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# Accumulation of Some Heavy Metals in *Tilapia Zillii* Organs From Lake Manzalah, Egypt

Mohamed Ali ZYADAH
Environmental Sciences Department, Faculty of Science at Damietta, (Mansoura University), Damietta, Egypt

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**Abstract:** The accumulation of copper, zinc, cadmium and lead in flesh, gills, liver and gonads of *Tilapia zillii* were determined. Fish sizes, sexes and metal accumulation by the fish organs were studied. The levels of those heavy metals are occasionally higher in females than in males, this could be attributed to the fact that females have a higher tendency to accumulate heavy metals in fish 8-11 cm in length were obtained, while medium sizes of fish (11-13 cm) showed more remarkable concentrations than the other sizes through both seasons and sites. The flesh accumulated low concentrations of heavy metals in comparison with the other organs. The values were in close agreement with other reported values in the area and the Mediterranean Region.

**Key Words:** *Tilapia zillii,* copper, zinc, cadmium, lead, Lake Manzalah.

## Mısır Manzalah Gölündeki *Tillapia zilli* Organlarında Bazı Ağır Metallerin Çevresel Değerlendirilmesi

**Özet:** Mısır'ın Menzalah Gölündeki *Tillapia zilli* balıklarının kas dokularında, solungaçlarında, karaciğerlerinde ve gonadlarında; bakır, çinko, kadmiyum, kurşun gibi ağır metallerin konsantrasyonları saptanmıştır. Balık organlarındaki ağır metal yüzdeleri ile balık boyu ve cinsiyeti arasında bir ilişki belirlenmiştir. Dişilerdeki ağır metal değerleri erkeklerinkinden yüksektir. Ağır metal konsantrasyonları her iki mevsim ve istasyonda da diğer boy gruplarına kıyasla; küçük boy grubundaki (8-11 cm) balıklarda daha az; fakat orta boy grubundaki (11-13 cm) balıklarda daha fazla bulunmuştur. Kas dokusundaki ağır metal konsantrasyonları diğer organlarınkinden daha dşüktür. Dişiler üreme organlarında erkeklerden daha çok ağır metal biriktirme eğilimindedirler. Elde edilen değerler çalışma yöresi ve Akdeniz Bölgesi'nde rapor edilen diğer değerlerle uyum göstermektir.

**Anahtar Sözcükler**: *Tillapia zilli,* bakır, çinko, kadmiyum, kurşun, Menzalah Gölü.

## Introduction

Lake Manzalah is considered an important source of fish in Egypt for many reasons. First, it has the largest overall area of the natural lakes in Egypt. Second, it is connected to the Mediterranean Sea from the north-norteastern coast and also to the Nile Damietta Branch at Damietta. Third, it is surrounded by five governorates which share the food resources among their populations (1).

The lake was a brackish environment, but recently it changed to nearly eutrophic fresh water. This change is a result of many causes: large amounts of drainage water from industrial and urban sewage that contribute about 98% of the total annual inflow water to the lake (2); large quantity of the agricultural drainage water affects the environment of Lake Manzalah especially after both the flow from the River Nile ceased in 1965 after the Aswan High Dam Construction (3); and the El-Salam Canal project which affected the aquatic environment of the lake. All these sources of pollution affect the physico-chemical characteristics of the water, sediment and biological components, and then badly affect the quality and quantity of fishes.

Cichlidae species are the most popular and highly economic fishes in most lakes in Egypt and they play the essential role in the Lake Manzalah fisheries (4). This family has many species in Lake Manzalah such as *Oreochromis aureus, Oreochromis niloticus, Tilapia zillii and Oreochromis gallili. Tilapia zillii* is distinguished by its adaptation to living in fresh, brackish and nearly saline water, and can survive in partially polluted water (5).

The purpose of this research was to quantify the accumulation of heavy metals (copper, zinc, cadmium and lead) within some organs of *Tilapia zillii* (flesh, gills, liver and gonads) where this fish is considered one of the commercial fish for both the fisheries and the local inhabitants for which it is a potential source of food. Studying the relation between the biological parameters of fish and the tendency of metal accumulation shows the environmental state. This will be useful as an alarm signal

to minimize he rate of pollution of heavy metals in the lake and for the management programs of the lakes.

**Material and Methods**

*Tilapia zillii* (Family:Cichlidae) was selected for the present study and collected from fives sites in Lake Manzalah during the four seasons from January to December 1996, where this species has a wide range of distribution in the aquatic habitat in Egypt. The study sites were selected to represent the regions of the lake, site I: Damietta in the north-west, site II: Matariya in the south, site III: Ibn-Salam near to the middle, site VI: Port-Said in the east and site V: Diba in the north, as illustrated in Figure 1.

Fresh fish were collected, and transported immediately to the laboratory in an ice-box. Three size groups were separated as follows: 8-11, 11-13 and 13-15 cm where 6-8 individuals were used for each size group from each site, both total weight and length were measured for the condition factor fish (K) and other parameters. The fish were dissected to separate some organs (flesh, gills, liver and gonads) according to FAO methods (6). Gonado-somatic index (GSI) and hepato-index (HI) were calculated from both weight of gonads and liver (4). The separate organs were digested using concentric nitric acid and hydrogen peroxide (1:1) v/v according to FAO methods (7). Atomic absorption spectrometry (AAS, Perkin Elmer 2380) was used for determination of copper, zinc, cadmium and lead. The results were calculated in microgram per gram wet weight (ug/g wet wt.).

**Result and Discussion**

Tables 1 to 4 show the mean values of the tested heavy metals (copper, zinc, cadmium and lead) in *Tilapia zillii* organs (flesh, gills, liver and gonads) in different sizes of fish (8-11, 11-13 and 13-15 cm), in the different selected sites of the lake during the four seasons of 1996. The lower concentrations of copper, zinc, cadmium and lead were usually recorded in flesh rather than the other organs while the higher values were recorded in the liver at both sites and seasons. From other research it is clear that the liver has a tendency to accumulate copper in high values as shown in many species of fish in different areas: in *Sparus auratus, sparus sargus, Mugil sp.* and *Siganus rivulatus* in the Mediterranean Sea (8); in *Clarias lazera* and *Oreochromis aureus* from Lake Manzalah (1); in some marine fishes from the Suez Canal and the Mediterranean Sea (9) and in some fish species of both cages and ponds of the aquaculture system in the River Nile and Lake Manzalah (10, 11).

Generally, higher concentrations of copper, zinc, cadmium and lead were observed in the medium sized fish (11-13), but lower concentrations of zinc were noted in the small sized fish (8-11 c m length), while the biggest size of organisms accumulated heavy metals more than the small size. The organs tended to accumulate high concentrations of heavy metal with the increase in size of fish at most sites, as shown in Table 2. In other research, it was found that the concentrations of Cd and Zn in muscles and visceral mass of pearl oyster *Pinctada radiata* from Red Sea increased with the increase in length (12).

In winter, as shown in Table 1, the small sized fish (8-11 cm) showed lower concentrations of copper in flesh than in the other organs, where the values of copper ranged between 0.65 µg/g wet weight in flesh at site V and 5.6 µg/g wet weight in liver in liver at site I. Zinc concentrations fluctuated between 7.15 and 44.5 µg/g wet weight. The lower value was in flesh at site VI but the higher value was in liver at site V. Cadmium concentrations were between 0.05 and 0.49 µg/g wet weight, the higher concentrations were recorded in gills and gonads at site II. Higher concentrations of lead were recorded in gills than in other organs.

In spring, as shown in Table 2, copper concentrations in *Tilapia zillii* organs at all sites were between 0.6 and 5.6 µg/g wet weight in both flesh at site V and liver at site I, respectively. Zinc concentrations were between 19.23 and 62.1 µg/g wet weight in both flesh and gonads at site II, respectively. The concentrations of zinc showed higher values (49.6 µg/g wet weight) in flesh at site I than the usual values. The higher concentrations were recorded in gonads at site I also. Cadmium concentrations were between 0.06 and 0.75 µg/g wet weight in flesh at site V and liver at site V and liver at site VI, respectively. Flesh showed high concentrations of cadmium at all sites except site V at which it had lower concentrations of cadmium at all sizes. There was no regular pattern of cadmium bioaccumulation through either different sizes of fish or different sites, but the bioaccumulation of zinc and cadmium in liver increased with the increase in size of fish as shown in Table 2. Lead concentrations were between 0.05 and 0.77 µg/g wet weight at both site IV in flesh and site VI in gonads, respectively. Gonads and liver showed higher values of lead especially at site III than at other sites.

In summer, as shown in Table 3, copper concentrations in *Tilapia zillii* organs were between 0.35 and 8.37 µg/g wet weight in both flesh at site I and liver at site V, respectively. Zinc cncentrations were between 5.4 and 39.3 µg/g wet weight in flesh at site V and in

Table 1. Heavy metal concentrations (ug/g wet wt.) in different organs of *Tilapia zillii* collected from five sites of Lake Manzalah during winter 1996.

| Parameter / Site | Size range (cm) | Total weight (g) | SE of fish weight | Sex | (GSI) | (HI) | (K) | Flesh | | | | Gills | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Cu | Zn | Cd | Pb | Cu | Zn | Cd | Pb |
| | 8.11 | 21.6 | ±1.3 | male | 1.14 | 2.85 | 2.1 | 0.231 | 9.05 | 0.05 | 0.33 | 1.32 | 25.09 | 0.08 | 0.51 |
| | 11–13 | 33.5 | ±1.8 | female | 1.01 | 2.66 | 1.74 | 0.38 | 13.35 | 0.07 | 0.41 | 1.48 | 33.51 | 0.12 | 0.6 |
| I | 13–15 | 80.2 | ±2.6 | male | 0.80 | 1.69 | 2.8 | 0.31 | 12.41 | 0.07 | 0.38 | 1.42 | 29.34 | 0.09 | 0.59 |
| Mean SE | | | | | | | | ±0.17 | ±2.36 | ±0.01 | ±0.15 | ±0.21 | ±2.52 | ±0.03 | ±0.15 |
| | 8–11 | 18.1 | ±1.8 | male | 0.26 | 2.5 | 1.79 | 0.38 | 10.26 | 0.08 | 0.26 | 1.56 | 34.15 | 0.36 | 0.59 |
| | 11–13 | 35 | ±2.3 | female | 0.88 | 1.86 | 1.8 | 0.49 | 15.01 | 0.13 | 0.29 | 1.79 | 40.72 | 0.44 | 0.68 |
| II | 13–15 | 53.6 | ±3.9 | female | 0.39 | 1.93 | 1.84 | 0.44 | 12.9 | 0.11 | 0.31 | 1.68 | 38.61 | 0.49 | 0.64 |
| Mean SE | | | | | | | | ±0.14 | ±1.22 | ±0.02 | ±0.07 | ±0.26 | ±4.15 | ±0.11 | ±0.21 |
| | 8–11 | 16.8 | ±0.9 | male | 0.64 | 2.53 | 1.76 | 0.28 | 8.35 | 0.06 | 0.21 | 2.01 | 24.33 | 0.17 | 0.61 |
| | 11–13 | 31.8 | ±2.1 | female | 1.05 | 2.45 | 1.65 | 0.42 | 12.94 | 0.08 | 0.28 | 2.18 | 30.15 | 0.21 | 0.67 |
| III | 13–15 | 59.4 | ±3.2 | female | 5.2 | 2.1 | 2.1 | 0.36 | 13.11 | 0.05 | 0.27 | 1.99 | 28.11 | 0.16 | 0.65 |
| Mean SE | | | | | | | | ±0.23 | ±2.74 | ±0.04 | ±0.10 | ±0.38 | ±6.55 | ±0.05 | ±0.15 |
| | 8–11 | 15.1 | ±1.8 | male | 0.2 | 2.9 | 1.56 | 0.46 | 7.15 | 0.08 | 0.18 | 1.33 | 26.21 | 0.11 | 0.76 |
| VI | 11–13 | 32 | ±2.3 | female | 3.2 | 2.8 | 1.63 | 0.56 | 11.33 | 0.12 | 0.23 | 1.46 | 35.1 | 0.13 | 0.81 |
| | 13–15 | 52.6 | ±4.2 | male | 0.46 | 1.9 | 1.86 | 0.57 | 10.27 | 0.10 | 0.25 | 1.41 | 37.18 | 0.13 | 0.68 |
| Mean SE | | | | | | | | ±0.11 | ±1.58 | ±0.02 | ±0.09 | ±0.29 | ±4.24 | ±0.05 | ±0.19 |
| | 8–11 | 17.4 | ±1.2 | male | 0.66 | 2.33 | 1.77 | 0.39 | 8.11 | 0.06 | 0.23 | 1.96 | 30.71 | 0.08 | 0.41 |
| V | 11–13 | 28.1 | ±2.1 | female | 2.91 | 2.5 | 1.4 | 0.49 | 12.09 | 0.08 | 0.29 | 2.12 | 41.16 | 0.11 | 0.55 |
| | 13–15 | 63.9 | ±3.6 | female | 0.53 | 1.78 | 2.3 | 0.54 | 13.61 | 0.07 | 0.27 | 1.99 | 38.82 | 0.09 | 0.52 |
| Mean SE | | | | | | | | ±0.18 | ±2.17 | ±0.01 | ±0.07 | ±0.13 | ±2.10 | ±0.04 | ±0.14 |

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| Liver | | | | Gonads | | | |
|---|---|---|---|---|---|---|---|
| Cu | Zn | Cd | Pb | Cu | Zn | Cd | Pb |
| 10.87 | 25.63 | 0.06 | 0.28 | 1.98 | 25.15 | 0.06 | 0.28 |
| 12.48 | 38.15 | 0.09 | 0.26 | 2.63 | 38.03 | 0.11 | 0.34 |
| 11.65 | 41.06 | 0.09 | 0.34 | 2.38 | 34.71 | 0.10 | 0.32 |
| ±1.86 | ±4.67 | ±0.02 | ±0.09 | ±0.43 | ±4.86 | ±0.05 | ±0.11 |
| 18.25 | 26.13 | 0.24 | 0.18 | 1.21 | 19.21 | 0.38 | 0.16 |
| 20.37 | 37.93 | 0.32 | 0.24 | 1.96 | 26.41 | 0.44 | 0.24 |
| 17.48 | 33.51 | 0.29 | 0.22 | 1.87 | 29.33 | 0.33 | 0.25 |
| ±2.41 | ±3.21 | ±0.08 | ±0.09 | ±0.51 | ±2.68 | ±0.15 | ±0.13 |
| 14.05 | 22.11 | 0.13 | 0.27 | 1.75 | 14.25 | 0.13 | 0.33 |
| 16.33 | 36.42 | 0.21 | 0.31 | 1.84 | 22.15 | 0.19 | 0.28 |
| 15.42 | 33.2 | 0.17 | 0.28 | 1.91 | 20.36 | 0.17 | 0.26 |
| ±1.10 | ±3.47 | ±0.04 | ±0.11 | ±0.36 | ±2.13 | ±0.06 | ±0.09 |
| 4.78 | 28.15 | 0.11 | 0.29 | 1.21 | 29.24 | 0.15 | 0.32 |
| 5.61 | 37.52 | 0.14 | 0.38 | 1.38 | 38.6 | 0.24 | 0.36 |
| 5.53 | 32.19 | 0.12 | 0.36 | 1.35 | 35.82 | 0.19 | 0.33 |
| ±0.62 | ±5.20 | ±0.05 | ±0.14 | ±0.37 | ±4.72 | ±0.11 | ±0.13 |
| 20.09 | 32.92 | 0.19 | 0.21 | 1.63 | 25.12 | 0.11 | 0.23 |
| 23.22 | 44.50 | 0.24 | 0.26 | 1.98 | 43.72 | 0.15 | 0.21 |
| 22.81 | 40.42 | 0.22 | 0.24 | 1.74 | 38.7 | 0.14 | 0.19 |
| 2.56 | ±4.25 | ±0.09 | ±0.12 | ±0.41 | ±5.24 | ±0.03 | ±0.10 |

SE: Standard error of metal concentrations
GSI: Gonado-somatic index of fish
HI: Hepatic index of fish
K: Condition factor of fish

gonads at site II, respectively. Gonads and liver, respectively showed higher values of zinc than the other organs especially at site I and II. Cadmium concentrations were between 0.05 and 0.36 µg/g wet weight in both flesh and gills, respectively at site V. The high concentrations of cadmium fluctuated between the organs, where it increased at site II. Lead concentrations were between 0.08 and 0.69 µg/g wet weight in both

Table 2. Heavy metal concentrations (ug/g wet wt.) in different organs of Tilapia zillii collected from five sites of Lake Manzalah during spring 1996.

| Parameter / Site | Size range (cm) | Total weight (g) | SE of fish weight | Sex | (GI) | (HI) | (K) | Flesh | | | | Gills | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Cu | Zn | Cd | Pb | Cu | Zn | Cd | Pb |
| | 8.11 | 18.1 | ±2.1 | female | 2.4 | 1.80 | 1.49 | 1.26 | 36.60 | 0.32 | 0.16 | 1.92 | 39.50 | 0.46 | 0.23 |
| | 11–13 | 25.7 | ±1.9 | female | 1.1 | 1.30 | 1.25 | 1.50 | 49.60 | 0.30 | 0.06 | 1.80 | 43.40 | 0.44 | 0.21 |
| I | 13–15 | 86.95 | ±1.4 | male | 0.2 | 1.40 | 2.3 | 2.10 | 42.10 | 0.24 | 0.21 | 1.77 | 51.50 | 0.33 | 0.32 |
| Mean SE | | | | | | | | ±0.27 | ±3.89 | ±0.07 | ±0.03 | ±0.54 | ±3.87 | ±0.12 | ±0.08 |
| | 8–11 | 22.3 | ±1.4 | female | 1.3 | 2.10 | 1.7 | 0.90 | 39.20 | 0.53 | 0.14 | 1.50 | 40.10 | 0.42 | 0.27 |
| | 11–13 | 27.6 | ±2.8 | female | 2.5 | 1.90 | 1.5 | 1.10 | 47.62 | 0.64 | 0.11 | 1.80 | 31.20 | 0.36 | 0.29 |
| II | 13–15 | 74.5 | ±3.5 | male | 0.8 | 2.00 | 1.56 | 0.80 | 19.23 | 0.39 | 0.13 | 0.90 | 34.40 | 0.51 | 0.30 |
| Mean SE | | | | | | | | ±0.19 | ±4.25 | ±0.15 | ±0.07 | ±0.17 | ±3.21 | ±0.12 | ±0.14 |
| | 8–11 | 21.5 | ±1.7 | male | 1.4 | 1.9 | 1.6 | 0.75 | 46.25 | 0.43 | 0.52 | 0.95 | 42.40 | 0.46 | 0.22 |
| | 11–13 | 25.9 | ±1.9 | male | 1.5 | 1.8 | 1.2 | 0.90 | 26.10 | 0.46 | 0.11 | 1.30 | 34.50 | 0.31 | 0.24 |
| III | 13–15 | 68.3 | ±2.3 | male | 1.2 | 1.8 | 2.2 | 0.70 | 33.25 | 0.29 | 0.12 | 0.90 | 35.90 | 0.41 | 0.25 |
| Mean SE | | | | | | | | ±0.17 | ±3.34 | ±0.18 | ±0.15 | ±0.27 | ±2.98 | ±0.12 | ±0.14 |
| | 8–11 | 21.9 | ±0.9 | male | 0.9 | 1.89 | 2.1 | 0.75 | 40.20 | 0.33 | 0.06 | 0.85 | 40.90 | 0.48 | 0.10 |
| VI | 11–13 | 46.7 | ±2.5 | female | 4.7 | 2.4 | 2.3 | 0.80 | 38.40 | 0.36 | 0.09 | 1.00 | 32.30 | 0.40 | 0.19 |
| | 13–15 | 60.5 | ±2.7 | male | 1.9 | 2.2 | 1.9 | 0.70 | 31.90 | 0.41 | 0.08 | 0.70 | 34.10 | 0.44 | 0.21 |
| Mean SE | | | | | | | | ±0.24 | ±2.57 | ±0.14 | ±0.01 | ±0.21 | ±4.12 | ±0.17 | ±0.04 |
| | 8–11 | 18.5 | ±0.8 | male | 0.5 | 2.4 | 1.8 | 0.60 | 40.20 | 0.07 | 0.23 | 0.8 | 30.71 | 0.08 | 0.41 |
| V | 11–13 | 34.9 | ±0.9 | male | 1.2 | 2.2 | 1.8 | 0.90 | 36.50 | 0.08 | 0.29 | 0.90 | 41.16 | 0.11 | 0.55 |
| | 13–15 | 53.2 | ±2.5 | male | 1.1 | 2.3 | 1.6 | 0.90 | 46.40 | 0.06 | 0.27 | 1.10 | 44.10 | 0.09 | 0.52 |
| Mean SE | | | | | | | | ±0.29 | ±3.88 | ±0.05 | ±0.07 | ±0.12 | ±3.11 | ±0.12 | ±0.02 |

Continued

| Liver | | | | Gonads | | | |
|---|---|---|---|---|---|---|---|
| Cu | Zn | Cd | Pb | Cu | Zn | Cd | Pb |
| 4.20 | 36.50 | 0.49 | 0.19 | 1.41 | 46.10 | 0.42 | 0.15 |
| 4.900 | 40.10 | 0.45 | 0.22 | 1.60 | 48.30 | 0.36 | 0.11 |
| 5.600 | 46.50 | 0.50 | 0.21 | 0.90 | 62.10 | 0.40 | 0.16 |
| ±0.49 | ±4.25 | ±0.14 | ±0.11 | ±0.32 | ±6.78 | ±0.12 | ±0.09 |
| 1.90 | 22.30 | 0.46 | 0.26 | 1.40 | 35.60 | 0.39 | 0.23 |
| 2.10 | 10.80 | 0.39 | 0.29 | 1.30 | 31.90 | 0.24 | 0.22 |
| 2.60 | 34.50 | 0.30 | 0.35 | 0.90 | 56.55 | 0.65 | 0.18 |
| ±0.24 | ±3.27 | ±0.09 | ±0.13 | ±0.25 | ±5.28 | ±0.08 | ±0.06 |
| 1.40 | 42.30 | 0.29 | 0.21 | 1.10 | 47.10 | 0.31 | 0.16 |
| 1.60 | 46.25 | 0.41 | 0.25 | 1.20 | 48.10 | 0.25 | 0.19 |
| 1.90 | 48.10 | 0.57 | 0.27 | 0.08 | 40.30 | 0.29 | 0.15 |
| ±0.25 | ±3.21 | ±0.12 | ±0.09 | ±0.11 | ±6.14 | ±0.13 | ±0.09 |
| 1.20 | 39.10 | 0.75 | 0.28 | 0.80 | 45.10 | 0.24 | 0.63 |
| 1.90 | 43.20 | 0.39 | 0.42 | 0.90 | 47.35 | 0.45 | 0.77 |
| 2.70 | 46.40 | 0.51 | 0.40 | 0.65 | 38.20 | 0.32 | 0.67 |
| ±0.51 | ±5.80 | ±0.21 | ±0.11 | ±0.28 | ±4.21 | ±0.09 | ±0.24 |
| 3.50 | 32.92 | 0.19 | 0.21 | 1.63 | 25.12 | 0.11 | 0.23 |
| 4.25 | 44.50 | 0.24 | 0.26 | 1.98 | 43.72 | 0.15 | 0.21 |
| 3.60 | 40.42 | 0.22 | 0.24 | 1.74 | 38.7 | 0.14 | 0.19 |
| ±0.45 | ±4.85 | ±0.15 | ±0.03 | ±0.34 | ±7.12 | ±0.11 | ±0.07 |

SE: Standard error of metal concentrations
GSI: Gonado-somatic index of fish
HI: Hepatic index of fish
K: Condition factor of fish

flesh at site I and gills at site V, respectively. Gonads and liver showed remarkable concentrations of lead at most sites.

In autumn, as shown in Table 4, copper concentrations in *Tilapia zillii* organs were between 0.4 and 11.65 µg/g wet weight in gonads at site IV and in

Table 3. Heavy metal concentrabitons (ug/g wet wt.) in different organs of *Tilapia zillii* collected from five sites of Lake Manzalah during summer 1996.

| Parameter / Site | Size range (cm) | Total weight (g) | SE of fish weight | Sex | (GI) | (HI) | (K) | Flesh Cu | Flesh Zn | Flesh Cd | Flesh Pb | Gills Cu | Gills Zn | Gills Cd | Gills Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8.11 | 18.1 | ±2.1 | female | 2.4 | 1.80 | 1.49 | 1.26 | 36.60 | 0.32 | 0.16 | 1.92 | 39.50 | 0.46 | 0.23 |
| | 11–13 | 25.7 | ±1.9 | female | 1.1 | 1.30 | 1.25 | 1.50 | 49.60 | 0.30 | 0.06 | 1.80 | 43.40 | 0.44 | 0.21 |
| I | 13–15 | 86.95 | ±1.4 | male | 0.2 | 1.40 | 2.3 | 2.10 | 42.10 | 0.24 | 0.21 | 1.77 | 51.50 | 0.33 | 0.32 |
| Mean SE | | | | | | | | ±0.27 | ±3.89 | ±0.07 | ±0.03 | ±0.54 | ±3.87 | ±0.12 | ±0.08 |
| | 8–11 | 22.3 | ±1.4 | female | 1.3 | 2.10 | 1.7 | 0.90 | 39.20 | 0.53 | 0.14 | 1.50 | 40.10 | 0.42 | 0.27 |
| | 11–13 | 27.6 | ±2.8 | female | 2.5 | 1.90 | 1.5 | 1.10 | 47.62 | 0.64 | 0.11 | 1.80 | 31.20 | 0.36 | 0.29 |
| II | 13–15 | 74.5 | ±3.5 | male | 0.8 | 2.00 | 1.56 | 0.80 | 19.23 | 0.39 | 0.13 | 0.90 | 34.40 | 0.51 | 0.30 |
| Mean SE | | | | | | | | ±0.19 | ±4.25 | ±0.15 | ±0.07 | ±0.17 | ±3.21 | ±0.12 | ±0.14 |
| | 8–11 | 21.5 | ±1.7 | male | 1.4 | 1.9 | 1.6 | 0.75 | 46.25 | 0.43 | 0.52 | 0.95 | 42.40 | 0.46 | 0.22 |
| | 11–13 | 25.9 | ±1.9 | male | 1.5 | 1.8 | 1.2 | 0.90 | 26.10 | 0.46 | 0.11 | 1.30 | 34.50 | 0.31 | 0.24 |
| III | 13–15 | 68.3 | ±2.3 | male | 1.2 | 1.8 | 2.2 | 0.70 | 33.25 | 0.29 | 0.12 | 0.90 | 35.90 | 0.41 | 0.25 |
| Mean SE | | | | | | | | ±0.17 | ±3.34 | ±0.18 | ±0.15 | ±0.27 | ±2.98 | ±0.12 | ±0.14 |
| | 8–11 | 21.9 | ±0.9 | male | 0.9 | 1.89 | 2.1 | 0.75 | 40.20 | 0.33 | 0.06 | 0.85 | 40.90 | 0.48 | 0.10 |
| VI | 11–13 | 46.7 | ±2.5 | female | 4.7 | 2.4 | 2.3 | 0.80 | 38.40 | 0.36 | 0.09 | 1.00 | 32.30 | 0.40 | 0.19 |
| | 13–15 | 60.5 | ±2.7 | male | 1.9 | 2.2 | 1.9 | 0.70 | 31.90 | 0.41 | 0.08 | 0.70 | 34.10 | 0.44 | 0.21 |
| Mean SE | | | | | | | | ±0.24 | ±2.57 | ±0.14 | ±0.01 | ±0.21 | ±4.12 | ±0.17 | ±0.04 |
| | 8–11 | 18.5 | ±0.8 | male | 0.5 | 2.4 | 1.8 | 0.60 | 40.20 | 0.07 | 0.23 | 0.8 | 30.71 | 0.08 | 0.41 |
| V | 11–13 | 34.9 | ±0.9 | male | 1.2 | 2.2 | 1.8 | 0.90 | 36.50 | 0.08 | 0.29 | 0.90 | 41.16 | 0.11 | 0.55 |
| | 13–15 | 53.2 | ±2.5 | male | 1.1 | 2.3 | 1.6 | 0.90 | 46.40 | 0.06 | 0.27 | 1.10 | 44.10 | 0.09 | 0.52 |
| Mean SE | | | | | | | | ±0.29 | ±3.88 | ±0.05 | ±0.07 | ±0.12 | ±3.11 | ±0.12 | ±0.02 |

Continued

| Liver Cu | Liver Zn | Liver Cd | Liver Pb | Gonads Cu | Gonads Zn | Gonads Cd | Gonads Pb |
|---|---|---|---|---|---|---|---|
| 4.20 | 36.50 | 0.49 | 0.19 | 1.41 | 46.10 | 0.42 | 0.15 |
| 4.900 | 40.10 | 0.45 | 0.22 | 1.60 | 48.30 | 0.36 | 0.11 |
| 5.600 | 46.50 | 0.50 | 0.21 | 0.90 | 62.10 | 0.40 | 0.16 |
| ±0.49 | ±4.25 | ±0.14 | ±0.11 | ±0.32 | ±6.78 | ±0.12 | ±0.09 |
| 1.90 | 22.30 | 0.46 | 0.26 | 1.40 | 35.60 | 0.39 | 0.23 |
| 2.10 | 10.80 | 0.39 | 0.29 | 1.30 | 31.90 | 0.24 | 0.22 |
| 2.60 | 34.50 | 0.30 | 0.35 | 0.90 | 56.55 | 0.65 | 0.18 |
| ±0.24 | ±3.27 | ±0.09 | ±0.13 | ±0.25 | ±5.28 | ±0.08 | ±0.06 |
| 1.40 | 42.30 | 0.29 | 0.21 | 1.10 | 47.10 | 0.31 | 0.16 |
| 1.60 | 46.25 | 0.41 | 0.25 | 1.20 | 48.10 | 0.25 | 0.19 |
| 1.90 | 48.10 | 0.57 | 0.27 | 0.08 | 40.30 | 0.29 | 0.15 |
| ±0.25 | ±3.21 | ±0.12 | ±0.09 | ±0.11 | ±6.14 | ±0.13 | ±0.09 |
| 1.20 | 39.10 | 0.75 | 0.28 | 0.80 | 45.10 | 0.24 | 0.63 |
| 1.90 | 43.20 | 0.39 | 0.42 | 0.90 | 47.35 | 0.45 | 0.77 |
| 2.70 | 46.40 | 0.51 | 0.40 | 0.65 | 38.20 | 0.32 | 0.67 |
| ±0.51 | ±5.80 | ±0.21 | ±0.11 | ±0.28 | ±4.21 | ±0.09 | ±0.24 |
| 3.50 | 32.92 | 0.19 | 0.21 | 1.63 | 25.12 | 0.11 | 0.23 |
| 4.25 | 44.50 | 0.24 | 0.26 | 1.98 | 43.72 | 0.15 | 0.21 |
| 3.60 | 40.42 | 0.22 | 0.24 | 1.74 | 38.7 | 0.14 | 0.19 |
| ±0.45 | ±4.85 | ±0.15 | ±0.03 | ±0.34 | ±7.12 | ±0.11 | ±0.07 |

SE: Standard error of metal concentrations
GSI: Gonado-somatic index of fish
HI: Hepatic index of fish
K: Condition factor of fish

liver at site II, respectively. Zinc concentrations were between 5.39 and 35.5 µg/g wet weight in both flesh and gills at site V, respectively. Cadmium concentrations were between 0.03 and 0.51 µg/g wet weight in both flesh at site V and gonads at site II, respectively. The higher concentrations of cadmium appeared in liver and gonads. Lead concentrations were between 0.19 and 0.78 µg/g wet weight in both gonads at site IV and liver at site II, respectively.

Table 4. Heavy metal concentrations (ug/g wet wt.) in different organs of *Tilapia zillii* collected from five sites of Lake Manzalah during autumn 1996.

| Parameter / Site | Size range (cm) | Total weight (gm) | tandar eror SE | Sex | Gonad index (GI) | Hepatic index (HI) | ondition factor (K) | Flesh Cu | Flesh Zn | Flesh Cd | Flesh Pb | Gills Cu | Gills Zn | Gills Cd | Gills Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8.11 | 25.1 | ±1.6 | male | 0.46 | 3.11 | 2.10 | 0.58 | 9.81 | 0.06 | 0.26 | 1.34 | 15.39 | 0.14 | 0.41 |
| | 11–13 | 40.2 | ±2.8 | male | 0.25 | 2.38 | 2.00 | 0.67 | 13.42 | 0.12 | 0.36 | 1.75 | 28.62 | 0.21 | 0.53 |
| I | 13–15 | 26.7 | ±5.1 | male | 0.16 | 2.42 | 1.80 | 0.73 | 11.65 | 0.09 | 0.22 | 1.57 | 23.30 | 0.17 | 0.51 |
| Mean SE | | | | | | | | ±0.22 | ±2.13 | ±0.05 | ±0.12 | ±0.34 | ±2.35 | ±0.09 | ±0.17 |
| | 8–11 | 27.4 | ±1.3 | male | 0.4 | 2.02 | 2.70 | 0.76 | 13.61 | 0.09 | 0.28 | 3.79 | 26.30 | 0.16 | 0.59 |
| | 11–13 | 42.7 | ±2.8 | female | 0.4 | 1.88 | 2.20 | 0.96 | 18.55 | 0.15 | 0.40 | 4.81 | 30.21 | 0.24 | 0.75 |
| II | 13–15 | 58.1 | ±3.5 | male | 0.5 | 1.76 | 2.00 | 0.85 | 18.11 | 0.14 | 0.38 | 4.35 | 28.71 | 0.19 | 0.69 |
| Mean SE | | | | | | | | ±0.28 | ±2.35 | ±0.02 | ±0.09 | ±0.85 | ±3.57 | ±0.12 | ±0.17 |
| | 8–11 | 25.5 | ±0.9 | male | 0.43 | 2.58 | 2.60 | 0.61 | 7.30 | 0.06 | 0.23 | 1.86 | 13.84 | 0.15 | 0.35 |
| | 11–13 | 41.1 | ±2.1 | female | 0.26 | 2.13 | 2.00 | 0.74 | 10.10 | 0.12 | 0.33 | 2.31 | 20.51 | 0.19 | 0.29 |
| III | 13–15 | 56.4 | ±2.9 | male | 0.25 | 1.75 | 1.90 | 0.63 | 9.15 | 0.11 | 0.29 | 1.97 | 17.40 | 0.18 | 0.41 |
| Mean SE | | | | | | | | ±0.18 | ±1.25 | ±0.05 | ±0.11 | ±0.24 | ±2.55 | ±0.05 | ±0.12 |
| | 8–11 | 19.3 | ±0.8 | male | 0.30 | 2.90 | 1.90 | 0.68 | 11.33 | 0.34 | 1.23 | 28.22 | 0.15 | 0.45 | 0.10 |
| VI | 11–13 | 39.6 | ±1.9 | male | 0.29 | 2.80 | 1.90 | 0.80 | 16.81 | 0.41 | 1.56 | 35.40 | 0.18 | 0.54 | 0.19 |
| | 13–15 | 70.7 | ±3.2 | female | 0.30 | 2.60 | 2.20 | 0.65 | 14.71 | 0.42 | 1.47 | 34.82 | 0.17 | 0.49 | 0.21 |
| Mean SE | | | | | | | | ±0.21 | ±2.56 | ±0.11 | ±0.19 | ±5.21 | ±0.09 | ±0.20 | ±0.04 |
| | 8–11 | 15.9 | ±1.2 | male | 0.60 | 2.70 | 2.70 | 1.60 | 0.41 | 0.07 | 0.23 | 0.8 | 30.71 | 0.08 | 0.41 |
| V | 11–13 | 44.6 | ±2.2 | male | 0.15 | 2.0 | 2.0 | 2.30 | 0.56 | 0.08 | 0.29 | 0.90 | 41.16 | 0.11 | 0.55 |
| | 13–15 | 61.2 | ±3.8 | male | 0.55 | 2.10 | 2.10 | 1.90 | 0.47 | 0.06 | 0.27 | 1.10 | 44.10 | 0.09 | 0.52 |
| Mean SE | | | | | | | | ±0.29 | ±30.18 | ±0.75 | ±0.07 | ±0.12 | ±3.11 | ±0.12 | ±0.02 |

Continued

| Liver Cu | Liver Zn | Liver Cd | Liver Pb | Gonads Cu | Gonads Zn | Gonads Cd | Gonads Pb |
|---|---|---|---|---|---|---|---|
| 4.20 | 36.50 | 0.49 | 0.19 | 1.41 | 46.10 | 0.42 | 0.15 |
| 4.900 | 40.10 | 0.45 | 0.22 | 1.60 | 48.30 | 0.36 | 0.11 |
| 5.600 | 46.50 | 0.50 | 0.21 | 0.90 | 62.10 | 0.40 | 0.16 |
| ±0.49 | ±4.25 | ±0.14 | ±0.11 | ±0.32 | ±6.78 | ±0.12 | ±0.09 |
| 1.90 | 22.30 | 0.46 | 0.26 | 1.40 | 35.60 | 0.39 | 0.23 |
| 2.10 | 10.80 | 0.39 | 0.29 | 1.30 | 31.90 | 0.24 | 0.22 |
| 2.60 | 34.50 | 0.30 | 0.35 | 0.90 | 56.55 | 0.65 | 0.18 |
| ±0.24 | ±3.27 | ±0.09 | ±0.13 | ±0.25 | ±5.28 | ±0.08 | ±0.06 |
| 1.40 | 42.30 | 0.29 | 0.21 | 1.10 | 47.10 | 0.31 | 0.16 |
| 1.60 | 46.25 | 0.41 | 0.25 | 1.20 | 48.10 | 0.25 | 0.19 |
| 1.90 | 48.10 | 0.57 | 0.27 | 0.08 | 40.30 | 0.29 | 0.15 |
| ±0.25 | ±3.21 | ±0.12 | ±0.09 | ±0.11 | ±6.14 | ±0.13 | ±0.09 |
| 1.20 | 39.10 | 0.75 | 0.28 | 0.80 | 45.10 | 0.24 | 0.63 |
| 1.90 | 43.20 | 0.39 | 0.42 | 0.90 | 47.35 | 0.45 | 0.77 |
| 2.70 | 46.40 | 0.51 | 0.40 | 0.65 | 38.20 | 0.32 | 0.67 |
| ±0.51 | ±5.80 | ±0.21 | ±0.11 | ±0.28 | ±4.21 | ±0.09 | ±0.24 |
| 3.50 | 32.92 | 0.19 | 0.21 | 1.63 | 25.12 | 0.11 | 0.23 |
| 4.25 | 44.50 | 0.24 | 0.26 | 1.98 | 43.72 | 0.15 | 0.21 |
| 3.60 | 40.42 | 0.22 | 0.24 | 1.74 | 38.7 | 0.14 | 0.19 |
| ±0.45 | ±4.85 | ±0.15 | ±0.03 | ±0.34 | ±7.12 | ±0.11 | ±0.07 |

SE: Standard error of metal concentrations
GSI: Gonado-somatic index of fish
HI: Hepatic index of fish
K: Condition factor of fish

Sites I, II and V, showed higher concentrations of copper, zinc, cadmium and lead than sites III and IV, where these sites receive huge amounts of mixed waste water (partially treated) discharged into site II from many sources (Bahr el-Bakar, Bahr Hadous and Bahr Ramsis). Port-Said city discharges its waste water into site IV, while site V is considered the connecting point between Damietta drains discharging into Lake Manzalah and the

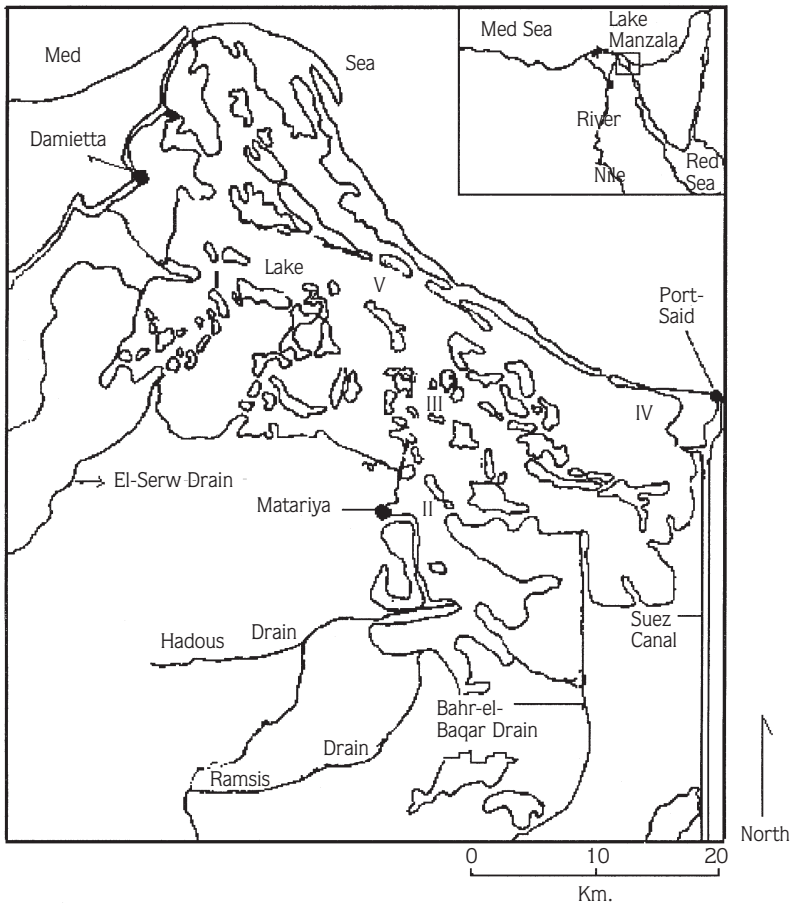


Figure 1. Map of Lake Manzalah showing the sites of sampling.

Nile Estuary (1, 15). In winter and spring higher values of copper, zinc, cadmium and lead were recorded than in the other seasons especially at sites V and II, this remarkable increase in winter and spring was due to the decrease in waste water from agricultural activities during this time. There was a positive significance (<0.05) between the concentrations of heavy metal concentrations within organs of fish and sites, while there was no clear significant between the comparable factors (site, season and organ).

Sometimes, females showed higher concentrations of heavy metals than males, the concentration increased with the increase in the gonado-somatic index, whereas the higher values of the gonado-somatic index (GSI) showed higher concentrations of heavy metals, especially in small sizes of fish in both winter and summer. This increase may be attributed to the higher tendency of accumulation by ovaries than testes. Other research in many aquatic organisms such as crustacean *Nephrops norvegicus* showed that the sex is an important factor for heavy metal levels, and females accumulated higher values than males (14). The higher concentrations of cadmium and lead in *Tilapia zillii* organs fluctuated in value between gills, gonads and liver, respectively. These results are consistent with other data on some fishes from Calcasieu Lake and Calcasieu River in USA (13).

A comparison of the results with other reported values in the flesh and liver of *Mullus barbatus* from the Mediterranean area gives Cu values (2.5 and 1.8); Zn values (26.3 and 13.7) and Cd values (0.23 and 0.26) ppm wet weight, respectively from Adriatic Sea in Yugoslavia (14). In the Mersin area in Turkey, the concentrations of Cu, Pb and Cd in the flesh of *Mullus barbatus* were 0.69, 0.12 and 0.04 ppm wet weight, respectively (14). In Italy, Cu, Zn, Cd and Pb in the flesh of *Mullus barbatus* were 10.75, 26.15, 0.02 and 0.2 ppm wet weight, respectively (14). In lebanon, Cu, Cd and Pb in the flesh of *Mullus barbatus* were 0.51, 0.19 and 1.2 ppm wet weight, respectively (14). In Israel, Cu, Zn, Cd and Pb in the flesh of fish were 1.15, 0.53, 0.51 and 6.73 ppm wet weight, respectively (14), and in some fishes from Lake Manzalah, Egypt (1). In addition studies

on *Oreochromis niloticus* and *Bagrus bayad* from River Nile, Egypt (11) showed that gills have a tendency to accumulate cadmium and lead in high concentrations.

These pollutants affect water, sediment and the food chain, the this change in the aquatic environment affects fish food, feeding and bioaccumulation (16, 17). Finally this bioaccumulation of heavy metals by fish organs accumulate in human blood and affects the public health (18). With respect to the world levels of heavy metals in aquatic organisms. the values should be less than this range: 0.03-30 Cu, 3.6-100 Zn, 0.03-2 Cd and 0.05-2 Pb µg/g wet weight according to Australian recommendations of NHMRC (19). It is clear that the concentrations of heavy metals were within the range of the world levels. The medium size of fish (11-13 cm) showed higher concentrations than other sizes, therefore small size of fish (8-11 cm) is recommended for eating.

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