

## **Study on Concentration of some Heavy Metals in Nile Tilapia, *Oreochromis niloticus* and Cat Fish, *Clarias gariepinus* from Lake Manzala, Egypt**

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### **Abstract**

The increasing demand for fish, driven by its high nutritional value, is challenged by heavy metal pollution in aquatic environments from urbanization and industrial activities. This study examines the accumulation of heavy metals (Cu, Zn, Pb, Cd, Hg) in *Oreochromis niloticus* (Nile tilapia) and *Clarias gariepinus* (African catfish) from Lake Manzala, Egypt, using Atomic Absorption Spectrophotometry. Results revealed species-specific metal accumulation patterns: *O. niloticus* accumulated higher levels of Zn (122.15 µg/g) and Cu (75.23 µg/g), whereas *C. gariepinus* showed elevated Pb (0.441 µg/g), Cd (0.235 µg/g), and Hg (0.183 µg/g) concentrations. Liver tissues consistently exhibited the highest metal concentrations, followed by gills, gonads, and muscles. The metal levels in fish muscles were below FAO/WHO legal limits, indicating their safety for human consumption. These findings highlight the importance of species-specific assessments and ongoing monitoring to understand environmental contamination and ensure food safety. Further research into the mechanisms of

metal accumulation and their ecological and health impacts is essential.

## Introduction

Fish is highly valued for its nutritional benefits, offering high-quality protein, essential vitamins (A, D, E), and minerals (phosphorus, selenium, iron, calcium, iodine, magnesium). Additionally, fish is a rich source of omega-3 fatty acids (EPA and DHA), which have been linked to numerous health benefits, including reduced risks of arrhythmias, endothelial dysfunction, coronary heart disease, Alzheimer's disease, and blood clotting (Burger & Gochfeld, 2005; Brunner et al., 2009; Tuzen, 2009; Ganjavi et al., 2010; Kromhout et al., 2012; Beveridge et al., 2013; Parian & Mullin, 2016). Consequently, the American Cancer Society and the American Heart Association recommend consuming fish at least twice a week (Fernandes et al., 2012).

However, the aquatic environments of fish are increasingly contaminated by pollutants, particularly heavy metals, due to human activities and industrialization. Heavy metals such as mercury, lead, and cadmium are toxic even at low concentrations, while essential metals like copper and zinc become harmful at high levels (Yilmaz, 2005; Turkmen et al., 2008; Tuzen, 2009; Sary & Velayatzadeh, 2014; Alkan et al., 2015). Lake Manzala in Egypt, a significant fishery resource, is heavily polluted with untreated industrial, domestic, and agricultural wastewater, resulting in metal contamination above permissible limits and posing risks to the ecosystem and human health (Ali, 2008; Abdel-Rasheed, 2011; Bahnasawy et al.,

2011; El-Khayat et al., 2015; Zahran et al., 2015; Arnous & Hassan, 2015).

A previous study conducted by (Sallam et al., 2019) reported heavy metal concentrations in three fish species from Lake Manzala: Nile tilapia, flathead grey mullet, and African catfish. The study found that the mean concentrations of mercury (Hg), lead (Pb), and cadmium (Cd) among these species followed the order Nile tilapia > African catfish > flathead grey mullet, while arsenic (As) concentrations were highest in flathead grey mullet. These findings highlight significant seasonal variations and species-specific accumulation patterns, with potential health hazards indicated for consumers (DOI: 10.1111/1750-3841.14676).

Given the critical role of Lake Manzala in Egypt's fish production amidst increasing contamination, it is essential to assess heavy metal residues in fish species commonly consumed in the region. Lake Manzala also faces eutrophication due to nutrient overloads from sewage and agricultural runoff (Hamed et al., 2013; El-Ghazali et al., 2015; Elmorsi et al., 2017). Despite these challenges, the lake contributes significantly to Egypt's fish production (Elmorsi et al., 2017). Assessing heavy metals in fish is critical for public health and environmental monitoring. Contaminated fish can lead to nutrient depletion, weakened immune defenses, growth issues, psychosocial impairments, and increased cancer risk (Achide & Oname, 2017). This study aims to measure levels of copper, zinc, lead, cadmium, and mercury in Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) from Lake Manzala to determine their safety for human consumption.

These species, which differ in habitat and feeding habits, are vital food sources in the region.

## Review of Literature

The pollution of the aquatic environment is a global concern, with heavy metals being significant toxicants due to their toxicity, persistence, and bioaccumulative properties (Usal et al., 2008). Industrial development, population growth, and urbanization have exacerbated heavy metal levels in aquatic ecosystems (Sarkar et al., 2016). These metals enter water bodies through atmospheric deposition, erosion, and anthropogenic activities such as industrial effluents, sewage, and mining (Raja et al., 2009; Aladetohun et al., 2013). They can accumulate in marine organisms, including fish, which are then consumed by humans, posing health risks such as liver damage, renal failure, and cardiovascular disease (Uzoamaka, 2016).

**Mercury (Hg):** One of the most toxic heavy metals, mercury, occurs naturally and is released through human activities, including industrial processes (Erdogrul, 2007). In aquatic systems, inorganic mercury is converted into highly toxic methylmercury by bacteria, which accumulates in fish and poses significant health risks to humans, such as neurological damage and kidney failure (Khallaf et al., 1998; Soliman, 2006).

**Cadmium (Cd):** Toxic to aquatic organisms, cadmium contamination arises from industries like ceramics, batteries, and agriculture (Dheina, 2007). It can cause renal failure, bone damage (Itai-itai disease), and various cancers in humans (Fatoki et al., 2002). Cadmium exposure also leads to severe

cellular damage and immune system impairment (Afshan et al., 2014).

**Lead (Pb):** Exposure to lead results in numerous health issues, including abdominal pain, cardiovascular diseases, and cognitive impairments (Ansari et al., 2004). Major sources include vehicle emissions, ceramics, and plumbing (El-Bakkoch, 2009).

**Copper (Cu):** An essential element, copper in high doses can cause anemia, liver, and kidney damage (Ansari et al., 2004).

**Zinc (Zn):** While essential for numerous bodily functions, excessive zinc intake can cause severe health issues, such as vomiting and liver damage (Khallaf et al., 1998).

Heavy metals enter fish through the skin, gills, and digestive tract, where they are absorbed and transported to various organs (Mohammed and Khamis, 2012). Prolonged exposure can lead to numerous abnormalities in fish, including behavioral changes and developmental disruptions (Akan et al., 2012). Fish, as the final link in the aquatic food chain, reflect the environmental contamination of their habitats (Shakweer, 1998).

Numerous studies have documented heavy metal accumulation in fish species worldwide. For instance, Adeyeye and Ayola (2013) found significant metal accumulation in the liver and gills of *Clarias gariepinus* in Nigeria, while Ibrahim et al. (2013) reported high levels in *Clarias gariepinus* from Egypt, deeming them harmful for consumption. Various regulatory bodies, such as the WHO, FAO, and EU, have established permissible limits for heavy metals in food (Achide and Omame, 2017).

Monitoring heavy metal levels in fish is crucial for public health and understanding aquatic ecosystem health.

## Materials and Methods

### Fish Collection and Preparation:

The study utilized two commercially important fish species with high nutritional value: Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*). These fish were purchased from local fishermen at Lake Manzala (El-Mataria region) during July and August 2017 (Figures 1 and 2).



**Fig. 1:** Nile tilapia, *Oreochromis niloticus*



**Fig 2 :** The African cat fish, *Clarias gariepinus*

Upon collection, the fish were placed in clean plastic bags, stored in an icebox, and transported to the Zoology Department Laboratory at the Faculty of Science, Damietta University. In the laboratory, the total length and weight of each fish were measured to the nearest millimeter and gram, respectively.

### **Sample Preparation:**

Each fish specimen was dissected using sterilized stainless-steel equipment. Samples of the epiaxial muscles, liver, gills, and gonads were placed in pre-weighed, clean, dry 25 ml beakers. These samples were then dried in an oven at 80°C for 48 hours.

### **Digestion Process:**

The dried samples were digested using a mixture of concentrated nitric acid ( $\text{HNO}_3$ , 69%) and concentrated perchloric acid ( $\text{HClO}_4$ , 70%) in a 2:1 ratio on a hot sand bath. Digestion was continued until the solution became clear. Once clear, the digest was allowed to cool, filtered through acid-resistant filter paper, and transferred to 25 ml volumetric flasks. The solutions were then diluted to the mark with distilled water and stored in clean, sterile plastic bottles until the determination of selected heavy metals using an Atomic Absorption Spectrophotometer (AAS).

### **Metal Concentration Determination:**

Metal concentrations in tissues were presented as micrograms of metal per gram of dry weight ( $\mu\text{g/g}$  dry weight). To prevent contamination, all glassware was soaked overnight in a dilute nitric acid solution, rinsed with distilled water, and dried before use.

### **Reagents and Blank Solution:**

All chemicals used were of analytical reagent grade. A blank solution was prepared to check for any possible traces of metals in the acids or distilled water used during the digestion and dilution of the samples.

## Quality Control:

To ensure the accuracy and reliability of the results, rigorous quality control measures were implemented. This included the use of analytical-grade reagents, contamination prevention protocols, and the preparation of blank solutions to monitor for potential contamination.

## Statistical analysis

The obtained data were subjected to one - way analysis of variance (ANOVA) and were used to assay whether sample varied significantly between species. Possibilities less than 0.05 (P 0.05) were be considered statistically significant. All statistical calculations were carried out with Spss.

## RESULTS

### Fish Lengths

The range and mean lengths of the investigated fish species are presented in Table 1 and Figure 3. The length of *Clarias gariepinus* ranged from 32.5 to 48.0 cm, with a mean length of 40.05 cm. In contrast, the length of *Oreochromis niloticus* ranged from 21.7 to 28.0 cm, with a mean length of 24.7 cm. There were significant differences between the lengths of the examined fish species (Table 1).

### Fish Weights

The range and mean weights of the studied fish species are shown in Table 2 and Figure 4. The weight of *Clarias gariepinus* ranged from 320 to 680 g, with a mean weight of 449 g. The weight of *Oreochromis niloticus* ranged from 215 to 420 g, with a mean weight of 285.5 g. Significant differences were

observed between the weights of the examined fish species (Table 2).

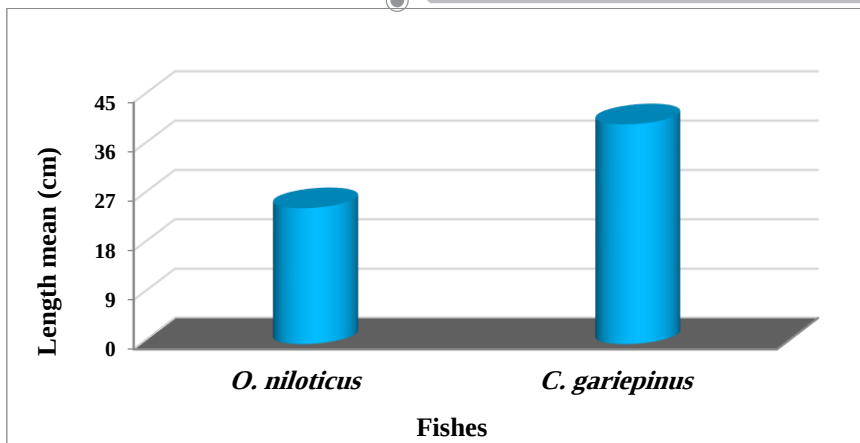
### Metal Concentrations

The mean concentrations and associated standard deviations of Cu, Zn, Pb, Cd, and Hg in the studied fish species (*Oreochromis niloticus* and *Clarias gariepinus*) are shown in Tables 3-7 and Figures 5-12. The general pattern of metal bioaccumulation in both fish species was as follows:  $Zn > Pb > Cu > Cd > Hg$ .

*Oreochromis niloticus* accumulated higher concentrations of Zn (122.15  $\mu\text{g/g}$  dry weight) and Cu (75.23  $\mu\text{g/g}$  dry weight). On the other hand, *Clarias gariepinus* contained higher levels of Pb (0.441  $\mu\text{g/g}$  dry weight), Cd (0.235  $\mu\text{g/g}$  dry weight), and Hg (0.183  $\mu\text{g/g}$  dry weight) (Table 3).

**Table 1.: The range and mean of fish lengths, cm.**

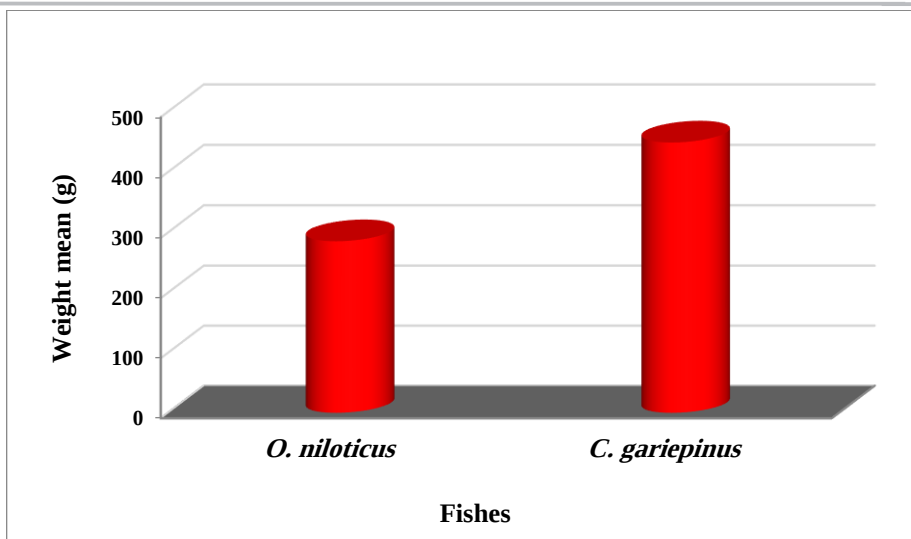
| Fishes                       | Range       | Length (cm) |            | T-test |       |                 |
|------------------------------|-------------|-------------|------------|--------|-------|-----------------|
|                              |             | Mean        | $\pm$ SD   | df     | T     | Sig.            |
| <i>Clarias gariepinus</i>    | (32.5 - 48) | 40.05       | $\pm$ 4.68 | 1      | 9.397 | <b>0.001***</b> |
| <i>Oreochromis niloticus</i> | (21.7 - 28) | 24.74       | $\pm$ 2.15 |        |       |                 |



**Figure 3.: Means of fish lengths.**

**Table 2.: The range and mean of fish weights, g.**

| Fishes                       | Range     | Weight (g)          | T-test |       |                |
|------------------------------|-----------|---------------------|--------|-------|----------------|
|                              |           | Mean $\pm$ SD       | df     | T     | Sig.           |
| <i>Clarias gariepinus</i>    | (320-680) | 449.00 $\pm$ 123.13 | 1      | 3.666 | <b>0.002**</b> |
| <i>Oreochromis niloticus</i> | (215-420) | 285.50 $\pm$ 68.78  |        |       |                |



**Figure 4.: Means of fish weights.**

**Table (3): Mean heavy metals concentrations ( $\mu\text{g/g}$  dry wt.) in the investigated fishes.**

| Heavy metals | Fishes                    |                              |                    | T-test |             |
|--------------|---------------------------|------------------------------|--------------------|--------|-------------|
|              | <i>Clarias gariepinus</i> | <i>Oreochromis niloticus</i> | Total              | T-test | Sig.        |
|              | Mean $\pm$ SD             | Mean $\pm$ SD                | Mean $\pm$ SD      | T-test | Sig.        |
| Zinc         | 120.73 $\pm$ 78.18        | 122.151 $\pm$ 68.01          | 121.44 $\pm$ 72.81 | 0.08   | 0.93        |
| Copper       | 30.535 $\pm$ 44.28        | 75.23 $\pm$ 135.82           | 52.88 $\pm$ 102.85 | 1.97   | <b>0.05</b> |
| Lead         | 0.441 $\pm$ 0.38          | 0.326 $\pm$ 0.227            | 0.38 $\pm$ 0.318   | 1.63   | 0.10        |
| Cadmium      | 0.235 $\pm$ 0.17          | 0.177 $\pm$ 0.102            | 0.206 $\pm$ 0.141  | 1.87   | 0.06        |
| Mercury      | 0.183 $\pm$ 0.13          | 0.135 $\pm$ 0.084            | 0.159 $\pm$ 0.108  | 2.02   | <b>0.05</b> |

\* Significant at level 0.05

## Zinc (Zn) Concentrations

Zinc concentrations detected in the organs of *O. niloticus* and *C. gariepinus* are shown in Table 4 and Figure 6. Zn levels in the organs of the two fish species followed the order: gonads > liver > gills > muscles (Table 4). Zn concentrations varied significantly between the organs of the studied fish species.

In *O. niloticus*, Zn concentrations ranged from 30.76 to 186.53 µg/g dry weight, while in *C. gariepinus*, Zn concentrations ranged from 42.51 to 172.18 µg/g dry weight. The highest Zn concentrations were found in the gonads of both *O. niloticus* (186.53 µg/g dry weight) and *C. gariepinus* (172.18 µg/g dry weight).

The liver of *O. niloticus* accumulated higher concentrations of Zn (152.56 µg/g dry weight) compared to the liver of *C. gariepinus* (144.46 µg/g dry weight). The gills of *C. gariepinus* contained higher levels of Zn (123.77 µg/g dry weight) than the gills of *O. niloticus* (118.74 µg/g dry weight). Muscles had the lowest Zn values in both *O. niloticus* (30.76 µg/g dry weight) and *C. gariepinus* (42.51 µg/g dry weight).

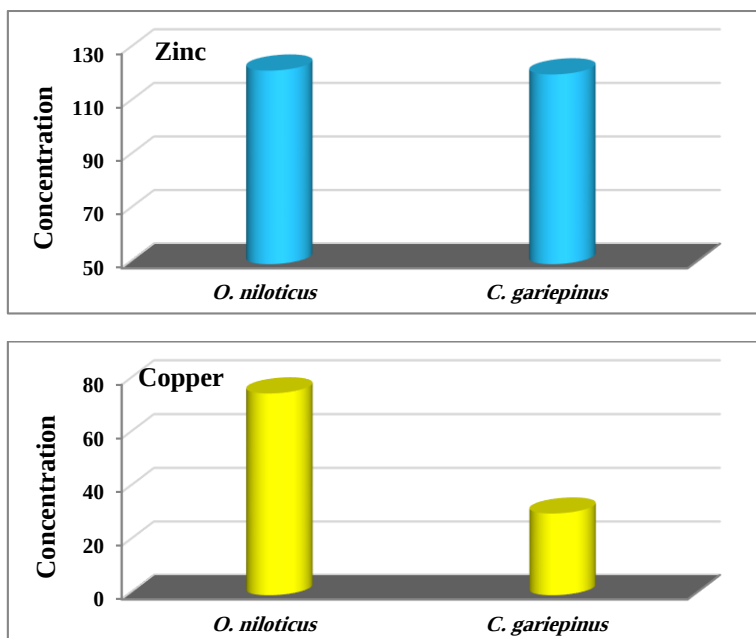
## Copper (Cu) Concentrations

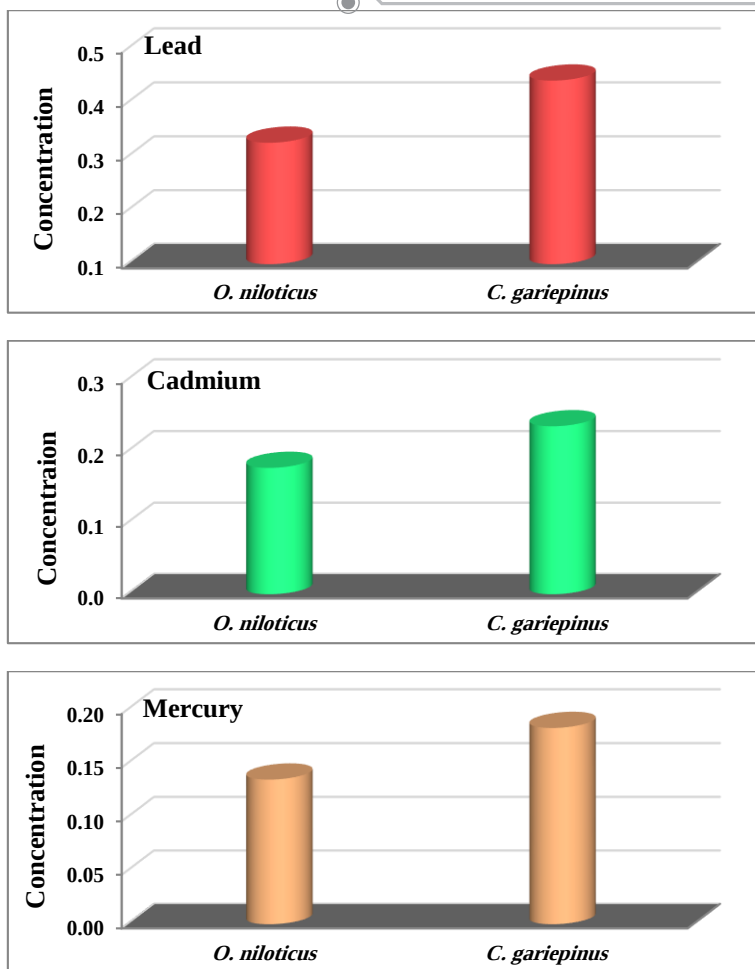
Copper concentrations in the organs of *O. niloticus* and *C. gariepinus* are shown in Table 5 and Figure 7. Cu levels in the organs of the two fish species followed the order: liver > gills > gonads > muscles. Cu concentrations varied significantly between the organs of the studied fish species (Table 5).

In *O. niloticus*, Cu concentrations ranged from 1.63 to 285.28 µg/g dry weight, while in *C. gariepinus*, Cu concentrations ranged from 3.29 to 98.92 µg/g dry weight. The highest Cu

concentrations were found in the liver of both *O. niloticus* (285.28  $\mu\text{g/g}$  dry weight) and *C. gariepinus* (98.92  $\mu\text{g/g}$  dry weight) (Table 5).

The gills of *C. gariepinus* accumulated higher concentrations of Cu (16.05  $\mu\text{g/g}$  dry weight) than the gills of *O. niloticus* (7.42  $\mu\text{g/g}$  dry weight). The gonads of *O. niloticus* contained higher levels of Cu (6.56  $\mu\text{g/g}$  dry weight) than the gonads of *C. gariepinus* (3.87  $\mu\text{g/g}$  dry weight). Muscles had the lowest Cu values in both *O. niloticus* (1.63  $\mu\text{g/g}$  dry weight) and *C. gariepinus* (3.29  $\mu\text{g/g}$  dry weight) (Table 5).



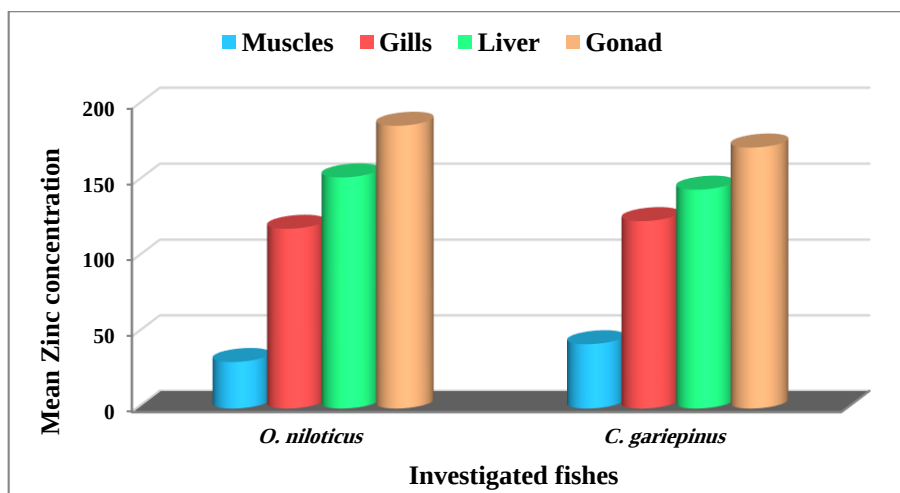


**Fig. 5. Mean heavy metals concentrations ( $\mu\text{g/g}$  dry wt.) in the investigated fishe**

**Table (4): Mean Zinc concentrations ( $\mu\text{g/g}$  dry wt.) in various organs of the investigated fishes.**

| Heavy metals         | Organs                            |                                    |                                    |                                     |                               | F-test |              |
|----------------------|-----------------------------------|------------------------------------|------------------------------------|-------------------------------------|-------------------------------|--------|--------------|
|                      | Muscles                           | Gills                              | Liver                              | Gonad                               | Total                         |        |              |
|                      | Mean $\pm$ SD                     | Mean $\pm$ SD                      | Mean $\pm$ SD                      | Mean $\pm$ SD                       | Mean $\pm$ SD                 | F      | Sig.         |
| <i>O. niloticus</i>  | 30.7 $\pm$ 8.79<br>6 <sup>a</sup> | 118.7 $\pm$ 26.9<br>4 <sup>b</sup> | 152.5 $\pm$ 26.5<br>6 <sup>c</sup> | 186.5 $\pm$ 60.11<br>3 <sup>d</sup> | 122.1 $\pm$ 68.0<br>5 $\pm$ 1 | 34.99  | 0.001**<br>* |
| <i>C. gariepinus</i> | 42.5 $\pm$ 28.8<br>1 <sup>a</sup> | 123.7 $\pm$ 25.5<br>7 <sup>b</sup> | 144.4 $\pm$ 38.4<br>5 <sup>b</sup> | 172.1 $\pm$ 114.6<br>8 <sup>b</sup> | 120.7 $\pm$ 78.1<br>3 $\pm$ 7 | 7.73   | 0.001**<br>* |
| Total                | 36.6 $\pm$ 21.6<br>3 $\pm$ 3      | 121.2 $\pm$ 25.6<br>6 $\pm$ 8      | 148.5 $\pm$ 32.4<br>1 $\pm$ 3      | 179.3 $\pm$ 89.38<br>5 $\pm$ 38     | 121.4 $\pm$ 72.8<br>4 $\pm$ 1 |        |              |

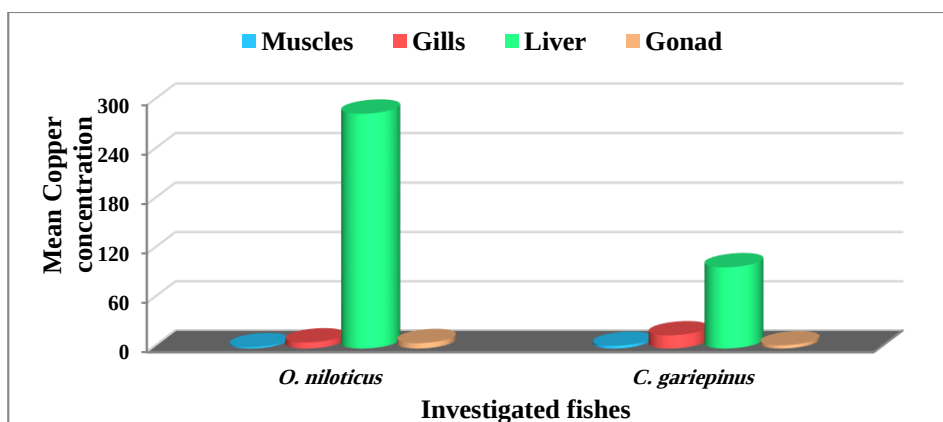
\*\*\* Significant at 0.00

**Fig. 6. Mean Zinc concentrations ( $\mu\text{g/g}$  dry wt.) in various organs of the investigated fishes**

**Table (5): Mean Copper concentrations ( $\mu\text{g/g}$  dry wt.) in various organs of the investigated fishes.**

| Heavy metals         | Organs                           |                                   |                                      |                                  |                                     | F-test |              |
|----------------------|----------------------------------|-----------------------------------|--------------------------------------|----------------------------------|-------------------------------------|--------|--------------|
|                      | Muscles                          | Gills                             | Liver                                | Gonad                            | Total                               |        |              |
|                      | Mean $\pm$ SD<br>n               | Mean $\pm$ SD                     | Mean $\pm$ SD                        | Mean $\pm$ SD<br>n               | Mean $\pm$ SD<br>n                  | F      | Sig.         |
| <i>O. niloticus</i>  | 1.63 <sup>a</sup> $\pm$ 0.5<br>0 | 7.42 <sup>a</sup> $\pm$ 1.3<br>9  | 285.28 <sup>b</sup> $\pm$ 120.5<br>3 | 6.56 <sup>a</sup> $\pm$ 3.3<br>6 | 75.22 <sup>b</sup> $\pm$ 135.8<br>1 | 53.96  | 0.001**<br>* |
| <i>C. gariepinus</i> | 3.29 <sup>b</sup> $\pm$ 1.1<br>0 | 16.05 <sup>b</sup> $\pm$ 5.0<br>4 | 98.92 <sup>a</sup> $\pm$ 37.70       | 3.87 <sup>b</sup> $\pm$ 1.3<br>7 | 30.53 $\pm$ 44.27                   | 58.29  | 0.001**<br>* |
| <b>Total</b>         | 2.46 $\pm$ 1.1<br>9              | 11.74 $\pm$ 5.7<br>0              | 192.10 $\pm$ 129.2<br>0              | 5.22 $\pm$ 2.8<br>5              | 52.88 $\pm$ 102.8<br>5              |        |              |

\*\*\* Significant at 0.001



**Fig.7. Mean Copper concentrations ( $\mu\text{g/g}$  dry wt.) in various organs of the investigated fishes**

### Lead (Pb) Concentrations

The mean concentrations of Pb in various organs of the investigated fish species are shown in Table 6 and Figure 8. There was a significant difference in Pb concentrations among

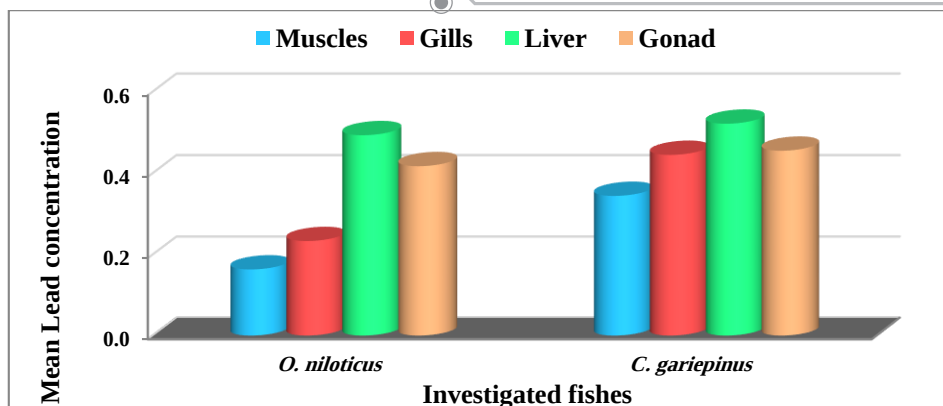
different organs of *O. niloticus*, whereas the concentration of Pb in the organs of *C. gariepinus* did not vary significantly (Table 6).

Pb concentrations in *O. niloticus* and *C. gariepinus* followed the order: liver > gonad > gills > muscles. *C. gariepinus* accumulated the highest levels of Pb in its liver (0.521 µg/g dry weight), gonads (0.455 µg/g dry weight), gills (0.445 µg/g dry weight), and muscles (0.344 µg/g dry weight). In *O. niloticus*, the concentrations of Pb in the organs were as follows: liver (0.493 µg/g dry weight), gonads (0.417 µg/g dry weight), gills (0.233 µg/g dry weight), and muscles (0.163 µg/g dry weight).

**Table (6): Mean Lead concentrations (µg/g dry wt.) in various organs of the investigated fishes.**

| Heavy metal    | Organs                               |                                      |                                      |                                      |                                     | F-test |              |
|----------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|-------------------------------------|--------|--------------|
|                | Muscles                              | Gills                                | Liver                                | Gonad                                | Total                               | F      | Sig.         |
|                | Mean±SD                              | Mean±SD                              | Mean±SD                              | Mean±SD                              | Mean±SD                             |        |              |
| <i>Claria</i>  | 0.344± <sup>0.32</sup> <sub>3</sub>  | 0.445± <sup>0.38</sup> <sub>9</sub>  | 0.521± <sup>0.54</sup> <sub>2</sub>  | 0.455± <sup>0.25</sup> <sub>8</sub>  | 0.441± <sup>0.38</sup> <sub>2</sub> | 0.35   | 0.792        |
| <i>Tilapia</i> | 0.163± <sup>0.03</sup> <sub>a3</sub> | 0.233± <sup>0.05</sup> <sub>c5</sub> | 0.493± <sup>0.27</sup> <sub>b3</sub> | 0.417± <sup>0.25</sup> <sub>b5</sub> | 0.326± <sup>0.22</sup> <sub>7</sub> | 6.64   | 0.001**<br>* |
| <b>Total</b>   | 0.254± <sup>0.24</sup> <sub>2</sub>  | 0.339± <sup>0.29</sup> <sub>2</sub>  | 0.507± <sup>0.41</sup> <sub>8</sub>  | 0.436± <sup>0.25</sup> <sub>0</sub>  | 0.384± <sup>0.31</sup> <sub>8</sub> |        |              |

\*\*\* Significant at 0.001



**Fig. 8. Mean Lead concentrations ( $\mu\text{g/g}$  dry wt.) in various organs of the investigated fishes.**

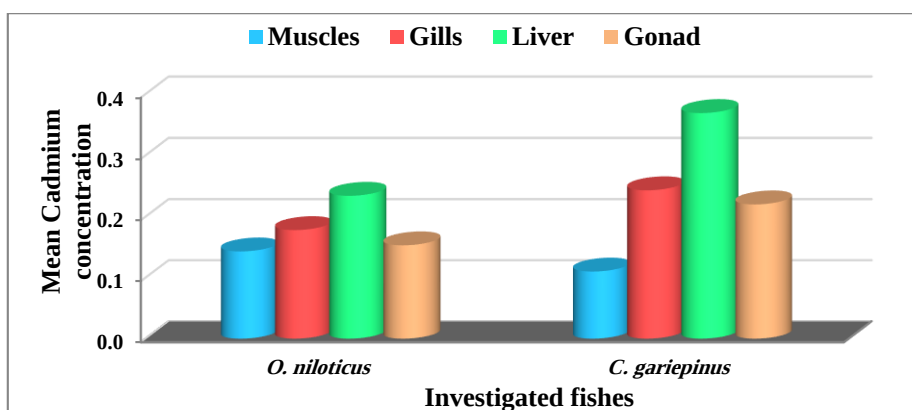
The mean concentrations of Cd in various organs of *O. niloticus* and *C. gariepinus* are shown in Table 7 and Figure 9. There was a significant difference in Cd concentrations among different organs of *C. gariepinus*, while no significant difference was observed in the Cd concentrations among the organs of *O. niloticus*. Cd concentrations in the organs of both *O. niloticus* and *C. gariepinus* increased in the following order: liver > gills > gonads > muscles.

*C. gariepinus* accumulated the highest levels of Cd in its liver (0.369  $\mu\text{g/g}$  dry weight), gills (0.243  $\mu\text{g/g}$  dry weight), and gonads (0.220  $\mu\text{g/g}$  dry weight). In contrast, *O. niloticus* exhibited a higher level of Cd in its muscles (0.143  $\mu\text{g/g}$  dry weight) compared to the muscles of *C. gariepinus* (0.110  $\mu\text{g/g}$  dry weight). The concentrations of Cd in the organs of *O. niloticus* were as follows: liver (0.234  $\mu\text{g/g}$  dry weight), gonads (0.153  $\mu\text{g/g}$  dry weight), and gills (0.178  $\mu\text{g/g}$  dry weight). The muscles of both *O. niloticus* and *C. gariepinus* had the lowest levels of Cd (Table 7).

**Table (7): Mean Cadmium concentrations ( $\mu\text{g/g}$  dry wt.) in various organs of the investigated fishes.**

| Heavy metal<br>s | Organs                             |                                                 |                                    |                                                 |                       | F-test |        |
|------------------|------------------------------------|-------------------------------------------------|------------------------------------|-------------------------------------------------|-----------------------|--------|--------|
|                  | Muscles                            | Gills                                           | Liver                              | Gonad                                           | Total                 | F      | Sig.   |
|                  | Mean $\pm$ SD                      | Mean $\pm$ SD                                   | Mean $\pm$ SD                      | Mean $\pm$ SD                                   | Mean $\pm$ SD         |        |        |
| <i>Claria</i>    | 0.110 $\pm$ 0.08<br>b <sub>9</sub> | 0.243 <sup>a</sup> $\pm$ 0.05<br>c <sub>8</sub> | 0.369 $\pm$ 0.24<br>a <sub>0</sub> | 0.220 <sup>b</sup> $\pm$ 0.12<br>c <sub>5</sub> | 0.235 $\pm$ 0.16<br>8 | 5.36   | 0.004* |
| <i>Tilapia</i>   | 0.143 $\pm$ 0.06<br>8              | 0.178 $\pm$ 0.13<br>7                           | 0.234 $\pm$ 0.11<br>3              | 0.153 $\pm$ 0.05<br>8                           | 0.177 $\pm$ 0.10<br>2 | 1.69   | 0.186  |
| <b>Total</b>     | 0.126 $\pm$ 0.07<br>9              | 0.211 $\pm$ 0.10<br>8                           | 0.302 $\pm$ 0.19<br>5              | 0.186 $\pm$ 0.10<br>1                           | 0.206 $\pm$ 0.14<br>1 |        |        |

\*\* Significant at 0.01

**Fig. 9. Mean Cadmium concentrations ( $\mu\text{g/g}$  dry wt.) in various organs of the investigated fishes.**

### Mercury (Hg) Concentrations

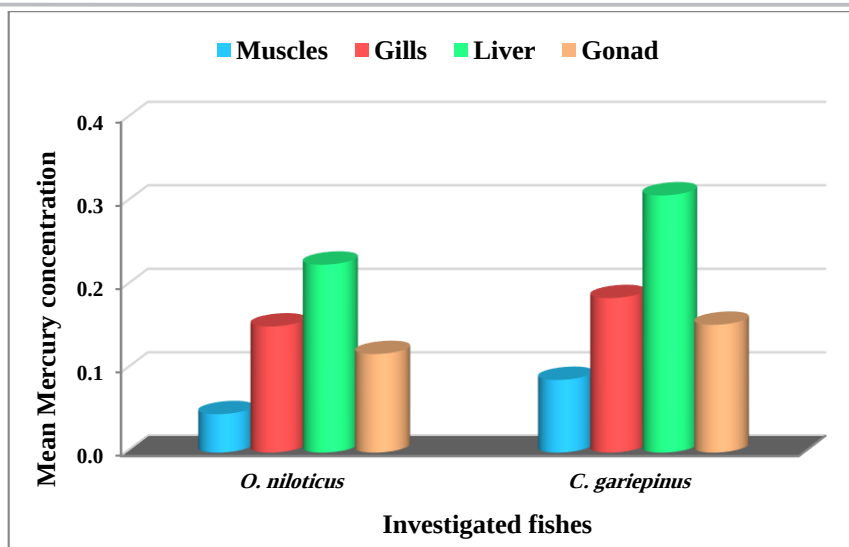
The mean concentrations of Hg in various organs of *O. niloticus* and *C. gariepinus* are shown in Table 8 and Figure 10. Significant differences were found in Hg concentrations among different organs for both *O. niloticus* and *C. gariepinus*. Hg

concentrations detected in *O. niloticus* and *C. gariepinus* increased in the following order: liver > gills > gonads > muscles. The liver of both *O. niloticus* and *C. gariepinus* accumulated the highest levels of Hg. Additionally, all the organs of *C. gariepinus* accumulated higher levels of Hg than those of *O. niloticus*. The concentrations of Hg in the organs of *C. gariepinus* were as follows: liver = 0.308 µg/g dry weight, gills = 0.185 µg/g dry weight, gonads = 0.153 µg/g dry weight, and muscle = 0.087 µg/g dry weight. Meanwhile, the concentrations of Hg in the organs of *O. niloticus* were as follows: liver = 0.225 µg/g dry weight, gills = 0.151 µg/g dry weight, gonads = 0.118 µg/g dry weight, and muscle = 0.046 µg/g dry weight.

**Table (8): Mean Mercury concentrations (µg/g dry wt.) in various organs of the investigated fishes.**

| Heavy metals   | Organs                    |                           |                           |                                    |                           | F-test |              |
|----------------|---------------------------|---------------------------|---------------------------|------------------------------------|---------------------------|--------|--------------|
|                | Muscles                   | Gills                     | Liver                     | Gonad                              | Total                     |        |              |
|                | Mean± SD                  | Mean± SD                  | Mean± SD                  | Mean ± SD                          | Mean ± SD                 | F      | Sig.         |
| <i>Claria</i>  | 0.087 ± 0.02<br>b ± 5     | 0.185 ± 0.02<br>c ± 3     | 0.308 ± 0.04<br>a ± 6     | 0.153 <sup>b</sup> ± 0.02<br>c ± 5 | 0.183 ± 0.12<br>5         | 8.87   | 0.001**<br>* |
| <i>Tilapia</i> | 0.046 ± 0.03<br>a ± 3     | 0.151 ± 0.06<br>b ± 9     | 0.225 ± 0.05<br>c ± 5     | 0.118 <sup>d</sup> ± 0.05<br>6     | 0.135 ± 0.83<br>6         | 18.35  | 0.001**<br>* |
| <b>Total</b>   | <b>0.066 ± 0.06<br/>2</b> | <b>0.168 ± 0.07<br/>1</b> | <b>0.266 ± 0.11<br/>5</b> | <b>0.136 ± 0.06<br/>9</b>          | <b>0.159 ± 0.10<br/>8</b> |        |              |

\*\*\* Significant at 0.001



**Fig.10. Mean Mercury concentrations ( $\mu\text{g/g}$  dry wt.) in various organs of the investigated fishes.**

### Heavy Metal Concentrations in Fish Organs

Heavy metals concentrations in the organs of fish species are presented in Tables 9 and 10 and Figures 11 and 12.

Significant differences were observed between Zn, Cu, Pb, and Hg concentrations in muscles, gills, liver, and gonads of *O. niloticus*, while Cd did not show significant differences between these organs (Table 9).

For *O. niloticus*, the distribution of metals in the fish organs followed this descending order:  $\text{Zn} > \text{Cu} > \text{Pb} > \text{Cd} > \text{Hg}$ . The total concentration values of Cu, Cd, and Hg in the fish organs were detected in the following order: liver > gills > gonads > muscles. The sequence of Zn concentration in the organs followed this order: gonads > liver > gills > muscles. Pb concentrations took the following order: liver > gonads > gills > muscles (Table 9, Figure 11).

Similarly, for *C. gariepinus*, significant differences were observed between Zn, Cu, Cd, and Hg concentrations in muscles, gills, liver, and gonads, while Pb did not show significant differences between these organs (Table 10). The accumulation order of heavy metals in fish organs was as follows: Zn > Cu > Pb > Cd > Hg. The total concentration values of Cu, Cd, and Hg in fish organs were detected in the following order: liver > gills > gonads > muscles. Zn contents in fish organs were as follows: gonads > liver > gills > muscles. Pb concentrations took the following order: liver > gonads > gills > muscles (Table 10, Figure 12).

**Table (9): Mean heavy metals concentrations (µg/g dry wt.) in various organs of *O.niloticus*.**

| Heavy metals | Organs   |            |             |            |             | F-test |       |
|--------------|----------|------------|-------------|------------|-------------|--------|-------|
|              | Muscles  | Gills      | Liver       | Gonad      | Total       | F      | Sig.  |
|              | Mean±SD  | Mean±SD    | Mean±SD     | Mean±SD    | Mean±SD     |        |       |
| Zinc         | 30.7±8.7 | 118.7±26.9 | 152.5±26.54 | 186.5±60.1 | 122.1±68.01 | 34.    | 0.001 |
| Copper       | 1.63±0.5 | 7.429±1.39 | 285.2±120.5 | 6.565±3.36 | 75.22±135.8 | 53.    | 0.001 |
| Lead         | 0.16±0.0 | 0.233±0.05 | 0.493±0.273 | 0.417±0.25 | 0.326±0.227 | 6.6    | 0.001 |
| Cadmium      | 0.14±0.0 | 0.178±0.13 | 0.234±0.113 | 0.153±0.05 | 0.177±0.102 | 1.6    | 0.186 |
| Mercury      | 0.04±0.0 | 0.151±0.06 | 0.225±0.055 | 0.118±0.05 | 0.135±0.836 | 18.    | 0.001 |

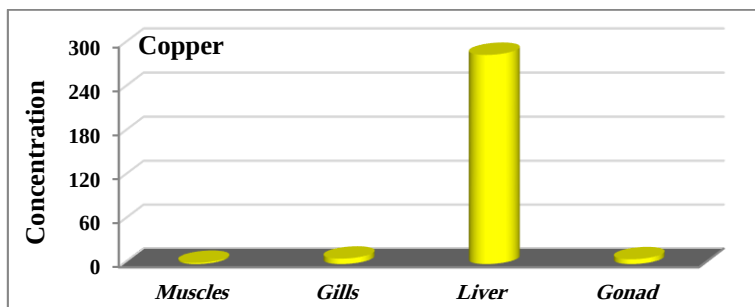
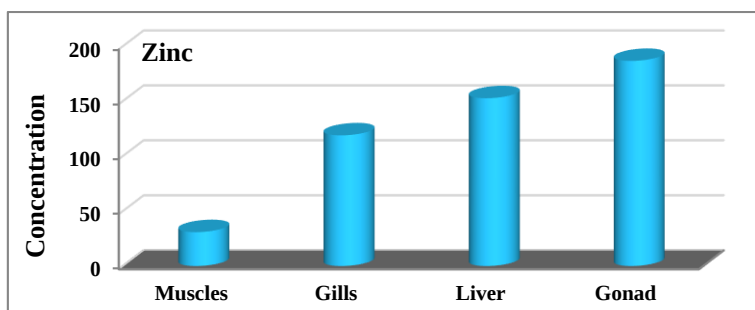
\*\*\* Significant at 0.001

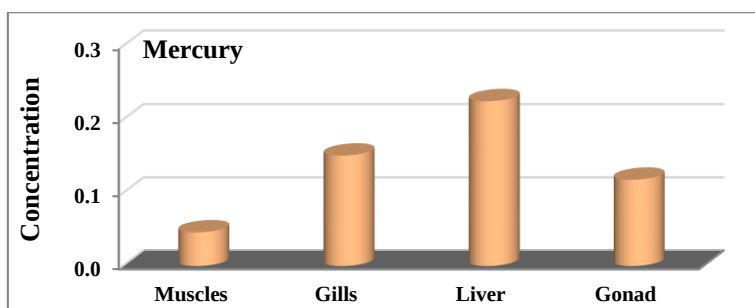
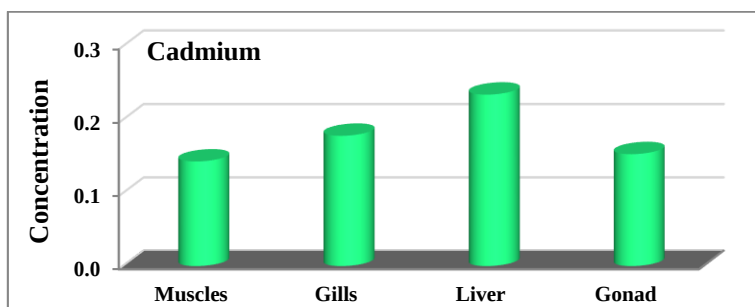
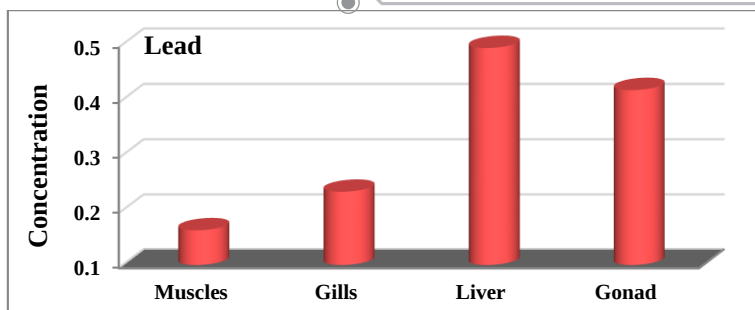
**Table (10 ): Mean heavy metals concentrations ( $\mu\text{g/g}$  dry wt.) in various organs of *C.gariepinus***

| Heavy metals | Organs             |                  |                  |                  |                    | F-test |       |
|--------------|--------------------|------------------|------------------|------------------|--------------------|--------|-------|
|              | Muscles            | Gills            | Liver            | Gonad            | Total              |        |       |
|              | Mean $\pm$ SD<br>n | Mean $\pm$ SD    | Mean $\pm$ SD    | Mean $\pm$ SD    | Mean $\pm$ SD<br>n | F      | Sig.  |
| Zinc         | 42.5 $\pm$ 28.8    | 123.7 $\pm$ 25.5 | 144.4 $\pm$ 38.4 | 172.1 $\pm$ 114. | 120. $\pm$ 78.1    | 7.7    | 0.001 |
| Copp         | 3.29 $\pm$ 1.10    | 16.05 $\pm$ 5.04 | 98.92 $\pm$ 37.7 | 3.875 $\pm$ 1.37 | 30.5 $\pm$ 44.2    | 58.    | 0.001 |
| Lead         | 0.34 $\pm$ 0.32    | 0.445 $\pm$ 0.38 | 0.521 $\pm$ 0.54 | 0.455 $\pm$ 0.25 | 0.44 $\pm$ 0.38    | 0.3    |       |
| Cadm         | 0.11 $\pm$ 0.08    | 0.243 $\pm$ 0.05 | 0.369 $\pm$ 0.24 | 0.220 $\pm$ 0.12 | 0.23 $\pm$ 0.16    | 5.3    | 0.004 |
| Merc         | 0.08 $\pm$ 0.02    | 0.185 $\pm$ 0.02 | 0.308 $\pm$ 0.04 | 0.153 $\pm$ 0.02 | 0.18 $\pm$ 0.12    | 8.8    | 0.001 |

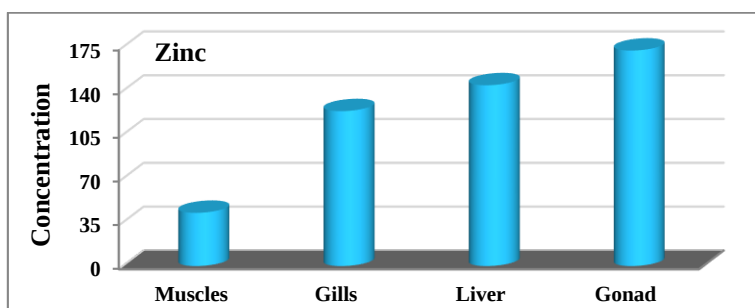
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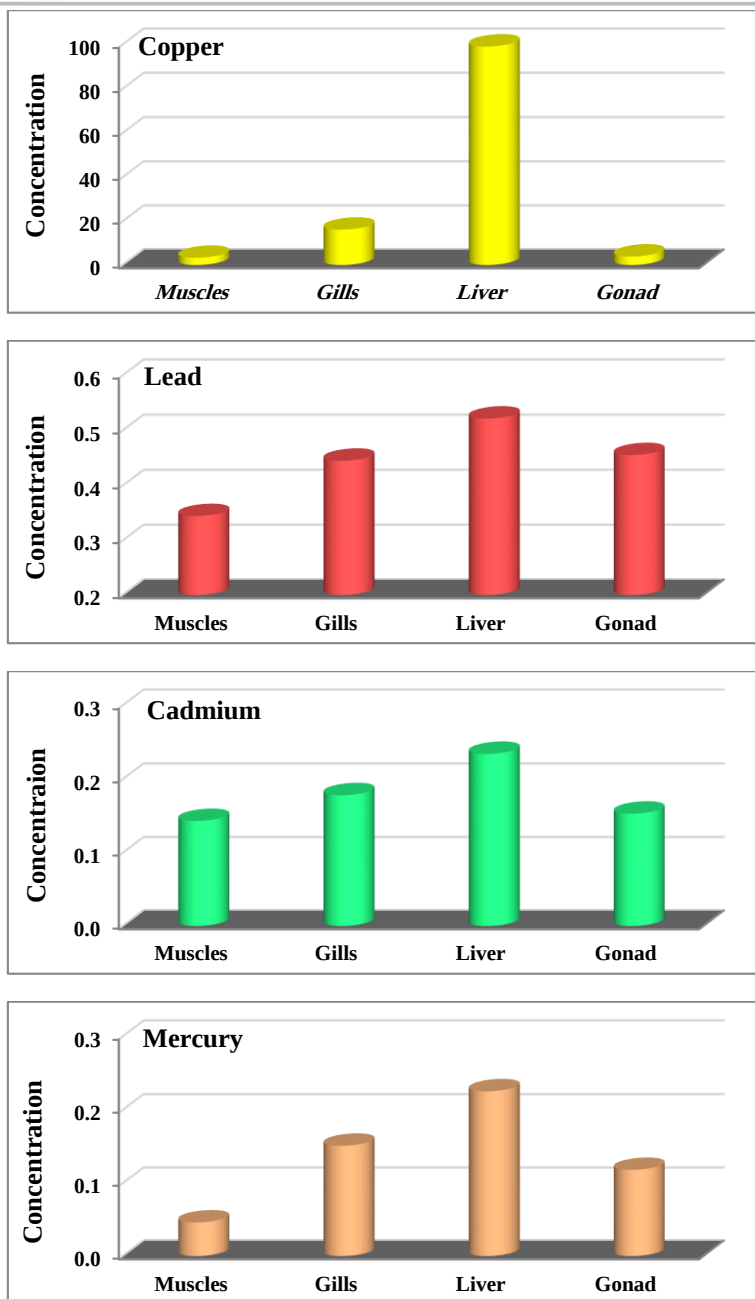
\*\*\* Significant at 0.001





**Fig.11. Mean heavy metals concentrations (µg/g dry wt.) in various organs of *O.niloticus***





**Fig.12. Mean heavy metals concentrations ( $\mu\text{g/g}$  dry wt.) in various organs of *C.gariepinus***

## Pearson correlation between heavy metals in the investigated fish

The Pearson's correlation matrix between the concentrations of heavy metals in the investigated fishes is shown in Table 11. Zinc showed a positive significant correlation with copper ( $r=0.233$ ), lead ( $r=0.225$ ), cadmium ( $r=0.323$ ), and mercury ( $r=0.388$ ). Copper is correlated with lead ( $r=0.283$ ) and mercury ( $r=0.366$ ). There was a correlation between lead and cadmium ( $r=0.242$ ), and a correlation between cadmium and mercury ( $r=0.341$ ).

**Table (11): The correlations coefficient between heavy metals concentrations in the investigated fishes.**

| Heavy metals | Zinc | Copper | Lead   | Cadmium | Mercury |
|--------------|------|--------|--------|---------|---------|
| Zinc         |      | 0.233* | 0.225* | 0.323** | 0.388** |
| Copper       |      |        | 0.283* | 0.196   | 0.366** |
| Lead         |      |        |        | 0.242*  | 0.091   |
| Cadmium      |      |        |        |         | 0.341** |
| Mercury      |      |        |        |         |         |

\* Significant at 0.05

\*\* Significant at 0.01

In *O.niloticus*, there was a remarkable positive correlation between Zinc and lead ( $r=0.637$ ), zinc and mercury ( $r=0.434$ ). Copper had positive correlation with lead ( $r=0.561$ ) and mercury ( $r=0.556$ ) (table 12).

**Table (12): The correlations coefficient between heavy metals concentrations in all organs of *O.niloticus***

| Heavy metals   | Zinc | Copper | Lead   | Cadmium | Mercury |
|----------------|------|--------|--------|---------|---------|
| <b>Zinc</b>    |      | 0.284  | 0.637* | 0.211   | 0.434** |
| <b>Copper</b>  |      |        | 0.561* | 0.254   | 0.556** |
| <b>Lead</b>    |      |        |        | 0.241   | 0.311   |
| <b>Cadmium</b> |      |        |        |         | 0.183   |
| <b>Mercury</b> |      |        |        |         |         |

\* Significant at 0.05

\*\* Significant at 0.01

In *C.gariepinus*, a positive correlation was found between zinc and cadmium ( $r=0.404$ ), Zinc and mercury ( $r=0.386$ ), copper and cadmium ( $r=0.481$ ), copper and mercury ( $r=0.551$ ). Cadmium had positive correlation with mercury ( $r=0.361$ ) (table 13).

**Table (13): The correlations coefficient between heavy metals concentrations in all organs of *C.gariepinus*.**

| Heavy metals   | Zinc | Copper | Lead  | Cadmium | Mercury |
|----------------|------|--------|-------|---------|---------|
| <b>Zinc</b>    |      | 0.254  | 0.073 | 0.404** | 0.386*  |
| <b>Copper</b>  |      |        | 0.242 | 0.481** | 0.551** |
| <b>Lead</b>    |      |        |       | 0.202   | 0.05    |
| <b>Cadmium</b> |      |        |       |         | 0.361*  |
| <b>Mercury</b> |      |        |       |         |         |

\* Significant at 0.05

\*\* Significant at 0.01

## Discussion

The increasing human population has heightened the demand for food, with fish being a staple for many worldwide due to their nutritional benefits. However, aquatic environments are facing pollution from urbanization and industrial development, particularly heavy metals, which pose significant health risks. Fish can accumulate these metals, impacting human health upon consumption. This study investigated heavy metal accumulation in various fish species, revealing species-specific patterns influenced by factors like feeding habits, habitat, and pollution levels.

The results indicated differential heavy metal accumulation among fish species, with *Oreochromis niloticus* accumulating high levels of Zn and Cu, while *Clarias gariepinus* showed elevated concentrations of Pb, Cd, and Hg. Such variations align with previous studies, highlighting species-specific bioaccumulation tendencies. Factors such as feeding habits, habitat proximity to sediment, and pollution levels influence metal accumulation. The findings from Sallam et al. (2019) support these results, as Nile tilapia showed higher mean concentrations of Hg, Pb, and Cd compared to African catfish and flathead grey mullet in their study. This pattern suggests that Nile tilapia may be more susceptible to accumulating heavy metals due to its feeding habits and habitat proximity to polluted sediments in Lake Manzala.

Liver tissue consistently exhibited the highest metal concentrations, particularly Cu, Pb, Cd, and Hg. The liver serves as a vital organ for detoxification and metabolism, storing metals for subsequent elimination. Gills, being in direct

contact with water, also accumulated significant metal levels due to their role in gas exchange and osmoregulation. Muscles, with lower metabolic activity, showed the lowest metal concentrations, consistent with previous findings across fish species.

Comparisons with other studies [including that of Sallam et al. \(2019\)](#) underscored variability in metal accumulation across different water bodies and species, influenced by ecological factors and sampling conditions. Importantly, metal levels in the analyzed fish remained below legal limits set by regulatory bodies like the FAO/WHO, reassuring the safety of consuming these fish.

In summary, this study elucidates species-specific patterns of heavy metal accumulation in fish, driven by ecological factors and pollution levels. Understanding these dynamics is crucial for assessing environmental health and ensuring food safety. Further research into the mechanisms of metal accumulation and their impacts on ecosystems and human health is warranted.

## Conclusion

This study addresses a critical knowledge gap by investigating heavy metal concentrations in *Oreochromis niloticus* and *Clarias gariepinus* from Lake Manzala. Significantly different metal levels were observed between the two fish species, highlighting the importance of species-specific assessments in understanding environmental contamination.

Moreover, significant variations were found among the accumulation of metals in different organs of the studied species. The accumulation pattern for Cu, Cd, and Hg showed a

hierarchy of liver > gills > gonads > muscle, while Zn exhibited a pattern of gonads > liver > gills > muscles. Pb concentrations followed the order of liver > gonads > gills > muscle.

Regarding food safety, the findings suggest that the muscle tissue of the investigated fish species falls within acceptable limits proposed by the WHO and FAO. Thus, based on the samples collected and analyzed, consumption of the muscle tissue appears to be suitable for human consumption without posing significant health risks due to heavy metal contamination.

This study not only contributes valuable data on heavy metal concentrations in fish from Lake Manzala but also underscores the importance of ongoing monitoring and regulation to ensure food safety and environmental health. Continued research in this area is essential for mitigating potential risks associated with heavy metal pollution in aquatic ecosystems.

## References

**Abdallah, M. A. M. (2008).** Trace element levels in some commercially valuable fish species from coastal waters of Mediterranean Sea, Egypt. *Journal of Marine Systems* 73: 114- 122.

**Aboul Naga, W. and Al Deep, M. K. Z (2005).** Trace metal concentration in the liver tissues of four fish species from Alexandria coastal waters, Egypt. *Arab Gulf Journal of Sci. Res.*, 23 (4): 158-164.

**Acheshi, A. S. and Omame, O. A (2017).** Bioaccumulation of Heavy Metals on Some Organs of *Oreochromis Niloticus* (Nile Tilapia Fish). *Int. Journal of Applied Science and Mathematical Theory* 3(1): 2489-009.

**Adeyeye, A. and Ayoola, B. P. (2013).** Heavy Metal Concentration in Some Organs of African Catfish (*Clarias gariepinus*) from Eko-Ende Dam, Ikirun, Nigeria. *Continental Journal Applied Sciences* 8(1): 43-48.

- Afshan, S.; Ali, S.; Ameen, S. U.; Farid, M.; Bharwana, A. S.; Hannan, F. and Ahmad, R. (2014).** Effect of Different Heavy Metal Pollution on Fish. *Research Journal of Chemical Environmental Sciences* 2(2): 35-40.
- Ahmad, A. K. and Al-Mahageri, A. S. (2015).** Human Health Risk Assessment of Heavy Metals in Fish Species Collected from Catchments of former Tin Mining. *Int. Journal of Research Studies in Science, Engineering and Technology* 2, 4: 9-21.
- Ahmet, A. M and Hussein, M. M. (2004).** Residual Levels of Some Heavy Metals in Fish Flesh and Water from El-Manzala Lake, Egypt. *Journal King Saud Univ.* 16, (2): 187-196.
- Akan, C. J.; Mohmoud, S.; Yikala, S. B. and Ogugbuaja, O. V. (2012).** Bioaccumulation of Some Heavy Metals in Fish Samples from River Benue in Vinikilang, Adamawa State, Nigeria. *American Journal of Analytical Chemistry*, 3: 727-736.
- Aladetohun, F. N.; Sakiti, G. N. and Emmanuel, E. B. (2013).** Bioaccumulation of Heavy Metals and Bioindicator Species Using Mugilidae Fish (*Liza Falcipnnis*) Infected with Parasitic Worm in Mequon Area of the Lagos Lagoon, Nigeria. *Research Journal of Chemical and Environmental Sciences* 1 (4): 69-73.
- Alkan, A. F.; Koksai, E. M.; Ergun, D. D.; Karis, D.; Ozsobaci, P.N. and Barutcu, B. U. (2015).** Element intoxication by marine food. *Medical Science and Discovery* 2(2): 176-181.
- Al-Kazaghly, R. F.; (2011).** Study on Concentration of Some Heavy Metals in Six Economic Fish Species from Zelitan Coast at Great Jamahiriya. M.Sc. Thesis. Academy of Graduate Studies, Libya.
- Ansari, M. T.; I.L. Marr, L. I. and Tariq, N. (2004).** Heavy Metals in Marine Pollution-A Mini Review. *Journal of Applied Sciences* 4 (1): 1-20.
- Azaman, F.; Juahir, H. ; Yunus, K.; Azid, A.; Kamarudin, M.; Toriman, M.; Mustafa, A.; Amran, M.; Hasnama, C.; Saudi, A. (2015).** Heavy metal in fish: Analysis and human health-a review. *Jurnal Teknologi*, 77 (1), 61-69.
- Bahhari, A. H.; Al-Switi, I. N and Al-Rajab, A. (2017).** Concentration of heavy metals in Tissues of *Mugil cephalus* and *Lethrinus miniatus* from

Jazan Coast, Saudi Arabia. Journal An International Quarterly Scientific 16 (2): 647-651.

**Bahnasawy, M. and El-Bakkoch, F. (2009).** Concentration of heavy Metals in water, *sediment* and fish from the Mediterranean coast Of Libya. Egypt J. Aquat. Biol. And fish., 13 (4): 211-230.

**Bahnasawy, M.; Khide, A and Dheina, N. (2009).** Seasonal Variations of Heavy Metals Concentrations in Mullet, Mugil ephalus and Liza Ramada (Mugilidae) from Lake Manzala, Egypt. Journal of Applied Sciences Research 5(7):845-852.

**Beveridge, M. C. M.; Thilsted, H. S.; Phillips, J. M.; Metian, M.; Troell, M. and Hall, J. S. (2013).** Meeting the food and nutrition needs of the poor: the role of fish and the opportunities and challenges emerging from the rise of aquaculture. Journal of fish Biology, 83:1067-1084.

**Blasco, J.; Rubio, J.; Forja, J.; Gomez-parra, A. and Establier, R. (1998).** Heavy metals in some fishes of the mugilidae family from salt-ponds Of Cadiz Bay, Spain. Ecotoxicol. Environ. Restore., 1(2):71-77.

**Burger, J. and Gochfeld, M. (2005).** Heavy metals in commercial fish in New Jersey. Environmental Research 99: 403-412.

**Canbek, M.; Demir, A. T.; Uyanoglu, M.; Bayramoglu, G.; Emiroglu, O.; Arslan, N. and Koyuncu, O. (2007).** Preliminary Assessment of Heavy Metals in Water and Some Cyprinidae species from the Porsuk River, Turkey. Journal of Applied Biological Sciences 1 (3): 91-95.

**Canli, M and Atli, G. (2003).** The relationships between heavy metal (Cd, Ce, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. J. Environmental Pollution 121: 129-136.

**Canli, M and Atli, G. (2003).** The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn ) levels and the size of six Mediterranean fish species. Environmental Pollution 121: 129-136 .

**Celik, U. and Oehlenschlager, J. (2005).** Zinc and copper content in Marine fish samples collected from the eastern Mediterranean Sea. Eur. Food Res. Technology, 220:37-41.

**Chouba.; Kraiem, L.; Njimi, M.; Tissaoui, W.; Thompson, Ch. JR and Flower, RJ. (2007).** Seasonal variation heavy metals (Cd, Pb, and Hg) in

sediments and in mullet, *Mugil cephalus* (Mugilidae), from the Ghar El Melh Lagoon (Tunisia). J. Transit Waters Bull 4: 45-52.

**De Pinho, P. A.; Guimaraes, D. R. J.; Martins, S. A.; Costa, S. A.P.; Olavo, G. and Valentin, J. (2002).** Total Mercury in Muscle Tissue of Five Shark Species from Brazilian Offshore waters: Effects of Feeding Habit, Sex, and Length. Environmental Research Section A 89, 205-258.

**Dhinakaran,D. ; Muthukrishnan,S. ; Kaleeswaran, A.;Jeyanthinatha S.; Umasankari M. and Thilagavathi, S. (2014).** Bioaccumulation of Heavy Metals in Two Marine Fishes (*Pristis microdon* and *Scomberomorus guttatus*) Middle East J. Sci. Res. 22 (3): 333-338.

**Edem, C.A.; Osabor, V.; Iniama, G.; Etiuma, R. and Eke, J. (2009).** Distribution of heavy metals bones, gills, liver and muscle of (Tilapia) *Oreochromis niloticus* from Hens haw Town Beach market, in Calabar, Nigeria. Pak. J. Nutrition, 8 (8): 1209-1211.

**El-Bakkoch, F. (2009).** Assessment of some heavy metals pollution in Some marine fishes at El-Khoms region, Great Jamahiriya. M Sc. Thesis, Faculty of Science El-Merghib University, Libya .

**Elnabris, K.J., Muzyed, S.K. and El-Ashgar, N.M. (2013).** Heavy Metal Concentrations in Some Commercially Important Fishes and Their Contribution to Heavy Metals Exposure in Palestinian People of Gaza Strip (Palestine). Journal of the Association of Arab Universities for Basic and Applied Sciences, 13: 44-51.

**Eridogrul, O. (2007).** Determination of mercury levels in edible tissues of various fish samples from Sir. Dam lake. Turk. J. Biol. 31:197-201.

**Fatoki, OS.; Lujiza, N. and Ogunfowokan, AO. (2002).** Trace metal pollution in Umtata River. Water AS 28(2): 183-189.

**Ganjavi, M.; Ezzatpanah, H.; Givianrad, M. and Shams, A. (2010).** Effect of canned tuna fish processing steps on Lead and cadmium contents of Iranian tuna fish. Food Chemistry 118: 525-528.

**Genc, T. O and Yilmaz, F. (2018).** Heavy Metals Content in Water, Sediment, and Fish (*Mugil Cephalus*) From Koycegiz Lagoon System Turkey: Approaches for Assessing Environmental and Health Risk. J. Agr. Sci. Tech. 20: 1-11.

**Gupta, S. and Singh, J. (2011).** Evaluation OF Mollusc as Sensitive Indicator of Heavy Metal Pollution In Aquatic System: A review. The IIOAB Journal ,2 (1):49-57.

Ibrahim, A. ; Bahnasawy, M. ; Mansy, S. and EL-Fayomy, R. (2000). On some heavy metal levels in water, sediment and marine organisms from the Mediterranean Coast of Lake Manzala. Egypt. J. Aquat. Biol & Fish., 4(4): 61-81.

**Ibrahim, N. and Abu El-Regal, M. (2014).**Heavy Metals Accumulation in Marine Edible Molluscs, Timsah Lake,Suez Canal, Egypt. ARPN Journal of Science and Technology,4(4): 282-288.

**Kalay, M.; Ay, O. and canli, M. (1999).** Heavy metal concentrations in Fish tissues from the Northeast Mediterranean Sea. Bull. Environ. Contam. Toxicol., 63 : 673-681.

**Karthikeyan, S.; Palaniappan, PL.RM and Sabhanayakam, S. (2007).** Influence of pH and water hardness upon nickel accumulation in edible fish *Cirrhinus mrigala*. j. of Environmental Biology 28 (2): 489-492.

**Kasherwani, D.; Lodhi, S. H.; Tiwari, Ji. K.; Shukla, S. and Sharma, D. U. (2009).** Cadmium Toxicity to Freshwater Catfish, *Heteropneustes fossilis* (Bloch). Asian Journal Sci. 23, 1: 149-156.

**Khalifa, K. M.; Hamil, A. M.; Al-Houni, A. Q. A and Ackacha, M. A. (2010).** Determination of heavy metals in fish species of the Mediterranean Sea (Libyan coastline) using Atomic Absorption Spectrometry. International Journal of Pharm . Tech. Research, 2(2) : 1350-1354.

**Khallaf, E. ; Galal, M. and Authman, M. (1998).** Assessment of heavy Metals pollution and their effects on *Oreochromis niloticus* in Aquatic drainage canals. J. Egypt. Ger. Soc. Zool ., 26 (B) : 36-74.

**Khayatzadeh, J and Abbasi, E. (2010).** The Effects of Heavy Metals on Aquatic Animals. International Applied Geological Congress, Department of Geology, Islamic Azad University-Mashhad Branch, Iran, 26-28.

**Kotze, p.; Du preez, H. and Van Vuren, J. (1999).** Bioaccumulation of Copper and Zinc in *Oreochromis mossambicus* and *Clarias gariepinus*, from the Olifants River, Mpumalanga, South Africa. Water SA, 25 (1) : 99-110 .

**Kris-Etherton, P., Harris, W. ; Lawrence, J.; Appel, L.(2002).** Fish Consumption, Fish Oil, Omega-3 Fatty Acids, and Cardiovascular Disease. *Circulation*, 106: 2747-2757.

**Krishan, P. V.; Rao, K. M.; Swaruparani, V and Rao, D. S. (2014).** Heavy Metals Concentration in Fish *Mugil cephalus* from Machilipatnam Coast and Possible Health Risks to Fish Consumers. *Journal British Biotechnology* 4(2): 126-135.

**Kucuksezgin, F.; Uluturhan, E.; Kontas, A. and Altay, o. (2002).** Trace metal concentrations in edible fishes from Izmir Bay, Eastern Aegean. *Baseline/ Marine Pollution Bulletin* 44: 816-832.

**Makedonski, L.; Peycheva, K. and Stancheva, M. (2017).** Determination of heavy metals in selected black sea fish species. *Food Control* 72: 313-318

**Mendil, D.; Unal, F. O.; Tuzen, M. and Soylak, M. (2010).** Determination of trace metals in different fish species and sediments from the River Yesilirmak in Tokat, Turkey. *Food and Chemical Toxicology*.

**Mohammed, N. K and Khamis, F. O. (2012).** Assessment of heavy metal contamination in vegetables consumed in Zanzibar's. *Natural Science* 4 (8): 588-594.

**Nwoko, O. C. and Egonwa, I. (2015).** Assessment of trace metal contamination of catfish (*Clarias gariepinus*) and tilapia (*Oreochromis niloticus*) obtained from Choba and Aluu Axis of New-calabar River, Rivers state Nigeria. *Universal Journal of Environmental Research and Technology*. 5(6): 265-277.

**Obasojan, E. E. (2007).** Heavy Metals concentrations in the offal, gill, muscle and liver of a freshwater mudfish (*Parachanna obscura*) from Ogba River, Benin city, Nigeria. *African Journal of Biotechnology* 6(22): 2620-2627.

**Raja, P.; Veerasingam, S.; Suresh, Marichamy, G. and Venkatachalapathy, R. (2009).** Heavy Metals Concentration in Four Commercially Valuable Marine Edible Fish Species from Parangipettai Coast, South East Coast of India. *International Journal Concentration Veterinary Advances* 1(1): 10-14.

**Rayment, E. G and Barry, A. G. (2000).** Indicator Tissues for Heavy Metal Monitoring - Additional Attributes. *Marine Pollution Bulletin* 41, 7-12. 353-358.

**Renieri, E.; Alegakis, A.; Kiriakakis M.; Vinceti M.; Ozcagli E.; Wilks M. and Tsatsakis, A.(2014).** Cd, Pb and Hg Biomonitoring in Fish of the Mediterranean Region and Risk Estimations on Fish Consumption. *Toxics*, 2 : 417-442.

**Romeo, M.; Siau, Y.; Sidoumou, Z and Gnassia-Barelli, M. (1999).** Heavy metal distribution in different fish species from the Mauritania coast. *J. The Science of the Total Environment* 232: 169-175.

**Rossi, A.R.; Rye, M.; Triantafyllidis, A and Tsigenopoulos, C.S. (2006).** *Gilthead seabream-Sparus aurata*. Proceedings of the WP1 workshop of domestication breeding and enhancement of performance of fish and shellfish, Viterbo, Italy.

**Sallam, K.I., Abd- Elghany, S.M. and Mohammed, M.A., 2019. Heavy metal residues in some fishes from Manzala Lake, Egypt, and their health- risk assessment. *Journal of food science*, 84(7), pp.1957-1965.**

**Sary, A. A. and Velayatzadeh, M. (2014).** Determination of lead and zinc in king mackerel (*Scomberomorus guttatus* Bloch & Schneider, 1801), Spanish mackerel (*Scomberomorus commerson lacepede*, 1800) and Tiger-toothed Croaker (*Otolithes ruber* Bloch and Schneider, 1801) from Persian Gulf, Iran in 2001 and 2011. *Journal of Biodiversity and Environmental Sciences (JBES)* 5 (1): 322-329.

**Seixas, S.; Bustamante, P. and pierce, G. (2005).** Accumulation of Mercury in the tissues of common octopus, *Octopus vulgaris* , in Two localities on Portuguese Coast. *Total Environ* , 340 : 113-122.

**Soliman, Z. I. (2006) .** A study of heavy metals pollution in aquatic Organisms in Suez Canal in Port-Said Harbor. *Journal of Applied Sciences Research* 2 (10) : 657-663 .

**Sreemivasa, R. J.; Vasudeva, R. Y.; Devindra, S. and Longvah, T. (2014).** Analysis of Heavy Metal Concentrations in Indian marine fish using ICP-MS after closed vessel micro wave digestion method. *Int. Journal of Analytical and Bioanalytical Chemistry* 4(3): 67-73.

**Storelli, M. ; Storelli, A.; Giacomini-Stuffler, R. and arcotrigiano, G. (2005).** Mercury speciation in the muscle of two commercially important fish, hake (*Merluccius merluccius*) and striped mullet (*mullus barbatus*) from the Mediterranean Sea : estimated weekly intake. Food Chemistry, 89 : 295-300.

**Turkmen, A.; Turkmen, M.; Tape, Y and Akyurt, I . (2005) .** Heavy Metals in three commercially valuable fish species from Iskenderun Bay, northern east Mediterranean Sea, Turkey. food Chemistry, 91 (10)167-172.

**Turkmen, M.; Turkmen, A.; Tepe, Y.; Ates, A. And Gokkus , K. (2008) .** Determination of metal concentrations in Sea foods from Marmara, Aegean and Mediterranean Seas, twelve fish species. Food chemistry 108 : 794-800 .

**Tuzen, M. (2009) .** Toxic and essential trace elemental contents in fish Species from the Black Sea, Turkey . Food and Chemical Toxicology 47:1785-1790.

**U. S. E. P. A. (United States Environmental Protection Agency) (1986).** Quality criteria for Water .EPA 440 15-86- 002.

**Uluozlu, O. D.; Tuzen, M. ; Mendil, D. and Soylak, M. (2007).** Trace Metal content in nine species of fish from the Black and Aegean Seas, Turkey . Food Chemistry, 104 : 835-840.

**Uysal, K.; Emre, Y. and Kose, E . (2008).** The determination of heavy Metal accumulation ratios in muscle, Skin, and gills of some Migratory fish species by inductively coupled plasma – optical Emission spectrometry (ICP-OES) in Beymelek Lagoon (Antalya, Turkey). Micro chemical Journal, 90 (1) : 67-70 .

**Uzoamaka, S. O. (2016).** Assessment of Heavy Metal Concentration in Gills and Livers of Fresh Water Fish (*Clarias gariepinus*) from Asu River, Akpoha in Ebonyi State, Abakaliki. Int. Journal of Biological and Environmental Engineering, 1(1): 1-6.

**Valavanidis, A. and Vlachogianni, T. (2010).** Metal Pollution in Ecosystems Ecotoxicology Studies and Risk Assessment in the Marine Environment. Science advances on Environmental, Toxicology Ecotoxicology issues 1-14.

**Yilmaz, F. (2009).** The Comparison of Heavy Metal Concentrations (Cd, Cu, Mn, Pb and Zn) in Tissues of Three Economically Fish (*Anguilla anguilla*, *Mugil cephalus* and *Oreochromis niloticus*) Inhabiting Koycegiz Lake-Mugla (Turkey). Turkish Journal of Science & Technology 4 (1): 7-15.

**Zaqoot, H.A.; Aish, A.M and Wafi, H.N. (2017).** Baseline Concentration of Heavy Metals in Fish Collected from Gaza Fishing Harbor in the Mediterranean Sea along Gaza Coast, Palestine. Turkish Journal of Fisheries and Aquatic Sciences 17: 101-109.