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# The Seasonal Assessment of Heavy Metals Bioaccumulation in European Seabass (*Dicentrarchus labrax*) Inhabiting Damietta Fishing Harbor, Egypt

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## ABSTRACT

The current study was conducted to investigate the bioaccumulation of copper (Cu), zinc (Zn), manganese (Mn), nickel (Ni), cadmium (Cd), lead (Pb), chromium (Cr), and iron (Fe) in the liver and the muscle tissues of European seabass (*Dicentrarchus labrax*) collected in winter and spring (2021) from Damietta fishing harbor and the surrounding area, Damietta, Egypt. For this purpose, four samples of water and fish were collected from four sites. Besides, human health risk was assessed using estimated daily intake and target hazard quotients. The bioconcentration factor of the above-mentioned heavy metals was also determined. Although the bioaccumulation of all heavy metals in fish was lower than the permissible limits mentioned by FAO and WHO, their bio-concentrations showed remarkable differences among seasons and fish organs. The bioaccumulation of heavy metals in the liver was higher than that found in muscles with respect to all metals. Spring recorded higher bioaccumulation compared to winter considering Mn, Cd, Cr, and Fe. The concentration of heavy metals in water in winter was in order as follows: Ni >Fe > Zn > Cd > Cr > Pb > Cu > Mn, while in spring, it was Ni > Fe >Pb > Zn > Cr > Cd > Cu > Mn. On the other hand, the bioaccumulation of these metals in fish organs was shown in the following order: Fe > Zn > Mn > Pb > Cu > Ni> Cr > Cd. In conclusion, the human risk assessment indicated that European seabass in the present study was safe for human consumption.

## INTRODUCTION

Coastal areas provide many substantial benefits to human beings in terms of foodstuff resources and ecology amenities. Human being's activities may have significant adverse effects on the ecosystem's health and the sustainability of resources **(França *et al.*, 2005; Connell *et al.*, 2009)**. Marine pollution is a universal and environmental problem caused by human activities in the coastal area and marine water as well as the discharge of various kinds of pollutants including heavy metals found in marine ecosystems **(Censi *et al*., 2006; Pote *et al*., 2008)**. Heavy metals pollution has become a radically worldwide source of apprehension due to their toxicity, intrinsic persistence, non-biodegradable nature, and accumulative behaviors **(Abdel-Tawwab *et al.*, 2017 a,b; Islam *et al*., 2018)**. Heavy metals accumulation in the aquatic environment could be derived from acid mine drainage, industrial emissions, traffic and atmospheric deposits, domestic sewage, storm water, and building materials **(Xia *et al*., 2011)**. Heavy metals, such as copper (Cu), zinc (Zn), manganese (Mn), nickel (Ni), cadmium (Cd), lead (Pb), chromium (Cr), and iron (Fe) have high levels of toxicity and persistence capacity for biomagnification, bioaccumulation, and combination into the food chain subsequently reaching a certain limit in the aquatic environment **(Ahmed *et al*., 2015; Kibria *et al.*, 2016)**. Heavy metals are generally bioaccumulated in fish throughout ingestion, ion exchange via gills or membrane surface, in addition to the adsorption in different tissues of fish **(Ahmed *et al*., 2014)**.

Fish wordwide consumption is due to fish nutritious value, their high-quality proteins, great omega-3 fatty acid content, and low saturated fat contents as well as the levels of vitamins and minerals included **(Dytham, 2011; Arulkumar *et al*., 2017; Gu *et al*., 2017; Özden *et al*., 2019).** It is anticipated that fish contributes about 17% of animal protein and almost 6% of all protein consumed by human beings **(Domingo *et al*., 2007)**. The bioaccumulation of heavy metals in fish gills, muscles, and livers have attracted great attention because of their potentially toxic effects; not only on fish but also on human individuals who consume polluted fish **(Burger & Gochfeld, 2005)**. Heavy metals bioaccumulation occurs in different portions of different fish species due to the variable soluble nature of metals in water, bioavailability, and the different habitats, life cycles, nature of feeding, ecology, and physiological nature of fish **(Perugini *et al*., 2014; Anandkumar *et al*., 2017).** Consequently, the determination of heavy metal concentrations in fish is an important tool for both environmental management and human consumption. To estimate the potential risks on human health derived from heavy metals accumulated in fish, a fast method was required to  to evaluate the hazard impacts on human health and determine the suitable measures of treatment. Thus, risk assessment was used to attain the data required, which could help in solving the environmental problem that happens in daily life **(Ashbolt *et al*., 2013)**.

European seabass (*Dicentrarchus labrax*) is one of the most important fish species in Egypt and in other parts of the world as well **(Abdel-Tawwab *et al*., 2020; Abdel-Tawwab *et al*., 2021)**. In this context, the present study was conducted to assess the general levels of some heavy metals in the Mediterranean seawater with respect to this fish species inhabiting the coastal of Damietta fishing harbor in Egypt during both winter and spring seasons.  Additionally, human health risks of heavy metals accumulated in fish was also detected.

## MATERIALS AND METHODS

### 2.1. Samples sites

Damietta port is a marine harbor lying just west to Damietta city on the coast of the Nile Delta, Egypt. It was constructed in 1982, about 10 km to the west of Damietta outlet of the Nile River (Fig. 1). It is generally agreed that the harbor activities such as loading and off-loading of goods, cleaning, ballasting, fuelling and many others contributes to the dumping of significant amounts of wastes directly into the sea **(Idris, 2008)**.


**Fig. 1.** Location map of Damietta fishing port and the surrounding environmental parts of the Mediterranean Sea area in Damietta, Egypt, where 1, 2, 3, and 4 are the sampling sites

### 2.2. Water properties

During January and May 2021, the pH values of surface water were measured in the site using a digital pH-meter (Orion Research Model PTI20). Dissolved oxygen (DO), electric conductivity (EC), and water temperature (T) were measured using Multi-parameter Analyzer (model YK-22DO). Water turbidity was measured using Eutech Instruments (Cyberbcan WL Turbidimeter TB1000).

### 2.3. Heavy metals analysis in water samples

One-liter water samples (50 cm below the water surface) were collected from each studied sites in January and May 2021 in clean polyethylene bottles then acidified to pH 2 with concentrated sulfuric acid. Water samples were then filtered using 0.45 μm cellulose acetate membranes using vacuum filtration to avoid the clogging of spectrometry instruments during analysis **(Hamzah *et al*., 2014)**. Afterward, filtered water samples were diluted ten times using ultra-pure water and were kept at 4$^o$C until analysis **(APHA, 2005)**. Heavy metals were measured in the obtained solution using a Flame Atomic Absorption Spectrophotometer (Perkin Elmer Analyst 100) with a standard solution of each heavy metal.

### 2.4. Sampling and analysis of heavy metals in fish

A total of 20 individual samples of European seabass, *D. labrax,* was purchased during the period extending from January to May 2021 and its weight ranged from 205 g to 320 g in winter and 200 g to 335 g in spring season. The sampling process was performed with the aid of an expert fisherman at Damietta city. The specimens were placed immediately in polyethylene bags, put into isolated containers of polystyrene icebox, and then, brought to the environment laboratory at the Faculty of Agriculture, Mansoura University. For each fish, the total length (from the tip of the snout to the margin of the caudal fin) and weight were recorded.

After determing the measurements, fish samples were washed with deionized water and dissected. Muscle and liver tissues were taken with the help of a stainless steel stiletto and were separately oven-dried to a constant weight at 105°C; after that they were ground to powder. The powdered samples were digested according to the method of **Sreedevi *et al.* (1992)**. Briefly, one gram of each sample was digested using 1:5:1 mixture of 70% perchloric acid: concentrated nitric acid: concentrated sulphuric acid at 80°C in a fume chamber, till colorless liquid was obtained. Each digested sample was diluted to 20 ml with deionized water and analyzed for heavy metals in a Buck Scientific Accusys 211 atomic absorption spectrophotometer. The heavy metals concentration were recorded in μg/g dry weight.

### 2.5. Human health risk assessment

#### 2.5.1. Estimated daily intake (EDI)

The estimated daily intake of metals (EDI) depends both on the metal concentration level and its amount of consumption. The EDI for adults was assessed using the following equation **(Zhuang *et al*., 2009)**:

$$EDI= (C \times FIR)/BW$$

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

### 2.5.2. Non-carcinogenic risk

The target hazard quotient (THQ) is used to assess the non-carcinogenic risk level due to pollutant exposure following the guidelines recommended by **US EPA (1989)** using the following equation:

$$THQ = \frac{ED \times C \times FIR \times EF \times CF}{RfD \times BW \times AT} \times 10^{-3}$$

Where; THQ is the target hazard quotient; ED is the exposure duration (70 years, average lifetime); C is the heavy 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 0.208 (to convert dry weight to fresh weight considering 79% of moisture content of the fish fillet **(Rahman *et al.*, 2012)**, and 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 -1 day -1 for Cu, Zn, Mn, Ni, Cd, Pb, Cr and Fe, respectively **(US EPA, 2000)**. BW is the average adult body weight (70 kg); AT is the average exposure time (365 days/year × exposure years, assumed as 70 years = 25.550 days);

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

$$HI = \Sigma THQi, \quad \text{i.e:} \quad HI = THQ(Pb) + THQ(Cd) + THQ(Cr) \quad \text{----------------} \ (4)$$

Where; " i " represent each metal. When the value of THQ and/or HI exceeds 1.0, there would be a concern for potential health effects **(Huang *et al*., 2008).**

## 2.6. Bioconcentration factor (BCF) estimations

Bioconcentration is a state in which the levels of a pollutant in an organism surpass the levels of that in the surrounding environment. Bioconcentration factors (BCFs) are known as the relative between the steady-state metal ion concentrations in the fish tissue and the concentration in water/sediments **(Orata & Birgen, 2016)**. The higher the ratio, the more become the bioconcentration of pollutants. In the current study, the BCFs were calculated using the following equation of **Gobas *et al*. (2009)**:

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

## 2.7. Statistical analysis

The obtained data were subjected to two-way ANOVA to test the effect of season, fish species, and fish organ vs heavy metal concentration. Duncan's Multiple Range Test was used as a post-hoc test to compare means at $P \leq 0.05$ using SPSS software, version 20 (SPSS, Richmond, Virginia, USA) according to **Dytham (2011)**.

## RESULTS

### 1. Water quality parameters

Fig. 2 shows the mean values of water quality parameters of the sampling locations. The results indicate that water temperature ranged from 18.8°C to 27.4°C, in winter and spring, respectively; pH ranged from 7.7 - 7.9; EC was from 58.8 – 66.1 µs/cm; dissolved oxygen (DO) was from 7 - 6.6 mg/L, while turbidity ranged from 6.6 – 6.3 NTU in winter and spring, respectively.

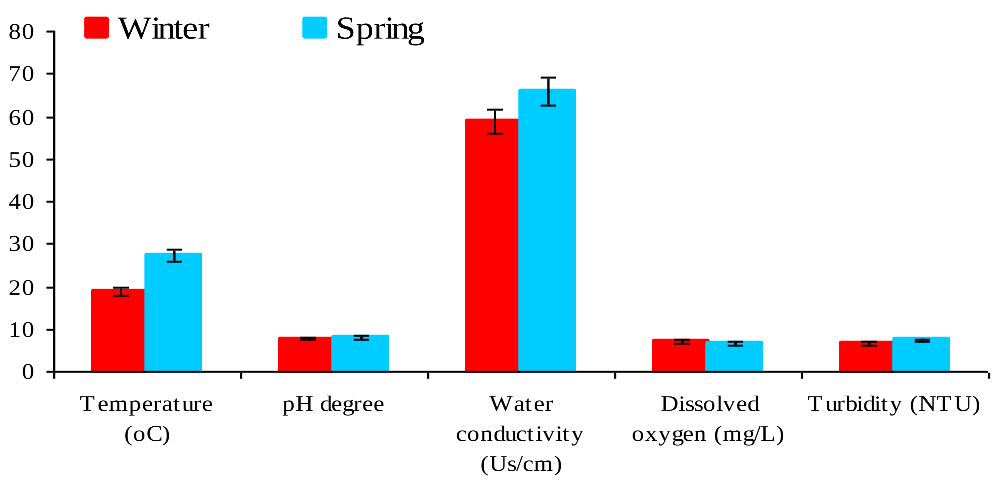


**Fig. 2.** Parameters of water samples collected from Damietta fishing harbor in winter and spring 2021

### 2. Heavy metals in water

The metals concentrations in seawater collected from Damietta harbor coastal area is shown in Fig. 3. The concentrations of heavy metals in winter was in order of Ni >Fe > Zn > Cd > Cr > Pb > Cu > Mn, while in spring their order was Ni > Fe > Pb > Zn > Cr > Cd > Cu > Mn.

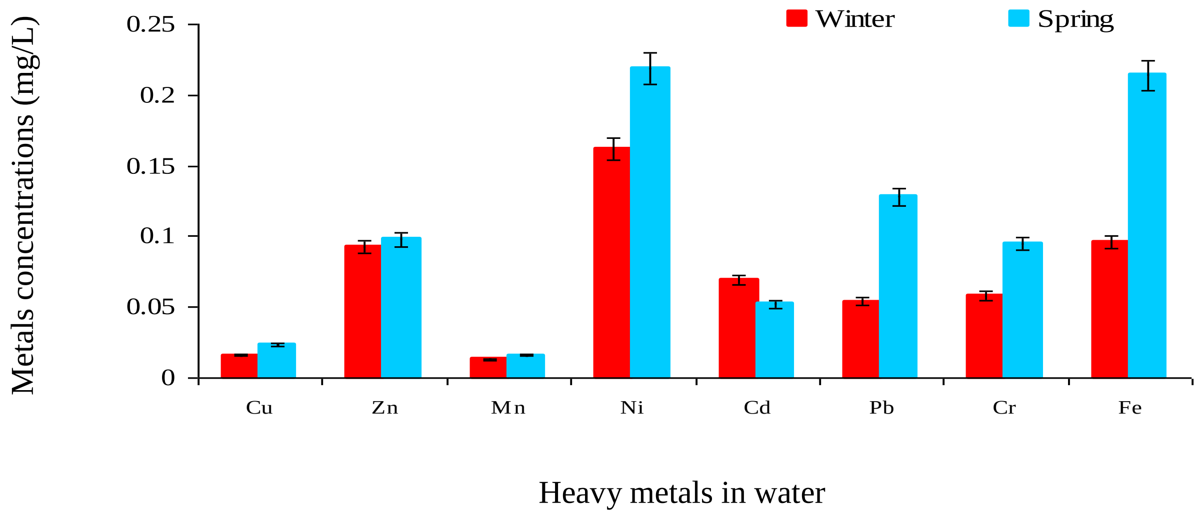


**Fig. 3.** Heavy metals concentrations (mg/L) in water samples collected from Damietta fishing harbor and the surrounding environment area in winter and spring 2021

### 3. Heavy metals in fish organs

Significant variation in metal concentrations was observed among fish organs for Cu, Zn, Ni, Cd and Pb only, whereas Mn, Cr, and Fe were not affected by seasons, organs or their interaction (Table 1). Metals in winter in both fish organs were lower than those in spring and their concentrations in the fish liver were higher than those in fish muscles. It was also found that the metals' order in fish organs was Fe > Zn > Mn > Pb > Cu > Ni > Cr > Cd where; Fe was the most abundant metal in fish organs, and it ranged from 18.93 µg/g in fish muscles in winter to 23.32 µg/g in the fish liver in spring (Table 1).

### 4. Bioconcentration factors

The BCFs value was significantly affected by seasons for Fe and Pb and/or organs for all metals except Mn, Cr, and Fe, where their values in the liver were higher than in muscles for all metals. Whereas, in spring, they were higher compared to those in winter for Mn, Cd, Cr, and Fe (Table 2). The highest BCFs value was 95.03 for Mn at the fish liver in spring, followed by 45.59 for Fe at the fish liver in winter; while, the lowest value was 0.30 for Cd in the fish muscle in spring (Table 2).

### 5. Health-risk assessment for fish consumption

### 5.1. Estimated daily intake (EDI)

The average daily intake (EDI) of metals (µg/kg BW/day) was assessed for the European seabass in winter and spring 2021 and is represented in Table 3. The EDI value was lower in winter than in spring, and its range in the current study was 0.047 - 0.049.

**Table 1.** Heavy metals concentration (µg/g dry weight) of European seabass (n = 10 each per season) collected from Damietta fishing port and the surrounding environment parts of the Mediterranean Sea area in winter and spring 2021

| Season | Organ | Cu | Zn | Mn | Ni | Cd | Pb | Cr | Fe |
|---|---|---|---|---|---|---|---|---|---|
| Winter | Liver | 0.94±0.06 ab | 16.54±0.46 a | 5.15±1.15 ab | 0.53±0.13 a | 0.33±0.12 ab | 1.08±0.06 ab | 0.27±0.17 | 21.04±1.97 |
| | Muscles | 0.38±0.13 b | 10.98±0.55 b | 2.87±0.09 b | 0.17±0.08 b | 0.03±0.02 b | 0.66±0.01 c | 0.12±0.03 | 18.93±1.09 |
| Spring | Liver | 1.43±0.40 a | 17.17±2.67 a | 7.31±0.59 a | 0.63±0.05 a | 0.41±0.11 a | 1.29±0.11 a | 0.50±0.07 | 23.32±0.89 |
| | Muscles | 0.39±0.04 b | 13.95±0.02 ab | 5.61±1.23 ab | 0.47±0.06 a | 0.08±0.02 b | 0.88±0.05 bc | 0.40±0.08 | 20.38±0.95 |
| Two-Way ANOVA | | | | | *P* value | | | | |
| Season | | 0.360 | 0.263 | 0.052 | 0.056 | 0.463 | 0.134 | 0.065 | 0.224 |
| Organs | | 0.017 | 0.034 | 0.089 | 0.025 | 0.017 | 0.016 | 0.269 | 0.123 |
| Season × Organs | | 0.377 | 0.445 | 0.762 | 0.431 | 0.823 | 0.883 | 0.826 | 0.764 |
| Permitted Level (mg/g wet wt) **(WHO, 1989)** [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 | – |

Means 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 fresh weight to dry weight

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

**Table 2.** BCFs for Cu, Zn, Mn, Ni, Cd, Pb, Cr, and Fe in organs of European seabass collected from Damietta fishing port and the surrounding environment parts of the Mediterranean Sea area in winter and spring 2021

| Fish | Organ | Cu | Zn | Mn | Ni | Cd | Pb | Cr | Fe |
|---|---|---|---|---|---|---|---|---|---|
| Winter | Liver | 12.22±0.81 a | 36.99±1.03 a | 82.48±18.32 | 0.69±0.16 a | 0.98±0.35 ab | 4.15±0.24 a | 0.97±0.61 | 45.59±4.27 a |
| | Muscles | 4.88±1.76 b | 24.56±1.23 b | 45.92±1.44 | 0.22±0.10 b | 0.09±0.06 b | 2.52±0.02 b | 0.43±0.11 | 41.00±2.35 a |
| Spring | Liver | 12.93±3.62 a | 36.44±5.67 a | 95.03±7.67 | 0.60±0.05 a | 1.64±0.44 a | 2.10±0.17 b | 1.09±0.15 | 22.67±0.87 b |
| | Muscles | 3.48±0.32 b | 29.60±0.03 ab | 72.87±15.93 | 0.44±0.05 ab | 0.30±0.06 b | 1.42±0.07 c | 0.87±0.16 | 19.80±0.92 b |
| Two Way ANOVA | | | | | | *P* value | | | |
| Season | | 0.737 | 0.488 | 0.196 | 0.423 | 0.199 | 0.002 | 0.443 | 0.001 |
| Organs | | 0.012 | 0.031 | 0.083 | 0.028 | 0.017 | 0.007 | 0.309 | 0.213 |
| Season × Organs | | 0.760 | 0.396 | 0.603 | 0.264 | 0.471 | 0.090 | 0.664 | 0.750 |

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

1.370 – 1.741, 0.358 - 0.700, 0.021 - 0.059, 0.004 - 0.010, 0.082 - 0.118, 0.015 - 0.050, 2.362 – 2.543 µg/kg BW/day for Cu, Zn, Mn, Ni, Cd, Pb, Cr, and Fe, respectively. The EDI of metals via fish consumption can be ordered as follows: Fe > Zn > Mn > Pb > Ni > Cr >Cu > Cd .

**Table 3.** The estimated daily intakes (EDI) of heavy metals (µg/kg BW/day) through the consumption of European seabass by adult people (assuming 70 kg person)

| Season | Cu | Zn | Mn | Ni | Cd | Pb | Cr | Fe |
|---|---|---|---|---|---|---|---|---|
| Winter | 0.047 | 1.370 | 0.358 | 0.021 | 0.004 | 0.082 | 0.015 | 2.362 |
| Spring | 0.049 | 1.741 | 0.700 | 0.059 | 0.010 | 0.110 | 0.050 | 2.543 |
| PTDI | 38 | 300 | 140 | 20 | 1.0 | 3.6 | 1500 | 700 |

PTDI, permissible tolerable daily intake in µg/ kg body weight/day **(US EPA, 2000)**.

### 5.2. Non-carcinogenic risk

Neither THQ nor HI was detected greater than 1.0 through the consumption of European seabass, which indicates that health risks associated with heavy metals exposure were insignificant (Table 4). The THQ values were higher in spring than in winter, recording values of 0.001, 0.006, 0.005, 0.003, 0.010, 0.031, 0.000033, 0.0036, and 0.059 for Cu, Zn, Mn, Ni, Cd, Pb, Cr, and Fe, respectively. On the other hand, the lowest and the largest HI values were 0.039 and 0.059 for European seabass in winter and spring, respectively.

**Table 4.** Target hazard quotient (THQ) for different heavy metals, their hazard index (HI) from consumption of European seabass collected in winter and spring 2021 from Damietta fishing port and the surrounding environment parts of the Mediterranean Sea area

| Season | Cu | Zn | Mn | Ni | Cd | Pb | Cr | Fe | hazard index (HI) |
|---|---|---|---|---|---|---|---|---|---|
| Winter | 0.001 | 0.005 | 0.003 | 0.001 | 0.004 | 0.023 | 0.000010 | 0.0034 | 0.039 |
| Spring | 0.001 | 0.006 | 0.005 | 0.003 | 0.010 | 0.031 | 0.000033 | 0.0036 | 0.059 |

## DISCUSSION

### 1. Heavy metals in water

Heavy metals in the water of Damietta fishing harbor followed the order of Ni > Fe > Zn > Cd > Cr > Pb > Cu > Mn in winter, while in spring their order was Ni > Fe > Pb > Zn > Cr > Cd > Cu > Mn (Fig. 2). The levels of heavy metals recorded in water in the present study were generally low when compared to the limits of chronic referencial values suggested by **WHO (1985)** and **US EPA (1986)**. The high levels of Fe in the water of Damietta fishing harbor may be attributed to the Fe release from sediments **(Abo El Ella *et al*., 2005)**. It is worth noting that Ni is a fairly movable metal in natural waters, and values of soluble Ni are fewer than those of suspended and bed sediments **(USPHS, 2005)**. Furthermore, Zn is sometimesreleased into the aquatic environment in considerable amounts, and its harmful effect was observed at lower sub-lethal values, particularly after extended exposure **(Bryan & Langston, 1992; UNEP/FAO/WHO, 1996)**. The presence of Pb may have 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 less toxic organo-metal complexes. This factor will also reduce the toxicity of ionic Cu discharged into such areas. For those reasons, the UK WRC state that marine communities may be unaffected in areas where the proposed standard is surpassed because of adaptation of the organisms and the formation of soluble cupro-organic complexes **(UNEP/FAO/WHO, 1996)**. When Mn concentration in natural waters exceeds 0.2 mg/L, it can be frequently attributed to anthropogenic activities, rather than natural enrichment of the water by Mn **(Nagpal, 2001)**. Mn toxicity in the aquatic environment is impacted by several factors, such as salinity, water hardness, the pH, and the occurrence of other pollutants. However, in the current study, Mn concentrations in water samples were less than 0.2 mg/L. Besides, the existence of Ni, Cu, and Pb in water samples may have resulted from boat activities including the disposal of liquid wastes and the use of paints.

**2. Heavy metals in fish organs**

In the current study, the heavy metals concentration in muscle and liver of European seabass was assessed. The metals concentrations exhibited significant variations ($P < 0.05$) among fish organs for Cu, Zn, Ni, Cd, and Pb only. Metals concentrations in liver tissues were generally higher than those in the muscles. Although it is well known that fish muscles is not an active tissue in accumulating heavy metals **(Bahnasawy *et al*., 2009)**, the current investigation covered the heavy metals accumulation in fish muscles since it is the consumed part for human nutrition. Correspondingly, it was documented that some fish abundant in polluted ecosystems may accumulate substantial amounts of metals in their tissues, and sometimes they exceeded the maximum acceptable levels **(Kalay *et al*., 1999)**. The fish liver is frequently considered a good biomarker of water's metals pollution since their concentrations are proportional to those present in the environment **(Dural *et al*., 2007)**. The high accumulation levels of heavy metals in liver tissues is linked to the detoxification role of fish liver, which is the site of metals' metabolism **(Zhao *et al*., 2012)**. This is due to natural binding proteins in hepatic tissues such as metallothioneins (MT) **(Görür et al., 2012; Abdel-Tawwab & Wafeek, 2014)**. Metallothioneins acts as an essential metals store (i.e., Zn and Cu) to fulfill enzymatic and other metabolic demands **(Roesijadi, 1996; Amiard *et al.*, 2006; Abdel-Tawwab & Wafeek, 2014)**. In the same way, Fe tends to be accumulated in hepatic tissues due to the physiological role of the liver in blood cells and hemoglobin synthesis **(Görür *et al.*, 2012).** Furthermore, the liver correspondingly showed high levels of non-essential metals such as Cd; this finding could be explained by the ability of Cd to displace the normally 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 highest values in both fish muscle and liver, followed by Zn, whereas Cd and Cr were generally the lowest ones. Similar situations were reported by many researchers **(Farkas *et al*., 2003; Dural *et al*., 2007; Uluozlu *et al.*, 2007; Tepe *et al.*, 2008; Türkmen *et al.*, 2008).**

**3. Bioconcentration factors (BCF)**

Toxin bioconcentration is a situation in which the levels of a toxin in an organism exceed the levels of that toxin in the surrounding environment. This term is often used specifically in studies with reference to aquatic environments and aquatic organisms. Arithmetically, BCFs are obtained by dividing the levels of a toxin in an organism by the levels in the surrounding water to find a ratio. The higher ratio indicates the more severe of the toxins bioconcentration **(Orata & Birgen, 2016)**.

The BCFs results in the current study showed that bioconcentration of heavy metals in European seabass does not exclusively depend on the concentration levels of aqueous exposure alone. Table 1 and Fig. 2 show that, the concentrations of heavy metals in the seawater samples are lower than their concentrations obtained in various fish organs. These observations are an indicator of the bioconcentration of heavy metals in the fish organs. The bioconcentration observed in fish in the current study is explained as the difference in the amounts of various metals accumulation in the fish body resulting from the different affinity of metals to fish tissues, different uptake, deposition, and excretion rates among others **(Koca *et al.*, 2005; Jezierska & Witeska, 2006)**. Generally, the type of chemical, metabolic properties of the tissues, and the degree of environmental pollution affect the BCF levels **(Ayaş, 2007; Ozmen *et al*., 2008; Uysal *et al*., 2009; Younis *et al*., 2015).** The bioaccumulation of metals might cause a high death rate or several biochemical and histological modifications in the survived fish **(Rashed, 2001 a, b; Soltan *et al*., 2005)**. Previous studies in both field and laboratory established a relationship between metal concentrations in fish and water **(Linde *et al*., 1996; Zhou *et al.*, 1998)**. It should, however, be emphasized that the body metals levels are related to their waterborne concentrations only if these metals are taken up by the fish from the water.

## 4. Health-risk assessment for fish consumption

### 4.1. Estimated daily intake (EDI)

Heavy metals tend to be accumulated in various organs of marine organisms, especially fish which in turn may affect the human metabolism through consumption causing serious health hazards **(Bravo et al., 2010)**. Thus, the daily intake of studied heavy metals was estimated and compared to the recommended values to assess whether the metal levels found in fish samples from the Damietta harbor region were safe for human consumption or not (Table 3). This examination was conducted only for the fish muscles as this tissue was the most important part consumed by the human individuals. Estimates of fish (muscles) consumption in Egypt indicate that the adult population consumes 42g/day according to **GAFRD (2005)**. Notably, the BW is the adult's body weight with an estimatd average of 70 kg **(Albering *et al*., 1999)**. The EDI values represented in Table 3 for the examined fish samples are below the recommended values by **US EPA (2000)**, demonstrating that health risk related to the intake studied heavy metals through the consumption of examined fish samples was absent.

### 4.2. Non-carcinogenic risk:

The target hazard quotients are considered 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, no hazard exists, however, when values are in the range of 0.1–1.0, the hazard is low **(Kalogeropoulos *et al*., 2012)**. In the current study, the HQ and THQ values calculated for European seabass were <0.1, indicating negligible chronic-toxic effects on human health through fish consumption.

## CONCLUSION

The current study indicates that the water of Damietta fishing harbor and the surrounding environment areas of the Mediterranean Sea are by far suitable for fishing activity, and the consumption of European seabass inhabiting this area is safe. However, it is quite clear that there was bioaccumulation of heavy metals in fish tissues, and its health status may get worse. Subsequently, steady surveillance of heavy metal accumulations in fish is indispensable.

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## ARABIC SUMMARY

# التقييم الموسمى للتراكم الحيوى للعناصر الثقيلة فى أسماك القاروص (*Dicentrarchus labrax*) المتواجدة فى ميناء دمياط ، مصر

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أجريت هذه الدراسة للتحقق من التراكم الحيوي لعناصر النحاس (Cu) والزنك (Zn) والمنجنيز (Mn) والنيكل (Ni) والكادميوم (Cd) والرصاص (Pb) والكروم (Cr) والحديد (Fe) في أنسجة الكبد والعضلات فى أسماك القاروص (*Dicentrarchus labrax*) التي تم جمعها في فصلي الشتاء والربيع (٢٠٢١) من ميناء صيد دمياط والمنطقة المحيطة به. تم جمع أربع عينات من المياه والأسماك من أربعة مواقع مختلفة. بالإضافة إلى ذلك ، تم تقييم المخاطر على صحة الإنسان باستخدام المقدار اليومي المقدّر وحصائل المخاطر المستهدفة. كما تم تحديد عامل التركيز الأحيائي للمعادن الثقيلة المذكورة أعلاه. وأظهرت هذه الدراسة انه على الرغم من أن التراكم الحيوى لجميع المعادن الثقيلة في الأسماك كان أقل من الحدود المسموح بها التي ذكرتها منظمة الأغذية والزراعة ومنظمة الصحة العالمية ، فإن التركيزات الحيوية لها أظهرت اختلافات ملحوظة بين المواسم وأعضاء الأسماك. كان التراكم الحيوى للمعادن الثقيلة في الكبد أعلى منه في العضلات لجميع المعادن وفي الربيع كان أعلى منه في الشتاء بالنسبة للمنجنيز والكادميوم والكروم والحديد. كان تركيز المعادن الثقيلة في الماء في الشتاء بالترتيب Ni> Fe> Zn> Cd> Cr> Pb> Cu> Mn بينما في الربيع كان الترتيب كالتالى Ni> Fe> Pb> Zn> Cr> Cd> Cu> Mn. من ناحية أخرى ، يأتي تراكم هذه المعادن في أعضاء الأسماك بالترتيب التالي: Fe> Zn> Mn> Pb> Cu> Ni> Cr> Cd. أخيرًا ، أشار تقييم المخاطر البشرية إلى أن أسماك القاروص في هذه الدراسة آمن للاستهلاك البشري.