ENVIRONMENTAL PROBLEMS IN TWO EGYPTIAN SHALLOW LAKES SUBJECTED TO DIFFERENT LEVELS OF POLLUTION

Massoud A.H. Saad and A.M. Safty

Oceanography Department, Faculty of Science, Alexandria University,
Moharem Bey, Alexandria, Egypt

ABSTRACT

The two study areas are Lake Mariut and the Nozha Hydrodrome. The water of Lake Mariut is pumped to the Mediterranean Sea. It is the heavily polluted basin in Egypt receiving huge amounts of contaminated drainage waters and untreated domestic and industrial wastes. The Hydrodrome was separated in 1939 from Lake Mariut and became polluted in recent years from the feeding contaminated Nile water. The present study, a part of a research project on pollution of both lakes, deals with their limnological characteristics to illustrate the influence of developmental projects in their surroundings and to compare between their levels of pollution.

The effect of thermal stratification was ignored in both lakes, due to their shallowness and the effect of prevailing winds. Seasonal variations of water temperatures followed those of the air. The chlorosity in Lake Mariut, affected mainly by drainage waters, was noticeably higher than that in the Hydrodrome. In Lake Mariut, chlorosity showed a highly significant positive correlation with dissolved oxygen (DO) and a highly significant negative correlation with hydrogen sulphide, confirming that the main source of this toxic gas is the heavily polluted Qalaa Drain. Except in some occasions, Lake Mariut water was nearly depleted from DO. The oxygenated region in this lake constituted about 10-15% of its area. The DO problem affects markedly fish survival. The DO average value in Umum Drain, partially supplying Lake Mariut with oxic waters, was nearly double that in the feeding water of the Hydrodrome. Hydrogen sulfide was found in most parts of Lake Mariut and was never detected in the Hydrodrome. This gas dissolved in the lake water caused anoxic conditions and thus destroyed the aquatic life. Significant positive correlations were found in Lake Mariut between temperature, pH and DO, possibly reflecting the high influence of pollution and intensity of photosynthesis. The temperature and pH correlation in the Hydrodrome was less significant. Poor correlations existed in both lakes between pH and chlorophyll-a. Based on above data and others, solutions have been suggested for restoration of Lake Mariut and returning of both lakes to their previous healthy conditions.

Keywords: Pollution, problems, Delta lakes, Egypt

INTRODUCTION

In the last three decades, Lake Mariut has suffered from intensive pollution, although at one time it was a highly productive lake. This pollution increases with time; due to the successive increase in population and industry around the lake different types of untreated pollutants (sewage and industrial wastes and agricultural run-off) entering into the lake changed it into a highly eutrophic state. This beside reclamation of great areas from the lake has affected dramatically its fish production.

In the past, the Hydrodrome received unmodified Nile water. In the last two decades, however, its feeding water became contaminated with untreated sewage and industrial wastes, but at lower levels when compared with Lake Mariut. The present study, a part of a research project on pollution of both lakes, deals with their limnological characteristics to illustrate the influence of the developmental projects in their surroundings and to compare between their levels of pollution.

DESCRIPTION OF STUDY AREAS

Lake Mariut is one of the northern Nile Delta lakes situated along the Mediterranean coast of Egypt south Alexandria. The present lake, representing a small portion of a large ancient basin (Lake Mariutus) is divided artificially into four basins (Fig. 1). The area of the main basin (lake proper) selected for the present study reaches 17 km^2 and its depth varies from 90-150 cm. It is the lethargic polluted region of the lake receiving most of its waters from the heavily polluted Qalaa Drain, beside the industrial outfalls of Mogama Drain and the raw sewage of Kabbary and Gheit Enab Drain (Fig. 1). Mex Pumps discharge the surplus water from the lake to the sea to maintain its level at 2.8 m below sea level.

Mogama Drain discharges industrial effluents of eight factories; Salt and Soda, Extracted Oils, National Paper, Starch and Yeast, Nile Matches, South Alexandria Mills and Alexandria Foundry. These represent the major industrial pollution source to Lake Mariut deteriorating its environment at an alarming rate. Besides, the agricultural drainage waters laden with pesticides and fertilizers participate actively in polluting this lake.

In 1939, the Nozha Hydrodrome was isolated by an embankment from Lake Mariut. It has an area of 5.04 km^2 and average depth of 2.11 m. It receives its water from the Nile via the contaminated Mahmoudia Canal through the Feeding Canal (Fig. 2).

MATERIAL AND METHODS

Six stations were selected in Lake Mariut and four in the Hydrodrome to represent different regions in each lake. Monthly sampling occurred from August 1990 to July 1991 at 30 cm below the lake water surface to avoid floating matter. Also, monthly water sampling occurred from the drain of Lake Mariut and the Feeding Canal of the Hydrodrome.

Air temperatures were measured at sampling by a simple thermometer and water temperatures by the bucket thermometer. pH was measured by a portable digital pH meter. Chlorosity was determined by the titration method. Dissolved oxygen was determined by the Winkler method described by APHA (1975) and hydrogen sulfide by Strickland & Parsons (1972).

RESULTS

(a) Temperature

Lake Mariut

The air temperatures gave a lowest in January (13.4±0.8°C) and a highest in August (32.2±0.05°C). The monthly averages of water temperatures varied from 14.17 ± 0.75°C in January to 29.5 ± 0.63°C in July. Mogama Drain showed highest readings relative to the other drainage water temperatures. The lowest temperature recorded for the drainage waters was 14.5°C in January in Umum Drain and the highest (32.5°C) in August in Mogama Drain (Table 1).

Nozha Hydrodrome

The air temperatures scored a minimum of 14.0°C in January and a maximum of 32.0°C in July. The monthly averages of water temperatures, ranging from 13.5 ± 1°C in January to 28.8 ± 0.5°C in August, showed significant variation ($P < 0.001$). The temperatures of the Feeding Canal varied from 18.0°C in January to 29.5°C in August (Table 2).

(b) Hydrogen ion concentration

Lake Mariut

The seasonal variation in pH values was limited, ranging from 7.02±0.33 in November to 7.77±0.38 in August, giving an annual mean of 7.42± 0.16 (Table 1). The regional pH variation was also limited, varying from 7.15 ± 0.20 at station II to 7.54 ± 0.22 at station III (Table 3). The pH values in the drainage waters varied from 5.91 in Mogama Drain in July to 8.80 in Gheit Enab Drain in August. Umum Drain gave the highest annual mean of 7.45 and Mogama Drain the lowest of 6.63 (Table 1).

Nozha Hydrodrome

The monthly average values varied from 8.09 ± 0.31 in November to 8.70 ± 0.07 in February, giving an annual mean of 8.42 ± 0.6 (Table 2). The minimum regional average value was scored at station I (8.35 ± 0.31) and the maximum at stations II and III (8.47 ± 0.16). The Feeding Canal pH values, ranging from 6.99 in November to 8.62 in February and giving an annual mean of 7.50 ± 0.55, were less than those of the Hydrodrome in all months (Table 2).

(c) Chlorosity

Lake Mariut

The monthly averages (Table 1) varied from 0.9 ± 0.19 g l^{-1} in October to 2.49 ± 1.89 g l^{-1} in December, giving an annual mean of 1.61 ± 0.43 g l^{-1}. The maximum coefficient of monthly variations was 76% in December and did not exceed 50% in the other months. The regional average values (Table 3) reached a minimum of 1.15 ± 0.27 g l^{-1} at station II and a maximum of 2.46 ± 1.32 g l^{-1} at station IV and their coefficient of variation was below 50%. The chlorosity of the drainage waters ranged from 0.31 g l^{-1} in Kabbary Drain in May to 5.20 g l^{-1} in Umum Drain in July, giving the lowest and highest annual means of 1.00 and2.60 g l^{-1}, respectively (Table 1).

Nozha Hydrodrome

Variations of the monthly average values were noticeable, ranging from 0.40 ± 0.08 g l^{-1} in October to 1.54 ± 0.23 g l^{-1} in July, giving an annual mean of 0.95 ± 0.03 g l^{-1} (Table 2). Fluctuation of the regional averages was very narrow, oscillating between 0.91 ± 0.34 g l^{-1} at station I and 0.98 ± 0.49 g l^{-1} at station IV (Table 3). The values in the Feeding Canal varied from 0.30 g l^{-1} in October to 2.80 g l^{-1} in September, giving an annual mean of 1.21 ± 0.66 g l^{-1} (Table 2).

(d) Dissolved oxygen (DO)

Lake Mariut

DO was not detected at most stations. The monthly average maxima were scored in August and July (2.77 ± 3.81 and 2.30 ± 2.56 mg l^{-1}, respectively) and the annual mean reached 1.57±0.55 mg l^{-1} (Table 1). The regional averages varied from 0.05 ± 0.13 mg l^{-1} at station V to 5.23 ± 1.77 mg l^{-1} at station IV (Table 3) and the coefficient of variations exceeded 200% at stations I, V and VI. DO appeared in all months in Umum Drain and the highest concentrations of 8.48 and 9.84 mg l^{-1} were recorded in October and December, respectively. However DO was completely depleted in Qalaa and Kabbary Drains and appeared in January in Gheit Enab Drain and in two months in Mogama Drain (Table 1).

Nozha Hydrodrome

The monthly averages fluctuated significantly ($P < 0.001$) between 3.98 ± 0.49 mg l^{-1} in October and 8.02 ± 1.44 mg l^{-1} in January, giving an annual mean of 6.02 ±

0.97 mg l^{-1} (Table 2). The regional variations were significant ($P < 0.001$), ranging from 4.74 ± 1.66 mg l^{-1} at station I to 7.10 ± 1.84 mg l^{-1} at station IV (Table 3). The DO concentrations in the Feeding Canal varied from 0.75 mg l^{-1} in January to 5.96 mg l^{-1} in February, giving an annual mean of 2.41 ± 1.89 mg l^{-1} (Table 2).

(e) Hydrogen sulfide

Lake Mariut

The monthly average values varied from 5.72 ± 8.09 ml l^{-1} in June to 20.37 ± 14.0 ml l^{-1} in October, giving an annual mean of 10.0 ± 3.58 ml l^{-1} (Table 1). The regional averages ranged from 4.94 ± 7.04 ml l^{-1} at station III to 17.11 ± 7.57 ml l^{-1} at station II (Table 3) and the very high coefficient of variations at station III resulted from the appearance of H_2S in four months only. Also, this gas did not appear at station IV. H_2S was never detected in Umum Drain and the order of its level in the drainage waters was: Qalaa > Mogama > Kabbary > Gheit Enab (Table 1).

DISCUSSION

(a) Temperature variations

Variations of air temperature over Lake Mariut and the Hydrodrome were significant ($P < 0.001$). Thermal stratification in both lakes is ignored, due to their shallowness and the effect of prevailing winds in mixing the water column. The monthly variations of water temperatures which were significant ($P < 0.001$) followed those of the air. Statistical analysis yielded very strong significant correlations between both readings in Lake Mariut ($r = 0.953$, $p < 0.001$) and in the Hydrodrome ($r = 0.939$, $p < 0.001$). Temperature is an important factor affecting phytoplankton (Abbas, 1980).

Statistical analysis yielded a significant correlation between water temperature and chlorophyll-a in the Hydrodrome ($r = 0.332$, $p < 0.001$). However, this correlation was not found in Lake Mariut, due to disturbance of its ecosystem from severe pollution. The highest temperatures recorded in Mogama Drain reflect the hot industrial wastewaters from cooling and other industrial operations causing thermal pollution in Lake Mariut (Table 1).

(b) Hydrogen ion concentration variations

The highest seasonal average pH value in Lake Mariut in August was accompanied by the rise in temperature (Table 1) and abundance of aquatic plants. A significant positive correlation was observed between water temperature and pH values ($r = 0.451$, $p < 0.001$). This correlation was less significant in the Hydrodrome ($r = 0.341$, $p < 0.01$). However, poor correlations were observed in both lakes between pH and chlorophyll-a values. Consumption of dissolved oxygen by decomposition of organic matter may reduce pH (Bishay & Yousef, 1977; El-Hehyawy, 1977). This may explain the minimum regional pH value in the polluted Mogama Drain (Table 1). However, the highest regional pH averages were recorded in the oxic waters at stations III and IV (Table 3). A positive significant correlation was found in Lake Mariut between pH and oxygen ($r = 0.451$, $p < 0.001$). Abdel-Moati (1985) found the same result in the heavily polluted area of Bahr-El-Baqar in Lake Manzalah.

In the Hydrodrome, the minimum regional average pH value at station I (Table 3) reflects the low pH of the Feeding Canal (Table 2). However, the maxima at stations II and III (Table 3) selected in the lake middle coincided with settlement conditions at these locations. The annual mean pH value for the Hydrodrome was higher than that for lake Mariut by 1 unit (Tables 1 and 2), reflecting the level of pollution in the mother lake.

(c) Chlorosity variations

The distribution of chlorosity in Lake Mariut was controlled by the drainage water discharges. The maximum average value for the drainage waters appeared in Umum Drain (Table 1) transporting water from new reclaimed agricultural land. The low values in Qalaa, Kabbary and Gheit Enab Drains (Table 1) decreased the chlorosity in the lake near their discharges. The annual mean chlorosity value for Lake Mariut was lower than the earlier means obtained by Aleam & Samaan (1969) and Morcos *et al*., (1969), indicating the decrease in the lake chlorosity with progress of time from the discharges of large amounts of drainage waters. In Lake Mariut, the highest seasonal average value in winter (December) resulted from rainfall and in summer (July) from high drainage water discharges accompanied by high evaporation.

Chorosity gave in Lake Mariut a significant positive correlation with dissolved oxygen ($r = 0.410$, $p \leq 0.001$) and a significant negative correlation with hydrogen sulfide ($r = -0.388$, $p \leq 0.001$). Accordingly, high chlorosity appeared in the areas of high oxygen content and the main source of H_2S in the lake is the drainage water discharges.

The chlorosity values in Lake Mariut were noticeably higher than those in the Hydrodrome in all months (Tables 1 and 2). The annual mean for the Feeding Canal was 1.21 ± 0.66 g l^{-1} and this feeding water affected the chlorosity of the Hydrodrome.

(d) Dissolved Oxygen (DO) variations

Several factors control the distribution of DO in the lake water; temperature, chlorosity, pH, photosynthesis, aeration, respiration of living organisms and decomposition of organic matter (Guerguess, 1979; Abbas, 1980).

Except in some occasions, the water of Lake Mariut was nearly depleted from DO and H_2S dominated in a noticeable part of the lake. The annual mean DO concentration (1.57±0.55 mg l^{-1}) gave 20% percentage saturation. This affected much fish survival in Lake Mariut. This mean was very low compared with that obtained by Ahdy (1982) from the same lake, confirming the increase in pollution with progress of time.

The maximum average DO value in Lake Mariut appeared in August (Table 1) in absence of wind action. However, the prevailing wind in winter (December, January and February) was not capable in aerating the highly anoxic lake water and thus the average DO values in these months were low (Table 1).

The drains of Lake Mariut discharge industrial wastes and raw sewage waters converting the lake into anoxic regions in the vicinity of discharges. However, station IV in front of Umum Drain transporting oxic water gave the highest average value (Table 3). The average value of Umum Drain (5.34±2.07 mg l^{-1}) was more than double that of the Feeding Canal of the Hydrodrome (2.41±1.89 mg l^{-1}). The oxygenated region in Lake Mariut is localized in the western and mid southern part, constituting from 10-15% of the lake area. It is evident from DO data of the Hydrodrome and its Feeding Canal (Table 2) that DO of this lake was not supplied by this canal, as it transports low oxygen bearing water.

(e) Hydrogen sulfide (H_2S) variations

H_2S was present in most parts of Lake Mariut, except at station IV opposite to the oxic Umum Drain, leading to anoxic conditions. Qalaa Drain is the main source of H_2S to thelake. Mogama Drain was nearly anoxic all the year and Gheit Eneb Drain showed also anoxic character. The H_2S/chlorosity correlation indicates the presence of other sources of H_2S than the drainage water discharges, such as sulfate reduction and enrichment of organic matter in the lake sediments. According to Kimoto & Fujinaja (1990) the production of organic compounds by photosynthesis is very active in the surface water and biodegradation in the bottom water produces remarkably anoxic conditions. At low temperatures the majority of sulfides were derived from organic matter, whereas sulphate reduction predominated at higher temperature. The appearance of insignificant variations in the monthly H_2S averages (Table 1) possibly coincided with the effect of prevailing winds in stirring up the shallow water column and the continuous flow of H_2S bearing drainage waters. The present H_2S ranges (Table 1) were markedly higher than earlier data obtained by Ahdy (1982) from the same lake, confirming the increase in organic pollution with progress of time.

REFERENCES

Abbas, M.H., 1980. Limnological conditions and distribution of phytoplankton in Rosetta branch of the Nile. M.Sc. Thesis, Fac. Sci., Alexandria Univ.

Abdel-Moati, M.A.R., 1985. Studies on the chemistry of Lake Manzalah waters "Egypt". Ph.D. Thesis. Fac. Sci., Alexandria Univ.

Ahdy, M.H., 1982. Distribution of heavy metals in Lake Mariut and Nozha Hydrodrome and their accumulation in fish. M.Sc. Thesis. Fac. Sci., Alexandria Univ.

Aleem, A.A. & A.A. Samaan, 1969. Productivity of Lake Mariut, Egypt. Part II; Primary production. Int. Revue ges. Hydrobiol. 54(4): 491-314.

American Public Health Association. 1975. Standard Methods for the examination of water and wastewater. Inc. New York. 1193, pp.

Bishai, H.M. & S.F. Yossef, 1977. Some aspects on the Hydrography, Physicochemical characteristics and fisheries of Lake Manzalah. Bull. Inst. Oceanogr. & Fish., A.R.E. Vol.7.

El-Hehyawi, E., 1977. Some aspects of the chemistry of Lake Manzalah water. Bull. Inst. Oceanogr. & Fish. A.R.E. Vol. 7.

Guerguess, S.K., 1979. Plankton and environmental conditions in Lake Manzalah. Ph.D. Thesis, Fac. Sci., Alexandria Univ.

Kimoto, T. & T. Fujinaga, 1990. Non-biotic synthesis of organic polymers on H_2S - rich sea floor: a possible reaction in the origin of life. Mar. Chem. 30:179-192.

Morcos, S.A., S.K. El-Wakeel & A.A. Mahlis, 1969. Chlorinity, salinity and density of Lake Mariut waters. Bull. Fac. Sci. Alexandria Univ., 60:119-141.

Strickland, J.D.H. & T.R. Parsons, 1972. A practical handbook of seawater analysis. Fish. Res. Bd. Canada Bull. 167, 310 pp.

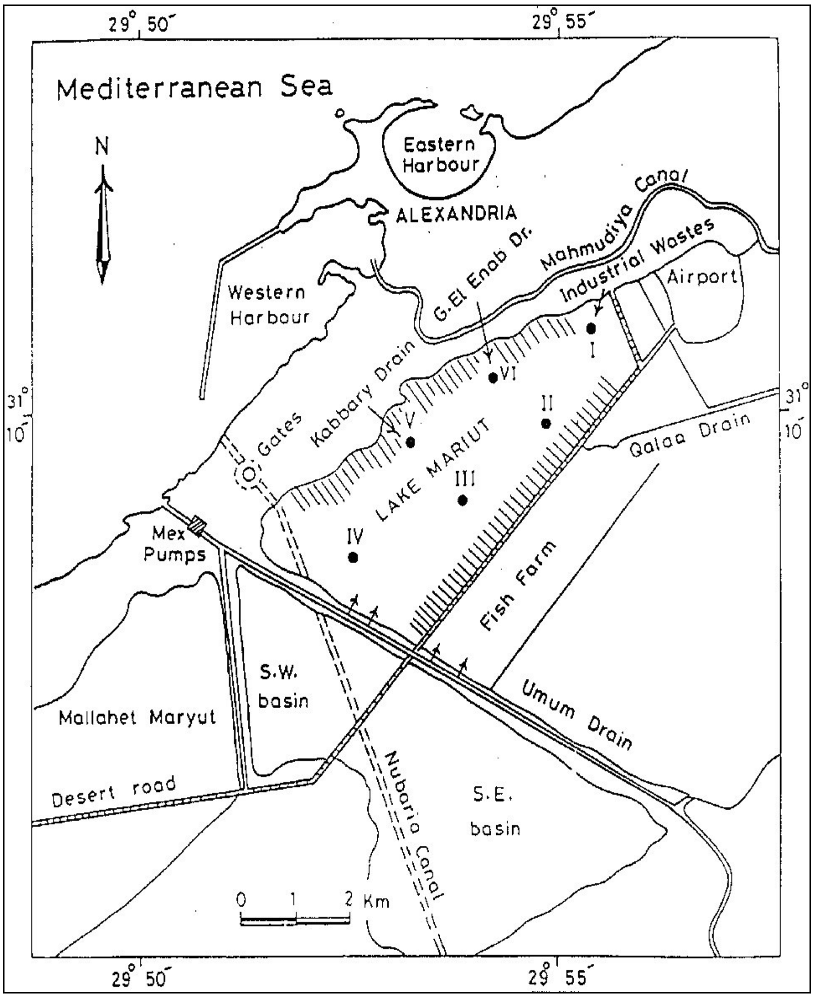

Fig. 1. Lake Mariut

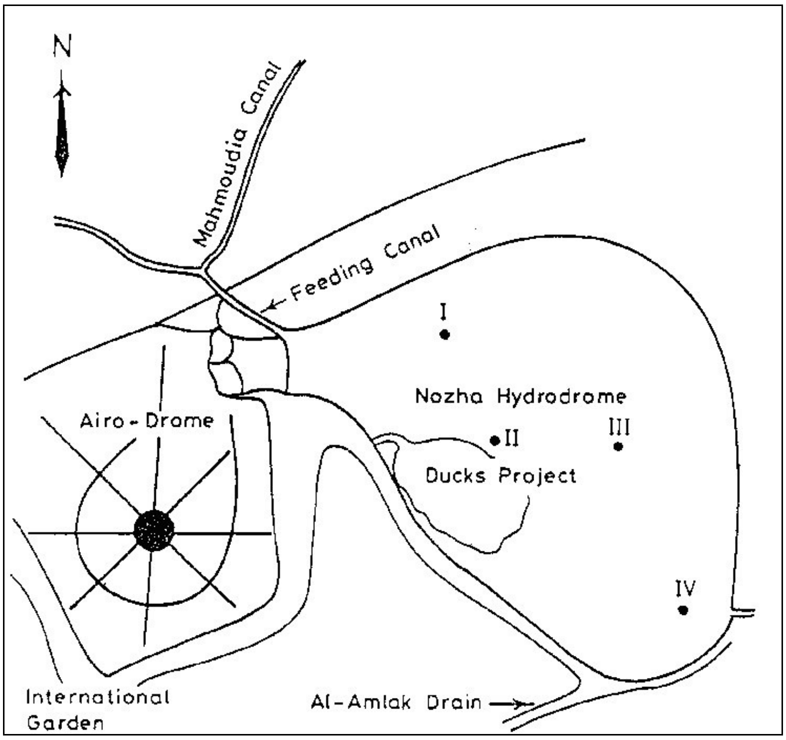

Fig. 2. Nozha Hydrodrome

Table 1. Monthly average values and annual means of the environmental characteristics in Lake Mariut and its feeding drains

Parameters	Study areas	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Annual means
Water temp. (°C)	Lake	29.42 ±0.79	26.25 ±0.76	25.55 ±0.34	22.17 ±0.75	18.5 ±1.2	14.17 ±0.75	18.97 ±0.62	21.85 ±0.99	23.38 ±0.53	23.66 ±0.68	29.0 ±0.86	29.5 ±0.63	
	Mogama	32.5	31.0	32.0	27.0	25.5	17.0	26.0	23.0	28.0	31.5	31.0	31.6	
	Qalaa	29.0	27.0	25.5	21.0	19.0	15.5	19.0	23.0	24.0	23.0	29.0	29.8	
	Umum	27.5	26.0	24.0	21.0	17.5	14.5	17.5	22.0	22.5	23.0	27.5	29.6	
	Kabbary	29.0	28.5	26.5	24.0	19.0	15.0	19.0	23.0	23.0	23.2	28.5	29.4	
	Gh. Eneb	30.0	29.5	27.2	23.0	21.0	16.0	21.0	23.5	23.5	23.2	28.5	30.0	
pH	Lake	7.77 ±0.38	7.48 ±0.23	7.25 ±0.26	7.02 ±0.33	7.27 ±0.21	7.21 ±0.24	7.48 ±0.30	7.38 ±0.29	7.38 ±0.26	7.55 ±0.46	7.75 ±0.46	7.46 ±0.56	7.42 ±0.16
	Mogama	6.80	6.10	6.55	6.54	6.66	7.31	7.71	6.56	6.94	6.41	6.53	5.91	6.63
	Qalaa	7.30	6.90	6.85	6.73	7.08	7.03	7.10	7.12	7.19	7.28	7.25	7.04	7.07
	Umum	7.80	7.70	6.95	7.09	7.38	7.30	7.30	7.54	7.43	7.68	7.64	7.61	7.45
	Kabbary	7.00	6.90	6.94	6.84	6.75	7.00	6.83	7.11	7.39	7.12	7.02	7.03	6.99
	Gh. Eneb	8.80	6.80	6.51	6.58	8.05	6.56	7.66	7.04	7.08	7.03	7.02	7.16	7.19
Chlorosity ($g.l^{-1}$)	Lake	1.68 ±0.94	1.24 ±0.25	0.90 ±0.19	1.25 ±0.58	2.49 ±1.89	1.57 ±0.35	1.94 ±0.56	1.65 ±0.24	1.39 ±0.28	1.69 ±0.69	1.25 ±0.34	2.27 ±0.45	1.61 ±0.43
	Mogama	2.29	2.08	1.04	0.83	1.87	2.70	1.98	2.08	2.08	2.29	2.49	3.70	2.12
	Qalaa	1.25	0.83	2.29	4.37	0.94	1.46	1.25	1.25	0.73	1.04	1.04	2.10	1.55
	Umum	2.49	2.49	1.04	3.12	2.29	2.49	3.12	3.74	1.25	2.08	1.87	5.20	2.60
	Kabbary	0.62	0.62	0.62	3.62	0.42	1.04	0.42	0.83	0.62	0.31	1.66	1.30	1.00
	Gh. Eneb	1.04	1.25	1.25	1.46	3.12	1.35	1.14	0.83	1.25	1.14	2.29	1.00	1.43

Dissolved Oxygen (mg l^{-1})	Lake	2.77 ±3.81	1.08 ±1.53	1.12 ±2.5	2.18 ±3.23	1.31 ±2.29	1.61 ±2.54	1.06 ±1.55	1.00 ±1.59	1.30 ±2.22	1.42 ±2.01	1.75 ±1.9	2.30 ±2.56	1.57 ±0.55
	Mogama	N.D	N.D	N.D	N.D	N.D	N.D	0.40	N.D	N.D	N.D	4.34	N.D	0.40
	Qalaa	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N,D	N.D
	Umum	4.89	4.40	8.48	3.01	9.84	6.93	5.46	4.09	5.26	3.79	3.68	4.3	5.34
	Kabbary	N.D	N.D	N.D	N.D	N.D.	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
	Gh. Eneb	N.D	N.D	N.D	N.D	N.D	0.23	N.D	N.D	N.D	N.D	N.D	N.D	0.02
Hydrogen sulfide (ml l^{-1})	Lake	6.57 ±6.58	8.93 ±6.44	20.37 ±14.0	10.70 ±7.78	9.58 ±6.80	10.80 ±7.66	8.03 ±8.05	10.77 ±7.83	11.42 ±8.10	9.75 ±7.09	5.72 ±8.09	7.40 ±7.45	10.00 ±3.58
	Mogama	16.8	17.1	16.4	17.2	15.4	15.2	N.D	16.8	15.9	15.9	16.4	17.3	15.03
	Qalaa	13.3	13.9	51.6	14.1	16.4	17.5	15.3	13.8	17.2	17.6	17.9	14.2	18.57
	Umum	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
	Kabbary	13.0	16.2	13.7	15.9	13.4	15.7	10.2	16.9	15.2	14.3	16.8	14.3	14.64
	Gh. Eneb	14.2	13.1	13.6	13.2	16.3	N.D	14.4	17.8	17.2	13.3	17.3	17.4	13.98

Table 2. Monthly average values and annual means of the environmental characteristics in the Nozha Hydrodrome and its Feeding Canal

Parameters	Study areas	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Annual means
Temperature	Lake	28.8	27.7	25.9	18.8	17.5	13.5	18.9	21.5	23.9	24.0	26.5	27.9	
(°C)		±0.5	±0.4	±0.3	±1.0	±1.0	±1.0	±0.7	±0.5	±0.1	±0.1	±1.3	±0.3	
	Feeding Canal	29.5	28.0	25.5	22.0	19.0	18.0	18.2	20.6	24.0	25.0	28.0	N.D	
	Lake	8.36	8.62	8.53	8.09	8.38	8.12	8.70	8.35	8.31	8.39	8.56	8.44	8.42
pH		±.14	±.14	±.26	±.31	±.44	±.42	±.07	±.04	±.16	±.09	±.01	±.02	±.06
	Feeding Canal	7.10	7.28	7.00	6.99	7.54	7.00	8.62	8.23	7.96	7.50	7.30	N.D	7.50
														±.55
	Lake	0.74	0.42	0.40	1.02	0.81	1.14	1.10	0.86	1.14	1.09	1.16	1.54	0.95
Chlorosity		±.51	±.10	±.08	±.05	±.05	±.50	±.25	±.13	±.22	±.26	±.20	±.23	±.03
(g l^{-1})	Feeding Canal	1.30	2.80	0.30	0.94	0.60	1.56	1.26	0.94	0.91	1.04	1.66	-	1.21
														±.66
Dissolved	Lake	6.28	5.28	3.98	4.8	6.57	8.02	6.76	7.85	5.55	5.05	5.71	6.4	6.02
oxygen		±1.16	±1.24	±.49	±1.5	±3.65	±1.44	±1.36	±0.38	±1.05	±1.98	±.92	±.8	±.97
(mg l^{-1})	Feeding Canal	1.8	3.9	1.00	0.8	2.68	0.75	5.96	5.42	2.2	0.81	1.23	-	2.41
														±1.89

Table 3. Regional average values of the environmental characteristics in Lake Mariut and the Nozha Hydrodrome

Study areas	Stations	pH	Chlorosity ($g\ l^{-1}$)	Dissolved oxygen ($mg\ l^{-1}$)	Hydrogen sulfide ($ml\ l^{-1}$)
Lake Mariut	I	7.29 ±0.63	1.75 ±0.70	1.17 ±2.34	10.73 ±7.79
	II	7.15 ±0.2	1.15 ±0.27	ND	17.11 ±7.57
	III	7.54 ±0.22	1.59 ±0.59	2.58 ±2.52	4.94 ±7.04
	IV	7.53 ±0.25	2.46 ±1.32	5.23 ±1.77	ND
	V	7.51 ±0.24	1.36 ±0.35	0.05 ±0.13	13.23 ±5.97
	VI	7.47 ±0.46	1.35 ±0.34	0.40 ±0.90	14.02 ±8.68
Nozha Hydrodrome	I	8.35 ±0.31	0.91 ±0.34	4.74 ±1.66	ND
	II	8.47 ±0.16	0.95 ±0.33	6.08 ±1.67	ND
	III	8.47 ±0.16	0.97 ±0.43	6.15 ±1.33	ND
	IV	8.40 ±0.39	0.98 ±0.49	7.10 ±1.84	ND