand the highest concentrations of this inorganic compound in the drainage water were recorded during winter. This means that the main source of ammonia to the lake is the drainage water outflow through Kom Belag and Bersik drains.

The increased concentrations of ammonia in the drainage water during winter can be attributed to the application of high rate of ammonium nitrate as fertilizers during this period of the year. The type and rate of fertilization depends to great extent on the variations in agricultural activities from one season to another. However it is obvious that the average concentration of ammonia in the lake water increased obviously during the last 20 years. Kenawy (1974) in her study on the

chemistry of lake Edku water indicated that the concentrations of ammonia ranged from 0.12 to 0.19µg/L with an average of 0.15 µg/L The average concentrations of both nitrites and nitrates tended to fluctuate within the same pattern of ammonia where the highest concentrations were found in winter.

It is to be indicated that the most important factors affecting the concentration and distribution of nitrate in the lake are, the discharge of drainage water, dissolved oxygen, decomposition of organic remains regeneration from the bottom sediments and assimilation by aquatic plants.

2- Higher concentrations of ammonia, nitrite and nitrate were existing at the eastern area of the lake. The average concentrations of these dissolved organic nitrogen compounds at the eastern area during the whole period of study were found to be 19.64, 9.68 and 15.14 µg/L for the three compounds respectively. On the other side these concentrations were found as 9.22, 4.35 and 19.14 µg/L at the western area.

The higher concentrations of ammonia and nitrite at the eastern area can be attributed to the increased values of the concentrations of these nitrogenous compounds in Kom Belag water which outflows at the east of the lake where the average concentrations of ammonia was 24.23 µg/L and the average concentrations of nitrite was 9.36µg/L.

It seems on the other hand that ammonia and nitrites were oxidized with higher rates at the western area of the lake in comparison with that at the eastern area. Therefore higher concentrations of nitrates were existing at this part of the lake.

b- Percentages of ammonia, nitrites and nitrates to total nitrogen compounds:

The percentage of ammonia, nitrite and nitrate to total nitrogen compounds dissolved in the lake Edku and the drainage water were calculated as given in tables (13), (14). It can be observed from the data given that the dominant compound through out the whole year was the nitrate where it constituted 47.28% and 46.11% of the total dissolved nitrogen compounds in the total areas of the lake and drainage water respectively.

The dominance of nitrate in both the lake and drainage water indicate that the dissolved Oxygen in that water was sufficient to oxidize most of the ammonia and nitrites. As for the seasonal variations of these percentages it can be observed that ammonia dominated the nitrogenous compounds at the eastern area during winter and spring. On the other hand it dominated during spring only at the western area, where the nitrate comprised 83.11%, 63.87%, and 61.60% during summer, Autumn and winter respectively.

It can be observed also that ammonia dominated the nitrogen compound in the drainage water of Kom Belag drain during spring and autumn comprising 48.53% and 55.75% of the total nitrogen compounds during these two seasons. In Bersik drain the most dominant of these species was the nitrate where it constituted 48.03%, 71.77% and 68.12% during spring, summer and winter in respective.

This indicates that the water of Bersik drain provided the lake with drainage water more fertilized with nitrogenous compounds in comparison with the other Kom Belag drain. This is due to the fact that the water of Bersik drain is composed mainly of agriculture. It is worth to point out to the fact that most of the domestic and fish farm wastes of the area around Lake Edku is discharged to the lake through Kom Belag drain while the drainage water of Bersik drain is mainly composed of agricultural wastes. It must be pointed out also to the fact that the distribution of ammonia in the lake water is affected by several factors such as temperature, dissolved Oxygen, decomposition of organic matter and assimilation by plant organisms.

Table (11): Ammonia, nitrite and nitrate concentrations (μg/L) in the water of Lake Edku.

	Area	Eastern area			Western area			Whole lake		
Season		Min.	Max.	Av.	Min.	Max.		Min.	Max.	Av.
NH_4	Spring	12.76	36.84	28.61±10.865	1.62	45.12	14.28±15.946	1.62	45.12	20.01±15.221
	Summer	2.79	8.96	*7.15*±7.163	0.26	1.55	0.8±0.424	0.26	8.96	3.34±0.285
	Autumn	3.07	18.2	8.62±6.612	0.26	6.16	1.84±2.255	0.26	18.2	4.55±5.446
	Winter	28.17	38.51	34.2±5.151	0.7	35.55	16.93±13955	0.7	38.51	26.71±12.14
	Whole year	3.07	38.51	19.64±14.137	0.26	45.12	9.22±13.15	0.26	45.12	13.65±14.242
NO_2	Spring	1.93	2.89	2.36±0.454	0.51	3.05	1.933±1.317	0.51	3.05	2.1±1.039
	Summer	2.79	8.96	5.92±2.549	0.79	5.62	1.81±1.917	0.79	8.96	3.46±2.951
	Autumn	9.49	16.11	13.64±2.921	0.38	12.45	4.71±4.598	0.38	16.11	8.28±5.926
	Winter	9.67	14.72	11.03±2.663	5	11.39	8.96±2.251	5.2	14.72	9.79±2.513
	Whole year	2.97	16.11	9.68±6.399	0.38	12.45	4.35±3.956	0.38	16.11	5.91±4.748
NO_3	Spring	9.57	10.94	10.18±0.586	5.77	10.41	10.59±8.257	5.77	10.94	10.41±9.166
	Summer	12.16	16.32	14.33±1.707	5.58	29.39	12.89±10.31	5.58	29.39	13.46±7.782
	Autumn	0.08	4.62	2.51±1.878	7.06	15.79	11.58±3.944	0.08	15.79	7.5±5.556
	Winter	24.52	41.42	33.56±8.741	29.19	70.23	41.54±14.946	24.52	70.23	38.35±12.937
	Whole year	0.08	41.42	15.14±12.503	5.58	29.39	19.14±16.29	0.08	70.23	17.54±14.852

Table (12): Ammonia, nitrite, and nitrate concentrations (μg/L) in the drainage water discharging in lake Edku.

	Area / Season	Kom Belag			Bersik			Total drains		
		Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
NH_4	Spring	28.61	35.71	30.72±4.72	1.44	34.08	14.08±15.82	1.44	35.71	24.07±13.031
	Summer	3.07	29.71	*15±9.443*	4.24	9.96	6.7±2.891	3.07	29.71	11.68±5.41
	Autumn	5.92	29.82	16.77±8.283	4.11	13.89	8.12±4.363	4.11	29.82	13.13±7.968
	Winter	3.28	38.27	34.73±2.608	3.82	18.11	15.23±1.958	3.28	38.27	26.92±10.314
	Whole year	3.07	38.27	24.23±10.885	1.44	34.08	9.78±8.586	1.44	38.27	18.95±11.832
NO_2	Spring	5.34	11.34	9.83±2.274	1	9.57	6.4±3.842	1	11.34	8.46±3.307
	Summer	2.75	6.98	4.94±2.091	0.15	7.13	4.27±3.459	0.15	7.13	9.67±2.557
	Autumn	7.13	10.8	9.39±1.585	1.54	10.67	6.35±3.25	1.54	10.8	9.83±8.12
	Winter	11.15	15.14	13.38±1.356	2.18	9.62	6.04±3.458	2.18	15.14	4.45±2.624
	Whole year	2.75	15.14	9.36±3.514	0.15	10.67	5.62±3.75	0.15	15.14	7.926±3.985
NO_3	Spring	11.4	40.1	22.75±9.255	1.25	35.18	18.93±15.049	1.25	40.1	21.22±11.597
	Autumn	0.49	11.3	3.92±4.471	0.28	8.44	4.428±4.945	0.28	11.3	4.12±4.396
	Winter	33.8	38.19	34.68±2.272	39.24	54.26	45.44±6.53	33.8	54.26	38.955±15.509
	Whole year	0.49	44.81	22.23±13.442	0.28	52.84	24.17±18.954	0.28	54.26	23±15.674

Table (13): Percentages of ammonia nitrite and nitrate to the total nitrogen compounds dissolved in the water of the lake.

Area / Season	Eastern area			Western area			Whole area		
	NH_4	NO_2	NO_3	NH_4	NO_2	NO_3	NH_4	NO_2	NO_3
Spring	69.52	5.47	27.47	53.28	7.2	39.52	61.53	6.46	32.01
Summer	26.09	21.61	52.3	5.22	11.76	83.11	16.49	17.08	66.43
Autumn	34.8	55.07	10.13	10.15	25.98	63.87	22.38	40.73	36.89
Winter	43.41	14	42.59	25.11	13.29	61.6	35.68	13.08	51.23
Whole seasons	44.17	21.77	34.05	28.19	13.29	58.51	36.79	15.93	47.28

Table (14): Percentages of ammonia, nitrite and nitrate to the total nitrogen compounds dissolved in the drainage water.

Area / Season	Kom Belag			Bersik			Total drains		
	NH_4	NO_2	NO_3	NH_4	NO_2	NO_3	NH_4	NO_2	NO_3
Spring	48.53	15.53	35.93	35.73	16.24	48.03	44.78	15.74	39.48
Summer	31.59	10.4	58.01	17.24	10.99	71.77	24.11	19.96	55.92
Autumn	55.75	31.22	13.03	42.96	33.6	23.44	48.49	36.3	15.21
Winter	41.95	16.16	41.89	22.83	9.05	68.12	38.28	6.33	55.39
Whole seasons	43.41	16.77	39.82	24.72	14.2	61.08	37.99	15.9	46.11

c- Phosphorus Compounds:

The cycle of phosphorus in many lakes was indicated by Harvey (1974) in quite different way from that in the sea. He pointed out that while whole algae fall to the bottom, there being a much smaller zooplankton population to eat, crush or digest them while in suspension. However the algae are very slowly decomposed by bacteria and protozoa. Therefore large quantities of phosphorus remain locked up in the algal deposit. The water of lakes is in consequence often rich in salts containing nitrogen but very poor in phosphate.

However phosphorus is considered as one of the important nutrient element in the aquatic habitates. This element is a one of the limiting factors controlling the growth and reproduction of phytoplankton. The environmental signification of phosphorus arises out of its role as a major nutrient for both plants and micro organisms (Vanloon and Duffy, 2000). The concentrations of phosphates in the water of both the eastern and western parts of Lake Edku during the course of the present study are seasonally given in Table (15). The concentrations of such nutrient compound in the drainage water of Kom Belag and Bersik drains during the some period are given in Table (16).

It was found that:

1) Higher concentrations of phosphate were recorded in Kom Belage drain than that at Bersik one. The yearly average concentration of such phosphorus compound was found to be 12.11 and

10.87 µg/L in the water of the two drains respectively.

On the other hand the average concentrations of phosphate were found to be 8.08 and 6.59 µg/L in the water of the eastern and western areas of the lake respectively. It is believed therefore that the higher concentration of phosphate in Kom Belag drain increased its concentration in the eastern area where it discharges. In comparison with that the decreased concentrations in the western area can be attributed to the lower concentrations of this nutrient salt in Bersik drain water where its outlet lies near to this area.

2) The average concentrations of phosphates in the drains water were mostly higher than its concentrations in the lake water. This means that the drains are the main supply of phosphorus compounds to the lake. Washing up the cultivated lands near to the lake undertakes majors contribution in supplying the lake with such nutrient salts.

3) The least concentrations of phosphates in the lake water were recorded in summer as µg/L. This value is very low if compared with the average concentration of phosphate in the drainage water during summer where it was 11.21 and 10.81 µg/L in Kom Belag and Bersik water with an average of 11.05 µg/L. The obvious decrease of phosphate concentration in the lake water can be attributed to the maximum flourishment of phytoplankton and rooted plants in the lake during summer and consequently the uptake of large amounts of such nutrient salt.

d- Reactive Silicates:

The concentrations of silicate in the water of Lake Edku are in fact controlled by two main factors:

(1) The balance which may result from the rate of decomposition of decomposition and regeneration from the bottom and the rate of uptake undertaken by micro organisms specially diatoms.

(2) The rate and chemical composition of drainage water discharge where it is believed that the fresh water is rich with silicate.

The average concentrations of silicates in both the lake and drain water are given in tables (17) and (18) respectively.

Higher concentrations of silicates were mostly recorded in the water of eastern area of the lake close to outlet of Kom Belag drains. The maximum concentrations of silicate were found in this area during autumn as 171.08 µg/L.

On the other hand the concentrations of silicates in the lake attained lower values during spring and summer. This decrease may be attributed to the outburst of phytoplankton therefore the rate of consumption of silicon by diatoms is increased. According to Riley and Chester (1971) the spring blooming of phytoplankton cause a rapid decrease in the concentration of silicon. Same phenomena was observed in the drains water specially in spring season where the minimum concentrations of silicate were recorded in both Kom Belag and Bersik drains. Lower concentrations of silicate were found in the water of the western area of the lake in spite of the high concentrations of silicate in Bersik drain water which outflows mainly in such area. The decrease of silicate concentrations in the western area of the lake may have resulted from the effect of sea water inflow through the lake sea connection near to this area.

It was pointed out by several authors that the sea water is characterized by significantly lower concentrations of silicate. Riley and Chester (1974) indicated that the silicate content of river water is more than 5 times greater than that of the sea – El-Rayis (1973) found that the silicate content of the Eastern Harbor of Alexandria fluctuated between a maximum of 13.3 µg/L in January and a minimum of 2.90 µg/L in March.

Table (15): Average concentrations of phosphates µg/L at eastern and western parts of Edku Lake.

Area / Season	Western area			Eastern area			Whole lake		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	2.75	12.11	8.62±3.514	9.48	15.97	12.448±3.093	2.75	15.97	10.15±3.722
Summer	0.92	6.88	3.98±2.164	0.92	2.65	1.49±0.871	0.92	6.88	2.985±2.124
Autumn	1.53	3.12	3.1±1.307	3.39	6.91	5.15±1.467	1.53	6.91	3.92±1.669
Winter	8.19	12.11	10.64±1.514	12.29	14.32	13.25±0.835	8.19	12.29	11.68±1.82
Whole year	0.92	12.11	6.59±3.857	0.92	15.97	8.08±5.352	0.92	15.97	7.19±4.51

Table (16): Average concentrations of phosphates µg/L at eastern and western parts of Edku Lake.

Area / Season	Kom Belag			Bersik			Total drains		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	13.15	22.51	19.32±3.511	7.89	18.29	13.89±4.4	7.89	22.51	17.15±4.602
Summer	7.89	19.15	11.21±4.173	5.26	14.44	10.81±4.067	5.26	19.15	11.05±3.903
Autumn	5.6	12.16	9.84±2.63	4.96	11.38	7.85±3.442	4.96	12.16	9.04±2.974
Winter	1.14	15.93	8.1±4.815	10.28	11.32	10.95±0.477	1.14	15.93	9.24±3.889
Whole year	1.14	22.51	12.11±5.687	4.96	18.29	10.87±3.803	1.14	22.51	11.62±5.002

Table (17): Average concentrations of silicates µg/L at the eastern and western parts of Edku Lake.

Area / Season	Eastern area			Western area			Whole lake		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	32.85	80.03	53.03±20.381	12.68	68.93	42.38±18.053	12.68	80.03	46.58±18.675
Summer	3.68	44.4	30.38±18.15	39.75	51.6	45.45±4.17	3.68	51.6	39.45±13.433
Autumn	135.6	210.08	171.08±30.81	86.93	181.95	129.89±31.073	86.93	210.08	146.48±36.045
Winter	89.1	109.5	89.33±8.693	61.13	96.9	83.1±12.668	61.13	109.5	89.17±13.28
Whole year	3.86	210.08	88.2±58.62	12.68	181.95	75.23±40.44	3.68	210.08	88.4±48.24

Table (18): Average concentrations of silicates µg/L at eastern and western parts of Edku Lake.

Area / Season	Kom Belag			Bersik			Total drains		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
Spring	41.17	64.2	56.85±8.048	42.15	78.3	60.83±14.783	41.17	78.3	85.425±10.628
Summer	36.6	120.15	77.78±30.18	91.43	166.43	140.25±33.803	36.6	166.43	102.75±44.138
Autumn	50.85	142.58	83.78±33.743	40.05	112.58	90.53±33.915	40.5	142.58	86.48±32.063
Winter	44.55	204.83	82.2±15.825	84.53	183.83	138.08±40.86	44.55	204.83	104.55±59.123
Whole year	36.6	204.83	75.15±35.153	40.05	183.83	107.4±45.045	36.6	204.83	87.73±43.193

4. SUMMARY AND CONCLUSIONS

The following points can be concluded from the present investigation:

(1) The surface water temperature of the lake water seems to gain heat from the overlying air more rapidly than the slightly deeper running water of the drains. Therefore the average water temperature of the lake was slightly higher than the drainage water.

(2) The water transparency of the lake water attained the lowest level in spring due to the maximum flourishment of phytoplankton. Water was more transparent in summer and autumn as a result of its stagnancy.

(3) The highest values for total dissolved solids (TDS) in the lake water were found in winter due to both the decrease in the rate of drainage water discharge on one side and the invasion of subsurface Abu Qir sea water under the stormy wind action on the other side.

(4) The salinity of the drainage water was almost less than the salinity of the lake water. Therefore the drainage water plays an important role in decreasing the salinity of the lake water. This contributes in increasing the intensity of macrophytes in the lake.

(5) Determination of pH indicated that either the lake or drainage water were always on the alkaline side. The average values of pH were found to be 8.04 and 7.89 for the lake and drain water respectively. This means that the drainage water discharge decreases the pH of the lake water.

(6) The lake water was mostly well oxygenated where the recorded concentrations of dissolved Oxygen ranged between 5.44 mg/L and 14.07 mg/L with an average of 6.70 mg/L . On the other hand the dissolved Oxygen in the drainage water ranged between 4.29 ml/L and 9.60. The lower concentrations of dissolved oxygen in the drainage water can be related to oxidation of its high concentrations of organic matter.

(7) The drainage water is generally rich in dissolved nutrient salts with special reference to the periods when fertilization by nitrogen and phosphorus salts in applied through the cultivated areas around the lake. The weights of nitrogen and phosphorus compounds added to the lake water as a result of drainage water discharge were calculated as follows: 1065.62 metric tons of nitrogen and 646.61 metric tons of phosphorus compounds are annually discharged to the lake water.

(8) The highest concentrations of ammonia were found in the whole area of the lake in winter. Decreased concentrations were detected during spring and

summer as a result of its assimilation by the flourished aquatic vegetations during these two seasons.

(9) Higher concentrations of nutrient salt existed at the eastern basin of the lake where Kom Belag drain outlet to the lake.

(10) The dominant nitrogen compound in either the lake or drainage water mostly the nitrate. This indicates that this echosystem is generally well oxygenated.

(11) Higher concentrations of silicate were recorded at the eastern area of the lake throughout the whole period of the present study.

REFERENCES

Abbas, M. L.M. shakeer and D. Hassan: 2001, Chester, R., Stoner, J.A. (1974): The distribution of zinc, nickel, manganese, cadmium, copper and iron in some surface waters from the world ocean. Mar. Chem. 2:17-32.

El-Rayis, O.A.: 1973, Cycle of nutrient salts in Mediterranean sea water off Alexandria. M.Sc. Thesis. Fac. Sci. Alex. Univ. 128 pp.

El-Samra, M.: 1973, chemical and physical properties of the waters of lake Edku and the mixed waters between the lake and the sea. (Abu. Kir Bay) M.Sc. thesis. Alex. Univ., Fac. Sci. 110 pp.

FAO Fisheries Technical paper: 1975, Manual of Methods in Aquatic Environment Research part 1- Methods for Detection, Measurement and Monitoring of water pollution FAO Fisheries Technical paper no. 137, 1975, 237pp.

Grasshof, K.: 1976, Methods of sea water analysis with contribution by T.Almgreen, R. Dowson; M.Ehrhardt, S. Fonelnis, B.Josefsson, F. Korelff, and K. Kremiling. Auf Wenhem N.Y. 317 pp.

Harvey, H.W.: 1974, The chemistry and fertility of sea water. Cambridge Univ. press 240 pp.

Hutchinson G.E.: 1936, Alkali, deficiency and fish mortality science. 84:18.

Kenawy, S.: 1974, Hydrography and nutrient salts in the water of lake Edku (Egypt). M.Sc. Thesis, Alex. Univ. Fac. Sci. 224 pp.

Ketchum, B.H.: 1939, The development and restoration of deficiencies of phosphorus and nitrogen composition of unicellular plants J.cell. comp. physiol. 13:373.

Riley, J.P. and R. Chester: 1971, Introduction to marine chemistry. Academic Press, London and New York. 465 pp.

Ruttner, F.: 1968, Fundamentals of limnology. Univ. of limnology. Univ. of Toronto press 4th Edition 295 pp.

Samman, A.: 1974, primary production of lake Edku. Bull. Nat. In st. Ocean. Fish. A.R.E. vol. 1: 261-317.

Strickland, J.D.H. and T.R. parsons: 1968, A practical handbook of sea water analysis. Bull. Fish. Res. Board Can. 167: 33 p.

Vanloon G,W. and S.J. Duffy: 2000, In " Environmental chemistry" A Global perspective. Oxford. New York.

Welch, P.B.: 1952, Limnology. 2nd Edition, N.Y. Toronto, London, Mc Graw – Hill Book comp. Inc. 538 pp.