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STUDY OF THE ECOLOGICAL CONDITIONS OF MARIUT LAKE MAIN BASIN IN RELATION TO THEIR SUITABILITY FOR FISH LIVING IN THE BASIN

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ABSTRACT

A remarkable decline in the total landed fish catch from Lake Mariut especially from its Main Basin was observed during the eighties and early nineties of the last century. This decline is attributed mostly to the ecological changes that took place in the Main Basin; during the same period; caused by sewage disposal (domestic and industrial waste) and anoxic conditions in some areas. The present work is a study for the environmental factors (temperature, salinity, pH, dissolved oxygen and toxic ammonia) and some heavy metals (Cu, Pb, Cd and Zn) in both water and sediments of the lake Main Basin after the adoption of an amelioration plan in 1993. Since this plan started, both the water and the sediment quality of this basin showed a gradual improvement which in turn led to enhancement; to certain extent; in the suitability degree for the fishes to live in the basin. However, the present work also indicates that the Southwest side of this basin is the most suitable part for the living of the aquatic fauna in general specially Cichlids fish as it has better ecological conditions than the rest of the basin as well as the lowest possible biological effect for the studied metals in both water and sediments. The slight increase in the fish catch recently noticed, reflects the impact of the amelioration plan on the basin suitability for the fish fauna living in it.

1. INTRODUCTION

Lake Mariut is an inland, shallow (mean depth of 1m) lake situated south of Alexandria city along the Mediterranean coast of Egypt. The lake itself is artificially divided into four basins namely Main Basin (most polluted), Fishery Basin, Northwest Basin (NW-Basin) and Southwest Basin (SW-Basin) as shown in figure (1).

Generally, Lake Mariut has always faced many common problems like pollution, dry off, over-fishing, illegal fishing methods… etc. The Main Basin in particular (4,362 feddans [Youssof, 1999]) used to face three additional serious problems: 1) sewage disposal (domestic untreated wastewater and industrial wastes from both the high industrial activities and the domestic sewages of Alexandria city through Kalaa Drain and other outfalls), 2) agricultural runoff (through Omoum Drain), and 3) anoxic conditions in some areas (Metcalf & Eddy, 1997 and El-Rayis & Hinckely, 1998). This situation; lasted till 1993; affected the basin's ecology severely which in turn lowered the basin suitability for the well being of the fish living in it (Abaza, 2008).

Hence, if one can identify the ecological, biological and human components affecting

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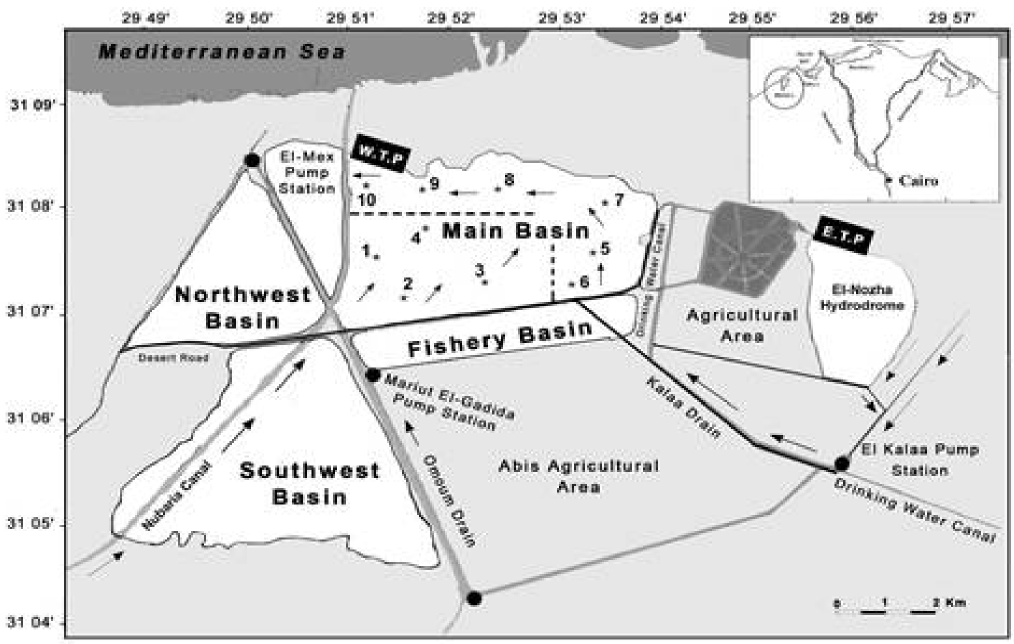
the basin, then it may be possible to modify some of these components towards improving the basin's environmental conditions. So in response to the deleterious effects of pollution on the basin, the local authorities in 1993 started an improvement plan; of several steps; to remedy such effect. These steps were: 1) building two treatment plants (West and East Treatment plant [WTP and ETP]) to primary treat the polluted water before it reaches the Main Basin, 2) controlling water plants and 3) enhancing water movements within the lake (El-Rayis *et al.*, 2001 and Abaza, 2008). These changes were expected to ameliorate the ecological conditions of the basin gradually.

Although different treatments have been applied to the effluents of many industries in addition to the treatment by WTP and ETP, there are still some heavy metal contaminants released to the basin (Abaza, 2008). Such discharges have their impact on both the ecosystem and the resources of the basin as well as on human health at present or in the future.

The present study aims to evaluate and depict the present ecological conditions of the Main Basin of Lake Mariut and its suitability for the well being of the fish fauna especially Cichlid fish (representing about 74% of the lake's total landed catch over the last 30 years [Abaza, 2008]).

2. MATERIALS AND METHODS

Ten sampling stations were selected representing all parts of the lake Main Basin (Fig.1). In the present study we divided the basin to three areas as follows: a) Southwest-area (St. 1, 2, 3 and 4), b) Northwest-area (St. 8, 9 and 10) and finally c) Eastern-area (St. 5, 6 and 7). Both water and sediment samples were collected during hot (summer), cold (winter) and mild (spring) weather. All samples were collected during day time between 9 am and 1 pm.



The dotted lines are artificial barrier controling the water movement in the basin (an amelioration step).

Fig. (1): Lake Mariut Main Basin showing both the sampling station and the water movement in the basin.

Temperature, pH and dissolved oxygen (DO) were measured in situ using "Water Analyzer model 7.0.5". The total dissolved solids (salinity) were also measured in situ using a "Refractometer". Total ammonia nitrogen (TAN) was determined spectrophotometerically according to the method described by Grasshoff (1976). The toxic un-ionized ammonia (NH_3) form in the basin water was then calculated using the conversion table found by Emerson *et al.* (1975).

For the evaluation of the heavy metals (Pb, Cu, Cd and Zn) in the basin water, the water samples were immediately filtered using 0.45 µm-pore-diam membrane filters (Millipore). The dissolved metals in the filtrates were measured according to Riley and Taylor (1968). The particulate metals retained in the filter as well as those in the basin sediments were analyzed according to the method described by Harper *et al.*, (1989) and measured using Atomic Absorption Spectrophotometer (Perkin Elemer 2380).

The Geo-accumulation Index (I_{geo}) introduced by Muller (1979) was adopted to assess metal pollution in the basin's sediments. This index is expressed as: $I_{geo} = \log_2[C_n/1.5(B_n)]$ where "C_n" is the concentration of the element "n" in the sediment sample, Bn is the geochemical background value in average shale of the element "n" (Turekian and Wedepohl, 1961) and "1.5" is the background matrix correction factor due to lithogenic effects.

3. RESULTS AND DISCUSSION

Lake Mariut was known to be the most fertile of the Egyptian north delta lakes. A quick look at table (1), one can notice that the average total landed fish catch during the period between 1976 to 2006 was remarkably declined from 13,125 tons (during 1976-1980) to reach its minimum (3,153 tones) in the early nineties of the last century before it gradually started to increase again till it reached 5,315 tons in the beginning of the new millennium (2001-2006).

3.1. Physico-chemical characteristics:

Many ecological parameters (e.g. temperature, salinity, pH, DO and NH_3) are usually of primary importance on living fish in aquatic ecosystem.

3.1.1. Temperature

The Water temperature of the basin varies between 15.5°C in winter and 29.6°C in summer (Table 2). It was slightly higher in the NW-side water than the rest of the basin, which could be attributed to the WTP-discharges to this area of the lake. Limited regional variations can be noticed in the basin water temperature (Table 2) which shows no clear indication to assume any thermal pollution affecting the basin water. The same conclusion was given by Mostafa (1994).

Table (1): Landed catch (tons) from Mariut Lake during 1976 – 2006.

Years	Total landed catch (ton)	Cichlids (ton)	% in catch	Clarias Lazera (ton)	% in catch	Others (ton)	% in catch
Average (76-80)	13,125	10,202	77.6	2,078	15.9	846	6.5
Average (81-85)	8,999	8,043	88.8	803	9.6	153	1.6
Average (86-90)	3,532	2,887	82.4	580	15.4	65	2.2
Average (91-95)	3,153	2,349	75.8	619	18.6	185	5.5
Average (96-00)	4,920	2,974	61.3	1,428	28.1	518	10.6
Average (01-06)	5,315	3,135	58.9	2,072	39.0	108	2.1

After Nour (2000) and GAFRD (1980-2006).

Table (2): Physico-chemical characteristics of the Main Basin water.

Locations	Temperature (°C)				Salinity (‰)			
	Summer	Winter	Spring	RegionalAv.	Summer	Winter	Spring	Regional Av.
East-side	29.27	15.90	19.63	21.6 ± 6.0	3.67	3.63	3.87	3.7 ± 0.3
NW-side	29.61	16.23	22.27	22.7 ± 5.8	5.33	5.80	5.63	5.59 ± 1.0
SW-side	28.93	15.50	19.08	21.2 ± 5.9	2.78	2.40	2.75	2.6 ± 0.6
Basin Average	**29.27**	**15.85**	**20.23**	**21.8 ± 5.7**	**3.84**	**3.83**	**3.98**	**3.9 ± 1.4**
Locations	**pH**				**Total Ammonia (mg/l)**			
	Summer	Winter	Spring	Regional Av.	Summer	Winter	Spring	Regional Av.
East-side	8.01	7.42	7.07	7.51 ± 0.5	12.33	11.47	11.57	11.8 ± 4.6
NW-side	7.93	7.36	7.22	7.5 ± 0.4	12.43	12.83	10.70	12.0 ± 3.8
SW-side	7.72	7.17	7.34	7.4 ±0.3	2.13	3.05	3.10	2.7 ± 1.6
Basin Average	**7.87**	**7.30**	**7.22**	**7.5 ± 0.4**	**8.57**	**8.76**	**8.08**	**8.5 ± 5.4**

Regional Av. = Regional average ± Standard deviation.

The water temperature values in the basin (Table 2), indicate that these values are quite suitable for the living of Tilapia fish all over the year (El-Sayed, 2006).

3.1.2. Salinity

During the present study, the salinity levels in the basin didn't exceed 7‰ even in the NW-side that is affected by El-Mex Pump Station (the basin connection to the Mediterranean Sea). According to El-Sayed (2006), Tilapia species tolerate well in such salinity level. *O.niloticus,* which is the least saline tolerant species, was found to thrive well at up to 15‰ and can reproduce at 10‰ and up to 29‰ (Popma and Masser, 1999 and Alfredo and Hector, 2002).

3.1.3. pH

In the present study, the pH values of the lake Main Basin water ranged from 7.2 ± 0.3 (st.2) to 7.8 ± 0.7 (St.6) with a regional average of 7.5 ± 0.4 (i.e. slightly alkaline). This finding is in agreement with that previously carried out by other workers like Magdi (1998) (7.4 to 8.5), Essa and Faltas (1997) (7.2 to 8.7) but is slightly lower than those reported by Youssef (1999) (7.1 to 9). These three determinations, as well as that of the present study, were carried out after the year 1993 (the year of construction of the two waste water treatment plants). Other authors who carried out their determinations around 1993 and before like Mostafa, 1994, WWCG, 1994 and Hafez, 1982 found the pH values to be ranged from 7.1 to 8.1, 6.5 to 9.0 and 8.4 respectively.

These pH levels, recorded in the basin (Table 2), are still within the range suitable for Tilapia fish as they are known to survive at pH values ranging between 5 and 10 (Popma & Masser, 1999).

3.1.4 Dissolved Oxygen (DO)

DO content in any aquatic basin is known to be essential for the survival of aquatic organisms. In the present work, the DO levels recorded in the Main Basin water (Table 2), indicate that the lowest regional average values were recorded in both the eastern-side (1.8 ± 1.5 mg/l) and the NW-side (1.8 ± 1.2 mg/l) of the basin compared to those recorded in the SW-side (5.6 ± 0.9 mg/l). These low levels of DO in both the eastern-side (especially at St.6 [nill mg/l]) and the NW-side (especially at St.9 [0.3 ± 0.3 mg/l]) of the basin could be attributed to the O_2 consuming wastes contributed to these two areas of the lake with the discharges from Kalaa Drain and WTP-outlet respectively. According to El-Rayis *et al.* (2001), these discharges are O_2 depleted and H_2S is intermittently produced and evolved. The low level of DO in the basin's water (regional average of 3.2 ± 2.2 mg/l) is a good indicator of the water contamination.

As regards to seasonal variations of DO, table (2) shows that there is no much difference between the different seasons. However, winter was slightly higher in DO levels which could be attributed to the fact that during warm seasons the rate of oxidation of oxygen consuming wastes is greater. During the hot climate, fish in the basin were seen skimming the water surface layer for oxygen as DO levels in the water column become low. Essa and Faltas (1997), claimed that the average values of DO content in the Main Basin water ranged from 0.05 to 11 mg/l while those recorded by Okbah (1995) and Metcalf and Eddy (1997) were lower (0 to 3.25 mg/l) and (3.4 mg/l) respectively. DO recorded in the basin during the present study ranged between (1.8 ± 1.2 and 5.6 ± 0.9 mg/l).

From figure (2a), it is easy to notice that DO levels in the lake Main Basin during the three seasons almost have the same distribution pattern. It shows very low values (<1 mg/l) in front of both Kalaa drain and WTP-outlet, while it gets better in the rest of the basin (>1 mg/l) especially in front of the Omoum Drain where the values reach as high as >6 mg/l. Thus, one can say that the SW-side of the basin is more suitable for fish fauna than the other two sides all year round.

3.1.5 Toxic ammonia (NH_3)

In the present work, the conversion of TAN to NH_3 using the conversion table found by Emerson *et al.* (1975) shows that the average NH_3 concentration in the basin under investigation varies between 0.031 mg/l in the SW-side of the basin during the spring and 1.29 mg/l in the basin eastern side during the summer (Table 2).

According to Durborow *et al.*, (1997), the NH_3 increases as the water temperature and pH increases. This finding can explain the high levels of NH_3 during summer (basin average 0.676 mg/l). The authors also mentioned that the dangerous level of NH_3 starts at about 0.6 mg/l, while the chronic (sublethal) level starts from 0.06 mg/l. At these chronic levels, several effects might have taken place on the living fish, such as reduction of food consumption (Popma and Masser, 1999), reduction in growth and reduction in the oxygen-carrying capacity by gills in addition to kidney damages were stated by Durborow *et al.* (1997).

Figure (2b) shows the horizontal NH_3 distribution in the surface water of the basin during the three studied seasons. The figure also indicates that the NH_3 levels in the basin's SW-side were suitable for fish population propagate (less than 0.06 mg/l) specially in the winter and spring with seasonal averages of 0.014 and 0.031 mg/l respectively. The table also shows that the eastern side water recorded the highest values of NH_3 (annual average 0.50±0.98 mg/l) followed by the NW-side (0.33±0.41 mg/l) then the SW-side (0.045±0.046 mg/l) during the study period. From figure (2b) it is easy to notice that the basin in both winter and spring can be divided to two zones: 1) the SW-side with NH_3 levels less than 0.06 mg/l which is suitable for fish life and 2) the rest of the lake basin with NH_3 levels ranges from ≥0.06 to 0.33 mg/l (chronic effect on fish). In summer, three zones can be noticed: 1) the SW-side with NH_3 levels of <0.06 mg/l (suitable for fish), 2) one with NH_3 levels of 0.06-0.6 mg/l (chronic effect on fish) in the basin middle zone, and 3) the rest of the basin with NH_3 levels of >0.6 mg/l (dangerous effect on fish).

From figures (2a and 2b), one can also notice that in the Main Basin, the suitable part for better fish growth all year round was the SW-side (well ventilated area) (DO is >4 mg/l and the NH_3 is <0.06mg/l).

3.2. Heavy metals

The basin, as stated above suffers from different pollutant types (i.e. heavy metals). These heavy metals may cause either a direct fish kill causing a decline in the basin landed fish catch or an accumulation in the fish organs including the edible fish muscles causing diseases to persons who consume it (Barania, 1992). Of all the heavy metals content in the basin water and sediments, the present work is concerned with only Cu, Pb, Cd and Zn in addition to their effect on living fish fauna in the basin.

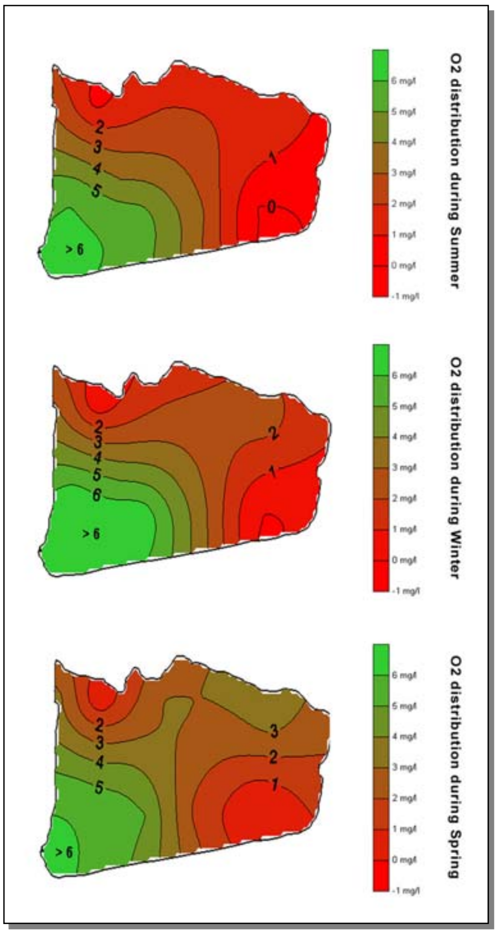


Fig. (2a): Horizontal surface distribution of DO in the lake Main Basin.

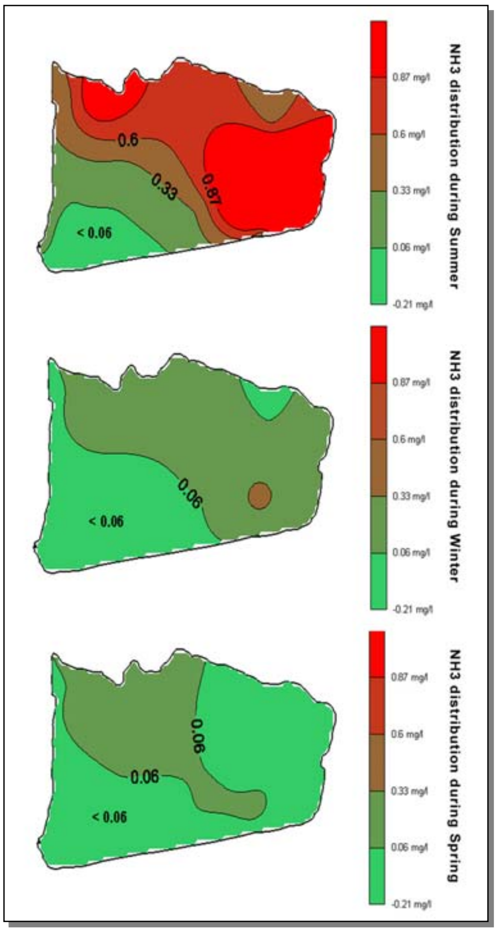


Fig. (2b): Horizontal surface distribution of NH_3 the lake Main Basin.

3.2.1. Heavy metals in water

The data in table (3) shows that the highest annual regional average levels for total Cu, Pb and Cd in the basin water are in the eastern side (21.6±3.2, 5.1±0.7 and 3.5±0.9 µg/l respectively) with an overall average of 19.9±3.2, 4.9±0.6 and 3.1±0.6 µg/l respectively. For Zn levels, the NW-side comes first with an average of 36.5±4.5 µg/l and overall average of 33.7±3.8 µg/l. Comparing the total concentrations of the studied heavy metals in the water to their possible biological effect in the basin shown in table (3); indicates that the Cu, Pb and Zn levels in the basin's water are far less than their chronic level (74, 49 and 656 µg/l) in the basin. Regarding Cd, same situation was also observed but more closer to the chronic level (6 µg/l) especially in the basin's eastern side.

Some environmental toxicologists make the argument that the dissolved metals in surface water represent most of what is biologically available and thus "total" metals parameters are not a good measure of potential biological effects. This is mostly true in many situations, but it should be kept in mind that aquatic organisms do not typically live in filtered water and that many of them live on and in the sediments in which they come in contact with toxic or harmful compounds (Irwin, *et al.*, 1997). The present data reveals that both dissolved and the total levels of the studied heavy metals in the basin's water are below (with different degree) the chronic levels. In other words, the basin's water are suitable for the living of fauna in the basin.

3.2.2. Heavy metals in sediments:

Most of the Zn as some other metals in water bodies settle on the bottom while small amount may remain either dissolved in water or as fine suspended particles (Agency for Toxic Substances and Disease Registry, 1992).

To determine and define the metals' contamination degree in the basin sediment, the present calculated I_{geo} values for each of the studied elements (Table 4) were compared to their corresponding I_{geo} key shown in table (5). This comparison reveals that both the eastern and NW-side of the basin are moderately polluted (class 3) with respect to Cd and Pb. In the mean time, they are less polluted with Zn and Cu (class 2). For the SW-side, one can see that the calculated I_{geo} values for the studied element laid mostly in class 2 (unpolluted to moderately polluted). If one takes the overall average for the three studied sides of the basin, he can see that the order of contamination of the studied metals was as follows: Cd (I_{geo}=2.1) > Pb (I_{geo}=1.9) > Zn and Cu (I_{geo}=1.6 and 1.5 respectively).

The present data in table (4), reveals that the Cu content in the basin sediments have severe biological effect (av.=189±76 µg/g) on the basin fauna which in turn affects the fish in the basin. The biological effect of the Pb, Cd and Zn content in the sediments of both the eastern and the NW sides of the basin ranges between low to slightly toxic effect, while it was low for the SW-side. This toxic effect is due to the high levels content of Pb, Cd and Zn in the sediments of both station 6; located in the eastern side; (161±15, 2.9±1.4 and 544±38 µg/g respectively) and Station 9; located in the NW-side; (159±5, 2.7±1.0 and 563±49 µg/g respectively) which were higher than the border lines of toxicity of these three metals studied (170, 3 and 540 µg/g respectively). These high levels could be attributed to the discharges inflowing to the basin from both Kalaa Drain (near station 6) and WTP-outlet (near station 9).

From the foregoing, it is easy to conclude that the basin's SW-side is the most suitable part of Lake Mariut Main Basin for the living of fish fauna as it has the best physico-chemical characteristics (Table 2) as well as the lowest possible biological effect for the studied metals in both water (Table 3) and sediments (Table 4) among the three sides of the basin.

In the last ten years, both total landed fish catch and Cichlids catch shown in table (1); have increased from 4,489 and 2,901 tons respectively in 1997 to 5,211 and 2,946 tons respectively in 2006 although the number of fishing boats were decreased from 1,241 in 1997 to 990 in 2006 (about 20%). This increase could be attributed mostly to the improvement plan that was adopted in 1993. These findings reflect a good promising effect of the improvement steps on the fish fauna of the lake in general which in turn affects the lake's landed catch.

Table (3): Annual regional average concentration (µg/l) of the studied heavy metals in the MainBasin water during the present study compared to their possible biological effects calculated using Suter and Magrey equations (1994).

Metals	Biological effects (Acute & Chronic)	Present levels (µg/l) ± Std. dev.				
		Water	East Side	NW-Side	SW-Side	Regional Av.
Cu	Acute conc. = 135 Chronic conc. = 74	D	5.9 ± 1.1	6.5 ± 1.7	5.4 ± 1.3	5.9 ± 1.2
		T	21.6 ± 3.2	19.9 ± 4.3	18.5 ± 2.7	19.9 ± 3.2
Pb	Acute conc. = 1263 Chronic conc. = 49	D	1.8 ± 0.4	2.0 ± 0.4	1.8 ± 0.5	1.8 ± 0.8
		T	5.1 ± 0.7	4.7 ± 0.7	4.8 ± 0.7	4.9 ± 0.6
Cd	Acute conc. = 44 Chronic conc. = 6	D	1.4 ± 0.3	1.3 ± 0.2	1.2 ± 0.3	1.3 ± 0.2
		T	3.5 ± 0.9	3.1 ± 0.3	2.8 ± 0.5	3.1 ± 0.6
Zn	Acute conc. = 725 Chronic conc. = 656	D	15.3 ± 2.6	19.2 ± 3.9	14.7 ± 3.7	16.3 ± 3.7
		T	33.5 ± 4.3	36.5 ± 4.5	31.7 ± 2.4	33.7 ± 3.8

D : dissolved concentration T : total concentration
RegionalAv. = Regional average ± Standard deviation.

Table (4): Annual regional average concentration (µg/g), background (µg/g) and I_{geo} of the studied heavy metals in the Main Basin sediments during the present study compared to their possible biological effects limits (µg/g) according to both Batts and Cubbage, (1995).

	Cu	Pb	Cd	Zn
Present annual regional average ± Std. dev.				
East-side	212 ± 88.5	119 ± 59.7	2.1 ± 1.2	436 ± 123
NW-side	211 ± 78.4	118 ± 42.3	2.2 ± 0.9	469 ± 103
SW-side	152 ± 77.9	105 ± 31.6	1.6 ± 0.7	364 ± 98
Average	189 ± 76.1	113 ± 38.3	1.9 ± 0.9	418 ± 102
Background in average shale (Turekian and Wedepohl, 1961)				
	45	20	0.30	95
I_{geo} [minimum –maximum, average]				
East-side	0.9-2.2, av.1.7	1.0-2.6, av.2.0	1.0-2.9, av.2.2	1.1-2.0, av.1.6
NW-side	1.0-2.1, av.1.6	1.3-2.4, av.2.0	1.5-2.8, av.2.3	1.4-2.0, av.1.7
SW-side	0.1-1.8, av.1.2	1.3-2.2, av.1.8	1.0-2.4, av.1.8	0.9-1.7, av.1.4
Average	0.7-2.0, av.1.5	1.3-2.3, av.1.9	1.2-2.6, av.2.1	1.1-1.9, av.1.6
Possible biological effects (Batts and Cubbage, 1995)				
Low effect	28	31	0.6	120
Toxic effect	86	170	3	540
Severe effect	110	250	10	820

Table (5): Degrees of enrichment above the background value ranging from unpolluted to very highly polluted sediment quality (I_{geo}-key). *

Igeo degree	Class	Pollution Intensity
0	0	Background concentration
0-1	1	Unpolluted
1-2	2	Unpolluted to moderately polluted
2-3	3	Moderately polluted
3-4	4	Moderately to highly polluted
4-5	5	Highly polluted
>5	6	Very highly polluted

*Source Praveena, *et al.*, (2007).

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In 2008, Abaza mentioned that in spite of these signs of improvement of the conditions in this basin since 1993, the mortality rates reveal that both *O.niloticus* and *T.zillii* (Cichlid fish species) still facing stress in the basin. This could be attributed to many factors that could be playing an important role in the lake basin ecological condition status. Of these many factors: 1) both bioavailability and biomagnifications affecting the dietary habits and feeding behavior especially if we know that Tilapia are generally herbivorous/omnivorous (El-Sayed, 2006) and 2) under some circumstances, synergism may take place between the pollutants (i.e. between Zn and NH_3) leading to higher toxicity media for the fish (Health and Environment Network, 1987). This could be the case in the both E-side and the NW-side of the basin where large areas where covered by the floating plants, and the NH_3 levels reached 0.503±0.977 and 0.329±0.411, respectively.

Several mitigating measures can be implemented, either as separate and/or as combined package, to improve the ecological conditions of the basin. These measures are: 1) increasing the capacity and efficiency of both the ETP and the WTP, 2) aerating and diluting the effluent in the Kalaa Drain or even diverting its path away from the basin, 3) dredging the contaminated sediments, 4) improving the water circulation and 5) removing the floating plants especially in the eastern and NW-side of the basin.

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