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ENVIRONMENTAL STUDIES ON THE IMPACT OF THE DRAINS EFFLUENT UPON THE SOUTHERN SECTOR OF LAKE MANZALAH, EGYPT

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Key Words: Water pollution, urban and agricultural wastes, trace metals, Lake Manzalah, Egypt

ABSTRACT

Effect of the drains effluent on the variations of trace metals and inorganic anions and cations of water were studied in the southern sector of Lake Manzalah during four successive seasons (1999-2000). The study revealed that an obvious depletion of dissolved oxygen has occurred in addition to a high increase in COD and BOD in the area which received the urban and agricultural wastes from Bahr El-Bagar drain. The concentrations of the nutrient salts showed a wide fluctuation and abrupt changes due to irregular influx of different wastes. Also, high and abnormal concentrations of ammonia, nitrate and orthophosphate were recorded. The levels of trace metals in lake water were high in areas received domestic and agricultural effluents.

INTRODUCTION

Lake Manzalah is the largest and most productive among all the Egyptian brackish lakes. It is located in the north-eastern extremity of the Nile Delta. The total area of the lake is about 872 Km^2 of which only 778 Km^2 represent open water with an average depth of about 140 cm. The area of the lake has been steadily decreased in size since records started in the early 1900's where it was estimated as 1647 Km^2. Land reclamation in the west and the south of the lake is the main cause of this decrease.

Now, the lake is considered as a sink for disposing industrial and human wastes. A total amount of about 7500 million cubic meters of untreated industrial, domestic and drainage water as well as agrochemical (fertilizers and biocides) is discharged annually into the lake through seven main drains (Ibrahim *et al.*, 1997a). Hadous, Ramsis and Bahr El-Bagar drains contribute about 75% of the total annual drainage water into the southern sector of the lake.

Consequently, the quality of water in the lake basin has been affected by many factors; the most significant of which are the location of the drains and the quality of their water inflow. The appearance of the pollution problem in the lake started since 1967 by closing of the inlets, which connected the lake with the sea. This situation led to the continuous disappearance of the marine fishes from the lake.

Khalil (1990) stated that the salinity and nutrients are important factors, which affect and still affect the ecology of lake Manzalah. The increase in nutrients and freshwater discharges has changed the fish community from a brackish (mixed species) to a freshwater (*Tilapia*) dominated one (Khalil and Salib, 1986). Ibrahim *et al.* (1997a) recorded three species of bottom fauna at the southern sector of lake compared by 16 species at sea-lake connection and added that the low number of species encountered is probably due to the high level of water pollution.

Previous studies on biological characteristics of the lake have been issued by Dowidar *et al.* (1990); El-Serafy and Abdel-Baky (1990); Aboul Ezz and Abdel-Razek (1991); Ibrahim *et al.* (1997b); Abdel-Baky *et al.* (1998); Fishar (1999a,b) and Sabae (2000).

The aim of the present study was to follow up the variations in water quality and trace metals in the southern sector of the lake in addition to the inflowing drains to assess the extent of eutrophication condition in Lake Manzalah.

MATERIAL AND METHODS

The sampling stations were chosen to cover the southern sector of Lake Manzalah and its inflowing drains. Water of study area is subjected to pollution via several and rather complicated routes; among them domestic and agricultural discharges are the most significant. Hadous-Ramsis drain has typical agricultural drainage water, which would be of moderate quality for agricultural use. However, water from Bahr El-Bagar, is quite different. Bahr El-Bagar serves as a wastewater stabilizing facility for Cairo sewage, allowing this wastewater to become biologically degraded into nutrient-rich by the time it reaches the lake.

The present study was extended from autumn 1999 to summer 2000. Six stations were determined to cover the area of investigation. Additional stations were chosen inside both Hadous-Ramsis and Bahr El-Bagar drains. The locations of sampling stations are presented in Fig. (1).

Water samples were taken from the surface layer by using polyvinyl chloride Van Dorn bottle. Samples were preserved in an ice-box and returned immediately to be analysed. The chemical parameters were analysed according to the methods described in APHA 1995. Salinity was calculated by multiplying the value of chlorosity by 1.80655 (Jacobosen and Kundsen, 1940).

For total trace metals, the samples were acidified with concentrated nitric acid (pH<2) and then digested by nitric-perchloric acid mixture (APHA, 1995). The total metal concentrations were determined by using Hitachi model 170-30 with graphite atomizer (GA-2) atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The present results showed a noticeable seasonal trend of temperature (17.6-24.6 and 25.0-30.5 °C during cold and hot seasons, respectively). However, the variations in water transparency and conductivity were almost local without clear–cut seasonal trends (Table 1). Generally, the decrease of transparency in the studied area may be due to increase in phytoplankton abundance, as the water acquired a characteristic greenish color. E.C. showed positive correlation with Na, K, Ca and Mg (r= 0.66, 0.86, 0.57 and 0.75, respectively) and with PO_4^{3-}, SO_4^{2-} and NH_3 (r= 0.45, 0.62 and 0.65, respectively).

Slightly acidic pH values were recorded at station 4 during autumn and in Bahr El-Bagar drain during autumn and winter seasons (Table 1). The relative decrease of pH may be attributed to the bacterial and fungal action in the sediment. These activities give rise to methane and hydrogen sulphide release as well as the formation of organic acids and other break down products (Elewa and Ghallab, 2000).

The values of dissolved oxygen (DO) ranged between 0.0 to 5.9 mgl^{-1} with remarkable seasonal and site variations (Table 2). The highest values were recorded during winter and the lowest during summer. Obvious depletion of DO was recorded at discharge point of Bahr El-Bagar into the lake and inside the drain itself. This may be attributed to the effect of pollution by sewage and agricultural wastes discharged, as well as, biochemical decomposition of organic matter. This is supported by the increase in COD at this station. As a general, the highest values of COD and BOD were observed at station 4 due to the high load of organic matter from Bahr El-Bagar drain during the different seasons (Table 2).

The bicarbonate concentrations of the lake (210.0-528.2 mgl^{-1}) indicate their high productivity and consequently favorable condition for fish production (Table 3). The salinity showed large fluctuation (614-3074 mgl^{-1}) at different stations with abrupt increase at the areas affected by domestic waste (Table 3). Thus, the fluctuation in salinity plays a key role in establishing the distribution and dynamics of the chemical water quality also, has a strong influence on the distribution of biological species (Ueda *et al.*, 2000). Statistically, salinity shows significant correlation at $p \leq 0.05$ with Na^+, K^+, Ca^{2+} and Mg^{2+} (r= 0.66, 0.86, 0.57 and 0.75, respectively) and with PO_4^{3-}, SO_4^{2-} and NH_3 (r= 0.48, 0.64 and 0.66, respectively).

The high increase in sulphate concentrations during different seasons at station 4 and Bahr El-Bagar drain may be due to the bacterial oxidation effect of detrital organic phase present in domestic sewage (Table 3).

Obviously, there was an increase in the concentration of eutrophication key elements (P and N). Nitrate content exhibited an extremely wide range of variation (1.71-821.09 μgl^{-1}) (Table 4). This is mainly due to domestic wastes and agricultural runoff beside fertilizers, which are considered one of the sources of nutrients, (Macdonald *et al.*, 1995). The depletion of nitrite at station 4 may be principally due to the its reduction to ammonia as well as, its uptake by phytoplankton in the surface water as reported by Elewa *et al.* (1995).

Ammonia concentrations are present in excess (1.13-20.35 mgl^{-1}) with relatively higher values at station 4 than other station (Table 4). These high values are attributed to the domestic and agricultural wastes, where ammonia and bicarbonate are the final products of the bacterial decomposition of organic matter (Abdel-Satar, 1998). The main factor that affects the toxicity of ammonia at this station is the dissolved oxygen depletion, as the decrease in dissolved oxygen increase the toxicity as reported by Deai *et al.* (1991). The present results showed significant positive correlation between ammonia and E.C. ($r = 0.65$, at $p \leq 0.05$), which proved, that the ionized form is predominate in the lake water.

The ortho- and total phosphate concentrations were varied in the range of 249.32-1399.56 μgl^{-1} and 0.486-2.066 mgl^{-1}, respectively (Table 5). The observed high concentrations of phosphorus content at station 4 may be due to the domestic wastes discharged from Bahr El-Bagar drain into this station, which contain high amount of phosphorus resulting from the organic matter degradation (Muscutt and Wither, 1996). The high anthropogenic inputs of nutrients has led to a deteriorating water quality and caused serious problems (Yoshimural *et al.*, 2000)

A negative significant correlation between both orthophosphate with dissolved oxygen exists ($r = -0.71$ at $p \leq 0.05$). This suggests that under aerobic conditions, the phosphate concentration is decreased due to the consumption by rooted hydrophytes and phytoplankton as mentioned by Olsen and Sommerfeld (1977).

There are decrease in the silicate concentration during hot seasons (0.93-5.55 mgl^{-1}) compared with high values recorded during cold seasons (10.29-16.34 mgl^{-1}) for all stations (Table 5). This is related to the uptake of silicate by diatoms, fungi, algae, phyto- and zooplankton and fish during hot seasons as reported by Abdel-Satar, (1998).

The most predominant cation in the studied area is sodium (103.3-251.2 mgl^{-1}) (Table 6). Water hardness is among the most important environmental factors which affects the toxicity of pollutants. Calcium and magnesium concentrations increase with increasing salinity. This is supported by the positive correlation between them and salinity ($r = 0.57$, 0.75, respectively).

Heavy metals transported into the environment originate either from natural sources, such as wind borne soil particles, or from anthropogenic sources (Birch *et al.*, 1996). The present results showed that the maximum value of Fe (6.255 mgl^{-1}) was recorded at station 1, which received the agricultural wastes discharged from Hadous-Ramsis drain (Table 7). These wastes contain high amount of suspended solids, where iron oxide are an intrinsic part of suspended solids as reported by Vander Weijden and Middelburge (1989). On the other hand, the maximum values of Mn. Zn. Cu and

Pb (441.4, 71.38, 26.44 and 70.52 $\mu g l^{-1}$) were recorded at station 4 (Table 7), which received domestic wastes discharged from Bahr El-Bagar drain. This is agreed with those reported by Nather Khan and Lim (1994), who stated that the concentrations of the metals depend on the types and amounts of waste discharged.

The decrease in Zn concentration at station 4 during summer may be due to the fact that Zn reacts with the high concentration of H_2S to form virtually insoluble zinc sulphide under anoxic condition (Birch *et al.*, 1996).

The relative decrease in Cu concentrations during cold seasons may be attributed to the formation of CuO, that rapidly changed to amorphous $Cu(OH)_2$ and precipitated at the bottom (Masoud *et al.*, 1994).

The maximum Pb concentration was obtained at station 4 in which the domestic wastes contain high amount of lead in both dissolved and particulate forms. Statistically, Mn level shows positive correlation with Cu and Pb ($r= 0.53$ and 0.66, respectively) and between Zn & Cu ($r= 0.55$) at $p\leq0.05$. Also, positive correlation between salinity and each of Mn, Zn, Cu and Pb ($r= 0.56$, 0.60, 0.48 and 0.72, respectively), and this may attributed to the decrease in sorption of these metals to solid phase with increase salinity.

Finally, we can conclude that the drains play an important role in increasing the eutrophication condition of lake water which cause serious effect on aquatic organisms. Also, the high levels of Fe, Mn and Pb indicate that these values exceed the allowable maximum concentration reported by Word Health Organization (0.3, 0.1 and 0.05 $mg l^{-1}$, respectively) which might cause a public health problem.

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Table (1): Seasonal variations of E.C., transparency and pH in lake Manzalah water during 1999-2000.

Season / Station	Autumn			Winter			Spring			Summer		
	E.C. μScm^{-1}	Trans. cm.	pH	E.C. μScm^{-1}	Trans. cm.	pH	E.C. μScm^{-1}	Trans. cm.	pH	E.C. μScm^{-1}	Trans. cm.	pH
1	1930	15	7.27	1960	18	7.62	2300	22	8.1	2640	25	7.58
2	3810	30	7.31	3560	23	7.7	4300	25	8.08	2890	20	7.4
3	2940	20	7.29	4020	18	7.6	2830	30	8.1	3540	30	7.52
4	6090	10	6.69	4950	10	7.13	5760	18	7.6	3530	15	7.3
5	2870	40	7.3	2420	22	7.62	2780	30	8.07	5410	25	7.9
6	2820	35	7.3	2050	23	7.67	2670	25	8.08	2610	28	7.6
Hadous Ramsis drain	1240	13	7.01	1590	15	7.2	2200	20	7.9	2960	20	7.4
Bahr El-Bagar drain	2380	8	6.05	4750	8	6.8	5720	14	7.2	6560	12	7.1

Table (2): Seasonal variations of DO, COD and BOD concentrations (mgl^{-1}) in lake Manzalah water during 1999-2000.

Season / Station	Autumn			Winter			Spring			Summer		
	DO	COD	BOD	DO	COD	BOD	DO	COD	BOD	DO	COD	BOD
1	5.8	13.8	6.2	5.8	6.4	3.6	4.8	7.2	3.5	3.1	4.0	2.1
2	5.8	12.8	6.0	5.6	6.4	3.7	4.8	8.8	4.3	3.5	10.0	4.9
3	5.9	14.1	7.0	5.6	6.0	3.3	5.0	6.8	3.8	3.4	9.6	4.6
4	0.0	23.4	13.4	1.8	19.6	10.5	0.0	21.4	11.8	0.0	18.9	11.1
5	5.9	13.6	6.3	5.9	4.4	2.1	5.6	14.4	6.9	4.1	12.2	7.2
6	5.7	9.2	4.6	5.9	3.2	1.4	5.4	10.4	5.3	4.6	9.2	4.5
Hadous-Ramsis drain	5.1	12.6	6.5	5.3	7.6	3.3	30	9.6	4.3	3.06	12.0	5.9
Bahr El-Bagar drain	0.0	30.4	16.2	0.5	20.8	12.1	0.0	24.8	15.1	0.0	19.8	10.9

Table (3): Seasonal variations of bicarbonate, salinity and sulphate concentrations (mgl^{-1}) in lake Manzalah water during 1999-2000.

Season / Station	Autumn			Winter			Spring			Summer		
	HCO_3^-	Salinity	SO_4^{2-}	HCO_3^-	Salinity	SO_4^{2-}	HCO_3^-	Salinity	SO_4^{2-}	HCO_3^-	Salinity	SO_4^{2-}
1	528.2	614	176.4	335.4	820	157.8	210.0	922	175.1	340.2	922	188.2
2	408.1	1537	172.4	321.8	1921	187.0	225.0	1588	198.5	372.1	1434	167.0
3	480.4	1225	221.5	361.6	2099	184.2	215.0	1332	125.7	344.6	1563	155.8
4	432.3	3074	252.0	258.9	2715	208.2	240.6	2767	232.1	332.8	2279	231.9
5	440.1	1166	198.9	335.6	1127	159.1	225.0	1537	184.6	220.2	2126	191.9
6	443.0	1127	196.3	309.8	896	176.4	225.0	1178	185.4	340.1	1485	174.3
Hadous-Ramsis drain	508.0	537	261.3	309.6	769	143.2	205.0	973	161.7	288.0	973	164.7
Bahr El-Bagar drain	384.0	3236	253.6	361.2	2920	236.1	300.0	2817	235.2	320.0	3074	238.9

Table (4): Seasonal variations of nitrite, nitrate and ammonia concentrations in lake Manzalah water during 1999-2000.

Station \ Season	Autumn			Winter			Spring			Summer		
	NO_2^- (μgl^{-1})	NO_3^- (μgl^{-1})	NH_3 (mgl^{-1})	NO_2^- (μgl^{-1})	NO_3^- (μgl^{-1})	NH_3 (mgl^{-1})	NO_2^- (μgl^{-1})	NO_3^- (μgl^{-1})	NH_3 (mgl^{-1})	NO_2^- (μgl^{-1})	NO_3^- (μgl^{-1})	NH_3 (mgl^{-1})
1	428	27.9	2.59	185	393.1	2.40	136	53.1	5.98	284	10.8	7.30
2	217	117.7	1.13	147	262.8	5.18	68	47.9	13.87	217	15.9	3.70
3	320	11.4	2.29	96	628.5	5.06	134	10.9	7.03	320	14.8	3.31
4	22	17.1	14.80	9	821.0	6.75	9	22.8	20.35	22	1.7	12.19
5	36	54.2	1.15	80	779.9	2.61	127	24.5	5.67	26	7.4	3.46
6	42	63.4	1.71	79	491.3	3.05	29	33.1	3.26	83	30.2	2.55
Hadous-Ramsis drain	129	148.5	1.65	177	289.1	7.03	19	54.8	7.81	469	70.2	4.91
Bahr El-Bagar drain	20	77.7	19.14	4	542.8	9.31	4	42.8	22.84	101	3.4	14.74

Table (5): Seasonal variations of orthophosphate, total phosphate (t-P) and silicate concentrations in lake Manzalah water during 1999-2000.

Station \ Season	Autumn			Winter			Spring			Summer		
	PO_4^{3-} (μgl^{-1})	t-P (mgl^{-1})	SiO_3^{2-} (mgl^{-1})	PO_4^{3-} (μgl^{-1})	t-P (mgl^{-1})	SiO_3^{2-} (mgl^{-1})	PO_4^{3-} (μgl^{-1})	t-P (mgl^{-1})	SiO_3^{2-} (mgl^{-1})	PO_4^{3-} (μgl^{-1})	t-P (mgl^{-1})	SiO_3^{2-} (mgl^{-1})
1	511.5	0.721	10.29	471.6	0.822	11.57	714.5	1.209	0.93	619.4	0.915	3.92
2	392.0	0.679	10.38	458.8	0.738	12.73	939.4	2.066	2.53	447.2	0.832	3.19
3	249.3	0.509	11.54	334.1	0.698	16.34	656.7	1.334	2.79	447.2	0.835	5.29
4	1116.8	1.423	12.50	289.1	0.589	11.48	1399.5	1.905	5.08	1157.9	1.868	5.55
5	314.8	0.584	10.84	296.8	0.486	12.21	726.1	1.233	3.72	303.3	0.740	3.22
6	344.4	0.643	10.43	284.0	0.627	11.48	484.5	1.103	2.29	307.1	0.801	2.73
Hadous-Ramsis drain	396.6	0.905	11.16	467.8	0.796	10.78	729.9	2.368	5.49	490.6	1.079	2.73
Bahr El-Bagar drain	1220.9	1.989	13.08	687.5	1.129	14.70	2542.0	4.544	6.19	1196.6	1.979	4.34

Table (6): Seasonal variations of major cations concentrations (mgl^{-1}) in lake Manzalah water during 1999-2000.

Station \ Season	Autumn				Winter				Spring				Summer			
	Na	K	Ca	Mg	Na	K	Ca	Mg	Na	K	Ca	Mg	Na	K	Ca	Mg
1	103.3	7.93	80.2	70.8	121.6	11.33	81.7	71.0	156.5	13.33	78.5	67.1	200.4	11.92	48.0	128.4
2	149.7	14.54	119.9	120.2	181.7	18.49	91.3	131.3	222.5	12.30	117.0	111.8	234.3	13.92	48.0	141.0
3	131.9	11.89	91.3	88.6	234.9	21.47	101.0	146.8	177.3	20.50	88.1	72.9	239.9	15.92	56.1	146.8
4	185.3	22.47	165.2	145.9	240.7	26.44	92.9	167.3	250.4	25.63	155.5	135.2	251.2	20.31	80.1	175.1
5	130.1	13.22	89.9	87.9	178.1	14.15	78.5	99.2	175.6	20.39	80.16	77.8	248.4	20.98	83.8	172.1
6	126.5	13.22	88.8	86.9	166.6	14.51	105.8	63.2	170.4	14.35	73.7	82.6	237.1	17.92	40.0	149.8
Hadous-Ramsis drain	100.8	8.93	78.2	70.2	134.5	10.34	75.3	78.7	142.5	14.35	65.3	61.2	146.8	11.52	56.1	116.7
Bahr El-Bagar drain	206.7	23.79	181.0	163.2	240.1	28.46	109.0	181.9	248.6	21.53	68.7	59.0	256.8	19.99	141.0	186.7

Table (7): Seasonal variations of trace metal concentrations in lake Manzalah water during 1999-2000.

Season / Station	Autumn					Winter					Spring					Summer				
	Fe (mgl^{-1})	Mn (μgl^{-1})	Zn (μgl^{-1})	Cu (μgl^{-1})	Pb (μgl^{-1})	Fe (mgl^{-1})	Mn (μgl^{-1})	Zn (μgl^{-1})	Cu (μgl^{-1})	Pb (μgl^{-1})	Fe (mgl^{-1})	Mn (μgl^{-1})	Zn (μgl^{-1})	Cu (μgl^{-1})	Pb (μgl^{-1})	Fe (mgl^{-1})	Mn (μgl^{-1})	Zn (μgl^{-1})	Cu (μgl^{-1})	Pb (μgl^{-1})
1	6.255	180.0	11.78	9.44	30.58	5.752	173.0	19.94	10.78	43.78	3.351	187.7	21.84	17.16	26.38	2.804	172.5	27.86	12.56	29.36
2	1.295	95.0	5.06	8.60	30.34	3.350	127.3	24.26	8.18	48.86	2.276	87.16	28.85	13.49	29.17	1.902	135.3	18.88	15.46	40.78
3	2.187	144.1	18.04	12.34	30.34	2.621	154.5	22.10	12.26	46.26	1.216	142.4	36.92	18.58	25.18	0.882	147.8	18.70	12.76	58.62
4	2.017	285.5	71.38	14.28	54.02	3.089	218.6	26.14	19.36	61.12	2.778	265.0	55.94	26.44	60.99	1.834	441.4	19.62	20.20	70.52
5	1.141	131.6	8.42	12.26	33.21	4.011	105.2	22.02	13.65	36.29	2.998	103.9	33.06	17.18	38.04	0.628	176.6	12.58	12.84	59.30
6	1.059	102.3	6.98	11.65	29.54	3.101	100.5	21.30	12.81	39.82	2.241	98.78	22.58	14.68	31.15	0.617	154.0	11.64	10.63	59.32
Hadous-Ramsis drain	6.852	162.1	21.58	23.29	45.80	2.414	184.1	26.14	14.88	46.20	2.006	184.16	27.60	16.24	21.99	5.850	180.3	24.34	17.66	57.70
Bahr El-Bagar drain	2.344	217.8	188.6	61.07	75.52	8.054	388.5	85.98	51.08	65.98	4.117	292.2	132.02	52.58	71.78	3.054	488.0	31.34	25.04	69.76

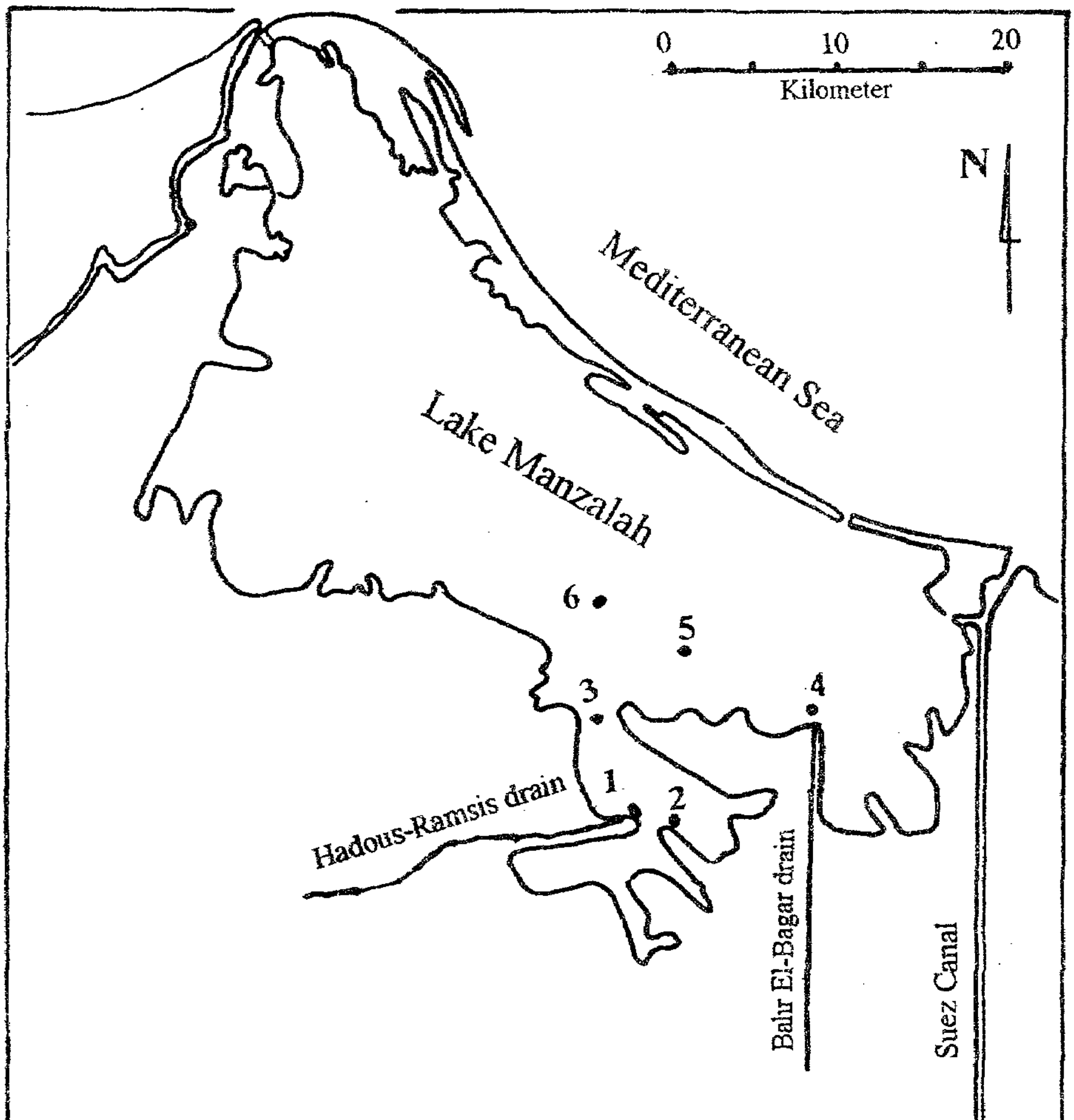

Fig. (1): Water quality sampling stations in Lake Manzalah