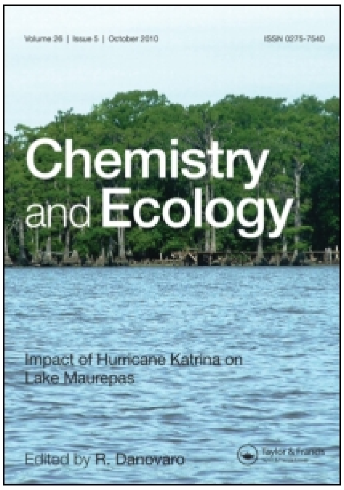


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Doaa H. Youssef; F. T. Tayel

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# METAL ACCUMULATION BY THREE *TILAPIA* SPP. FROM SOME EGYPTIAN INLAND WATERS

DOAA H. YOUSSEF* and F. T. TAYEL

*Marine Pollution Research Department, National Institute of Oceanography and Fisheries, Alexandria, Egypt*

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Five trace metals (Cu, Zn, Fe, Mn and Cd) were determined in different tissues and organs (muscle, liver, brain, gills, gonads and intestines) of some *Tilapia* spp. (*Oreochromis* spp. and *Sarotherodon galilaues*) collected from two Egyptian Lakes (Edku and Mariut, exposed to different types of pollutants), El-Umum Drain, and from the fishing farm El-Nozha Hydrodrome. Our results indicate that metal accumulation in different organs vary considerably between the same and among different *Tilapia* spp. There is a preferential accumulation of metals by different organs. Liver is a target organ for Cu accumulation, whereas the brain and flesh tissues clearly accumulate more levels of Zn than the other studied elements. Amongst the studied elements, Cd concentrations in the different organs are the lowest. It was found that edible parts of *Tilapia* spp. collected from Lake Mariut accumulate the highest levels of the studied elements (Fe, Zn, Mn and Cu for *S. galilaues* and Cd for *Oreochromis niloticus*), compared with those in the other studied areas. In general, the levels of Cd (0.0–0.11 ppm), Cu (0.25–1.85 ppm) and Zn (3.58–8.46 ppm) in the edible parts of studied fish cannot be considered as hazardous levels.

*Keywords*: Egypt; Lakes; *Tilapia* spp.; Trace elements

## 1 INTRODUCTION

The drastic expansion of human activities over the last century has contributed to an increase in the fluxes of several anthropogenic pollutants entering aquatic environments. Among such pollutants, heavy metals have received widespread attention as, in addition to their toxicity, they are not usually eliminated from the aquatic ecosystems by natural processes, in contrast to most organic pollutants (Förstner and Wittmann, 1981). Areas of special concern regarding chemical contamination are the Egyptian Lakes Mariut and Edku (two of the four Northern Nile Delta Lakes). These lakes have received various kinds of pollutants (sewage and industrial wastes as well as runoff) (Tayel, 1992; Shriadah and Tayel, 1992; Abd Alla, 1993; Youssef, 1999). Aquatic organisms are exposed to trace metals via different routes including water, sediment and food. The uptake, accumulation and toxicity of these ions strongly depend on the exposure conditions and vary orders of magnitude within and among species (Newman and McIntosh, 1991; Tessier and Turner, 1995; Newman *et al.*, 2001). Contaminants may bioaccumulate in the aquatic food web and eventually become hazards

* Corresponding author. Fax: 203-4801174; E-mail: doaa_hy@hotmail.com

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for wildlife and humans. Although some trace metals (Mn, Fe, Cu and Zn) are essential for biological functions, they become toxic at high concentrations (Menzel and Cose, 1977). In Egypt, *Tilapia* spp. is considered as one of the most commercial and common fish species used for human food consumption. During 2000, it represented 34.16% of the total fish production from natural resources (Statistics of fish production, 2000). In the present study, some *Tilapia* spp. (*Oreochromis* spp. and/or *Sarotherodon galilaues*), collected from Lakes Edku and Mariut, El-Umum Drain and from the fishing farm El Nozha Hydrodrome, were used to trace concentrations of some heavy metals (Fe, Mn, Cu, Zn and Cd) in different organs and to follow their spatial variations.

## 2 MATERIAL AND METHODS

### 2.1 Study Areas



*Lake Mariut*: it is one of the Northern Nile Delta Lakes. The lake (Fig. 1A) is situated along the Mediterranean coast of Egypt south of Alexandria city (longitude 29°51′00″–29°56′15″ E, latitude 31°04′15″–31°10′45″ N). It is closed, having no connection with the sea. At the beginning of the past century, the area of the lake was about 210 $km^2$. Subsequently, the lake area has shrunk enormously, partly due to silting and partly to land reclamation projects (Abdel-Moneim, 1977). Today its area is less than 58.8 $km^2$. Lake Mariut was divided artificially into four basins (the fish farm, the north-western (NW), the south-western (SW), and the lake proper basins). The lake proper basin (LP) receives most of its water from a heavily polluted drain El-Kalaa Drain of an average of 920,000 $m^3$ waste water per day (Youssef, 1999). The northern sector of the heavily polluted basin of the lake received daily an average of 170,000 $m^3$ partially treated wastes (Mitwally *et al.*, 1996).

*Lake Edku*: it lies along the Mediterranean coast, west of the Rosetta branch of the Nile, between latitudes 31°10′ and 31°18′ N, and longitudes 30°8′ and 30°22′ E (Fig. 1B). The Lake has numerous densely vegetated islets that emerge about 30–5 cm above water level (Samir, 2000). Two drains namely El-Khairy and Barsiek discharge huge volumes of drainage water mainly agricultural, domestic and to less extent industrial effluents.

*El-Umum Drain*: this drain (Fig. 1A) carries mainly agricultural drainage water from El-Beheira Prefecture. There is an opening between Lake Mariut and El Drain at the extreme Northwestern end of the lake that permits the disposal of surplus lake water into the drain. El-Umum Drain has the largest outflow of all the west delta drainage canals (about 8–10 million cubic meters per day).

*El-Nozha Hydrodrome*: it was separated artificially from Lake Mariut during 1939. It covers an area of about 5.04 $km^2$ and receives its water from the Nile through Mahmoudia drinking Canal. For a long time, the Hydrodrome has been used as a fish farm for some fish species (Fig. 1A).

### 2.2 Sampling

Fish samples of *Oreochromis* spp. were collected from different fishing localities of Egypt (Lake Edku, the proper basin of Lake Mariut, El-Umum Drain and El-Nozha hydrodrome). *Sarotherodon galilaues* was sampled from Lake Edku and the main basin of Lake Mariut. Samples were frozen until used. In the laboratory, total weight and total length were measured for each fish and classified into groups (Tab. I). Different organs (muscle, liver, brain, gills, gonads and intestines) were taken separately for each species and homogenized to make composite sample. From each composite sample, 2 g were taken as analytic sample and digested

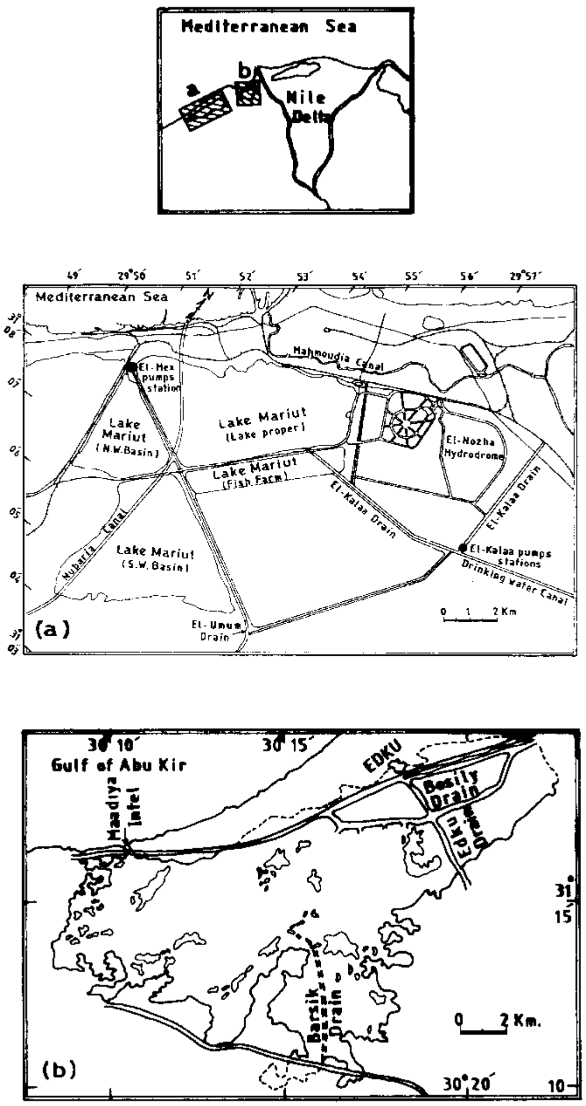


FIGURE 1 Study Areas. Reported areas are: a) Lake Mariut, El-Umum Drain, El-Nozha Hydrodrome; b) Lake Edku.

TABLE I Ranges of Total Length and Weight of Studied Fish.

| *Species* | *Region* | *Total length (cm)* | *Total weight (g)* |
|---|---|---|---|
| *O. niloticus* | Lake Edku (L) | 26–27 | 397.5–431 |
| | Lake Edku | 16–18 | 91.5–125 |
| | Lake Mariut | 14.5–17 | 60–110 |
| | El-Umum Drain | 21.5–23 | 194.9–262.9 |
| *S. galilaeus* | Lake Edku | 11.5 | 28.9–37.5 |
| | Lake Mariut | 8.0–11 | 3.6–30 |
| *O. oreus* | Lake Edku | 10.5–12 | 21–31.2 |
| | El-Nozha Hydrodrome | 18–20 | 112.6–151.8 |

*Note*: L Large size.

by $HNO_3$ inside closed teflon crucible and a hot plate with thermostatic control according to (Oregioni and Aston, 1984). The digestate was dissolved in a known volume of metal free distilled water and preserved in acid-clean PVC bottles for analysis. Concentrations of the metals (Fe, Mn, Cu, Zn and Cd) were determined using a Perkin Elmer 28301 flame atomic absorption spectrophotorneter.

## 3 RESULTS AND DISCUSSION

### 3.1 Iron

Fe is one of the essential elements for living organisms; its concentration in different tissues of fish is mainly due to the presence and metabolism of hemoglobin (Bryan, 1976). Moreover, it is the most abundant transition element (Förstner and Wittmann, 1981). Indeed, Table II shows that Fe is the dominant element in intestines, liver, gonads and gills of the studied fish. Fe concentrations fluctuated greatly not only between different organs but also between the same organ. The highest concentration of 2202.26 μg/g was recorded in intestines of *Oreochromis niloticus*, however the lowest ranges (1.41–4.74 μg/g) were found in the flesh tissue of studied species.

Fe concentration in the flesh of *S. galilaeus* from Lake Mariut is double that of Lake Edku. *Oreochromis niloticus* from Lake Edku have the lowest Fe concentration compared with that from El-Umurn Drain and Lake Mariut. According to Abdel Moati and El-Sammak (1996), Lake Mariut is the most polluted Nile Delta Lake. On the other hand, most organs of *Oreochromis aureus* from El-Nozha hydrodrome accumulated lower Fe than that of Lake Edku.

### 3.2 Zinc

Zn concentrations in gills, liver and gonads of studied fish were represented in Table III. Brain and flesh tissues clearly accumulate more levels of Zn (Tab. III) than the other studied elements (Tabs. II, IV–VI).

Based on the range values, Zn concentration range was the highest in the brain tissues (20.82–105.33 μg/g). Considerable levels of Zn were also detected in the reproductive organ (gonads), especially that of *O. niloticus* from Lake Edku (67.02 μg/g). The lowest concentration ranges of Zn were recorded in the flesh tissue of most studied species (3.58–8.46 μg/g). This trend of Zn accumulation in different organs in the present study agrees with that observed by Shakweer *et al.* (1993) for some fish species collected from Lake Edku. Chipman *et al.* (1958) pointed out that the internal organs of fish rapidly take up Zn in large amounts. The uptake and rate of loss in these organs is usually rapid. The rate of uptake in muscle and bone may be slow.

Concerning the variation in the levels of Zn in the edible part of the studied species, it was observed that *S. galilaeus* from Lake Mariut had the highest level of Zn not only in the flesh tissue (8.46 μg/g) but also in its brain (105.33 μg/g). Although *O. niloticus* was sampled from different habitats, there was no spatial variation in the level of Zn and it had the lowest Zn concentration among the studied species. The level of Zn in *O. aureus* from Lake Edku (6.21 μg/g) was close to that from El-Nozha Hydrodrome (7.04 μg/g).

### 3.3 Manganese

Mn concentrations in gills, liver and gonad of studied fish were represented in Table IV. Although Mn concentrations considerably fluctuated within the same organ, the highest

TABLE II Concentrations of Fe in Different Organs of Studied Fish (μg/g wet wt).

| *Species* | *Region* | *Muscle* | *Brain* | *Gonads* | *Liver* | *Intestines* | *Gills* |
|---|---|---|---|---|---|---|---|
| *O. niloticus* | Lake Edku (L) | 1.41 | 77.87 | 48.12 | 52.61 | 1259.73 | 34.21 |
| | Lake Edku | 1.74 | 88.33 | 27.38 | 604.26 | 2202.26 | 34.04 |
| | Lake Mariut | 2.82 | 23.93 | 44.82 | 272.24 | 938.78 | 191.79 |
| | El-Umum Drain | 3.95 | 9.32 | 23.33 | 546.55 | 12.81 | 110.65 |
| *S. galilaeus* | Lake Edku | 2.19 | n.d. | n.d. | n.d. | 522.09 | 64.71 |
| | Lake Mariut | 4.74 | n.d. | 32.01 | 190.38 | 695.49 | 94.69 |
| *O. oreus* | Lake Edku | 3.55 | 18.81 | 221.93 | 279.76 | 427.50 | 184.88 |
| | El-Nozha Hydrodrome | 1.53 | 21.20 | 21.86 | 99.02 | 1251.27 | 70.23 |
| Range | | 1.41–4.74 | 9.32–88.33 | 21.86–221.93 | 52.61–604.26 | 12.81–2202.26 | 34.04–191.79 |

*Note*: n.d., Not determined.

TABLE III Concentrations of Zn in Different Organs of Studied Fish (µg/g wet wt).

| *Species* | *Region* | *Muscle* | *Brain* | *Gonads* | *Liver* | *Intestines* | *Gills* |
|---|---|---|---|---|---|---|---|
| *O. niloticus* | Lake Edku (L) | 0.21 | 20.82 | 27.88 | 21.17 | 16.69 | 21.12 |
| | Lake Edku | 0.36 | 27.05 | 67.02 | 16.63 | 53.08 | 19.26 |
| | Lake Mariut | 0.24 | 21.25 | 29.1 | 22.67 | 89.6 | 23.4 |
| | El-Umum Drain | 0.18 | 28.12 | 26.27 | 21.14 | 33.46 | 22.15 |
| *S. galilaeus* | Lake Edku | 0.61 | n.d. | n.d. | n.d. | 5.56 | 24.32 |
| | Lake Mariut | 2.27 | 105.33 | 39.04 | 24.45 | 14.23 | 27.22 |
| *O. oreus* | Lake Edku | 0.6 | 44.31 | 24.11 | 3.73 | 3.21 | 23.52 |
| | El-Nozha Hydrodrome | 0.15 | 57.19 | 12.19 | 23.33 | 31.09 | 29.02 |
| Range | | 3.58–8.46 | 20.82–105.33 | 12.19–67.02 | 3.73–24.45 | 3.21–89.6 | 19.26–29.02 |

*Note*: n.d., Not determined.

TABLE IV Concentrations of Mn in Different Organs of Studied Fish (μg/g wet wt).

| *Species* | *Region* | *Muscle* | *Gonads* | *Liver* | *Intestines* | *Gills* |
|---|---|---|---|---|---|---|
| *O. niloticus* | Lake Edku (L) | 0.21 | 0.58 | 2.48 | 47.28 | 3.85 |
| | Lake Edku | 0.36 | 21.07 | 12.83 | 324.5 | 8.14 |
| | Lake Mariut | 0.24 | 0 | 50.2 | 59.55 | 4.05 |
| | El-Umum Drain | 0.18 | 0.21 | 0.9 | 1.15 | 3.44 |
| *S. galilaeus* | Lake Edku | 0.61 | n.d | n.d. | 61.34 | 21.56 |
| | Lake Mariut | 2.27 | 11.78 | 12.06 | 59.95 | 7.99 |
| *O. oreus* | Lake Edku | 0.6 | 27.95 | 5.16 | 43.43 | 10.12 |
| | El-Nozha Hydrodrome | 0.15 | 1.16 | 0.51 | 58.07 | 1.85 |
| Range | | 0.15–2.27 | 0–27.95 | 0–12.83 | 1.15–324.5 | 1.85–21.56 |

*Note*: n.d., Not determined.



levels were recorded in the intestines (1.15–324.50 μg/g) and the lowest concentrations were in the edible parts (0.15–2.27 μg/g). There is, to some extent, an obvious trend of spatial variation in the concentration of Mn in the flesh of studied fish. Thus the level of Mn in the flesh of *S. galilaeus* from Lake Mariut is about four times higher than that of Lake Edku. The same concentration pattern was found for *O. aureus* collected from Lake Edku and El Nozha Hydrodrome, respectively. Moreover, for most organs of *O. aureus* (gonads, liver and gills) from Lake Edku, Mn concentrations are much higher than those of El Nozha hydrodrome.

## 3.4 Copper

Table V shows the levels of Cu in different organs of studied fish. The levels of Cu in the liver (1.34–17.48 μg/g) are much higher than those of other organs, suggesting that liver might be a target organ for accumulation of Cu. Indeed, Buckley *et al.* (1982) and Salanki *et al.* (1982) stated that, the liver of fish is a major storage organ for Cu. The preferential accumulation of Cu in liver of different fish species from the Egyptian water is extensively observed (Shakweer *et al.*, 1993; Shakweer and Abbas, 1996; Shakweer and Abbas, 1997).

Concerning the edible tissues, it was noticed that the flesh of the studied fish have the lowest levels of Cu (0.25–1.85 μg/g). Again, the flesh of *S. galilaeus* from Lake Mariut had the highest concentration. The flesh tissues of *O. niloticus* and *O. aureus* from different regions contained nearly the same level of Cu.

## 3.5 Cadmium

Cd is non-essential element (C1ESM, 2002). Cd concentrations in the different organs of the studied fish can be shown in Table VI. Gills and intestines have appreciable levels of Cd (0.16–0.23 μg/g and 0.08–1.11 μg/g, respectively). In most cases, the concentration of Cd in the brain of the studied fish is not detected. The concentration of Cd in liver tissue varied within a narrow range (0.06–0.10 μg/g). Based on the range values, the edible part contained the lowest value (0.03–0.11 μg/g). Ray and Mcleese (1987) stated that, in most organisms, whether vertebrates or invertebrates, muscle tissue contains only negligible amounts of Cd.

It was observed that, the gonads of *O. niloticus* from Lake Mariut have the highest level of Cd (1.22 μg/g). However, in the edible tissues, the concentration of Cd does not exceed 0.11 μg/g that is measured in the flesh tissue of the mentioned fish species. Although, the

TABLE V Concentrations of Cu in Different Organs of Studied Fish (µg/g wet wt).

| *Species* | *Region* | *Muscle* | *Brain* | *Gonads* | *Liver* | *Intestines* | *Gills* |
|---|---|---|---|---|---|---|---|
| *O. niloticus* | Lake Edku (L) | 0.25 | 1.98 | 1.35 | 11.35 | 3.98 | 0.54 |
| | Lake Edku | 0.28 | 3.52 | 3.2 | 10.73 | 9.06 | 0.67 |
| | Lake Mariut | 0.28 | 1.05 | 4.18 | 3.51 | 4.55 | 0.58 |
| | El-Umum Drain | 0.29 | 0.73 | 1.21 | 17.48 | 1.03 | 0.45 |
| *S. galilaeus* | Lake Edku | 0.32 | n.d. | n.d. | n.d. | 1.49 | 0.81 |
| | Lake Mariut | 1.85 | 1.6 | 2.33 | 4.5 | 4.31 | 0.88 |
| *O. oreus* | Lake Edku | 0.37 | 1.32 | 3.24 | 1.34 | 0.96 | 1.12 |
| | El-Nozha Hydrodrome | 0.3 | 2.48 | 0.68 | 13.4 | 10.48 | 0.63 |
| Range | | 0.25–1.85 | 0.73–3.52 | 0.68–4.18 | 1.34–17.48 | 0.96–10.48 | 0.45–1.12 |

*Note*: n.d., Not determined.

TABLE VI Concentrations of Cd in Different Organs of Studied Fish (µg/g wet wt).

| *Species* | *Region* | *Muscle* | *Brain* | *Gonads* | *Liver* | *Intestines* | *Gills* |
|---|---|---|---|---|---|---|---|
| *O. niloticus* | Lake Edku (L) | 0.098 | n.d. | 0.3 | 0.06 | 0.185 | 0.18 |
| | Lake Edku | 0.083 | n.d. | 0.93 | 0.1 | 0.253 | 0.16 |
| | Lake Mariut | 0.11 | n.d. | 1.22 | 0.09 | 0.202 | 0.18 |
| | El-Umum Drain | 0.056 | 0.21 | 0.04 | 0.08 | 1.11 | 0.23 |
| *S. galilaeus* | Lake Edku | 0.031 | n.d. | n.d. | n.d. | 0.109 | 0.17 |
| | Lake Mariut | 0.048 | n.d. | n.d. | 0.07 | 0.177 | 0.18 |
| *O. oreus* | Lake Edku | 0.068 | n.d. | 0.25 | 0.08 | 0.08 | 0.23 |
| | El-Nozha Hydrodrome | 0.079 | 0.36 | 0.05 | 0.06 | 0.275 | 0.18 |
| Range | | 0.03–0.11 | 0–0.36 | 0–1.22 | 0.06–0.10 | 0.08–1.11 | 0.16–0.23 |

*Note*: n.d., Not determined.

concentration of dissolved Cd in the water of Lake Edku (l.44 ± 0.58 μg/l, unpublished data) an Mariut (1.25 ± 0.72 μg/l, Youssef, 1999) is more or less the same, accumulations of Cd in the flesh tissue of the species from Lake Mariut are higher than those from Lake Edku. This indicates that the ambient medium concentration is not the only factor influencing the mentioned accumulation. Jensen and Bro-Rasmussen (1992) mentioned that the biomagnification of Cd within marine or fresh water food webs, but an uptake of free cadmium ions followed by accumulation in individual organisms can take place directly from the water. Aquatic organisms can be classified in order of decreasing accumulation as follows: algae > mollusks > crustaceans > fish.

In general, for both Lakes Edku and Mariut, it was noticed that the edible part of *S. galilaeus* accumulates considerably higher levels of Mn, Fe and Cu than that of *O. niloticus.* The reverse situation was true for Cd. Although the flesh of *O. niloticus* had higher concentrations of Cd (toxic element) than that of *S. galilaeus*, Akel (1989) observed that *S. galilaeus* is much affected by pollution which results in lower weight, condition factor and survival than other *Tilapia* spp. Essa and Faltas (1997) mentioned that the total mortality of *S. galilaeus* in Lake Mariut is relatively higher than that of *O. niloticus.*

Metal accumulation in different organs vary considerably within the same and among different *Tilapia* spp. In addition, some tissues are strong accumulators for metals (*e.g.* liver is a target organ for accumulation of Cu) and others are much weaker accumulators (muscle tissue). Amongst the studied elements, Cd concentrations in the different organs are the lowest. These differences can be explained by the effects of physical, chemical and biological factors on the uptake, accumulation and toxicity of the metals (Newman and McIntosh, 1991; Tessier and Turner, 1995; Newman *et al.*, 2001). Moreover, metal accumulation processes in internal organs vary from organ to another. As an example, metal accumulation mechanisms in flesh are related to metabolized metals via food, while gills are the primary site of metal uptake from the water (Romeo *et al.*, 1994). Regulation of metals can occur in two different ways, either by matching metal excretion to metal uptake so that the body concentration of the metal remains constant, or by sorting part of the metal in a physiologically inactive pool.

In the present study, the obtained levels of Cd, Cu and Zn in the edible parts of studied fish cannot be considered as hazardous levels. According to the National Health and Medical Research Council in Australia (NHMRC), the recommended concentrations for Cd, Cu and Zn in the edible parts of fish based on the wet weight are 2, 30 and 1000 ppm, respectively (Bebbington *et al.*, 1977). The level of the investigated metals in the present study is an example of low content of metals in most of the edible part of fish in the Egyptian water (examples, Shakweer *et al.*, 1993; Shakweer and Abbas, 1996; Shakweer and Abbas, 1997).

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