OCCURRENCE AND DISTRIBUTION OF CHEMICAL POLLUTANTS IN LAKE MARIUT, EGYPT. II. HEAVY METALS

MASSOUD A. H. SAAD, A. A. EZZAT, O. A. EL-RAYIS, and H. HAFEZ
Oceanography Department, Faculty of Science, Alexandria University, Moharem Bey, Alexandria, U.A.R.

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Abstract. The occurrence and distribution of heavy metals in the water of Lake Mariut, a heavily polluted brackish water lake in Egypt, and their accumulation in the different parts of *Tilapia* fish in this lake were studied. The variations in concentrations of the metals (Zn, Cu, Fe, Mn, and Cd) in the lake water are mostly due to variations in the discharge rate of dumped wastes. The mean concentrations of these metals in different fish parts were much higher than those in the lake water.

1. Introduction

The description of Lake Mariut was given in Part I. Several factories are close to the northern side of this Lake. The industrial and sewage wastes of these factories as well as the domestic wastes of a part of southern Alexandria are dumped directly without treatment into the northern side of the Lake. In addition, Qala Drain, transports to it large amounts of industrial and sewage wastes into the eastern side of Lake Mariut. The untreated industrial and sewage wastes increased the levels of heavy metals in the water and sediments of Lake Mariut. Consequently, these metals were accumulated in considerable concentrations in the biota of the lake. It is urgently necessary to determine the levels of the different chemical pollutants present in the water and sediments of Lake Mariut as well as in the common fish (*Tilapia* species), since this lake is used as a fishing ground for human consumption mainly for the city of Alexandria. The present study, which is the second part of a pilot project on pollution of Lake Mariut supported by IAEA, deals with the occurrence and seasonal distribution of heavy metals in the water and *Tilapia* fish of this lake.

2. Materials and Methods

Six stations were chosen to represent different regions in Lake Mariut. Two other stations were selected at the connections of Umum Drain and Qala Drain with the lake (Figure 1 in Part I). Water sampling was conducted monthly at all stations during the period from August 1978 to September 1979. Water samples were taken (about 20 cm) below the water surface to avoid floating matter, kept in polyethylene bottles and filtered, using millipore 0.45 μm. *Tilapia* were captured monthly from the northern and southern sides of the lake.

Determination of heavy metals (Zn, Cu, Fe, Mn, and Cd) in the lake water was carried out according to the method described by Riley and Taylor (1968), using Atomic

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Absorption Spectroscopy (Shumadzu-) under its recommended conditions given in the manual for each metal.

For determination of these metals in the fish *Tilapia*, the fish samples were dissected into subsamples from different parts of the fish body. The samples were treated in a similar way described by Riley and Segar (1970). The extracted acidic solutions obtained after treatment of the fish samples were measured for the heavy metals, using Atomic Absorption Spectroscopy.

TABLE I

Monthly average values of heavy metals in $\mu g\, l^{-1}$ in the water of Lake Mariut as well as average values for the Nile water

Months	Average concentrations in $\mu g\, l^{-1}$ [a]				
	Zn	Cu	Fe	Mn	Cd
August, 1978	11.8	3.7	6.5 −	1.3 −	1.14 +
September	9.1	3.0	6.9	3.0	0.71
October	3.4 −	2.1 −	8.1	2.5	0.62
November	8.0	3.0	10.6	10.8	0.80
December	7.1	2.2	15.5	48.6	0.36 −
January, 1979	10.7	4.6	16.9	61.5 +	0.71
February	10.2	4.3	28.2	24.9	0.43
March	6.5	3.3	19.9	57.0	0.47
April	10.3	4.2	8.3	—	0.43
May	20.5 +	4.0	13.1	—	0.54
June	11.0	5.2	26.5	—	0.37
July	17.7	6.2	54.6 +	—	0.73
August	10.9	5.4	25.5	—	0.83
September	15.9	7.7 +	26.5	—	0.60
Mean	10.9	4.2	19.1	26.2	0.62
Nile[b]	—	1.5	2.3	0.5	0.47

[a] Average concentrations calculated from the values at 8 stations.

[b] Mean values of 35 determinations carried out in the water of Rosetta Branch of the Nile (unpublished data).

The minimum averages are designated by (−) and maximum by (+).

3. Results and Discussion

3.1. Water

The monthly average values of heavy metals are given in Table I. Manganese was not measured during the period from April to September 1979, due to a technical difficulty in its determination. The mean concentrations of Zn, Cu, Fe, Mn and Cd in the lake water were 10.9, 4.2, 19.1, 26.2 and 0.62 $\mu g\, l^{-1}$, respectively.

The monthly average values of Zn varied from a minimum of 3.4 $\mu g\, l^{-1}$ in October 1978 to a maximum of 20.5 $\mu g\, l^{-1}$ in May 1979. The monthly averages of Cu ranged from

2.1 $\mu g\, l^{-1}$ in October 1978 to 7.7 $\mu g\, l^{-1}$ in September 1979. The range of the monthly average values of Fe was considerable, fluctuating between 6.5 and 54.6 $\mu g\, l^{-1}$ in August 1978 and July 1979, respectively. A considerable wide range of variations was also found for Mn, fluctuating between 1.3 and 61.5 $\mu g\, l^{-1}$ in August 1978 and January 1979, respectively. The monthly averages for Cd varied from 0.36 $\mu g\, l^{-1}$ in December 1978 to 1.14 $\mu g\, l^{-1}$ in August 1978. Generally speaking, the average concentrations of Fe and Mn showed relatively considerable differences during the various months of the study period. However, there were no large differences between the monthly average values of Zn, Cu, and Cd. The variations in the average concentrations of heavy metals in the water of Lake Mariut during the 14 mo of study are mostly attributed to variations in the discharge rate of the industrial and sewage wastes entering into the lake in the different months.

The influence of pollution by heavy metals in Lake Mariut can be ilustrated by comparing the levels in the water of this lake with those in the water of Rosetta Branch of the Nile (Table I). The mean concentrations of Cu and Cd for the surface water of Lake Mariut were relatively higher than those for the surface water of the Nile. However, the mean concentrations of Fe and Mn for Lake Mariut water were much higher than those for the Nile water.

The regional average values of heavy metals are shown in Table II. The regional averages of Zn ranged from 8.8 to 14.1 $\mu g\, l^{-1}$ at stations IV and VI, respectively. The regional averages of Cu varied slightly from 3.0 to 5.8 $\mu g\, l^{-1}$ at stations III and V, respectively. The regional average values of Fe and Mn showed a considerably wide range of variations. The averages of Fe varied from 8.6 $\mu g\, l^{-1}$ at station IV to 37.9 $\mu g\, l^{-1}$ at station VIII and those of Mn fluctuated between 4.1 and 55.7 $\mu g\, l^{-1}$ at stations IV and I, respectively. The regional averages of Cd varied slightly from 0.49 $\mu g\, l^{-1}$ at station VI to 0.81 $\mu g\, l^{-1}$ at station V.

TABLE II

Regional average values of heavy metals in $\mu g\, l^{-1}$ in the water of Lake Mariut

Stations	Average concentrations in $\mu g\, l^{-1}$ [a]				
	Zn	Cu	Fe	Mn	Cd
I	12.7	4.3	22.4	55.7 +	0.64
II	10.6	4.3	14.9	39.4	0.61
III	9.7	3.0 −	10.5	11.8	0.56
IV	8.8 −	3.2	8.6 −	4.1 −	0.69
V	12.6	5.8 +	17.7	41.2	0.81 +
VI	14.1 +	4.7	31.3	24.2	0.49 −
VII	8.8 −	4.1	10.4	4.3	0.71
VIII	10.8	4.4	37.9 +	26.1	0.51
Mean	11.0	4.2	19.2	25.9	0.62

[a] Average concentrations calculated from the values of 14 mo.
The minimum averages are designated by (−) and the maximum by (+).

It is clear from Table II that Lake Mariut can be divided into two different water bodies according to their contents of dissolved heavy metals: the western region (stations III, IV, and VII) and the eastern region including the rest of stations. The concentrations of Zn, Cu, Fe, and Mn found in the eastern waters were relatively higher than those obtained from the western waters. This can be attributed to the discharge from the heavily polluted Qala Drain as well as industrial and sewage wastes dumped into the north-eastern side of the lake. A noticeable phenomenon can be seen from Table II that the regional distribution of Cd was nearly opposite to that of the other metals. The regional averages of Cd found in the western waters (stations IV and VII) as well as in the middle of the lake (station V) were slightly higher than those at the other stations. This is probably due to the affinity of Cd to be in the soluble form in waters of high chloride content. The Cd ion has a great affinity toward formation of soluble Cd-chloro-complexes (Dyrssen, 1970; El-Rayis, 1977). According to unpublished data on the chlorosity content of Lake Mariut, the western waters had relatively higher chlorosity values than the eastern waters. Analysis of the eastern waters showed that the concentration of dissolved oxygen was very low or depleted at most stations (unpublished data). The concentrations of dissolved Fe and Mn in this oxygen depleted waters were markedly higher than those found in the oxic western waters. This can be attributed either to chelation of these metals with soluble organic compounds present in the less oxygenated eastern waters or to their presence in a reduced soluble forms (Fe^{2+} and Mn^{2+}) or due to both reasons.

3.2. Fish

The minimum, maximum and average concentrations of heavy metals accumulated in the different parts of the common fish *Tilapia* captured from Lake Mariut during the study period are given in Table III. The mean concentrations of heavy metals found in the different parts of Tilapia compared with the mean concentrations obtained from the lake water are shown in Figure 1. It is clear from this Figure that the mean concentrations of Zn, Cu, Fe, and Cd found in the liver were considerably higher than those present in the stomach. This means that the liver concentrates these metals from the blood circulatory system. The Fe is present in the blood of the fish as a part of the haemoglobin structure. The liver contains many more blood vessels than the other parts of the body. This can explain the absolute highest mean concentration of Fe in the liver of the fish (1124.8 $\mu g\ g^{-1}$).

The mean concentrations of Zn, Cu, Fe, and Mn found in the stomach were markedly higher than those present in the edible flesh of the flank region and the caudal peduncle. This can be attributed to the type of food that the fish is feeding on. *Tilapia* is mainly considered as a herbivorous fish. Further analyses for heavy metals in the aquatic plants inhabiting the lake are needed to throw light on the cause of the high concentrations of the metals in the stomach. These analyses may also illustrate the reasons that the liver and stomach of fish caught from the northern part of the lake had, in general, relatively lower concentrations of metals than those in the liver and stomach of fish caught from the southern region. Figure 1 shows that the mean concentrations of heavy metals in the

TABLE III

Minimum, maximum and average concentrations of heavy metals in $\mu g\ g^{-1}$ dry weight accumulated in the different parts of *Tilapia* fish samples from the northern and southern regions of Lake Mariut during August 1978–September 1979

Metals	Fish parts	Regions	Minimum	Maximum	Average
Zn	Liver (L)	North (N)	11.9 (July)	248.5 (Feb.)	101.6
		South (S)	117.6 (Feb.)	764.0 (May)	264.3
	Peduncle (P)	N	20.8 (June)	70.5 (March)	43.6
		S	23.5 (July)	111.1 (March)	55.9
	Stomach (St)	N	4.4 (June)	125.6 (Dec.)	71.6
		S	12.9 (April)	151.9 (Feb.)	78.9
	Flesh (F)	N	16.5 (May)	72.9 (Feb.)	43.8
		S	14.1 (May)	56.8 (Sept. 78)	31.1
Cu	L	N	1.7 (Sept. 78)	73.9 (Feb.)	31.8
		S	5.5 (Feb.)	144.0 (May)	56.8
	P	N	4.2 (Nov.)	14.9 (July)	7.8
		S	4.3 (Dec.)	74.8 (March)	23.5
	St	N	2.0 (June)	113.9 (July)	33.1
		S	4.9 (April)	74.1 (March)	27.9
	F	N	2.1 (Nov.)	53.5 (June)	20.0
		S	2.8 (Nov.)	13.1 (Feb.)	17.2
Fe	L	N	6.1 (Sept. 78)	2786.9 (March)	1139.9
		S	527.5 (June)	1616.5 (March)	1109.7
	P	N	20.1 (June)	182.8 (Sept. 79)	67.2
		S	3.9 (Dec.)	160.9 (March)	59.9
	St	N	4.0 (June)	2336.4 (Dec.)	687.7
		S	16.1 (April)	1489.1 (Sept. 78)	750.9
	F	N	20.9 (April)	204.7 (Feb.)	56.4
		S	8.9 (Dec.)	144.4 (April)	55.2
Mn	L	N	3.5 (Sept. 78)	55.0 (Feb.)	36.4
		S	19.4 (March)	106.1 (Feb.)	53.6
	P	N	0.6 (Dec.)	5.8 (Feb.)	3.2
		S	0.5 (Jan.)	23.2 (Nov.)	7.0
	St	N	4.5 (Sept. 78)	186.3 (Dec.)	68.0
		S	61.1 (Nov.)	554.1 (Feb.)	230.2
	F	N	1.1 (Dec.)	6.8 (Jan.)	3.6
		S	1.9 (Nov.)	7.8 (March)	5.2
Cd	L	N	2.81 (June)	6.61 (Feb.)	2.10
		S	3.07 (Sept. 78)	6.51 (March)	3.17
	P	N	0.45 (Dec. & Feb.)	2.42 (March)	1.41
		S	0.21 (Jan.)	3.44 (Dec.)	1.64
	St	N	0.48 (Feb.)	1.42 (May)	0.89
		S	0.12 (May)	2.39 (Dec.)	0.89
	F	N	0.12 (June & Sept. 79)	1.37 (May)	0.68
		S	0.23 (Jan. & Sept. 79)	2.90 (Sept. 78)	0.83

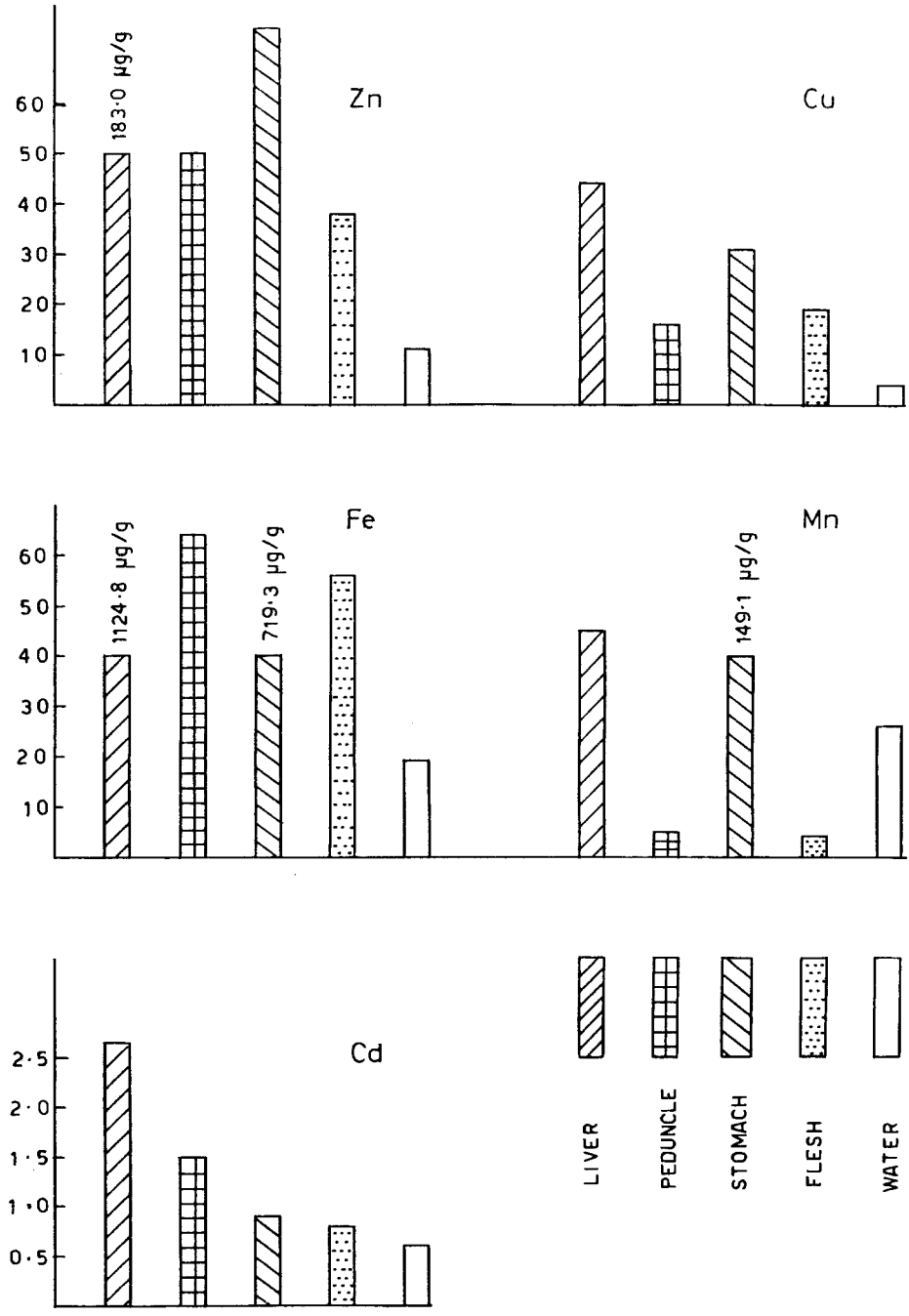

Fig. 1. Mean concentrations of heavy metals in $\mu g\, g^{-1}$ accumulated in the different parts of *Tilapia* fish sampled from Lake Mariut during August 1978–September 1979 compared with the mean concentrations found in the lake water in $\mu g\, l^{-1}$ during the same period.

lake water were much lower than those obtained from different parts of the fishes. This shows the ability of fish to concentrate metals in its different parts relative to those found in the surrounding water medium.

4. Summary

Occurrence and distribution of heavy metals in the water of the heavily polluted Lake Mariut during August 1978–September 1979 as well as the accumulation of these metals in the different parts of the common fish, *Tilapia* species, were studied and discussed. The mean concentrations of the measured Zn, Cu, Fe, Mn, and Cd in the lake water were 10.9, 4.2, 19.1, 26.2, and 0.62 $\mu g\, l^{-1}$, respectively. Generally, considerable differences were found between the monthly average concentrations of Fe and Mn, whereas no large differences were observed for Zn, Cu, and Cd. The variations in concentrations of the metals in the lake water are mostly attributed to variations in the discharge rate of the wastes entering into the lake. Lake Mariut can be divided into two different water bodies, the western oxic waters and the eastern anoxic waters. The concentrations of Zn, Cu, Fe and Mn in the eastern waters were relatively higher than those in the western waters, due to the direct effects of the dumped wastes.

The mean concentrations of heavy metals in the liver and the stomach of *Tilapia* were markedly higher than those present in the edible flesh parts of the fish. The mean concentrations of heavy metals found in the lake water were much lower than those obtained from different parts of the fishes.

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