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# Heavy Metals Bioaccumulation in Liver and Muscle Tissues of the Common Sole Fish (*Solea solea*) Inhabiting Damietta Fishing Harbor, Egypt

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## ABSTRACT

The current study aimed to investigate the accumulation of heavy metals {copper (Cu), zinc (Zn), manganese (Mn), nickel (Ni), cadmium (Cd), lead (Pb), chromium (Cr), and iron (Fe)} in common sole fish (*Solea solea*) sampled from Damietta fishing harbor and the surrounding area, Damietta, Egypt in winter and spring (2021). For this purpose, four water and fish samples had been collected from four sites purchased from Damietta harbor. Heavy metals (HM) concentrations in water samples collected in the winter season were in the order of Fe > Ni > Zn > Cd > Cr > Pb > Cu > Mn; meanwhile, it was Ni > Pb > Fe > Cr > Zn > Cd > Cu > Mn in the spring season. Although the HM bioaccumulation in this fish species was lower than the permissible limit by FAO and WHO. The HM bio-concentrations showed remarkable differences among the sampling season and fish organs. The HM bio-concentration in the liver tissues was higher than in the muscle tissues of common sole fish. The HM accumulation in liver and muscle tissues sampled in the winter season was in the following order: Fe > Zn > Mn > Cu > Pb > Ni> Cr > Cd. On the other hand, the HM accumulation in both organ tissues sampled in the spring season was in the order of Fe > Zn > Mn > Pb > Cu > Ni > Cr > Cd. The current investigation revealed that the common sole fish inhabiting the Damietta harbor and surrounding areas were safe for human consumption, but the various pollution sources should be disposed of to manage and control HM accumulation in fish and the human being who consume this fish.

## INTRODUCTION

Heavy metals (HM) pollution became a global problem, especially in aquatic ecosystems **(Ahmed *et al*., 2015; Arulkumar *et al*., 2017; Rajeshkumar *et al*., 2018; Al-Halani *et al*., 2021).** Natural and anthropogenic activities, including the drainage of industrial and domestic sewage, harbor activities, and atmospheric deposits, represented the sources of heavy metals pollution in aquatic ecosystems. Metals were of particular

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concern due to their non-biodegradable nature, long biological half-life, and potential to accumulate in different body parts of aquatic organisms **(Mohammadi *et al*., 2011)**. Hence, marine organisms may concentrate large amounts of heavy metals from the water and face potential hazards that would disturb their metabolic pathways in response to HM property and concentration. The concentrations of HM accumulated in aquatic organisms reflect the degree of environmental pollution. Among aquatic species, fish are often at the top of the aquatic food chain and may concentrate large amounts of metals, including copper (Cu), zinc (Zn), manganese (Mn), nickel (Ni), cadmium (Cd), lead (Pb), chromium (Cr), and iron (Fe). These metals could be accumulated differently in fish organs and thus cause serious health hazards to humans **(Mansour & Sidky, 2002; Al-Halani *et al*., 2021)**. Fish is a good bioindicator of the aquatic ecosystems pollution and could be used to estimate the degree of HM pollution and the potential risks of human consumption where metals can accumulate inside the human body via fish consumption **(Mansour & Sidky, 2002; Padmini & Usha Rani, 2008)**. Thus, the determination of HM in fish tissues is critical point of view for human health **(Ahmed *et al*., 2015; Arulkumar *et al*., 2017; Rajeshkumar *et al*., 2018; Al-Halani *et al*., 2021)**.

*Solea* sp. is recorded among Egypt's most essential and valuable commercial flatfishes and is greatly appreciated by consumers of marine fish products **(Zaghloul *et al*., 2011; Gabr *et al*., 2015)**. Different *Sole* species are benthic fish with direct contact with sediments and tend to occupy shallow, sandy, and sandy/muddy habitats as well as shallow lagoons. Common sole (*Solea solea*; Family: Soleidae) is one of the most crucial sole species in Egyptian waters **(El-Aiatt *et al*., 2019; El-Agri *et al*., 2021)**. Consequently, they feed on benthic invertebrates that accumulate metals, increasing the toxicity of these compounds through the bioaccumulation process **(Drake *et al.*, 1984; Dinis, 1992)**. Significant HM levels in this fish species can affect their physiological performance and negatively affect consumer health.

Thus, the present study investigated the seasonal variations of water HM, and the bioaccumulation factor in the liver and muscle tissues of common sole fish (*S. solea*) collected from different sites along Damietta fishing harbor and the surrounding environmental area.

## MATERIALS AND METHODS

### 1. Samples collection:

In winter and spring seasons (2021), water samples (5 L) were collected at 50 cm below the water surface from the studied 4 sites **(Fig. 1)** in clean polyethylene bottles, and then acidified to pH 2 with concentrated nitric acid ($HNO_3$). Fish samples had collected with the help of an expert from fishers at Damietta City at the same time and site. A total of 20 common sole fish (*S. solea*) were purchased, then the fish lengths and weights were measured (their ranges were 26.1 – 27.3 cm and 250 - 280 g, respectively). The fish specimens were washed with deionized water, placed immediately in polyethylene bags, preserved in a polystyrene icebox, and then transported to the environment laboratory at the Faculty of Agriculture, Mansoura University, Mansoura, Egypt.


**Fig. (1): Location map of Damietta fishing port and the surrounding environment parts of the Mediterranean Sea area where 1, 2, 3, and 4 are the sampling sites**

**2. Water quality measurements:**

The pH value was measured at the site using a digital pH meter (Orion Research Model PTI20). Water temperature (T), dissolved oxygen (DO) and electric conductivity (EC) were measured using (Multi-parameter Analyzer model YK-22DO). Water turbidity was measured using Eutech Instruments (Cyberbcan WL Turbidimeter TB1000).

**3. Heavy metals analysis in water samples:**

Water samples were filtered, using 0.45 μm cellulose acetate filter paper using a vacuum pump to obtain dissolved metals **(Hamzah *et al*., 2014)**. Then, heavy metals concentrations were measured in the obtained samples using a Flame Atomic Absorption Spectrophotometer (AAS: Perkin Elmer Analyst 100) using the standard solution of each heavy metal **(APHA, 2005)**. Sometimes, water samples were diluted using deionized water to reach readable concentrations.

**4. Heavy metals analysis in fish tissues:**

The sampled fish were dissected, and muscle and liver tissues were taken and separately oven-dried to constant weight at 105 °C. After that, these samples were grounded to powder and digested according to **Sreedevi *et al*. (1992)**. In brief, one gram per sample was digested in a fume room at 80 °C with a 1:5:1 mix of 70% perchloric acid, concentrated nitric acid, and concentrated sulfuric acid until a formation of a colorless solution. Each digested sample has diluted up to 20 ml with deionized water, and HM concentration was determined using Flame Atomic Absorption Spectrophotometer using the standard solution of each heavy metal **(APHA, 2005)**. The concentration of each metal had calculated in µg/g dry weight.

## 5. Human health risk assessment:

### 5.1. Estimated daily intake (EDI)

The estimated daily intake of metals (EDI) of each metal depends on the metal level and the possible amount of its consumption. The EDI for adults had calculated according to the following equation **(Zhuang *et al*., 2009)**:

$$\textbf{EDI} = (\textbf{C x FIR})/\textbf{BW}$$

Where; C is the heavy metal level in the fish sample (µg/g WW); FIR represents the average daily consumption of fish (muscle) in Egypt (42 g/day) according to **GAFRD (2005)**, and BW is the adult's body weight where the weight of the adult person is estimated in average as 70 kg **(Albering *et al*. 1999)**. EDI values were expressed as µg/kg BW/day for each metal. EDI values were then compared with metal's permissible tolerable daily intakes (PTDIs) according to **FAO & WHO (2011)**.

### 5.2. Non-carcinogenic risk

Target hazard quotient (THQ) is used to assess the non-carcinogenic risk level due to pollutant exposure followed the guidelines recommended by **USEPA (1989)** as follows:

$$\textbf{THQ = ED x C x FIR x EF x CF/RfD x BW x AT * 10}^{-3}$$

Where; THQ is the target hazard quotient; ED is the exposure duration (70 years, average lifetime); C is the metal concentration in fish muscle (µg/g d.w); FIR is the food ingestion rate (g/day); EF is exposure frequency (365 days/year). CF is the conversion factor of 0.208 (to convert dry weight to fresh weight considering 79% of moisture content of the fish fillet **(Rahman *et al*., 2012)**; RfD is the oral reference doses 0.038, 0.3, 0.14, 0.02, 0.001, 0.0036, 1.5 and 0.70 mg/kg/day for Cu, Zn, Mn, Ni, Cd, Pb, Cr, and Fe, respectively **(USEPA 2000)**. BW is the usual adult body weight (70 kg); AT is the average exposure time (365 days/ year × exposure years, assumed as 70 years = 25.550 days);

The hazard index (HI) from THQs is denoted as the total of the hazard quotients generated to evaluate the risk of the combined metals using the following equation:

$$\textbf{HI} = \Sigma \textbf{HQi}, \quad \textbf{i.e.:} \quad \textbf{HI = THQ (Pb) + THQ (Cd) + THQ (Cr)}$$

Where " i " represents each metal, when the value of HQ and HI exceeds 1.0, there is a concern for potential health effects **(Huang *et al*., 2008)**.

## 6. Bio-concentration factors (BCFs) estimation:

Bio-concentration factors (BCFs) are the relation between the steady-state metal ion concentrations in the fish tissue and its concentration in water **(Orata & Birgen, 2016)**. The higher the ratio is the more the bio-concentration of pollutants. In the current study, the BCFs were calculated utilizing the following equation **(Gobas *et al*., 2009)**:

$$\textbf{BCF} = \frac{\textbf{Concentration in fish at steady state (µg/g wet fish)}}{\textbf{Concentration in water (mg /L) at steady state}}$$

## 7. Statistical examination:

The collected data were subjected to two-way ANOVA to test the effect of sampling season and fish organs. Means were statistically compared using the Duncan multiple range test as a post-hoc test to compare between means at $P \leq 0.05$. The statistical investigation was done through SPSS software, version 20.0 (SPSS, Richmond, Virginia, USA) according to **Dytham (2011)**.

## RESULTS

The results obtained indicated that water temperature ranged from 18.8 to 27.4°C in winter and spring, respectively; pH 7.7-7.9, EC 58.8 – 66.1 µs/cm, dissolved oxygen (DO) 7 - 6.6 mg/L, turbidity 6.6 – 6.3 NTU for winter and spring seasons, respectively **(Fig. 2)**.

The total metal concentrations in seawater samples collected from the study area are presented in **Fig. (3)**. The concentrations of heavy metals in winter season were in the order of Fe > Ni > Zn > Cd > Cr > Pb > Cu > Mn, while they were Ni > Pb > Fe > Cr > Zn > Cd > Cu > Mn in spring season.

The HM concentrations in liver and muscle tissues of common sole fish sampled from Damietta fish harbor are summarized in **Table (1)**. The concentrations of Ni and Pb were significantly ($P < 0.05$) changed by sampling season and fish organs but not their interaction. The Cu levels were significantly ($P < 0.05$) higher in liver tissues than in muscle tissues, irrespective of sampling season. Other metals (Zn, Mn, Cd, Cr, and Fe) were insignificantly ($P > 0.05$) higher in liver tissues than in muscle tissues and insignificantly ($P > 0.05$) higher in spring than in the winter season. All HM concentrations showed no significant ($P > 0.05$) changes in the interaction between sampling season and fish organs **(Table 1)**.

Fe had found to be the most prevalent metal in both fish tissues, and its concentration was 17.15 and 16.82 µg/g in the liver in the spring and winter seasons, respectively **(Table 1)**. On the other hand, the lowest concentration had detected with Cd and Cr, especially in the winter season (0.07 and 0.16 µg/g). The HM concentrations were ranked in the following order Fe > Zn > Mn > Cu > Pb > Ni > Cr > Cd irrespective to sampling season and fish organs.

The average daily intake (EDI) of metals (µg/kg BW/day) for common sole fish in the winter and spring seasons was represented in Table 2. The daily consumption of Cu, Zn, Mn, Ni, Cd, Pb, Cr, and Fe in the current study in winter and spring seasons were 0.069 and 0.077, 1.183 and 1.338, 0.316 and 0.403, 0.063 and 0.065, 0.009 and 0.012, 0.076 and 0.093, 0.021 and 0.026, and 2.132 and 2.146 µg/kg BW/day, respectively. The lowest EDI value was observed in the winter season; meanwhile, its highest one was in the spring season. The average daily intake of each metal via fish consumption can be ordered as follows: Fe > Zn > Mn > Pb > Cu > Ni > Cd > Cr **(Table 2)**.

Neither THQ nor HI was greater than 1.0 through the consumption of seafood, indicating that health risks associated with HM exposure were insignificant **(Table 3)**. The highest THQ values for Cu, Zn, Mn, Ni, Cd, Pb, Cr and Fe in winter and spring seasons were 0.002 and 0.002, 0.004 and 0.004, 0.002 and 0.003, 0.003 and 0.003, 0.009

and 0.011, 0.020 and 0.025, 0.000013 and 0.000017, and 0.0029 and 0.0029, respectively. On the other hand, lowest and largest HI values were 0.043 and 0.051in the winter and spring seasons, respectively **(Table 3)**.

The BCFs were calculated based on aqueous contact **(Table 4)**. Accordingly, the highest BCFs value was 59.21 for Mn, followed by Fe, Zn, and Cu (36.44, 25.97, and 13.91, respectively) in the liver tissues of fish sampled in the spring season; meanwhile, the lowest value was 0.21 for Cd in the muscle tissues in the winter season **(Table 4)**.

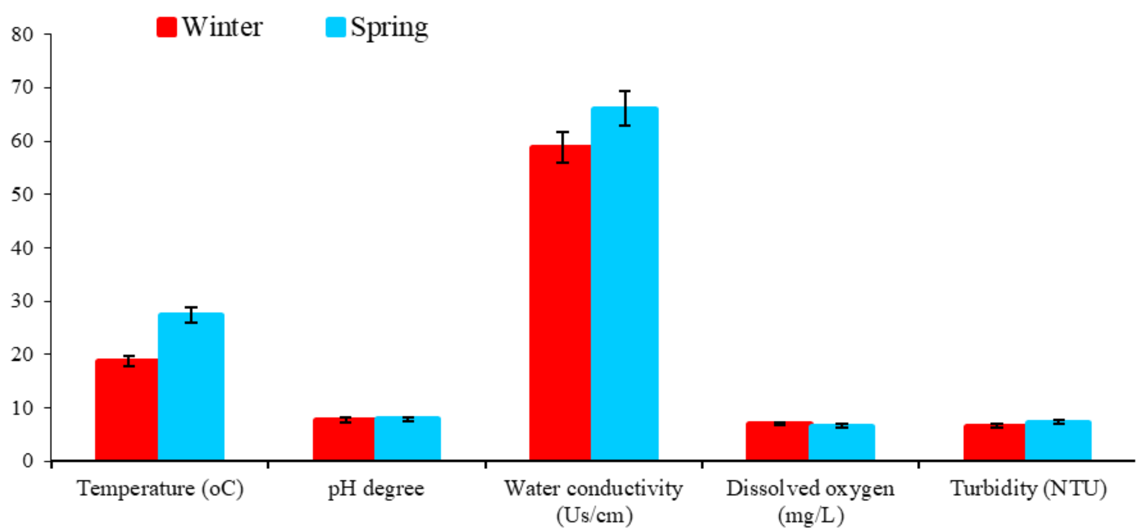


**Fig. (2): Parameters of water samples collected from Damietta fishing harbor and the surrounding area in the winter and spring seasons (2021)**

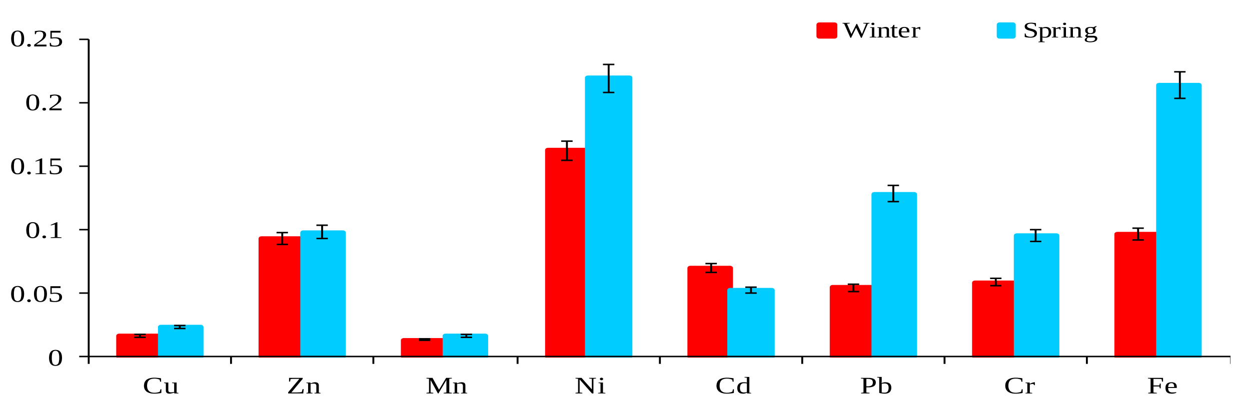


**Fig. (3): Heavy metals (HM) concentrations (mg/L) in a water sample collected from Damietta fishing harbor and the surrounding area in winter and spring (2021)**

**Table (1): Heavy metals concentration (µg/g dry weight) of sole fish, (n = 10) collected in winter and spring seasons (2021) from Damietta fishing harbor and the surrounding area**

| Sampling season | organ | Cu | Zn | Mn | Ni | Cd | Pb | Cr | Fe |
|---|---|---|---|---|---|---|---|---|---|
| Winter | Liver | 1.07±0.24 a | 10.68±2.45 | 3.51±0.81 | 0.71±0.09 b | 0.10±0.03 | 0.85±0.18 a | 0.21±0.08 | 17.15±2.12 |
| | Muscle | 0.53±0.26 b | 9.07±2.18 | 2.42±0.86 | 0.48±0.09 c | 0.07±0.02 | 0.58±0.13 b | 0.16±0.12 | 16.46±2.15 |
| Spring | Liver | 1.11±0.18 a | 11.61±3.07 | 4.64±0.70 | 0.84±0.07 a | 0.15±0.04 | 1.18±0.21 a | 0.32±0.11 | 16.82±2.70 |
| | Muscle | 0.59±0.31 b | 10.26±3.34 | 3.09±0.87 | 0.50±0.12 c | 0.09±0.02 | 0.71±0.15 b | 0.20±0.13 | 16.35±2.74 |
| **Two-Way ANOVA** | | ***P* value** | | | | | | | |
| **Sampling season** | | 0.217 | 0.524 | 0.153 | 0.011 | 0.399 | 0.190 | 0.115 | 0.704 |
| **Fish organs** | | 0.004 | 0.214 | 0.080 | 0.0001 | 0.250 | 0.026 | 0.202 | 0.448 |
| **Season × Organs** | | 0.977 | 0.995 | 0.877 | 0.557 | 0.754 | 0.847 | 0.807 | 0.672 |
| **Permitted Level (WHO, 1989) (mg/g wet wt.) [a]** | | 30 | 100 | 1 | 0.5 – 1.0 | 1 | 2 | 50 | 100 |
| **FAO maximum limits for fish [b]** | | 10 – 100 | 30 – 100 | – | – | 0.05 – 5.5 | 0.5 – 6.0 | 1 | – |

Values with different letters in the same column are significantly different ($P < 0.05$).

[a] Considering the conversion factor of 4.8 (79% moisture content) for conversion of fresh weight **to** dry weight

[b] (**Mokhtar *et al*., 2009**)

**Table (2): The estimated daily intakes (EDI) of heavy metals (µg/kg BW/day) through the consumption of common sole fish by adult people (assuming 70 kg per person)**

| Season | Cu | Zn | Mn | Ni | Cd | Pb | Cr | Fe |
|---|---|---|---|---|---|---|---|---|
| **Winter** | 0.069 | 1.183 | 0.316 | 0.063 | 0.009 | 0.076 | 0.021 | 2.132 |
| **Spring** | 0.077 | 1.338 | 0.403 | 0.065 | 0.012 | 0.093 | 0.026 | 2.146 |
| **PTDI** | 38 | 300 | 140 | 20 | 1.0 | 3.6 | 1500 | 700 |

PTDI is a proper daily intake in µg/ kg body weight/day (**USEPA, 2000**).

**Table (3): Target hazard quotient (THQ) for different heavy metals, their hazard index (HI) from consumption of common sole fish collected in winter and spring seasons (2021) from Damietta fishing harbor and the surrounding area**

| Season | Cu | Zn | Mn | Ni | Cd | Pb | Cr | Fe | Hazard index (HI) |
|---|---|---|---|---|---|---|---|---|---|
| **Winter** | 0.002 | 0.004 | 0.002 | 0.003 | 0.009 | 0.020 | 0.000013 | 0.0029 | **0.043** |
| **Spring** | 0.002 | 0.004 | 0.003 | 0.003 | 0.011 | 0.025 | 0.000017 | 0.0029 | **0.051** |

**Table 4: BCFs for Cu, Zn, Mn, Ni, Cd, Pb, Cr, and Fe in tissues of common sole fish collected at spring and winter seasons (2021) from Damietta fishing harbor and the surrounding area based on aqueous contact**

| Season | Organ | Cu | Zn | Mn | Ni | Cd | Pb | Cr | Fe |
|---|---|---|---|---|---|---|---|---|---|
| **Winter** | **Liver** | 10.04 | 22.50 | 56.16 | 0.799 | 0.30 | 1.918 | 0.70 | 16.67 |
| | **muscle** | 4.79 | 19.25 | 38.72 | 0.476 | 0.21 | 1.154 | 0.44 | 15.89 |
| **Spring** | **Liver** | 13.91 | 25.97 | 59.21 | 0.912 | 0.60 | 3.274 | 0.75 | 36.44 |
| | **muscle** | 7.67 | 22.95 | 39.43 | 0.616 | 0.36 | 2.234 | 0.57 | 35.66 |

## DISCUSSION

Heavy metals in the water of Damita harbor followed the order of Fe > Ni > Zn > Cd > Cr > Pb > Cu at winter season, while in spring season it was Ni > Pb > Fe > Cr > Zn > Cd > Cu > Mn. Our previous study recorded similar trends **(Al-Halani *et al*., 2021)**. The levels of HM found in water in this study were generally low when compared with the limits of chronic reference values suggested by **WHO (1985)** and **US EPA (1986)**. High levels of Fe in water samples of Damita harbor could be due to Fe released from sediments as sulfides **(Abo El Ella *et al*., 2005)**. Nickel is a fairly movable metal in natural waters. Commonly, values of soluble Ni are fewer than those of suspended and bed sediments **(USPHS, 2005)**. Zinc is sometimes free into the aquatic environment in considerable amounts and it is harmful at lower sub-lethal values, particularly after extended exposure **(Bryan & Langston, 1992; Scoullos & Constantianos, 1996)**.

The presence of Pb in water samples may be resulted from gasoline containing Pb from the fishery boats and ships. In the case of Cu, a further complicating factor is that some of the soluble Cu, particularly in inshore areas receiving organic inputs, will be in the form of more minor toxic organo-metal complexes. This factor will also reduce the toxicity of any ionic Cu discharged into such areas. For these reasons, marine communities may be unaffected in areas where the proposed metal standard is exceeded because of adaptation of the organisms and the formation of soluble cupro-organic complexes **(Scoullos & Constantianos, 1996)**. Manganese toxicity in the aquatic environment is impacted by several factors such as salinity, water hardness, pH, and the occurrence of other contaminants. When Mn concentration in waters surpasses 0.2 mg/L, this can frequently be attributed to anthropogenic activities rather than the natural water enrichment by Mn **(Nagpal, 2001)**. Mn concentration in water samples was less than 0.2 mg/L. Besides, Ni, Cu, and Pb in water samples may have resulted from boat activities that include the disposal of liquid wastes and the use of paints.

In the current study, HM concentrations in muscle and liver tissues of common sole fish exhibited significant ($P < 0.05$) variation among fish organs for Cu, Ni, and Cd only. Metals concentrations in liver tissues were generally higher than those in muscle tissues. Although it is well known that fish muscles are not an active site in HM bioaccumulations **(Bahnasawy *et al*., 2009)**, the current investigation covered the HM bioaccumulation in fish muscles since it is the most consumed part by human beings. Correspondingly, it was documented that some fish in polluted areas may accumulate substantial amounts of HM in their tissues and sometimes exceeded the maximum acceptable levels **(Kalay *et al*., 1999)**. Fish liver is frequently considered as a promising biomarker of HM pollution in water since its concentrations are proportional to those in the environment **(Dural *et al*., 2007)**. The HM accumulation in a high level in the liver tissues because it is the site of metals metabolism and detoxification **(Zhao *et al*., 2012a)**; due to natural binding proteins in hepatic tissues such as metallothioneins (MT) **(Görür *et al*., 2012)**, which acts as a crucial metal store (i.e., Zn and Cu) to accomplish enzymatically and other metabolic demands **(Roesijadi, 1996; Amiard *et al*., 2006)**. In the same way, Fe tends to be accumulated in hepatic tissues because of the physiological character of the liver in blood cells and hemoglobin synthesis **(Görür *et al.*, 2012)**. Furthermore, the liver correspondingly displayed high concentrations of non-essential metals, for instance, Cd; this conclusion could be clarified by the capability of Cd to displace the ordinarily MT-associated essential metals in hepatic tissues **(Amiard *et al*., 2006)**. Comparable results of high Zn, Cu, and Cd in the fish liver were observed in many field studies **(Dural *et al*., 2007; Eisler, 2009; Zhao *et al*., 2012)**. On the other hand, Fe displayed the highest values in fish muscle and liver, followed by Zn, whereas Cd and Cr were generally the lowest. Similar situations were reported by many researchers **(Dural *et al*., 2007; Tepe *et al*., 2008).**

Pollutants bio-concentration is a condition in which the pollutant levels in an organism exceed those in the surrounding environment. This term is often used specifically about aquatic environments and aquatic organisms. Bio-concentration factors (BCFs) are used to express bio-concentration levels numerically where the BCFs are determined by dividing the pollutant levels in the organism by the pollutant levels in the surrounding water. The higher BCF percentage, the more severe the bio-concentration of pollutant**s (Orata & Birgen, 2016).** The variability in BCFs results in the current study showed that HM bio-concentration in common sole fish is not exclusively dependent on the HM levels by aqueous exposure alone. As observed in Table 2 and Fig 2, the HM concentrations in the seawater samples were lower than their concentrations found in various fish organs. **Jezierska & Witeska (2006)** found that the variety of HM accumulation in fish organs is due to different affinity of metals to fish tissues and different uptake, deposition, and excretion rates **(Koca *et al*., 2005)**. The bioaccumulation type of HM in fish and other aquatic organisms depends on both uptake and elimination rates of contaminants. Due to the HM bioaccumulation, high death rate or several biochemical and histological modifications in the survived fish could be observed **(Rashed, 2001a & 2001b; Soltan *et al*., 2005)**. It has been indicated that BCFs from the environment to fish tissue change according to the chemical's species, the tissues' metabolite properties, and the environment's pollution degree **(Ayaş, 2007; Ozmen *et al*., 2008; Younis *et al*., 2015)**. The bioconcentration observed in the current study is explained as the difference in the amounts of various metal ions accumulation in the fish body results from the different affinity of metals to fish tissues, different uptake, deposition, and excretion rates **(Jezierska & Witeska, 2006)**. The type of chemical, metabolic properties of the tissues, and the degree of environmental pollution affect the BCF levels **(Uysal *et al*., 2009)**. Previous studies in both field and laboratory studies established a relationship between HM concentrations in fish and the water **(Zhou *et al*., 1998)**.

Heavy metals tend to be accumulated in various fish organs, which in turn may enter into the human metabolism through consumption, causing severe health hazards **(Bravo *et al*., 2010)**. Thus, the daily intake of studied HM was estimated and compared with the recommended values to assess whether the metal levels found in fish samples from the Damietta harbor area were safe for human consumption. This EDI was conducted only for the fish muscle as this tissue was the most crucial part consumed by the human population. Estimates of fish (muscle) consumption in Egypt indicated that the adult population consumes (42 g/day) according to **GAFRD (2005)**; and BW is the adult's body weight where the weight of the adult person is estimated on average as 70 kg **(Albering *et al*., 1999)**. The EDI values tabulated in Table 2 for the examined fish samples were below the recommended values **(USEPA, 2000),** demonstrating that health risk related to the intake studied HM through the consumption of analyzed fish samples was absent.

The THQ is used to recognize the non-carcinogenic health risks due to the pollutant exposure of the population **(Chien *et al*., 2002; Yi *et al*., 2017; Zhang *et al*., 2017)**. If the THQ exceeds 1.0, it denotes a non-carcinogenic health risk from the accumulative effects of heavy metals among the exposed population **(Yi *et al*., 2017)**. On the other hand, according to the guidelines, when HI values are lower than 0.1, there is no hazard; however, when its value is within the range of 0.1–1.0, the risk is low **(Kalogeropoulos *et al*., 2012)**. In the current study, HQ and THQ values calculated for the common sole fish indicate negligible chronic-toxic effects on human health through the consumption of this fish.

## CONCLUSION

The current study indicates that the seawater of Damietta fishing harbor and the surrounding area are suitable for fishing activity and consumption of the common sole fish collected from this site is safe. However, it is clear that there was bioaccumulation of heavy metals in the liver and muscle tissues of common sole fish, and this status may worsen. Subsequently, ongoing surveillance of heavy metals accumulations in fish is indispensable.

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## ARABIC SUMMARY

# التراكم الحيوى للعناصر الثقيلة فى أنسجة الكبد و العضلات فى سمكة موسى المتوطنة فى ميناء دمياط ، مصر

**علي أحمد مطهر سعد الهلاني1 و شيرين حسين هاشم شادى2 و أشرف محمد سليمان3**

1- قسم علوم الحياة –كلية التربية والعلوم التطبيقية – جامعة حجة – حجة – اليمن
2- قسم بيولوجى و بيئة الاسماك – المعمل المركزى لبحوث الثروة السمكية – مركز البحوث الزراعية – العباسة – ابو حماد – شرقية – مصر
3- قسم الليمنولوجى – المعمل المركزى لبحوث الثروة السمكية – مركز البحوث الزراعية – العباسة – ابو حماد– شرقية – مصر

أجريت هذه الدراسة لتقييم التراكم الحيوي لعناصر النحاس (Cu) والزنك (Zn) والمنجنيز (Mn) والنيكل (Ni) والكادميوم (Cd) والرصاص (Pb) والكروم (Cr) والحديد (Fe) في أنسجة الكبد والعضلات فى سمكة موسى التي تم جمعها من ميناء صيد دمياط والمنطقة المحيطة به في فصلي الشتاء والربيع 2021. تم فى هذه التجربة تجميع أربع عينات من المياه والأسماك من أربعة مواقع مختلفة. بالإضافة إلى ذلك ، تم تقييم المخاطر على صحة الإنسان باستخدام المقدار اليومي المقّدر وحصائل المخاطر المستهدفة. كما تم تحديد عامل التركيز الأحيائي للمعادن الثقيلة المذكورة أعلاه. وأظيرت هذه الدراسة انه على الرغم من أن التراكم الحيوى لجميع العناصر الثقيلة في الأسماك كان أقل من الحدود المسموح بها التي ذكرتها منظمة الأغذية والزراعة ومنظمة الصحة العالمية .كما اظهرت هذه الدراسة وجود اختلافات معنوية فى تركيز العناصر المختلفة بين المواسم وأعضاء سمكة موسى محل الدراسة فكان التراكم الحيوى للعناصر الثقيلة في انسجة الكبد اكبر منها في العضلات . كما كان التراكم الحيوى لهذه العناصر في فصل الربيع اكبر منه فى فصل الشتاء . كان ترتيب التنازلى للعناصر فى فصل الشتاء Fe>Ni>Zn>Cd>Cr>Pb>Cu>Mn كما كان الترتيب التنازلى فى فصل الربيع كالآتى: Ni>Pb>Fe>Cr>Zn>Cd>Cu>Mn. و على هذا أظهرت هذه الدراسة ان سمكة موسى الموجودة فى منطقة ميناء دمياط امنه كغذاء للانسان كما توصى هذه الدراسة بالعمل على تخفيف حمل التلوث فى هذه المنطقة لضمان سلامة الاسماك المتوطنه .