Assessment Of Pollution Levels In Fish And Water Of Main Basin, Lake Mariut

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ABSTRACT

Lake Mariut has suffered over the years from the untreated sewage, agricultural and industrial wastes dumped into it. Lake Mariut fish quality and quantity were adversely affected eventually being unfit for human consumption due to its poor water quality. The present study was carried out to evaluate the levels of metals in the fish caught from Lake Mariut main basin and its fitness for human consumption, and the water quality after the enforcement of the Egyptian Law for Environmental Protection (Law 4/1994). Fish and water samples were collected form Lake Mariut main basin through out the period from May to December 2000.
The results showed that mercury was totally undetected in fish and water samples. The levels of Fe obtained were very low compared to previous studies. Fe and Cr contents in fish flesh were higher compared to their levels in water samples. Also Cu has shown a decrease in both fish and water samples. Zn and Cd contents in water samples have decreased compared with former studies. However, they have not changed in fish flesh. Pb content in both fish flesh and water samples has shown a great decrease compared to previous studies. The Cd and Pb mean values in fish flesh of the present study (0.81 and 0.14 mg/kg) exceeded the Egyptian Standards No. 2360/1993 value (should not exceed 0.1 mg/kg for each). The results also showed that the water quality has changed compared with previous studies.

BOD has increased in north of Main Basin, east of Main Basin, South of Main Basin, and southwest of Main Basin; and decreased in WTP effluent; and Qalaa Drain. There has been an increase in TSS, TVSS, and NO3 levels compared to pervious studies. There has been a decrease in TS, TDS,

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COD,hardness, and chloride levels. This decrease, especially in COD, may be attributed to the enforcement of the Egyptian Law 4/1994. The pH and alkalinity were in agreement with the values shown by previous studies except for east of Main Basin which showed higher values. The study included some recommendations aiming at improving both water quality and fish of the Main Basin.
Key words: Pollution, fish flesh, Basins.

INTRODUCTION

Lake Mariut is one of four shallow lakes in the northern Nile Delta of Egypt. It is the smallest and most polluted of these Delta Lakes, and it is the only one that does not currently have a natural connection to the Mediterranean Sea. It is situated Southeast of the city of Alexandria.(1)

Due to the gradual and continuous land reclamation projects, the area of the lake shrinked to about 14,000 feddans with an average water depth of 120 cm and the water level ranges between 3.1 to 2.85 m below sea level. The lake is divided by the Desert Road, Nobaryia Canal, and Omoum Drain into four basins namely lake proper (Main Basin), Fish Farm, Southwestern, and Northwestern Basin. A pumping station is established at El-Max to keep the water of the lake below that of the surrounding cultivated land. The lake receives large amounts of drainage water mainly through El-Omoum Drain. Other sources of water supply entering the lake are the Qalaa Drain and the rainfall during winter.(2)

The Main Basin is a closed water basin and has an area of 5000 acres with a mean water depth of 80 cm. It is bordered by highways from three sides and by Nobaryia Canal and Omoum Drain from the west.(3) The main sources of its pollution were the pump station at Moharrem Bey Industrial Complex, Gheit El-Enab Drain, Kabbary Drain, and West Pump Station. This is in addition to the southern outfall from Qalaa Pump Station. The flows from such outfalls include domestic in addition to considerable amounts of industrial and agricultural wastes without any treatment. Consequently, its environmental conditions has deteriorated and it represents the highest eutrophic lake in Egypt. The industrial discharge contributes extremely high concentration of metals and other toxic chemicals. [4,5]

The effluents of these outfalls have been significantly changed quantitatively and qualitatively as a result of the primary treatment introduced in the two treatment plants that have been put in operation by July 1993. The northern four outfalls have been directed to Kabbary collector to be treated primarily in the West Treatment Plant. Presently, the Qalaa outfall is receiving the primary treated effluent of the east of Alexandria City. The organic load has been changed to the better especially at the north side of the basin, but it still has no obvious improvement at the southeast corner where the Qalaa Drain outfall is located.[6,7]

Fish production of Lake Mariut shows clearly a wide variation from one year to another. During the period of 1974 to 1992, the lake showed a decrease trend in its fish catch from 14,551 to 2,221 tonnes and catch per fisherman was gradually decreasing from 5.5 to 0.35 tonnes/fisherman/year. The recorded wholesale price of the lake fish catch of which *Tilapia* species "Bolty" represents about 90% of its composition, increased from *LE*400 to 5,500/tonne. However, fisherman annual income was slightly increasing from *LE*1,940 to reach *LE*4,336/year, which is approximately equal to the income rate in 1974.[3]

Law 4/1994 is by far the most comprehensive environmental legislation to date. It defines in articles 29-83 the protection of air, water, and land from all sources of pollution.[8] This study was carried out to re-evaluate the physical, chemical, and metals contamination of the lake water (Main Basin) as well as metal in fish caught from Lake Mariut and its fitness for human consumption after the operation of the two wastewater treatment plants and the enforcement of the Egyptian law 4/1994 that requires the pretreatment of waste effluents before being discharged into water bodies.

MATERIAL AND METHODS

Water samples were collected from six sites in the Main Basin throughout the studying period from May to December 2000. They were outlet of West Treatment Plant (site 1), north of Main Basin (site 2), east of Main Basin (site 3), south of Main Basin (site 4), southwest of Main Basin (site 5), and Qalaa Drain (site 6), Figure (1). The collected samples were analyzed according to the Standard Methods for the Examination of Water and Wastewater for the physical and chemical parameters.[9] The samples were also analyzed according to the same reference for some metals levels using Atomic Absorption Spectrophotometer (AAS). The samples were acidified and measured for Hg using hydride vapor technique.

Fresh fish (*Tilapia nilotica*) samples were bought immediately after boat landing throughout the study period. The sampled fish ranged from 10-15cm in length, and 70-150 gm in weight. Muscles of the fish were obtained and then chopped, mixed and divided into two groups. The first group was used for determination of moisture and ash contents according to Jorhem and Engman 2000 [10] and Jorhem 2000, [11] respectively. The second group was kept in deep freezing in tight containers for trace metal determination. The fish flesh was wet ashed using microwave oven. Air–acetylene flame system AAS was used for quantitative determination of Fe, Cu, and Zn according to Jorhem.[11]

The measurements of Pb, Cd, and Cr were carried out by using graphite furnace AAS. Mercury was determined using hydride vapor technique AAS as described by EPA.[12]

Data obtained were tabulated and presented as arithmetic mean and standard deviation. Statistical analyses were computed using SPSS version 9 program. Data were analyzed using Pearson's Correlation Coefficient and ANOVA to detect the correlation between the levels of contaminants in fish and water samples.

RESULTS AND DISCUSSION

1. Physico-chemical and metal analyses of Main Basin water

Tables (1 and 2) and figures (2-5) show the results of physico-chemical and metals analyses of water samples collected from the selected six sites.

It is clear that the pH values ranged between 6.8-7.65 at site 6 and 7.15-9.1 at site 3. The mean values of alkalinity ranged between 321 mg/l at site 5 and 541 mg/l at site three. All of these results were in agreement with Environmental Technical Report No. 8[13] (8.06 and from 300 to 370 mg/l, respectively) except for site three which showed higher values. This could be due to the presence of alkaline salts as bicarbonates in this site.[9]

Suspended material plays a noticeable role in the asphyxiation of fish leading to its death by plugging the active sites of gas transfer in the gills.[14] Site five showed the highest mean values of TSS and TVS (1212 and 3731 mg/l, respectively). It is clear also that site one showed low values (137 and 1093 mg/l, respectively) compared with the other sites. From this it is concluded that the suspended solids entering the Main

Basin via WTP and Qalaa Drain are accumulated in different parts of the Main Basin especially the Southwestern side.

Comparison of the mean values of the different types of solids concentrations of the six sites of the present study and those of the Environmental Technical Report No. 8, 1997[13], it has been found that TS and TDS values of the present study are much lower while the TSS and TVSS values are much higher. The TSS values of the present study were close to those obtained by El-Rayis *et al.*, (1994)[15] (ranged from 4 to 2468 mg/l) and TVSS values were close to the WWCG 1994 [16] report (ranged from 572 to 1201 mg/l).

Comparison of the BOD values of the present study with the Environmental Technical Report No. 8[13] (230 mg/l), it is noticeable that there are decreases in BOD mean values of all sites in the present study, mean values ranging from 80 mg/l to 209 mg/l. The BOD of the samples collected from site 6 (Qalaa Drain outfall) are lower than that of Mitwally *et al.*, (1996)[17] study (ranged from 140 to 210 mg/l). The increase in BOD values of the Main Basin may be attributed to the change in the load of the domestic wastewater with insufficient amounts of dissolved oxygen which helps in decomposing the organic materials.

The COD mean values of the present study were either lower or similar to those stated by El-Sharkawy (1978)[2]. This reduction indicates the lowering of the amount of organic wastes discharged from the industries into the northeastern and southern sides of the lake after the enforcement of the Egyptian law No. 4/1994. In general, site one showed the highest BOD and COD results (209 and 330 mg/l, respectively) throughout this study while site 4 showed the lowest values (66 and 91 mg/l, respectively).

Ammonia is present naturally in surface waters. It is produced largely by deamination of organic nitrogen-containing compounds and by hydrolysis of urea. Also it is the end product of nitrates reduction. Controversy results were obtained regarding the ammonia contents in the present study and previous ones. Ammonia mean levels of the Main Basin of the present study (0.73 mg/l at site 5 and 25.9 mg/l at site 1) were higher than those of Hafez *et al.*, 1982[18] and El-Rayis *et al.*, 1994[15] (0.5 and 1.8 mg/l, respectively) but they were lower than that of Environmental Technical Report No. 8.[13] (7.8 mg/l).

The nitrate concentrations in the different sites (between 2.06 mg/l at site 2 and 5.91 mg/l at site 3) were higher than those stated by previous studies[13,15,18] (0.34, 2, and 0.49 mg/l, respectively). This difference may be attributed to the change in load of chemical fertilizers from agricultural drainage water discharged into the lake as stated by Abdalla 1997.[19]

There is a great reduction in the total hardness (between 324 mg/l at site 1 and 762 mg/l at site 3) and chloride (between 36 mg/l at site 1 and 1544 mg/l at site 3) contents of water samples collected from the studied sites than previous studies[2,13,15,18], except site 3 which showed a higher value of chloride (1544 mg/l). The Cl concentration is usually higher in wastewater than in raw water because NaCl is a common article of diet and passes unchanged through the digestive system[9]. So the increase in Cl level in the studied sites could be attributed to high load of the domestic waste. The Cl mean values of the different sites, except site 3, are in agreement with the Environmental Technical Report No. 8[13] (710, 990, 940, 1300, 1200, and 740 mg/l).

The levels of the studied heavy metals in Lake Mariut Main Basin water have decreased. It is clear that Pb and Zn were the highest at site

6 (0.0047 and 0.0719 mg/l, respectively). Cu and Fe were the highest at site 4 (0.0232 mg/l and 0.7770 mg/l, respectively). Cd was the highest at site 1 (0.005 mg/l) and Cr was the highest at site 3 (0.0042 mg/l). The levels of some metals such as Fe, Cu, and Pb in fish flesh have decreased while the levels of Zn, Cd, and Cr have not changed which indicates their accumulation by fish organs. The decrease of their level in the lake water will eventually lead to their decrease in fish flesh.

Hg was undetected in both water and fish flesh which is a strong evidence that the environmental status of Lake Mariut is improving for Hg is a cumulative metal.

2. Heavy metals contents in fish flesh

The results of metals contents in Lake Mariut Main Basin fish flesh during months from May to December 2000 are shown in table (3).

It is clear from the results that Fe level in fish flesh ranged between 89.66 and 138.25 mg/kg in dry weight with a mean value of 113.2 mg/kg. The recorded values were lower than what had been obtained in 1981 by Saad *et al.*,[20] who found that the Fe content in the flesh of *Tilapia* collected from the north of lake Mariut reached a maximum value of 204.7 mg/kg in dry weight. Saleh *et al.*, in 1983[14] found that Fe content in fish muscle in highly polluted areas in Lake Mariut reached 990 mg/kg and in less polluted areas reached 141.5mg/kg. The results obtained in the present study are close to those of the less polluted areas. Fe levels in fish flesh during 1989[21] (between 4.7 and 17.9 mg/kg in dry weight) were much lower than that of the present study.

Table (1): Results of Physico-Chemical Analysis of Samples Collected from the Six Sites of Main Basin during the Period from May to December, 2000.

Variable mg/l	Site (1), WTP outlet		Site (2), North of Main Basin		Site (3), East of Main Basin	
	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD
pH, units	6.6-7.5	7.17 ± 0.32	6.75-7.85	7.51 ± 0.39	7.15-9.1	8.64 ± 0.84
TS	1322-1653	1476 ± 146	1066-2215	2064 ± 227	2479-4780	3952 ± 726
TDS	1157-1483	1323 ± 133	1521-2054	1858 ± 246	2191-3900	3328 ± 645
TSS	62-245	137 ± 81.7	75-650	206 ± 149.9	217-1002	648 ± 419
TVS	995-1180	1093 ± 95.7	1475-2025	1755 ± 263	1922-4610	3189 ± 1132
TFS	199-557	355 ± 138.9	190-463	308 ± 113.28	170-838	579 ± 300.1
TVDS	875-1092	934 ± 254.5	106-1895	2356 ± 2933	369-3752	2725 ± 985
TVSS	40-127	86 ± 54.52	45-155	91 ± 52.76	122-911	460 ± 356
BOD	164-267	209 ± 42.2	40-118	93 ± 22.02	70-113	101 ± 14.5
COD	260-400	330 ± 50.7	60-150	121 ± 27.71	100-170	137 ± 23.41
Total-Hard	295-340	324 ± 27.7	390-520	465 ± 71.65	550-940	762 ± 130.1
Ca-Hard.	105-155	132 ± 22.6	145-235	198 ± 45.09	150-280	224 ± 56.42
Mg-Hard.	170-210	195 ± 24.1	195-290	283 ± 52.39	325-690	531 ± 132.6
NH3-N	13.5-36.5	25.9 ± 15.1	11.33-25.2	17.23 ± 10.82	0.66-20.53	5.075 ± 10.4
NO3-N	4-6.56	5.29 ± 1.11	1.28-2.84	2.06 ± 0.671	4.88-8.02	5.91 ± 1.33
Alkalinity	330-410	357 ± 28.4	320-395	342 ± 39.8	400-610	541.4 ± 90.8
Cl	322-430	364 ± 48.02	375-755	604 ± 146.7	997-1805	1544 ± 299.3

Table (1): continuous.

Site (4), South of Main Basin		Site (5), Southeast of Main Basin		Site (6), Qalaa Drain outfall	
Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD
7.15-8.05	7.63 ± 0.391	6.8-7.9	7.6 ± 0.39	6.8-7.65	7.41 ± 0.39
2695-7800	3637 ± 1292	2995-4987	4209 ± 678	1340-1782	1576 ± 256.4
1823-3237	2527 ± 816	2311-3487	2925 ± 517	1275-1607	1451 ± 193.9
160-590	542 ± 378.4	495-1753	1212 ± 588	31-275	125 ± 108.4
2295-3429	2906 ± 514.9	2260-4662	3731 ± 739	115-1447	1064 ± 416.6
120-427	417 ± 263.7	220-1924	805 ± 802	130-615	298 ± 151.9
1718-2877	2310 ± 787	2065-3330	2625 ± 561	103-1419	1142 ± 385.9
92-572	423 ± 333.3	191-1759	1104 ± 640	28-112	66 ± 52.687
40-95	66 ± 27.11	27.5-140	80 ± 43.48	129-188	149 ± 40.89
60-130	91 ± 34.83	40-180	110 ± 56.43	160-280	214 ± 66.98
605-905	727 ± 110.8	605-900	738 ± 108.3	300-455	361 ± 83.65
110-340	267 ± 108.4	110-340	258 ± 96.5	95-220	140 ± 45.40
370-635	460 ± 113.41	350-675	474 ± 111.7	110-295	222 ± 77.87
0.33-9.213	1.207 ±1.528	0.46-1.3	0.73 ± 0.334	13.73-26.38	18.92 ± 8.45
4.1-7	5.219 ± 0.94	4.3-8.4	5.87 ± 1.710	3.2-6.44	4.25 ± 1.70
260-485	349 ± 92.81	270-475	321 ± 94.12	300-430	334 ± 35.67
782-1155	998 ± 173.4	770-1150	1016 ± 178	450-652	538 ± 117.2

Table (2): Results of Metals Analysis of Samples Collected from the Six Sites of Main Basin during the Period from May to December, 2000.

Metal	Site (1)		Site (2)		Site (3)		Site (4)		Site (5)		Site (6)	
	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD
Hg	ND	N.D	ND	N.D	ND	N.D	ND	N.D	ND	N.D	ND	N.D
Pb	0.0022-0.0060	0.004 ± 0.002	0.0012-0.0051	0.0029 ±0.002	0.0016-0.0060	0.0034 ± 0.002	0.0008-0.0049	0.0019 ± 0.002	0.0012-0.0048	0.0024 ± 0.002	0.0032-0.0075	0.0047 ± 0.003
Cd	0.003-0.0076	0.005 ± 0.003	0.0031-0.0064	0.0048 ± 0.002	0.0032-0.0054	0.0044 ± 0.002	0.0027-0.0049	0.0037 ± 0.001	0.0024-0.0045	0.0037 ± 0.001	0.0021-0.0047	0.0039 ± 0.001
Cr	0.0014-0.0052	0.003 ± 0.002	0.0017-0.005	0.0029 ± 0.002	0.0021-0.0088	0.0042 ± 0.003	0.0016-0.008	0.0035 ± 0.003	0.0014-0.0077	0.0034 ± 0.003	0.001-0.0059	0.0026 ± 0.002
Cu	0.009-0.035	0.023 ± 0.098	0.008-0.034	0.0189 ± 0.012	0.0045-0.0231	0.0133 ± 0.008	0.0002-0.04	0.0232 ± 0.018	ND-0.0411	0.0201 ± 0.014	0.002-0.0263	0.0184 ± 0.009
Fe	0.21-0.62	0.395 ± 0.21	0.171-0.318	0.2349 ± 0.07	0.215-0.589	0.3221 ± 0.174	0.451-1.353	0.7770 ± 0.473	0.4644-0.9261	0.7419 ± 0.302	0.3606-1.296	0.6235 ± 0.549
Zn	0.032-0.185	0.049 ± 0.026	0.027-0.048	0.04157 ± 0.023	0.0205-0.056	0.0391 ± 0.008	0.026-0.0.056	0.0420 ± 0.022	0.038-0.0732	0.0582 ± 0.143	0.0497-0.0873	0.0719 ± 0.018

According to the Egyptian Standards No. 2360/1993,[22] there is no limit for Fe in fish flesh. However, the acceptable daily intake of Fe is 56 mg/day for adult male (weighing 70 kg). The per caput supply of fish in Egypt in 1998 was 29.9 g/day.[23] If this fish came from lake Maruit, it would supply 0.75mg Fe/day which represents only 1.33% of the acceptable daily intake of iron.

On the other hand, Fe content in water samples collected from the six selected sites showed two maximum levels of 0.777 mg/l at site 4 and 0.741 mg/l at site 5. The minimum mean value (0.235 mg/l) was that of site 2. The levels of Fe obtained were very low compared to previous ones. In 1992 to 1993, it reached 9.495 mg/l at the Qalaa Drain and 81 mg/l in the Main Basin.[16] They were also lower than the Fe values in 1989[21] (ranged between 1.4 and 2.6 mg/l). The higher level of Fe in fish muscles compared with the level in water is explained previously by Niazzy *et al.*, 1995[24] who stated that fish muscle accumulated Fe to a great extent.

Copper level in fish flesh ranged between 2.35 and 5.756 mg/kg in dry weight with a mean value of 3.549 mg/kg. The levels recorded are lower than the level reported in 1981[20] (53.5 mg/kg) and by Ghoneim[21] (between 16.87 and 22.66 mg/kg). No limit of Cu in fish and fish products was specified in the Egyptian Standards No. 2360/1993[22] but the acceptable daily intake of Cu is 35 mg/day for adult male (70 kg). The per caput supply of fish is 29.9 g/day.[23] If this fish came from Lake Maruit, it would supply 0.023mg Cu/day which represent 0.066% of acceptable daily intake of Cu.

Copper in water samples ranged between 0.013 mg/l at site 3 and 0.023 mg/l at site 4. The concentration of Cu at Qalaa Drain outlet (0.018 mg/l) has changed with time. Its value was very close from the mean

Cu value recorded during the period from 1978 to 1979[18] (0.022 mg/l). On the other hand, it is lower than those mean values recorded during 1983[16], 1989[21], and 1992-1993[25], (0.865, 5-6.5, and 0.7 mg/l, respectively). Cu concentration of the Main Basin in the present study (0.017 mg/l) was also lower than that of former studies. In the period from 1978 to 1979 [18,26] it showed a mean value of 0.089 mg/l, however this value increased by 1983 to range between 0.16 and 0.40 mg/l.[25] In general, the decrease in Cu content is expected because the source of heavy metals especially Cu and Cd to the lake was the industrial wastewater of Moharrem Bey Complex[14] which was directed away from the Lake to WTP since its operation in 1993.

Zinc level in fish flesh ranged between 50.436 and 74.762 mg/kg on dry weight base with a mean value of 61.662 mg/kg. The values are close to the value obtained during 1981[20] (72.9 mg/kg). The acceptable daily intake of Zn according to the Egyptian Standards No. 2360/1993 is 70 mg/day for adult male (70 kg). Considering a per caput supply of fish 29.9 g/day,[23] this amount of Lake Maruit fish would supply 0.39 mg Zn/day which represents 0.55% of acceptable daily intake of Zn.

Zinc concentration in water samples ranged between 0.039mg/l at site 3 and 0.072 mg/l at Qalaa Drain outlet. This is in agreement with Saad *et al.*,[20] who found that the Zn maximum value was at the vicinity of Qalaa Drain. In 1983, Zn showed a mean value of 0.293 mg/l at Qalaa Drain and reached 0.303mg/l in the Main Basin.[16,25] From 1992 to 1993 it showed a mean value of 0.563 mg/l at Qalaa Drain and ranged between 0.191 and 0.460 mg/l in the Main Basin.[16] It is clear that Zn content in water samples of the present study has decreased compared with the former studies however, it has not changed in fish flesh which suggests the fish accumulation.

Lead mean value (0.142 mg/kg) in fish flesh (fresh weight base) is slightly higher than the value recommended by the Egyptian Standards No. 2360/1993 for Pb in fish flesh (not to exceed 0.1 ppm). Nonetheless, the results obtained in the present study are definitely lower than the level obtained in the study conducted by El-Sokkary (1980–1985)[27] (3.85 mg/kg in fresh weight). Additionally, the present study results revealed that the Pb content of fish ranging from 0.246 to 1.007 mg/kg on dry weight base with a mean value of 0.692 mg/kg is also lower than that of the level stated in the Environmental Technical Report No.8[13] (ranging from 1.7 to 2.3 mg/kg on dry weigh base with a mean value of 1.93 mg/kg). The values obtained in the present study were also lower than those of Ghoneim[21] (ranged from 0.5 to 1.72 mg/kg in dry weight). The acceptable weekly limit of Pb according to the Egyptian Standards No. 2360/1993[22] is 3.5 mg/week for adult male (70kg). Per caput supply of fish is 29.9 g/day.[23] If this fish came from Lake Maruit, it would supply 0.0298 mg Pb/week which represents 0.85% of maximum acceptable intake/week.

In water samples, Pb showed two maximum values, in site one (0.004 mg/l) and site six (0.0047 mg/l). According to the WWCG [16], the concentration of Pb of Qalaa Drain effluent was 0.48 mg/l which is extremely higher than that of the present study. By comparing the Pb concentration of the Main Basin (0.0008-0.0075mg/l) with its concentration in 1983 by WWCG[16] (0.2-0.747 mg/l) (before operation of WTP and ETP), it is clear that the Pb concentration in the Main Basin has decreased. In general, it is clear that the Lead content of both fish muscle and water of Lake Mariut's Main Basin has decreased reflecting the effectiveness of industrial waste treatment and/or the diversion of wastewater from Lake Mariut to WTP.

Cadmium level in fish flesh ranged between 2.731 and 4.361 mg/kg in dry weight with a mean value of 3.872 mg/kg (0.81 mg/kg fresh weight). The levels of Cd are very close to that of El-Sokkary study from 1980 to 1985[27] (0.75 mg/kg). Cd level in fish flesh has not changed from 1985 till the present study though its content in water has decreased.

According to the Egyptian Standards No. 2360/1993 the Cd content in fish should not exceed 0.1 mg/kg. By comparing this value with the Cd mean value from fish flesh of the present study (0.81 mg/kg), it is clear that Cd content in the flesh of fish caught from Lake Mariut Main Basin exceeded the Egyptian limit. Also the acceptable weekly limit of Cd according to the Egyptian Standards No. 2360/1993 is 0.58 mg for adult male (70 kg). Per caput supply of fish is 29.9 g/day.[23] If this fish came from Lake Maruit, it would supply 0.1695 mg Cd/week which represents 29% of maximum tolerable intake/week.

Cd in the water samples of the present study varied between 0.0037 mg/l at both sites 4 and 5, and 0.005 mg/l at site 1. From these results, it can be concluded that the WTP effluent contains the highest concentration of Cd which is in agreement with Saad *et al.*,[20] who stated that the Cd shows the highest concentration in the western region of the Main Basin. According to WWCG 1992 and 1994 reports,[16,25] Cd of Qalaa Drain effluent showed a concentration of 0.160 mg/l in 1983 which is extremely higher than that of the present study (0.0039 mg/l). Also its concentration in the Main Basin ranged between 0.045 and 0.085 mg/l in 1983 and between 0.039 and 0.063 mg/l in 1993. These results were also higher than the results obtained in the present study.

Chromium level in fish flesh ranged between 10.855 and 15.815mg/kg in dry weight with a mean value of 14.037 mg/kg. The level of Cr in fish flesh is higher than its level in the lake water (0.001-

0.0088 mg/l) which is expected due to the accumulation of metals by fish in various organs. This agreed with the observations of Niazzy *et al.*,[24] who stated that Cr showed a high concentration in the liver, muscle, and serum of fish collected from Lake Mariut compared with its lower concentration value in the water which may be due to the affinity of Cr to precipitate with the sediments. In 1993, Cr showed a mean value of 0.038 mg/l at the outlet of Qalaa Drain and ranged between 0.040 and 0.097 mg/l in the Main Basin[16] which were much higher than its contents in water in the present study.

Mercury levels were undetected in both fish and water samples. The absence of Hg was expected due to the termination of its source. The Hg cells of chlor-alkali plant of El-Max has been replaced with another Hg-free technique.

3. Results of Statistical analysis

Table (4) shows the statistical differences between the different sites for the measured parameters of lake water.

It has been found that there was a direct weak correlation (<0.25) for both Fe and Zn values between fish flesh and water samples. On the other hand, both Cu and Pb showed an indirect weak correlation between fish and water samples. As for Cd and Cr, Cd showed an indirect intermediate correlation (<0.75) at the 0.01 significant level (2-tailed) and Cr showed a direct intermediate correlation at the 0.01 significant level between fish and water samples.

Table (3): Metal Content of Lake Mariut Fish Flesh, mg/kg.

Month	Values of Fe Mean ± SD		Values of Cu Mean ± SD		Values of Zn Mean ± SD	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
May	19.08 ± 9.50	89.660	0.5 ± 0.00	2.350	13.63 ± 2.57	64.027
July	27.10 ± 10.0	135.70	0.6 ± 0.42	3.004	14.93 ± 6.71	74.762
August	27.80 ± 11.7	138.25	0.5 ± 0.00	2.486	12.3 ± 4.281	61.167
September	21.68 ± 6.75	106.38	0.5 ± 0.00	2.454	14.92 ± 6.33	73.247
October	20.40 ± 4.03	102.12	1.15 ± 1.0	5.756	10.075 ± 0.5	50.436
November	26.07 ± 7.81	108.38	0.98 ± 1.2	4.073	12.8 ± 1.202	53.200
December	23.72 ± 4.07	111.93	1.23 ± 1.4	4.720	11.611 ± 2.1	54.792
Total Mean	23.69 ± 3.42	113.20	0.78 ± 0.33	3.549	12.895 ± 1.8	61.662

Table (3): continuous.

Values of Cd Mean ± SD		Values of Cr Mean ± SD		Values of Pb Mean ± SD	
Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
0.928 ± 0.13	4.361	3.13 ± 0.41	14.729	0.191 ± 0.09	0.916
0.903 ± 0.25	4.522	2.89 ± 0.97	14.472	0.201 ± 0.23	1.007
0.876 ± 0.01	4.202	3.08± 1.09	15.328	0.189 ± 0.00	0.941
0.845 ± 0.05	4.147	2.21 ± 0.14	10.855	0.131 ± 0.00	0.645
0.789 ± 0.02	3.954	2.48 ± 0.97	12.410	0.106 ± 0.02	0.531
0.657 ± 0.06	2.731	3.81 ± 5.04	15.815	0.059 ± 0.03	0.246
0.675 ± 0.27	3.185	3.11 ± 3.16	14.652	0.118 ± 0.08	0.557
0.811 ± 0.11	3.872	2.96 ± 0.52	14.037	0.142 ± 0.05	0.692

Table (4): ANOVA Statistical Analysis between the Different Sites for the Measured Parameters.

	Site 2	Site 3	Site 4	Site 5	Site 6
Site 1	TDS(**), TVS(*), T.har.(**), NH3(**), NO3(***), BOD(***), COD(***),	pH(***), TS(***), TDS(***), TSS(**), TVS(***), TVSS(*), alk.(***), T.har.(***), NH3(***), BOD(***), COD(***), Cu(*),	pH(*), TS(***), TDS(***), TSS(*), TVS(***), TVSS(*), T.har.(***), NH3(***), BOD(***), COD(***), Fe(***), Pb(*), Cd(*)	TS(***), TDS(***), TSS(***), TVS(***), TVSS(***), T.har.(***), NH3(***), BOD(***), COD(***), Fe(***), Cd(*)	NH3(*), BOD(***), COD(***), Pb(*),
Site 2		pH(***), TS(***), TDS(***), TSS(**), TVS(***), TVSS(*), alk.(***), T.har.(***), NH3(***), NO3(***),	TS(***), TDS(**), TSS(*), TVS(***), TVSS(*), T.har.(***), NH3(***), NO3(***), Fe(***), Cu(*),	TS(***), TDS(***), TSS(***), TVS(***), TVSS(***), T.har.(***), NH3(***), NO3(***), Fe(***),	TDS(*), TVS(**), T.har.(*), NO3(**), BOD(**), COD(***), Cu(*),
Site 3			pH(***), TDS(***), alk.(***), BOD(*), COD(*), Fe(**),	pH(***), TDS(*), TSS(**), TVS(*), TVSS(***), alk.(***), Fe(**),	pH(***), TS(***), TDS(***), TSS(**), TVS(***), TVSS(*), alk.(***), T.har.(***), NH3(***), NO3(**), BOD(**), COD(***), Fe(*),
Site 4				TDS(*), TSS(***), TVS(**), TVSS(***),	TS(***), TDS(***), TSS(*),TVS(***), TVSS(*), T.har.(***), NH3(***), BOD(***), COD(***), Cu(**),
Site 5					TDS(***), TSS(***),TVS(***), TVSS(***), T.har.(***), NH3(***), NO3(**), BOD(***), COD(***), Cu(**),

* *significant difference at p<0.05*
** *highly significant difference at p<0.01*
*** *very highly significant difference at p<0.001*

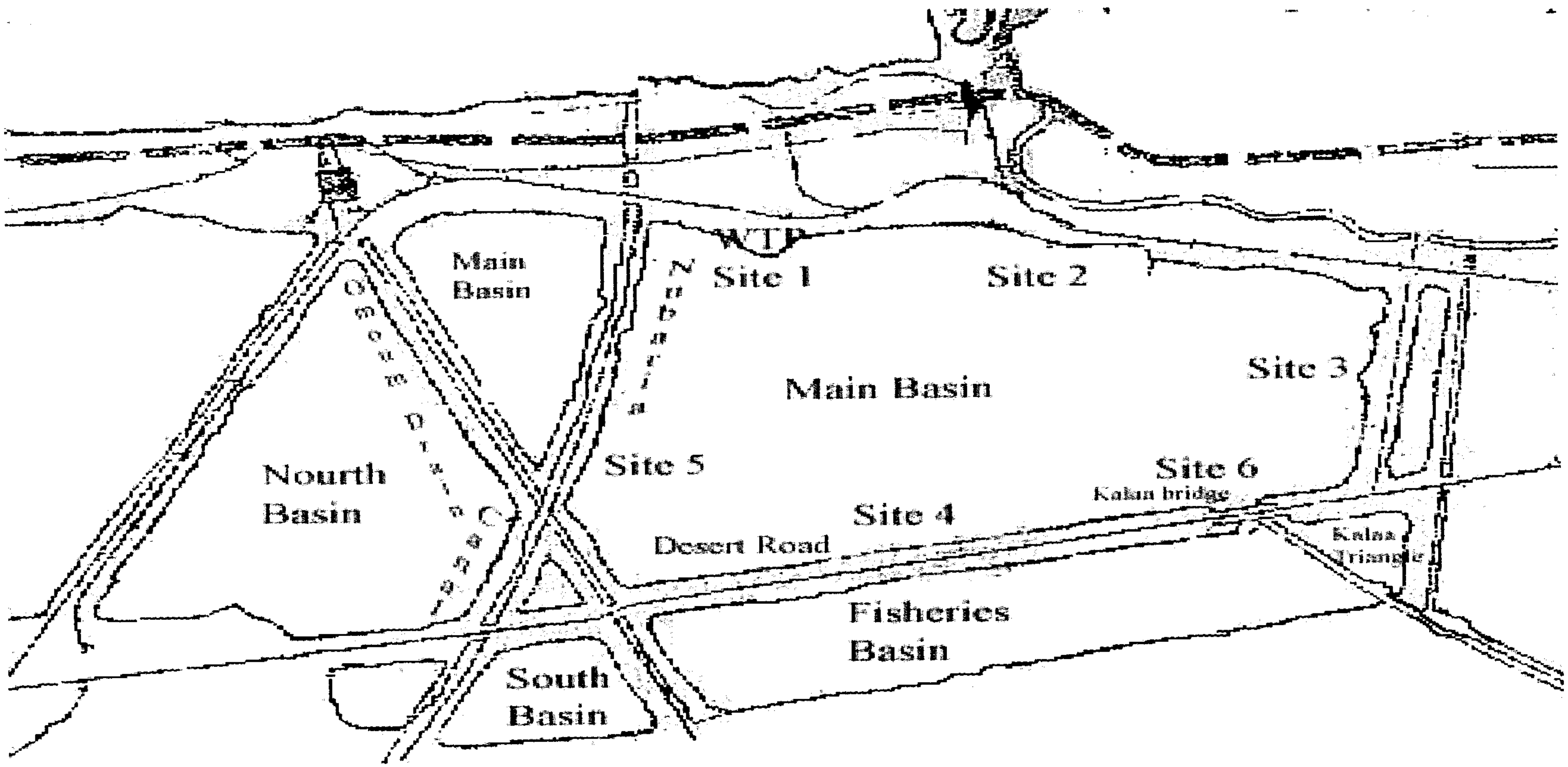

Figure (1): Lake Mariut Sampling Locations

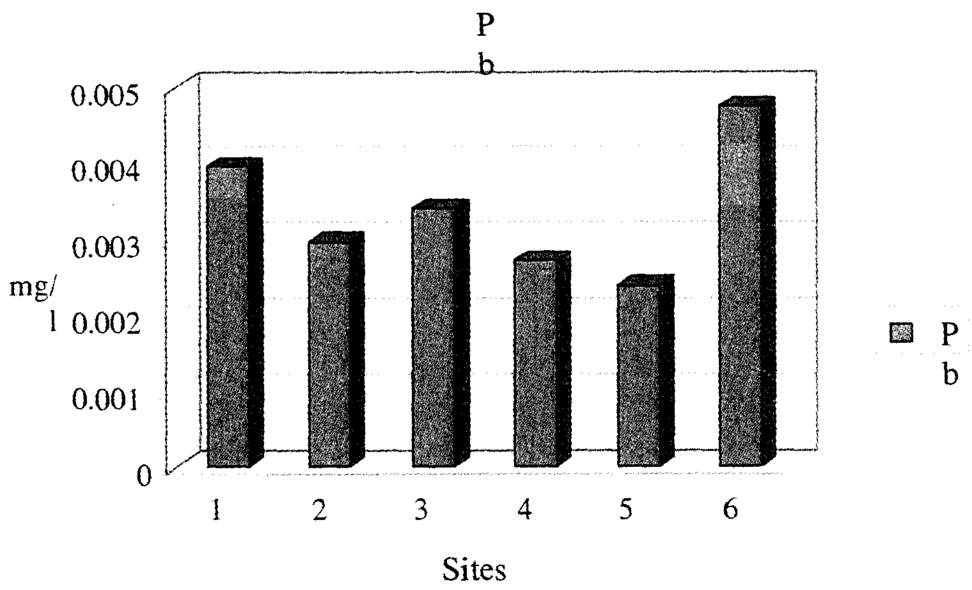

Figure (2): Concentration of Pb in Water Samples Collected from Six Sites of the Main Basin of Lake Mariut, Alexandria, 2000.

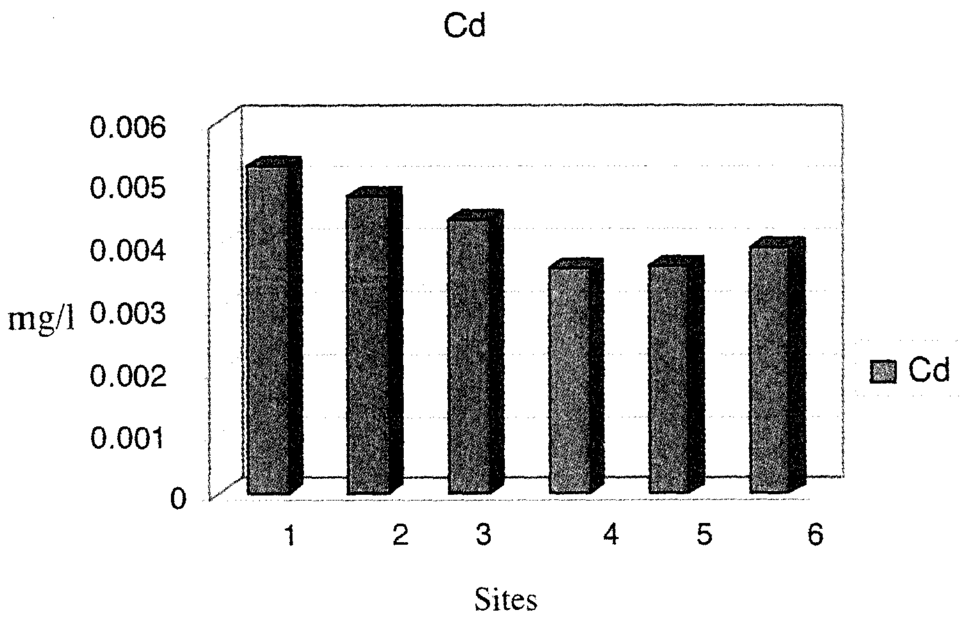

Figure (3): Concentration of Cd in Water Samples Collected from Six Sites of the Main Basin of Lake Mariut, Alexandria, 2000.

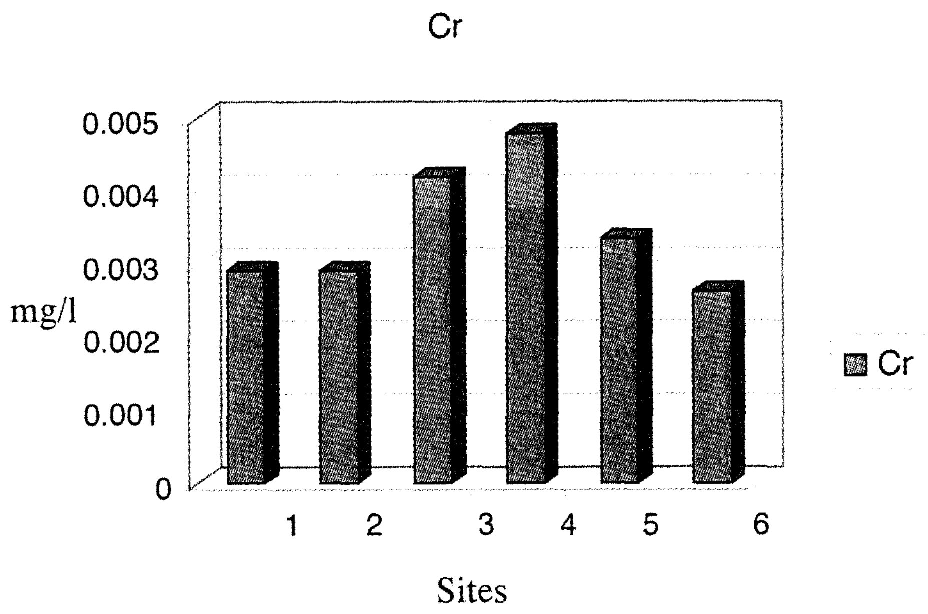

Figure (4): Concentration of Cr in water samples collected from six sites of the Main Basin of Lake Mariut, Alexandria, 2000.

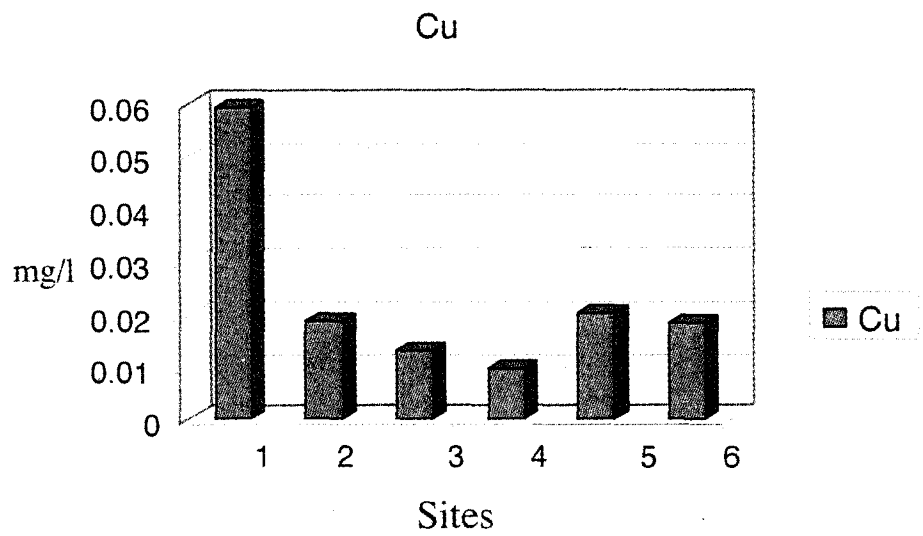

Figure (5): Concentration of Cu in water samples collected from six sites of the Main Basin of Lake Mariut, Alexandria, 2000.

CONCLUSION AND RECOMMENDATIONS

Based on the obtained results, the following has been concluded:

- The levels of all studied heavy metals in Lake Mariut Main Basin have decreased than that of previous studies.
- The physico–chemical parameters concentrations have changed. COD, TS, TDS, hardness, and chloride levels have decreased, especially COD, as a result of the reduction of the amount of organic wastes discharged from the industries into the lake after the enforcement of the Egyptian law for environment protection and the diversion of wastewater from the Lake to WTP.
- The levels of heavy metals in fish samples collected from Lake Mariut Main Basin were higher than their levels in water samples. The levels of some heavy metals such as Fe, Cu, and Pb in fish flesh have decreased. On the other hand, the levels of Zn, Cd, and Cr in fish flesh have not changed which indicate their accumulation by fish organs. The reduction of their levels in the lake water will eventually lead to their decrease in fish flesh.
- Being most hazardous for human consumption, Hg was one of the studied heavy metals in the present study. It was totally undetected in fish and water samples.

The following recommendations are suggested:

- Lower the consumption of the Main Basin fish till the heavy metals reach the acceptable levels.
- Periodic monitoring of heavy metals levels in both fish and water of the Main Basin.
- Appling treatments that will improve lake water quality such as mechanical aerators, removal of toxic sludge, diluting sources of

biodegradable pollution with clean or less polluted water, and increasing the capacities of WTP and ETP.

- Construction of secondary treatment units in WTP and ETP.
- Enforcing industrial facilities, which have not industrial wastewater treatment units, to establish on-site treatment units, and periodic inspection of the efficiency and operation of the already present treatment units.
- Raising funds and finding sponsors to finance Lake Mariut cleaning project.

REFERENCES

1. Saad MAH, El-Rayis O, Ahdy H. Status of nutrients in Lake Mariut, a Delta Lake in Egypt suffering from intensive pollution. Mar Poll Bull. 1984; 15(11): 408-11.

2. El-Sharkawy FM. Study of Lake Mariut pollution due to sewage and industrial wastes discharge. Final Report. Cairo: Academy of Scientific Research and Technology; 1978.

3. Thomas GH, El- Karyony IA, Aly AH, Hussein AH. Optimum utilization of the polluted basin (The Lake Proper) in Lake Mariut Socio-economic impacts. Bull. High Inst. Public Health 1994; 24(3): 713-34.

4. Wagdi F, Thomas GH. Statistic treatment of factors affecting the fish production in Lake Mariut. Bull High Inst Public Health. 1989;19(1):221-36.

5. Saad MA. Eutrophication of Lake Mariut, a heavily polluted lake in Egypt. Vienna: Int At Ebr Ag; 1980.

6. Bakhoum SA. Effect of water pollution on gonads, liver, and heart of two dominant Tilapias of *Oreochromis* species in Lake Mariut. Bull High Inst Public Health 1995; 25(1):113-8.

7. Hossam El-Din A. Lake Maryout hazardous focus: the problem and solution. Bull High Inst Public Health. 1998; 28(1):13550.

8. The Environmental Law No. 4, Ministry of Environmental Affairs, 1994. A.R.E.

9. Eaton AD, Clesceri LS, Greenberg AE. Standard methods for the examination of water and wastewater. 19th edition. Washington, DC: American Public Health Association; 1995.

10. Jorhem L, Engman J. Determination of lead, cadmium, zinc, copper, and iron in foods by atomic absorption spectrometry after microwave digestion: NMKL collaborative study. JAOAC Int. 2000; 83 (5): 1189-203.

11. Jorhem L. Determination of metals in foods by atomic absorption spectrometry after dry ashing: NMKL collaborative study. JAOAC Int. 2000; 83 (5): 1204-11.

12. Environmental Protection Agency (EPA) Standard Procedures Determination of Mercury in Water by Cold Vapor Atomic Absorption Spectrometry, EPA Method 245.1. Environmental Monitoring Systems Laboratory, Revision 3.0, May 1994.

13. Environmental Agency Engineering, Science, and Technology (EA-ESTI). Chemical and biological characterization of Lake Maryout final report. Environmental technical report No. 8. Draft, 5 June. AWP Phase II USAID Proj.263-0100. Prepared by EA for Metcalf & Eddy; 1997.

14. Saleh H, Hamza A, El-Baghdadi BS. Effect of water pollution in Lake Mariut on mortality and survival rates of *Tilapia zilli* GERV. Bull High Inst Public Health. 1983; 13(5):59-76.

15. El-Rayis OA, El-Sabrouti M, Hanafy H. Some hydrochemical observations from Lake Mariut prior to diversion of sewage of eastern districts of Alexandria. First Arab Conf Mar Environ Protec. 1994:191-204.

16. Wastewater Consultants Group (WWCG). Report on preliminary investigations of Lake Mariut water quality: past present and future. Prepared for the Arab Republic of Egypt, Alexandria General Organization for Sanitary Drainage (AGOSD), Alexandria: 1994.

17. Mittwally HH, Hussein AH, Hossam AH, El-Shal WI, Mohamed MA, Abdel-Kareem G, et al., Rehabilitation measures for Lake Mariut. International Conference on Health, Environment & Development. Alexandria: 14-17 Oct;1996.

18. Hafez HA. Distribution of heavy metals in Lake Mariut and Nozha Hydrodrome and their accumulation in fish. M.Sc. Thesis Alex. Univ. Egypt; 1982.

19. Abdalla AAF. Effects of increased nitrogen fertilization on water quality and yield of Nile *Tilapia, Oreochromis niloticus,* and common crap, *Cyprinus carpio,* in eastern ponds in Egypt. Journal of Applied Aquaculture. 1997;7(4):1-13.

20. Saad MA, Ezzat AA, El-Rayis OA, Hafez H. Occurrence and distribution of chemical pollutants in Lake Mariut, Egypt. II- Heavy Metals, Water Air and Soil Pollution. 1981;16:401-7.

21. Ghoneim EH. Alterations in the pattern and nutritional value of proteins of fish living in polluted waters. Alexandria University. Dr.PH Thesis, High Inst Public Health; 1989.

22. Egyptian organization for standardization and quality control Egyptian Standards No. 2360-1993.

23. Food balance sheet. Ministry of Agriculture and Land Reclamation (EAS), Egypt. Cairo; 1998.

24. Niazzy ZM, Abd El-Aziz T, Abou El-Wafa AM, Hussain AA, Amin TM. Evaluation of some heavy metals in serum and muscles in *Clarias lazera* in

different locations in Egypt. Bull High Inst Public Health. 1995;25(2):419-26.

25. WWCG (Wastewater Consultants Group). Alexandria wastewater program master plan update. Prepared for the Arab Republic of Egypt, Alexandria General Organization for Sanitary Drainage (AGOSD), Alexandria; 1992.

26. Wahby SD, Kinawy SM, Tahani ET, Abdel Moneim MA. Chemical characteristics of Lake Mariut, a polluted lake south of Alex, Egypt. Estuar Costal Mar Sci. 1978; 7: 17-28.

27. El-Sokkary IH. Contamination of the western area of the Nile Delta by cadmium, lead, and mercury. Wiley Eastern Ltd.; 1994. 231.