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Estimation of Hazards and Potential Health Risks for Heavy Metals by Consumption of Four Cichlid Species from Lake Burullus and the River Nile, Egypt

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ABSTRACT

This study was conducted to investigate the concentrations of some trace elements (Cd, Ni, Zn, Pb, and Cu) in the water of two sites at Lake Burullus (Balteem and El-Borg) and one site at the River Nile (at ElTebeen). In addition, the bioaccumulation of these metals was addressed in the liver, gills, and muscles of four cichlids (*Oreochromis aureus, O. niloticus, Sarotherodon galilaeus* and *Tilapia zillii*) and the potential health risk from consuming these fishes was assessed. The results clarified that the concentration of these elements in water did not exceed the permissible limits prescribed by EOS and the United States Environmental Protection Agency (US-EPA). The results of geometric mean metal accumulation showed a significant variation ($P \leq 0.05$) among metals, with , a sequencing order of Zn> Cu> Ni>Pb> Cd, while cadmium was not detected in Lake Burullus. A significant variation ($P \leq 0.05$) between the collection sites and species was recorded. Bioconcentration factors (BCF) for different metals showed low to moderate values in muscles and gills, and moderate to high values in the liver. The highest values were related to the presence of Cu and Zn in the liver, using the maximum consumption rate (62.25 g/person/day) of fish muscles. The estimated daily intake (EDI) did not exceed the permissible tolerable daily intake (PTDI) in µg per kg of body weight per day as recommended by US EPA for adults and children. The target hazard quotient indices for Cd, Ni, Zn, Pb, and Cu in the investigated sites were lower than those of US-EPA criteria (>1). Hazard indices (HI) were higher than the US-EPA criteria (>1) for children consumers of *Oreochromis aureus, Sarotherodon galilaeus* and *Tilapia zillii* collected from the Nile River. Moderate lifetime cancer risks were attributed to the presence of Ni in adults and children ($6.9E^{-03}$ and $9.8E^{-04}$, respectively).

INTRODUCTION

The Nile River is the principal irrigation and drinking water source in Egypt; however, huge amounts of industrial waste and agricultural drainage have been released into the water body in recent years **(Al-Halani, 2017**; **Ghannam, 2021)**. Furthermore, coastal lakes are very vulnerable to anthropogenic activities from watersheds because these coastal lakes absorb fresh and contaminated waters from a variety of sources carrying organic compounds and inorganic constituents, including industrial and urban activities **(Aliaume *et al.*, 2007)**. Significant amounts of waste materials are discharged without appropriate advanced treatment in these lakes, which gather vast amounts of wastewater from various drainage canals across the delta of the River Nile and finally flow to the Mediterranean Sea through El-Boughaz outlets **(Shaltout & Al-Sodany, 2008; Alprol *et al.*, 2021)**.

For the surface area, Lake Burullus is the second northern coastal lake in Egypt. It has piqued the curiosity of many people due to its environmental importance and economic value being a key source of fishes in Egypt. It has been subjected to fluctuations in water quality caused by wastewater it receives **(Aly *et al.*, 2020)**. It receives about 4.1 billion cubic meters of wastewater each year from 8 drains, as well as the Brinbal Freshwater Canal **(EMI, 2012; Farouk *et al.*, 2020)**.

The assessment of heavy metals in the environment has become a global concern. Even at low concentrations, they can create problems due to toxicity and their proclivity to penetrate the food chain. **(Foladifard & Ebrahimi, 2010)**. These metals enter the aquatic environments via agricultural drainage and discharged industrial effluents containing a variety of chemical compounds including heavy metals **(Malakootian *et al.*, 2016)**.

Fish are an important food source for humans due to the presence of omega 3 at high levels and polyunsaturated acids in addition to some fat-soluble vitamins, and essential minerals **(Maleki *et al.*, 2015)**. However, fish absorb contaminants including heavy metals, and particularly toxic metals such as cadmium, lead, nickel and mercury from food and water; unfortunately, contaminants are accumulated in fish tissues **(Ravanbakhsh *et al.*, 2020)**. Fish absorb metals through ingesting the floating particles in water, feeding, ion-exchange of dissolved metals across lipophilic membranes as in the gill, and subsequently these particles are adsorbed onto tissue and membrane surfaces **(Bekhit *et al.*, 2008)**. As a result of the tendency of fish to bio-accumulate and integrate pollutant loads, fish are regarded as bio-indicators of ecosystem quality **(Farag *et al.*, 2021)**. Heavy metals in fish may be measured to identify potential health concerns for people associated with fish-eating **(USEPA, 2000; Pokorska-Niewiada *et al.*, 2022)**.

At high concentrations, there are 23 heavy metals in the environment, which can cause toxicity and pose danger **(Jaishankar *et al.*, 2014)** to the population upon exposure to heavy metals, causing adverse serious health problems such as tumor, damage of organs, nervous tissues, autoimmune diseases, and even mortality in some cases **(Malassa *et al.*, 2013)**. The five metals addressed in the present article (Pb, Zn, Cd, Cu, and Ni) are the most often recognized in the environment. Furthermore, heavy metal pollution of the aquatic environment might impact aquatic biodiversity, generating ecological imbalances **(Calmuc *et al.*, 2021)**.

Cichlids were selected for our study because they are the most common fish group in the commercial catch of the River Nile and its tributaries as well as the northern Delta lakes. Namely, blue tilapia (*O. aureus)*,Nile tilapia *(O. niloticus)*, mango tilapia (*S. galilaeus)*, and redbelly tilapia (*T. zillii)* are the most common tilapia species in Egypt **(Mahmoud & Mazrouh, 2008)**.These cichlids are also involved in fish culture in most farms in Egypt. Since these species constitute the major bulk of the River Nile fish species, more than 33.0% of the total catch include cichlids **(GAFRD, 2015)**.

The main aims of the current study were to estimate and quantify the effect of human activities on the level of heavy metal accumulation in blue tilapia (*O. aureus*), Nile tilapia (*O. niloticus*), mango tilapia (*S. galilaeus*) and redbelly tilapia (*T. zillii*) from the River Nile and Lake Burullus and to investigate possible eco-toxicological human health risks associated with the consumption of studied fish.

MATERIALS AND METHODS

1. Study area

Sampling stations are shown in Table (1). Three collection sites were covered to investigate the level of heavy metals concentrations (Fig. 1). Balteem and El-Borg are two major cities on Lake Burullus with a large number of inhabitants, and the lake receives a large quantity of agricultural wastewater i.e. drainage **(EMI, 2012)**. ElTebeen is a site on the River Nile near Great Cairo, with a huge population of inhabitants and very high industrial activities.

Table 1. Sampling sites of the present study

Site	Latitude	Longitude	Type of pollution
Balteem	31°30'56"N	31°00'24" E	Agricultural and urban activities
El-Borg	31°34'10"N	30°59'52" E	Agricultural and urban activities
Nile (near ElTebeen)	29°47'33"N	31°17'37" E	Industrial and urban activities

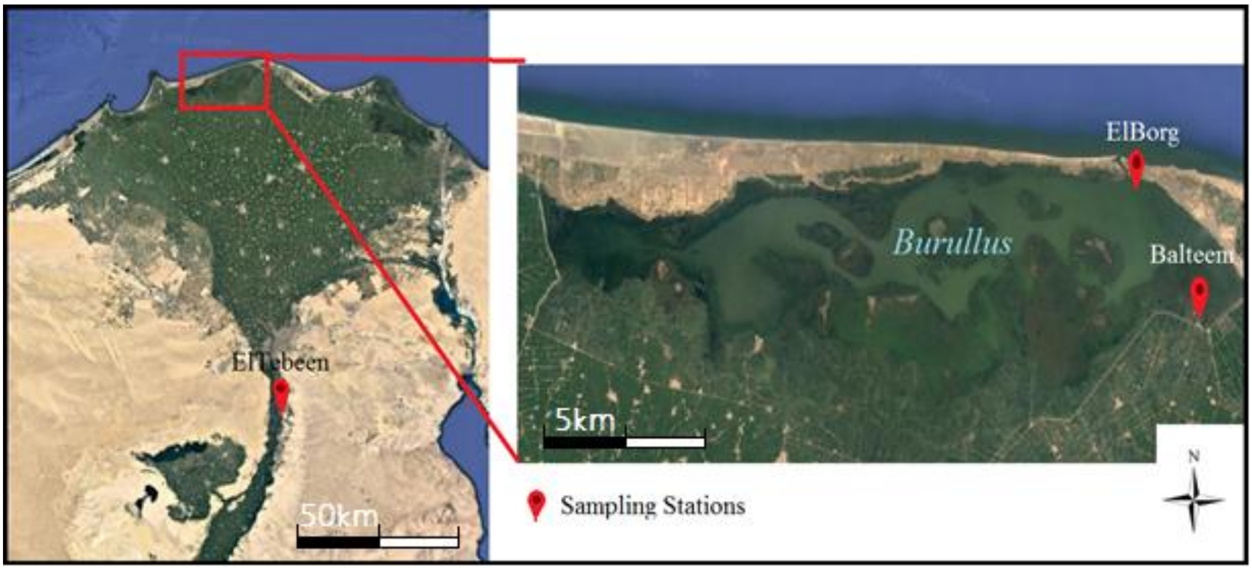

Fig. 1. A map of sampling locations in the River Nile (near ElTebeen), and Lake Burullus (Balteem and El-Borg)

2. Sampling of studied cichlid fish species

A total of 123 specimens of different cichled fish species (Fig. 2) were used in the present study. The fish species were blue tilapia (*Oreochromis aureus*), the Nile tilapia (*Oreochromis niloticus*), mango tilapia (*Sarotherodon galilaeus*) and redbelly tilapia (*Tilapia zillii*). Fish specimens were obtained from the different sites by using gill nets during the period from October to December 2020. The total length of each fish was measured to the nearest mm, and its weight was weighed to the nearest gram using an electric balance.

Lengths of fish used in this study ranged from 18 to 20cm, and their weights ranged from 100 to 180g, which were mostly of a marketable size and weight. Then, fish samples were washed with distilled water and placed separately within crushed ice till transferred to the laboratory. The samples were stored at -20°C until analysis.

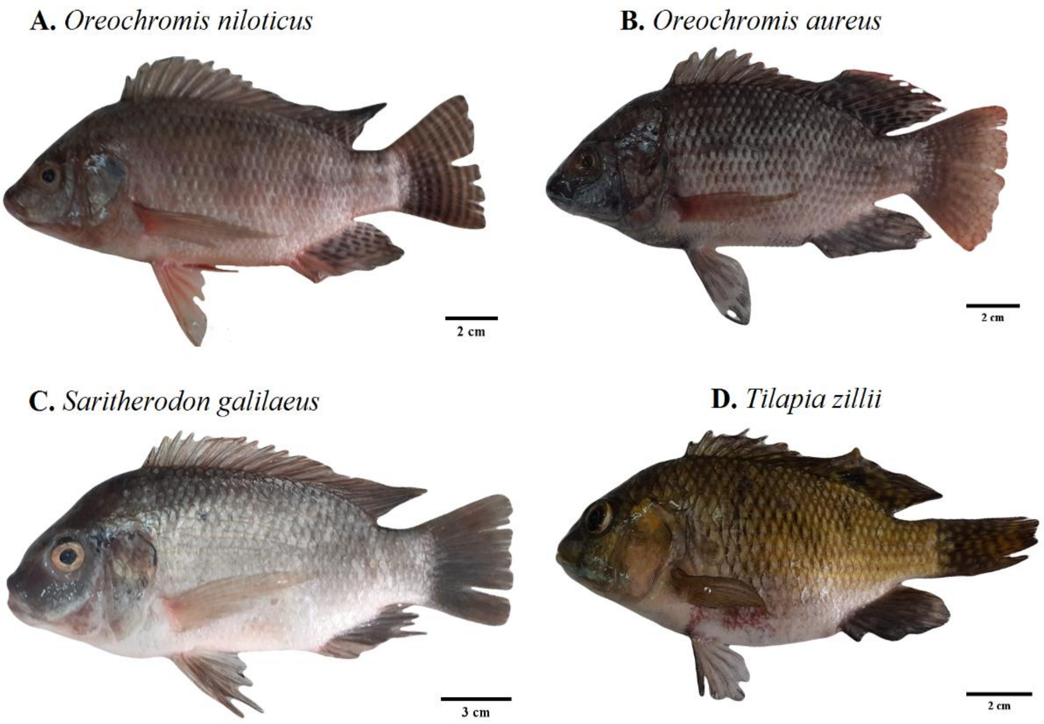

Fig. 2. The four studied species **A.** *O. niloticus*; **B.** *O. aureus*; **C.** *S. galilaeus*, and **D.** *T. zillii*

3. Determination of heavy metals in water samples

Heavy metals (Pb, Zn, Cd, Cu, and Ni) in water samples (in 3 replicates) were collected from the selected sites at a depth of 30cm under the water surface and kept in 1L pre-cleaned polyethylene bottles. They were cleaned by soaking 10% of nitric acid for one day before being rinsed with distilled water. Water samples were delivered to the laboratory as soon as possible and filtered in a measuring cylinder (1 L) using 0.45 µm Whatman filter paper. Individual filtrate water sample was pre-concentrated using the APDC-MIBK (ammonium pyrrolidine di-thiocarbamate) extraction technique **(APHA, 1999)**.The obtained results were expressed as µg/L for metals in water.

4. Determination of heavy metals in fish samples

Fish samples were left at room temperature until thawing, then they were carefully dissected to separate muscles, liver and gills. Each selected body tissue was separately homogenized and weighed. For sample digestion, a 3:1 combination of ultrapure nitric acid (65%) and hydrogen peroxide (35%) was utilized **(Durali *et al.*, 2010)**, and the samples were filtered by 0.45µm Whatman filter paper (Germany) in measuring cylinders and diluted with de-ionized water to a known volume for each tissue (liver, gills and muscles). The solution was then used for heavy metals analysis. Using an atomic absorption spectrophotometer (AAS) and an inductively coupled plasma (ICP-MS), the obtained samples were tested for Pb, Cd, Zn, Cu, and Ni, the heavy metals covered in this research. Perkin Elmer element standard solution was made by diluting stock solutions of 100mg/ml of each element. according to **Abdulali *et al.* (2003)**. The obtained results were expressed as µg/g wet weight for metals in fish tissue samples.

Unless otherwise specified, all reagents used in the present work were of analytical grade. All dilutions were made using deionized water. HNO_3 (65%) and H_2O_2 (30%) were both of a high purity grade (E. Merck, Darmstadt, Germany). Before usage, all plastic and glassware were soaked in HNO_3 10% (V/V) before being washed with distilled water.

5. Bio-concentration factor (BCF)

Bio-concentration estimations take place when the pollutants' levels in the studied fish tissues exceed the levels of those in the surrounding environment. Bio-concentration factors (BCFs) are the ratio of the steady-state metal ion concentrations in the fish tissue versus the concentration in water/sediments (**Orata & Birgen, 2016**). The BCFs were calculated according to **Gobas *et al.* (2009)** and **El-Batrawy *et al.* (2018)** by the following equation:

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

6. Human Risk Assessment

6.1. Estimated Daily Intake (EDI) of Trace Metals:

The Estimated Daily Intake **(EDI)** of Trace Metals through fish consumption can be determined using the equation:

$$EstimatedDailyIntake\ (EDI) = \frac{C \times IR}{Bw}$$

Where: **C** is the concentration of metal in different fish tissues (µg/g-wet wt);**IR** is the rate of daily ingestion of fish which is 62.25 g/ person/day (**Ministry of Agriculture and Land Reclamation, Egypt, 2017** and **Central Agency for Public Mobilization and Statistics, 2015**), and **BW** is the average body weight (15 kg for a child, and 70 kg for an adult).EDI values were expressed as the following formula: µg/kg BW/day for the heavy metals**(Albering, *et al.*, 1999** and **Abdel‑ Kader & Mourad, 2022).**

6.2. Non‑ carcinogenic Risk Estimation:

The target hazard quotient **(THQ)** calculations were carried out according to **US EPA (2012)** by the following formula:

$$THQ = \frac{EF \times ED \times IR \times C}{RfD \times WAB \times ATn} \times 10^{-3}$$

Where ***EF* :** exposure frequency (days/year); **ED:** exposure duration (years); ***IR*:** ingestion rate (g/day); **C:** concentration of metal in different fish tissues (µg/g-wet wt); ***RfD*:** oral reference dose (Pb= 0.0035; Cd= 0.001; Zn= 0.3; Ni= 0.02; and Cu= 0.04;); ***WAB*:** weight of average body (70 kg); ***ATn*:** averaged exposure time to non-carcinogenic heavy metals during 365 days through 70 years. **(US EPA, 2012; Pokorska-Niewiada *et al.*, 2022** and **Abdel‑ Kader & Mourad, 2022).**

6.3. Hazard Index (HI):

Hazard index was calculated as the total of the hazard quotients, and used to evaluate the combined risk of the metals using the following equation:

$$HI = \Sigma THQ_i,\ \text{i.e: } HI = THQ(Pb) + THQ(Zn) + THQ(Cd) + THQ(Cu) + THQ(Ni)$$

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

6.4. Target Carcinogenic Risk (TCR) Estimation:

Target carcinogenic risk **(TCR)** was calculated according to **US EPA (2000)** using the following formula:

$$TCR = \frac{EF \times ED \times IR \times C \times CSF}{WAB \times ATc} \times 10^{-3}$$

Where **CSF** is the cancer slope factor = oral (µg/g bw/day) $8.5\text{x}10^{-3}$ for Pb**, (US EPA, 2013)** 1.7 for Ni and 2.59 $\text{x}10^{-4}$ for Cd **(Javed & Usmani, 2016** and **US EPA, 2019)** ; and **ATc** is the average time for carcinogens "days/year × ED" **(Abdel- Kader & Mourad, 2022).**

Data were analyzed using Statistical Package for the Social Sciences (SPSS) software (version 22)(IBM Corp., Armonk, NY). Differences in metal concentrations were determined using analysis of variance (ANOVA). A significant level was determined at $P \leq 0.05$.

RESULTS

1. Heavy metals in water samples

Heavy metal concentrations in water were found to be in the following increasing order of concentrations. Zn (31.41) > Cu (20.01) >Ni> Pb (5.48) > Cd (3.41) (µg/l). No significant difference between lead concentrations at the collection site at ($P \leq 0.05$) while cadmium was significantly higher in Nile water than in Balteem. Both Zinc and Copper concentration shows a significant ($P \leq 0.05$) higher concentration in Balteem and El-Borg than in Nile. Nickel concentration was found significantly higher ($P \leq 0.05$) in El-Borg than in Nile and Balteem **(Table 2)**.

Table (2): The investigated concentrations of metals (Pb, Cd, Zn, Cu, and Ni) in water (µg/l) of Nile, Balteem, and El-Borg (Data are represented as Mean ± S.D.)

Sites	**Heavy metals**				
	Pb	Cd	Zn	Cu	Ni
Nile	$5.6^{a} \pm 2.36$	4.57 ± 0.99^{b}	20.43 ± 1.81^{a}	15.77 ± 2.47^{a}	5.4 ± 1.39^{a}
Balteem	$5.4^{a} \pm 1.57$	2.43 ± 0.9^{a}	35.9 ± 7.66^{b}	23.3 ± 2.87^{b}	5.83 ± 1.86^{a}
El-Borg	$5.43^{a} \pm 0.97$	$3.23 \pm 0.81^{a,b}$	37.9 ± 2.95^{b}	20.97 ± 2.35^{b}	9.3 ± 0.92^{b}
Total	5.48 ± 1.5	3.41 ± 1.22	31.41 ± 9.28	20.01 ± 4.02	6.84 ± 2.23

Different letters for means in the same column refer to be significantly different (Duncan test, $P \leq 0.05$) a< b< c<d.

None of the investigated metals have exceeded the permissible limits prescribed by **EOS (1993)** which are 50 µg/l for Pb, 5000 µg/l for Zn, 1000 µg/l for Cu, 10 µg/l for both Cd and Ni, and **(ECS, 1994)** from comparable "US Environmental Protection Agency(US-EPA)" standards are 5 mg/l for Zn, 1 mg/l for Cu, 0.01 mg/l for Cd, 0.005 mg/l for Pb (**US-EPA, 2000**).

2. Heavy metals bioaccumulation in fish tissues

The heavy metals concentrations in muscles, gills, and liver of our four studied fish species are presented in **Tables (3)**. Metal accumulation orders in muscles of all studied fish were found to follow the order of Zn> Cu> Ni>Pb> Cd. The result showed different mean concentrations of heavy metals in tissues among different collection sites and different species.

2.1. Heavy metals bioaccumulation in muscles

In muscle tissue, lead accumulation in *O. aureus, S. galilaeus, O. niloticus* and *T. zillii* collected from Nile was significantly higher than those collected from Balteem an El-Borg at ($P \leq 0.05$) while no significant different between Balteem and El-Borg except for *T. zillii* in which accumulation in muscles from Balteem shows no significant different with those from both Nile and El-Borg ($P \leq 0.05$). Cadmium was detected only in muscles of *S. galilaeus* collected from Nile water.

Zinc accumulation in muscles of O. *aureus, S. galilaeus* and *T. zillii* showed same situation as in lead. Zinc accumulation in muscles of the three above mentioned species from Nile was significantly higher than those collected from Balteem and El-Borg at ($P \leq 0.05$), in other hand, zinc accumulation in muscles *O. niloticus* showed different situation as showed the significantly highest accumulation in samples collected from Balteem followed by Nile then El-Borg at ($P \leq 0.05$).

In *S. galilaeus,* there was no significant difference ($P \leq 0.05$) in copper accumulation in muscles between the three collection sites, while in *T. zillii, O. aureus* and *O. niloticus* the situation was similar with lead and zinc, which means that copper accumulation in Nile samples was higher than those of Balteem and Burullus samples at ($P <0.05$).

For nickel accumulation in muscles, accumulation pattern from collection sites differs between different species but generally El-Borg samples showed the lowest significant accumulation of Ni in muscle tissues ($P \leq 0.05$)., in the other hand. Nile samples of *O. aureus* and *S. galilaeus* showed the highest accumulation of Ni. While, in *O. niloticus* and *T. zillii,* the highest accumulation of Ni in Muscles was found in samples collected from Balteem.

2.2. Heavy metals bioaccumulation in gills

In gills tissues, there was no significant difference ($P \leq 0.05$) in lead accumualtion between the collection sites in *O. niloticus*, while in *O. aureus, S. galilaeus* and *T. zillii* the highest significant accumulations were found in Nile samples ($P \leq 0.05$). The lowest significant accumulation was found in Balteem for *O. aureus*, Balteem and El-Borg for *T. zillii* and El-Borg for *S. galilaeus (*$P \leq 0.05$). Cadmium accumulation was detected only in the gills tissue of *O. niloticus* from Nile water. The accumulation of zinc in gills tissue of *O. niloticus, O. aureus, S. galilaeus* and *T. zillii* showed significantly ($P \leq 0.05$) higher concentrations in samples collected from Nile and Balteem than those collected from El-Borg which showed the lowest significant ($P \leq 0.05$) accumulation of Zn , moreover its accumulation showed no significant difference ($P \leq 0.05$) between Nile and Balteem samples in *O. niloticus, S. galilaeus* and *T. zillii, while in O. aureus* Nile sample showed significant higher accumulation than Balteem ($P \leq 0.05$).

In *O. aureus, S. galilaeus* and *O. niloticus* Cu accumulations in gills were found in Nile samples significantly higher ($P \leq 0.05$) than those in Balteem and El-Borg, while, no significant difference was detected ($P \leq 0.05$) in copper accumulation between the collection sites in *T. zillii*. For nickel accumulation in gills , there was no significant difference ($P \leq 0.05$) between all the three collection sites in *O. aureus* and *O. niloticus,* while it was highly significant in *S. galilaeus* and *T. zillii* ($P \leq 0.05$) in Balteem samples and lowest one was found in Nile and El-Borg samples.

2.3. Heavy metals bioaccumulation in liver:

In liver, lead accumulation pattern through collection sites showed large variation between studied fish, in O. aureus, the accumulation of Pb in Nile was significantly higher ($P \leq 0.05$) in Balteem than Nile and El-Borg, in *S. galilaeus* the significant different in accumulation follows the pattern Balteem ≥ Nile ≥ El-Borg ($P \leq 0.05$), in O. niloticus, Pb accumulation is significantly higher ($P \leq 0.05$) in Nile than in Balteem and El-Borg, in *T. zillii* the significant different in accumulation follow the pattern Balteem ≥ El-Borg ≥ Nile ($P \leq 0.05$). Cadmium in liver tissues was found only in Nile sample of *O. aureus, S. galilaeus* and *O. niloticus* and not detected in *Tilapia zillii.*

Table (3): Heavy metals concentrations (µg/g wet wt.) in fish tissues from different study sites
(Data are represented as Mean ± S.D)

Tissue	**Heavy metal**	**Sites**	**Fish species**			
			O. aureus	***S. galilaeus***	***O. niloticus***	***T.zillii***
Muscles	**Pb**	**Nile**	0.55^{b} ± 0.05	0.49^{b} ± 0.11	0.41^{b} ± 0.05	0.59^{b} ± 0.03
		Balteem	0.32^{a} ± 0.08	0.12^{a} ± 0.03	0.18^{a} ± 0.09	$0.37^{a,b}$ ± 0.15
		El-Borg	0.41^{a} ± 0.04	0.15^{a} ± 0.05	0.16^{a} ± 0.04	0.33^{a} ± 0.13
	Cd	**Nile**	ND	0.07 ± 0.06	ND	ND
		Balteem	ND	ND	ND	ND
		El-Borg	ND	ND	ND	ND
	Zn	**Nile**	8.69^{b} ± 0.63	9.01^{b} ± 0.42	$8.41^{a,b}$ ± 4.51	9.70^{b} ± 1.28
		Balteem	5.66^{a} ± 1.03	4.95^{a} ± 0.99	5.52^{a} ± 1.08	7.10^{a} ± 0.26
		El-Borg	5.43^{a} ± 0.13	5.79^{a} ± 1	13.47^{b} ± 4.35	$8.80^{a,b}$ ± 1.35
	Cu	**Nile**	3.26^{b} ± 1.05	3.33^{a} ± 1.96	1.98^{b} ± 0.36	3.08^{b} ± 0.29
		Balteem	1.32^{a} ± 0.42	0.86^{a} ± 0.12	1.28^{a} ± 0.15	1.72^{a} ± 0.23
		El-Borg	0.93^{a} ± 0.15	1.64^{a} ± 1.06	$1.44^{a,b}$ ± 0.36	1.26^{a} ± 0.52
	Ni	**Nile**	0.84^{b} ± 0.13	0.58^{b} ± 0.13	0.54^{a} ± 0.06	0.75^{a} ± 0.23
		Balteem	0.83^{b} ± 0.10	0.36^{a} ± 0.05	0.65^{b} ± 0.13	0.98^{b} ± 0.07
		El-Borg	0.49^{a} ± 0.09	0.42^{a} ± 0.04	0.59^{a} ± 0.13	0.74^{a} ± 0.16
Gills	**Pb**	**Nile**	0.29^{b} ± 0.04	1.36^{c} ± 0.26	0.52^{a} ± 0.55	0.50^{b} ± 0.1
		Balteem	0.14^{a} ± 0.04	0.73^{b} ± 0.06	0.69^{a} ± 0.06	0.26^{a} ± 0.05
		El-Borg	0.26^{b} ± 0.05	0.16^{a} ± 0.07	0.11^{a} ± 0.03	0.21^{a} ± 0.1
	Cd	**Nile**	ND	ND	0.1 ± 0.02	ND
		Balteem	ND	ND	ND	ND
		El-Borg	ND	ND	ND	ND
	Zn	**Nile**	21.07^{c} ± 1.38	20.37^{b} ± 1.5	15.7^{b} ± 1.95	19.15^{b} ± 1.99
		Balteem	15.88^{b} ± 2.10	20.59^{b} ± 2.19	12.41^{b} ± 1.52	17.66^{b} ± 2.65
		El-Borg	12.18^{a} ± 1.36	12.42^{a} ± 2.22	4.69^{a} ± 1.62	13.16^{a} ± 1.68
	Cu	**Nile**	2.01^{b} ± 0.28	2.14^{b} ± 0.35	1.63^{b} ± 0.26	2.1 ± 0.56
		Balteem	0.99^{a} ± 0.36	2.61^{c} ± 0.1	$1.46^{a,b}$ ± 0.47	2.45 ± 0.70
		El-Borg	1.23^{a} ± 0.29	1.18^{a} ± 0.13	$.83^{a}$ ± 0.17	1.75 ± 0.34
	Ni	**Nile**	0.48^{a} ± 0.09	0.58^{a} ± 0.11	0.48^{a} ± 0.05	0.34^{a} ± 0.1
		Balteem	0.29^{a} ± 0.17	0.95^{b} ± 0.22	0.42^{a}± 0.09	1.03^{b} ± 0.32
		El-Borg	0.51^{a} ± 0.18	0.39^{a} ± 0.12	0.52^{a} ± 0.11	0.77^{b} ± 0.06
Liver	**Pb**	**Nile**	0.38^{b} ± 0.07	$0.44^{a,b}$ ± 0.14	0.32^{b} ± 0.07	0.28^{a} ± 0.06
		Balteem	0.14^{a} ± 0.04	0.57^{b} ± 0.06	0.16^{a} ± 0.03	0.60^{b} ± 0.05
		El-Borg	0.37^{b} ± 0.14	0.32^{a} ± 0.1	0.073^{a} ± 0.03	$0.44^{a,b}$ ± 0.21
	Cd	**Nile**	0.08 ± 0.02	0.17 ± 0.14	0.14 ± 0.03	ND
		Balteem	ND	ND	ND	ND
		El-Borg	ND	ND	ND	ND
	Zn	**Nile**	19.38^{b} ± 1.8	19.63^{b} ± 2.15	17.28^{b} ± 0.34	18.39^{a} ± 0.13
		Balteem	18.92^{b} ± 1.67	18.27^{b} ± 1.96	12.28^{a} ± 2.27	20.58^{a} ± 4.34
		El-Borg	13.62^{a} ± 2.06	13.59^{a} ± 0.72	12.43^{a} ± 4.51	16.66^{a} ± 1.81
	Cu	**Nile**	23.74^{b} ± 9.09	23.46^{a} ± 12.34	12.13^{a} ± 3.7	16.11^{a} ± 2.53
		Balteem	7.37^{a} ± 2.29	8.06^{a} ± 5.11	9.43^{a} ± 4.99	15.12^{a}± 1.69
		El-Borg	$12.73^{a,b}$ ±2.11	7.57^{a} ± 1.47	7.54^{a} ± 0.95	14.76^{a} ± 3.06
	Ni	**Nile**	0.94^{b} ± 0.12	0.81^{a} ± 0.18	0.74^{a} ± 0.14	0.80^{a} ± 0.36
		Balteem	0.60^{a} ± 0.18	1.21^{b} ± 0.04	0.69^{a} ± 0.19	1.74^{b} ± 0.32
		El-Borg	1.33^{c} ± 0.19	0.54^{a} ± 0.26	0.58^{a} ± 0.1	$1.29^{a,b}$ ± 0.34

Different letters for means in the same column refer to be significantly different (Duncan test, P<0.05)
a < b < c < d.ND: Not Detected

Zinc accumulation shows no significant difference ($P \leq 0.05$) between collection site in *T. zillii*, while in *O.* aureus, *S. galilaeus* and *O. niloticus* higher significant accumulation ($P \leq 0.05$) was found in the Nile and lower one was found in El-Borg.

There were no significant difference ($P \leq 0.05$) in accumulation of copper between the collection sites in both *T. zillii*, *S. galilaeus*, *O. niloticus*, while in *O. aureus* liver Copper accumulation was significantly higher in Nile than El-Borg than Balteem samples.

Bioaccumulation of nickel in liver showed no significant ($P \leq 0.05$) difference between samples from different collection sites in *O. niloticus*, while in *S. galilaeus* and *T. zillii* it was found that Ni accumulation in Nile and El-Borg was significantly higher than that in Balteem.

In liver, lead accumulation pattern through collection sites showed large variation between studied fish, in O. aureus, the accumulation of Pb in Nile was significantly higher ($P \leq 0.05$) in Balteem than Nile and El-Borg, in S. galilaeus the significant different in accumulation follows the pattern Balteem ≥ Nile ≥ El-Borg ($P \leq 0.05$), in O. niloticus, Pb accumulation is significantly higher ($P \leq 0.05$) in Nile than in Balteem and El-Borg, in *T. zillii* the significant different in accumulation follow the pattern Balteem ≥ El-Borg ≥ Nile ($P \leq 0.05$). Cadmium in liver tissues was found only in Nile sample of *O. aureus, S. galilaeus* and *O. niloticus* and not detected in *Tilapia Zillii.*

3. Bioconcentration factor (BCF)

The bioconcentration factor (BCF) values were calculated in the muscle, gills, and liver tissues of *O. aureus*, *S. galilaeus*, *O. niloticus,* and *Tilapia zillii* consumption in the three collection sites **(Table 4**), vs exposure to heavy metals (Pb, Cd, Zn, Cu, and Ni) in water all sites. According to the BCF classification scale of **Landis *et al.* (2011)**, BCF showed low pollution (BCF< 250) for Pb, Cd, Cu and Ni and low to moderate pollution (BCF= 250-1000) for zinc in muscle tissue, in all studied species from different collection sites. As in muscles, A Similar situation was reported for gills except for Zinc Bio-concentration factor in gills of *O. aureus* from Nile fishes which were (1031.3 ± 67.5) and showed high pollution "BCF ≥ 1000" **(Table 4).**

BCF values for liver reported low pollution (BCF< 250) for Pb, Cd, and Ni in *O. aureus, S. galilaeus, O. niloticus* and *T. zillii* at all studied sites except for BCF for Ni in *T. zillii* from Balteem showed moderate pollution (297.7 ± 54.8), BCF of zinc in liver reported between 327.88 - 960.5 that showed moderate pollution **(Table 4)**.

Copper Bio-concentration factor in liver show moderate to high pollution highest value reported from the Nile was (1505 ± 576) while the lowest value reported from Balteem was (345.8 ± 219).

4. Human Risk Assessment

4.1. Estimated Daily Intakes (EDI)

Results displayed the estimated daily intake (EDI) in muscles of heavy metals (µg/kg BW/day) through the consumption of adults and child people (assuming 70 kg per person as an adult and 15 kg Child). The highest value of Pb, Cd, Zn, Cu, and Ni were 0.53, 0.6, 12.03, 2.97 and 0.75 respectively for adult. While for children highest values of Pb, Cd, Zn, Cu, and Ni were 2.45, 0.29, 40.27, 13.82, 4.05 respectively **(Table 5)**.

Table (4): Bio-concentration factor of heavy metals in fish tissues collected from different study sites
(Data are represented as Mean ± S.D)

Tissue	**Heavy metal**	**Sites**	**Fish species**			
			O. aureus	***S. galilaeus***	***O. niloticus***	***T.zillii***
Muscles	**Pb**	**Nile**	92.9 ± 24.2	86.9 ± 19.9	73.2 ± 9.45	105.4 ± 4.7
		Balteem	57.4 ± 27.3	22.22 ± 5.6	33.95 ±17.0	68.5 ± 28.5
		El-Borg	75.5 ± 6.64	28.2 ± 8.3	28.8 ± 7.44	60.12 ± 23
	Cd	**Nile**	ND	15.3 ± 12.2	ND	ND
		Balteem	ND	ND	ND	ND
		El-Borg	ND	ND	ND	ND
	Zn	**Nile**	425.45 ± 30.8	440.78 ± 20.6	411.6 ± 220.9	474.88 ± 62.7
		Balteem	157.7 ± 28.6	137.88 ± 27.5	153.8 ± 30.16	197.77 ± 7.37
		El-Borg	143.18 ± 3.34	152.77 ± 26.4	355.4 ± 114.7	232.37 ± 35.5
	Cu	**Nile**	206.98 ± 66.6	211.2 ± 124.2	125.8 ± 22.9	195.35 ± 18.4
		Balteem	56.65 ± 18.21	36.91 ± 5.27	54.79 ± 6.44	73.82 ± 9.9
		El-Borg	44.52 ± 6.98	78.38 ± 50.46	68.52 ± 16.93	60.1 ± 24.98
	Ni	**Nile**	155.56 ± 24.91	108.02 ± 24.1	100 ± 11.26	138.27 ± 42.12
		Balteem	142.86 ± 17.84	62.29 ± 8.1	111.43 ± 22.48	167.43 ± 11.67
		El-Borg	52.69 ± 9.19	44.8 ± 4.35	63.8 ± 13.83	79.57 ± 17.6
Gills	**Pb**	**Nile**	52.38 ± 6.27	242.9 ± 45.77	92.26 ± 59.29	89.29 ± 18.64
		Balteem	25.93 ± 6.68	134.57 ± 11.2	127.16 ± 11.9	48.15 ± 9.8
		El-Borg	48.47 ± 8.3	28.83 ± 13.31	20.86 ± 5.92	38.04 ± 17.49
	Cd	**Nile**	ND	ND	21.9 ± 4.4	ND
		Balteem	ND	ND	ND	ND
		El-Borg	ND	ND	ND	ND
	Zn	**Nile**	1031.3 ± 67.5	997.06 ± 73.6	769 ± 95.29	937.2 ± 97.2
		Balteem	442.34 ± 58.4	573.44 ± 60.9	345.59 ± 42.3	492.01 ± 73.85
		El-Borg	321.37 ± 35.9	327.6 ± 58.58	123.83 ± 42.6	347.1 ± 148.67
	Cu	**Nile**	127.5 ± 17.45	135.5 ± 21.97	103.4 ± 16.78	133.2 ± 35.36
		Balteem	42.63 ± 15.45	112. ± 4.46	62.66 ± 19.96	105.15 ± 29.8
		El-Borg	58.66 ± 13.68	56.28 ± 6.24	39.43 ± 8.18	83.62 ± 16.42
	Ni	**Nile**	89.51 ± 17.21	107.41 ± 19.6	88.27 ± 9.32	63.58 ± 18.6
		Balteem	49.14 ± 29.21	162.3 ± 36.86	72.57 ± 15.93	177.1 ± 54.9
		El-Borg	55.2 ± 19.36	41.58 ± 12.92	55.91 ± 11.63	82.44 ± 6.21
Liver	**Pb**	**Nile**	67.86 ± 11.7	79.17 ± 25	57.7 ± 12.67	49.4 ± 10.91
		Balteem	26.54 ± 6.5	104.9± 10.9	29.01 ± 5.35	111.1 ± 9.26
		El-Borg	67.48 ± 26.3	59.5 ± 18.44	13.5 ± 5.62	80.37 ± 39.1
	Cd	**Nile**	16.8 ± 4.56	37.2 ± 1.1	30.66 ± 5.8	ND
		Balteem	ND	ND	ND	ND
		El-Borg	ND	ND	ND	ND
	Zn	**Nile**	948.3 ± 88.1	960.5 ± 283	845.5 ± 16.42	900 ± 6.3
		Balteem	527 ± 46.62	509 ± 157	342.06 ± 63.1	573.3 ± 120.8
		El-Borg	359.5 ± 54.4	358.5 ± 19.1	327.88 ± 69.7	439.5 ± 47.67
	Cu	**Nile**	1505 ± 576.3	1488.2 ± 782	769.1 ± 234.9	1021.8 ± 160
		Balteem	316.3 ± 98.11	345.8 ± 219.4	404.6 ± 214.1	648.78 ± 72.5
		El-Borg	607.3 ± 100.7	361.05 ± 70.2	359.5 ± 45.35	703.8 ± 146
	Ni	**Nile**	174.1 ± 21.8	150.6± 32.6	137 ± 25.73	147.6 ± 66.9
		Balteem	103.43 ± 3	206.86 ± 6.9	117.7 ± 33.3	297.7 ± 54.8
		El-Borg	142.7 ± 20.9	57.7 ± 27.84	62.4 ± 10.91	138.4 ± 36.3

Different letters for means in the same column refer to be significantly different (Duncan test, P<0.05)
a < b < c < d.ND: Not Detected

Table (5): Estimated daily intake (µg/kg BW/day) of heavy metals inmuscles of different fish species through consumption by adult (assuming 70 kg /person) and Child (assuming 15 kg /person)people (Data are represented as Mean ± S.D)

	Heavy metal	**Sites**	**Fish species**				**PTDI**
			O. aureus	***S. galilaeus***	***O. niloticus***	***T.zillii***	
Adult	**Pb**	**Nile**	0.46	0.43	0.36	0.53	**3.6**
		Balteem	0.27	0.11	0.17	0.33	
		El-Borg	0.37	0.14	0.14	0.29	
	Cd	**Nile**	ND	0.06	ND	ND	**1.0**
		Balteem	ND	ND	ND	ND	
		El-Borg	ND	ND	ND	ND	
	Zn	**Nile**	7.76	8.04	7.51	8.66	**300**
		Balteem	5.06	4.42	4.93	6.34	
		El-Borg	4.85	5.17	12.03	7.86	
	Cu	**Nile**	2.91	2.97	1.77	2.75	**38**
		Balteem	1.18	0.77	1.14	1.54	
		El-Borg	0.83	1.47	1.28	1.12	
	Ni	**Nile**	0.75	0.52	0.48	0.67	**20**
		Balteem	0.74	0.33	0.58	0.87	
		El-Borg	0.44	0.37	0.53	0.66	
Child	**Pb**	**Nile**	2.16	2.02	1.70	2.45	**3.6**
		Balteem	1.29	0.50	0.76	1.54	
		El-Borg	1.70	0.64	0.65	1.36	
	Cd	**Nile**	ND	0.29	ND	ND	**1.0**
		Balteem	ND	ND	ND	ND	
		El-Borg	ND	ND	ND	ND	
	Zn	**Nile**	36.08	37.38	34.90	40.27	**300**
		Balteem	23.49	20.54	22.91	29.47	
		El-Borg	22.52	24.03	55.90	36.55	
	Cu	**Nile**	13.54	13.82	8.23	12.78	**38**
		Balteem	5.48	3.57	5.30	7.14	
		El-Borg	3.87	6.82	5.96	5.23	
	Ni	**Nile**	3.48	2.42	2.24	3.10	**20**
		Balteem	3.46	1.51	2.70	4.05	
		El-Borg	2.04	1.73	2.46	3.07	

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

4.2. Non-carcinogenic risk

Target hazard quotient (**THQ**) of Pb, Cd, Zn, Cu, and Ni through *O. aureus, O. Niloticus, S. galilaeus and T. zillii* muscles consumption by average Egyptian adult and child is presented in **Table (6)**. The means of Pb, Cd, Zn, Cu, and Ni were used to compute THQ and (HI) of metals in fish. The result revealed that the adult individual mean THQ values of each metal were less than one (1) indicating no adverse effect in adults. But in children, HI was reported to be >1 in *O. aureus, S. galilaeus, and T. zillii* collected from the Nile water. Moderate lifetime cancer risks were found caused by Ni in adults and children from 6.9E^{-03} to 9.8E^{-04}, respectively **(Table 7)**.

Table (6): Target hazard quotient (THQ) for heavy metals, their hazard index (HI)in muscles of different fish species through consumption by adult (assuming 70 kg /person) and Child (assuming 15 kg /person) people (Data are represented as Mean ± S.D)

	Heavy metal	**Sites**	**Fish species**			
			O. aureus	***S. galilaeus***	***O. niloticus***	***T.zillii***
Adult	**Pb**	**Nile**	0.128	0.120	0.101	0.146
		Balteem	0.077	0.030	0.045	0.091
		El-Borg	0.101	0.038	0.039	0.081
	Cd	**Nile**	ND	0.062	ND	ND
		Balteem	ND	ND	ND	ND
		El-Borg	ND	ND	ND	ND
	Zn	**Nile**	0.026	0.027	0.025	0.029
		Balteem	0.017	0.015	0.016	0.021
		El-Borg	0.016	0.017	0.040	0.026
	Cu	**Nile**	0.076	0.078	0.046	0.072
		Balteem	0.031	0.020	0.030	0.040
		El-Borg	0.022	0.038	0.034	0.029
	Ni	**Nile**	0.037	0.026	0.024	0.033
		Balteem	0.037	0.016	0.029	0.043
		El-Borg	0.022	0.019	0.026	0.033
HI		**Nile**	**0.268**	**0.313**	**0.197**	**0.280**
		Balteem	**0.161**	**0.081**	**0.120**	**0.196**
		El-Borg	**0.161**	**0.112**	**0.139**	**0.169**
Child	**Pb**	**Nile**	0.599	0.561	0.473	0.680
		Balteem	0.357	0.138	0.211	0.427
		El-Borg	0.473	0.177	0.181	0.377
	Cd	**Nile**	ND	0.291	ND	ND
		Balteem	ND	ND	ND	ND
		El-Borg	ND	ND	ND	ND
	Zn	**Nile**	0.120	0.125	0.116	0.134
		Balteem	0.078	0.068	0.076	0.098
		El-Borg	0.075	0.080	0.186	0.122
	Cu	**Nile**	0.356	0.364	0.217	0.336
		Balteem	0.144	0.094	0.139	0.188
		El-Borg	0.102	0.179	0.157	0.138
	Ni	**Nile**	0.174	0.121	0.112	0.155
		Balteem	0.173	0.075	0.135	0.203
		El-Borg	0.102	0.086	0.123	0.154
HI		**Nile**	**1.250**	**1.461**	**0.918**	**1.306**
		Balteem	**0.753**	**0.376**	**0.562**	**0.915**
		El-Borg	**0.751**	**0.523**	**0.647**	**0.790**

ND: Not Detected

Table (7): Target Cancer Risk TCR) for heavy metals in muscles of different fish species through consumption by adult (assuming 70 kg /person) and Child (assuming 15 kg /person) people(Data are represented as Mean ± S.D)

	Heavy metal	**Sites**	**Fish species**			
			O. aureus	***S. galilaeus***	***O. niloticus***	***T.zillii***
Adult	**Pb**	**Nile**	3.9E-06	3.7E-06	3.1E-06	4.5E-06
		Balteem	2.3E-06	9.1E-07	1.4E-06	2.8E-06
		El-Borg	3.1E-06	1.2E-06	1.2E-06	2.5E-06
	Cd	**Nile**	ND	1.6E-08	ND	ND
		Balteem	ND	ND	ND	ND
		El-Borg	ND	ND	ND	ND
	Ni	**Nile**	1.3E-03	8.8E-04	8.2E-04	1.1E-03
		Balteem	1.3E-03	5.5E-04	9.8E-04	1.5E-03
		El-Borg	7.4E-04	6.3E-04	9.0E-04	1.1E-03
Child	**Pb**	**Nile**	1.8E-05	1.7E-05	1.5E-05	2.1E-05
		Balteem	1.1E-05	4.2E-06	6.5E-06	1.3E-05
		El-Borg	1.5E-05	5.4E-06	5.5E-06	1.2E-05
	Cd	**Nile**	ND	7.5E-08	ND	ND
		Balteem	ND	ND	ND	ND
		El-Borg	ND	ND	ND	ND
	Ni	**Nile**	5.9E-03	4.1E-03	3.8E-03	5.3E-03
		Balteem	5.9E-03	2.6E-03	4.6E-03	6.9E-03
		El-Borg	3.5E-03	2.9E-03	4.2E-03	5.2E-03

ND: Not Detected

DISCUSSION

Heavy metals are significant hazards because of their profound impact on aquatic body stability, bioaccumulation in life forms, toxicity persistence, and tendency to concentrate in water. Pb, Ni, and Cd are poisonous to living species even at very trace doses, but Zn and Cu are more physiologically important as essential metals for aquatic life and their toxicity appears only at high concentrations. Erosion of rocks or anthropogenic activities such as effluents from industrial activities, sewage, and mining wastes represent major sources of metal in the aquatic environment (**Bahnasawy *et al.*, 2011**).

Zinc is an essential element, but it may be hazardous to fish in high doses, causing growth retardation, reproductive dysfunction, and death (**Sorenson, 1991**). Zinc can combine with other elements, resulting in antagonistic, additive, or synergistic effects **Baumann & May (1984).** Zn ions contents ranged between 20.43 - 37.9 µg/l. Dense phytoplankton blooms influence copper complexation in water (**Chemistry, 1981**). The mean Cu concentration in the current investigation varied from 15.77 to 20.97 g/l. Ni levels in bodies of water are ascribed to industrial and urban activities, and they can accumulate in a variety of fish and macrophytes (**Hayward, 1969**). Ni ion concentrations in the current investigation varied from 5.4 to 9.3 g/l. Because Ni has been scavenged directly from water by hydrous MnO2, its greater value is related with Fe and Mn (**Masoud & Mohamed, 2005**).

Cd is one of the most toxic metals having broad carcinogenic effects on humans, and its concentration in drinking and irrigation water is deemed harmful if it surpasses 0.01 mg/l (**Ashour *et al.*,2018**). Cd ion concentrations varied from 2.43 to 4.57 g/l. Pb is an important ion in the aquatic system (**Al Prol *et al.*, 2019).** The greatest levels of lead can harm the health of phytoplankton, which is a vital source of oxygen in oceans. The high quantity of lead may be due to agricultural and industrial effluents, as well as the spill of fishing vessels along the research area's shore. Many ships, however, have been painted using a dye that has a high proportion of Pb^{2+} metal. Pb^{2+} at high amounts produces hemorrhages as well as congestion of the fish's gastrointestinal system and kidneys. (**Abdelhamid & El-Ayouty, 1991**). Pb ions contents ranged between 5.4 – 5.6 µg/l.

In present study the metal concentration in water fellow the order Zn > Cu >Ni>Pb> Cd. Metal concentrations in water (Table 2) were compared with National Recommended Water Quality Criteria by U.S. EPA and permissible limits prescribed by **EOS (1993)**. Results show that Zn, Cu, Ni, Pb, and Cd concentrations in this study were lower and within the range of **EPA** criteria and **EOS (1993).**

The levels of trace metals in fish tissues were consistently higher than in water (**Chale, 2002**). Heavy metal absorption occurs in a variety of fish organs. From these organs, the highest accumulation of metal is always found in the liver so it has been widely used to examine bioaccumulation mechanisms. Heavy metal concentrations in the liver, kidney, and gills were found to be greater (**Golovanova, 2008**). each organ in the body accumulates a specific metal at certain extents, whereas some accumulate at high levels, others do not its presence in the medium (**Al-Kahtani, 2009**). Pb accumulated in the following order in the current study: gills > liver > muscle. Our findings demonstrate that the highest level of metal has been accumulated by the liver, followed by the gills and muscles which have the lowest accumulation. Fish liver and gills, both metabolically active organs, accumulated all metals substantially better than muscle**. Jabeen *et al.* (2012)** had similar findings. According to **Yacoub (2007)**, this might be due to an increase in metal-binding protein generated in the gills and liver. lower metal accumulation in muscle can be explained by one of two factors: 1) A mucous layer on the fish skin surface produces a barrier that protects fish muscle tissue by creating compounds with heavy metals in the surrounding environment. **(Uysal, 2008).** Detoxification does not occur directly in the muscle **(Jagakumar & Paul, 2006).** As a result, other tissues do not carry heavy metals to muscle. According to our research, the liver contains the most metals. This might be as a result of metal interactions with target organ components (**Sorensen, 1991**). Fish liver presented less of a risk to human health since it was rarely consumed.

Contaminant accumulation patterns in fish are affected by both absorption and removal rates (**Hakanson, 1984**). In the current investigation, the low accumulation of Cu in the gills may be attributed to the development of various defense mechanisms such as increased mucus production and gill clogging, this is agreed with **Eissa *et al.* (2013**) and **Badr *et al.*(2014)** interpretation.

While the Bio-concentration factor (BCF) varies depending on the organism, tissue, and metal **(Chale, 2002)**, this study found that the BCFs in both fish species were greater in the liver than in other tissue. According to **Fernandes *et al.* (2007)**, the greatest BCFs were found in tissues involved in metal metabolism. As Heavy metals are typically stored in metabolically active organs including the liver, kidney, and gills (**Dural *et al.,* 2006**). According to the literature, the liver plays an important role in basic metabolism, pollutant storage, redistribution, detoxification, and transformation (**Malik *et al.,* 2010**). As a result, the liver is a good environmental biomarker of chronic metal exposure and water pollution **(Fernandes *et al.,* 2007).** After the liver, the gills reported the greatest concentration of heavy metals in our study being the first tissues that are exposed to suspended sediment particles, hence they might be important sites of heavy metal interaction (**Dural *et al.,* 2006** and **Fernandes *et al.,* 2007**). Furthermore, elevated metal concentrations in the gill might be created by a metal conjunction with mucus that cannot be cleared from it (**Bahnasawy *et al.,* 2009**). In contrast, findings from various fish species indicate that muscle tissues are not an active site for metal storage. In fish, the muscles have the lowest essential and nonessential metal concentrations (**Fernandes *et al.*, 2007** and **Kamaruzzaman *et al.*, 2010**).

There were species-specific variations in metal concentrations in our four studied species (*P*<0.05). Based on our findings, accumulation of metals in aquatic organisms may be species-dependent which agreed with **Fernandes *et al.* (2007)** and **Kamaruzzaman *et al.* (2010).** Besides, comparable results from several fish species reported that concentrations of heavy metals varied between species due to dietary habits (**Malik *et al.*, 2010**), numerous metabolic activities differences (**Dural *et al.*, 2006**), diverse environmental needs (**CHI *et al.*, 2007**), and differences in absorptive ability by many animals and anatomical aspects (**Mohammadnabizadeh *et al.*, 2014**).

Heavy metals accumulate in numerous fish organs, which can then have an impact on human metabolism via diet, posing major health risks **(Bravo *et al.*, 2010).** Consequently, the daily intake of the heavy metals analyzed was calculated and compared to the recommended data to estimate if the metal levels detected in fish samples from Balteem, El Borg, and the Nile were safe to be consumed by humans (Table 9). our research was limited to edible tissues, which are the only tissues eaten by humans. and according to our findings, There is no threat from consuming investigated fish muscles in both adults and children based on EDI and acceptable tolerable daily intake in µg/ kg body weight/day **(US EPA, 2000)**

THQs are used to identify non-carcinogenic health concerns associated with population pollutant exposure **(Yi *et al.*, 2017** and **Zhang *et al.*, 2017).** If the THQ reaches 1.0, it indicates a non-carcinogenic health risk from heavy metal accumulative effects in the exposed population (**Yi *et al.*, 2017**). According to the recommendations, when HI levels are less than 0.1, there is no concern; however, when values are between 0.1 and 1.0, the hazard is minimal (**Khan *et al.*, 2020**) According to our findings, the individual mean HQ values of each metal were less than one (1) indicating no adverse effect in adult but in child, HI reported to be more than (1) in *Nile O. aureus, S. galilaeus, and T. zillii.*

The carcinogenic risk of Pb, Cd, and Ni which has been predicted in *O. niloticus*, *O. aureus*, *S. galilaeus*, and *T. zillii* to be minimal. Similarly, according to the New York State Department of Health (**NYSDOH**, 2007) when TR $\leq 10^{-6}$, is considered low risk; when10^{-4} to 10^{-3} then considered risk is moderate; if 10^{-3} to 10^{-1} then considered risk is high; if $\geq 10^{-1}$ then considered risk is very high. Similarly, THQ, the TR, is not a precise assessment of anticipated tumors. Instead, the upper limit of the possibility that the individual may get cancer at some point throughout his or her lifetime if additional exposure to that chemical occurs.

REFERENCES

Abdelhamid, A.M. and **El-Ayouty, S.A. (1991).** Effect on catfish (*Clarias Lazera*) composition of ingestion rearing water contaminated with lead or aluminum compour. Arch. Anim. Nutr. Berlin., **41:** 757–763.

Abdel‑ Kader, H.H. and **Mourad, M.H. (2022).** Estimation of cadmium in muscles of five freshwater fish species from Manzalah Lake, and possible human risk assessment of fish consumption (Egypt). Biological Trace Element Research. https://doi.org/10.1007/s12011-022-03188-5

Abdulali, T.; Shuhaimi, O.M. and **Ahmad, A.K. (2003).** Assessment of heavy metals in tilapia fish (*Oreochromis niloticus*) from the Langat River and engineering lake in Bangi, Malaysia and evaluation of the health risk from tilapia consumption. Ecotoxicology and Enviromental Safety, **93:** 45-51

Alprol, A.E.; El-Metwally, M.E.A. and **Amer, A. (2019).** *Sargassum latifolium* as eco-friendly materials for treatment of toxic nickel (II) and lead (II) ions from aqueous solution. Egypt. J. Aquat. Biol. Fish., **23:** 285–299.

Albering, H.; Rila. J.; Moonen, E.; Hoogewerff, J. and **Kleinjans, J. (1999).** Human health assessment in relation to environmental pollution in two artificial freshwater lakes in the Netherlands. Environ Health Perspectives, **107:** 27–35.

Aliaume, C.; Viaroli, P.; Zaldivar, J. M. and **Do Chi, T. (2007):** Coastal lagoons of Southern Europe: recent changes and future scenarios. Transitional Waters Monographs, **1**: 1–12.

Alprol, A. E.; Heneash, A. M. M. ; Soliman, A. M.; Ashour, M.; Alsanie,W. F.; Gaber, A. and **Mansour, A. T. (2021).** Assessment of water quality, eutrophication, and zooplankton community in Lake Burullus, Egypt. Diversity, **13**(6)**:** 268.

Aly, M. Y. M.; El-Gaar, D. M. K.; Salaah, S. M. and **Abdo, M. H. (2020).** Evaluation of heavy metals and oxidative stress with biochemical parameters as bio-indicators of water pollution and fish in Lake Burullus, Egypt. Mari. Scie. Res. Ocean. J., **3**(1)**:** 30-34.

Al-Halani, A.A. (2017). Ecological studies on effects of water quality on some teleosts: african catfish (*Clarias gariepinus*) and Nile Tilapia (*Oreochromis niloticus*) from different freshwater habitats. Ph. D. Thesis. Faculty of Science, Mansoura University

Al-Kahtani, M.A. (2009). Accumulation of heavy metals in Tilapia fish (*Oreochromis niloticus*) from Al-Khadoud spring, Al-Hassa, Saudi Arabia. American Journal of Applied Sciences, **12:**2024-2029.

APHA (1999). American Public Health Association, Standard methods for the examination of water and wastewater, 20th ed., Washington, DC, USA.

Ashour, M.; Abo-Taleb, H.; Abou-Mahmoud, M. and **El-Feky, M.M.M. (2018)**. Effect of the integration between plankton natural productivity and environmental assessment of irrigation water, El-Mahmoudia Canal, on aquaculture potential of *Oreochromis Niloticus.* Turk. J. Fish. Aquat. Sci., **18**: 1163-1175.

Badr, A.M.; Mahana, N.A. and **Eissa, A. (2014).** Assessment of heavy metal levels in water and their toxicity in some tissues of Nile Tilapia (*Oreochromis niloticus*) in River Nile basin at Greater Cairo, Egypt Global Veterinaria, **13 (4):** 432-443.

Bahnasawy, M.; Khidr, A.A. and **Dheina, N. (2009).** Seasonal variations of heavy metals concentrations in mullet, *Mugil cephalus* and *Liza ramada* (Mugilidae) from Lake Manzala, Egypt. Journal of Applied Sciences Research, **5(7):** 845–852.

Bahnasawy, M.; Khidr, A. and **Dheina, N. (2011).** Assessment of heavy metal concentrations in water, plankton, and fish of Lake Manzala, Egypt. Turk. J. Zool., **35:** 271–280.

Baumann, P.C. and **May, T.W. (1984).** Nickel residues in fish from inland waters of the United States. In: Workshop Proceedings, The effects of trace elements on aquatic ecosystems. Electric Power Research Institute, Palo Alto, CA, **7:**1-16.

Bekhit, A.D.; Morton, J.D.; Dawson, C.O. (2008). Effect of processing conditions on trace elements in fish roe from six commercial New Zealand fish species. J. Agric. Food Chem., **56**: 4846–4853.

Bravo, A.G.; Loizeau, J.-L.; Bouchet, S.; Richard, A.; Rubin, J.F.; Ungureanu, V.G.; Amouroux, D. and **Dominik, J. (2010).** Mercury human exposure through fish consumption in a reservoir contaminated by a chlor-alkali plant: Babeni reservoir (Romania). Environmental Science and Pollution Research, **17:** 1422–1432.

Calmuc, V.A.; Calmuc, M.; Arseni, M.; Topa, C.M.; Timofti, M.; Burada, A.; Iticescu, C. and **Georgescu, L.P. (2021).** Assessment of heavy metal pollution levels in sediments and of ecological risk by quality indices, applying a case study: The Lower Danube River, Romania. Water**, 13:** 1801.

Central agency for public mobilization and statistics (2015). Annual bulletin of statistics fish production in the Arab Republic of Egypt for 2015. Reference No. 71–22112–2015

Chale, F.M. (2002). Trace metal concentration in water, sediments and fish tissues from lake Tanganyika. Science of Total Environment, **299:** 155 – 161.

Chemistry, S.M. (1981) Analytical fractionation of dissolved copper, lead and cadmium in coastal seawater. Mar. Chem., **10:** 487–503.

CHI, Q.Q.; Zhu, G.W. and **Langdon, A. (2007).** Bioaccumulation of heavy metals in fishes from Taihu Lake, China. Journal of Environmental Sciences, **19** (12): 1500–1504.

Dural, M.; Lugal G¨oksu, M. Z.; Ozak, A. A. and **Derici, B. (2006).** Bioaccumulation of some heavy metals in different tissues of *Dicentrarchus Labrax L*, 1758, *Sparus Aurata L*, 1758 and *Mugil Cephalus L*, 1758 from the CamlIk lagoon of the eastern cost of Mediterranean (Turkey). Environmental Monitoring and Assessment, **118 (**1–3**):** 65–74.

Durali, M.; Omer F.U.; Mustafa, T. and **Mustafa, S. (2010).** Determination of trace metals in different fish species and sediments from the River Yesilırmak in Tokat, Turkey. Food Chem. Toxicol., **48:** 1383–1392.

ECS (Egyptian Chemical Standards) (1994). Protection of the Nile River and Water Stream from pollution, Ministry of Irrigation, Cairo, Egypt, Law No 4.

Eissa, A.E.; Tharwat, N.A. and **Zaki, M.M. (2013).** Field assessment of the mid-winter mass kills of trophic fishes at Mariotteya stream, Egypt: chemical and biological pollution synergistic model. Chemosphere, **90:** 1061-1068

El-Batrawy, O.A.; El-Gammal, M.I.; Mohamadein, L.I.; Darwish, D.H.; and **El-Moselhy K.M. (2018).** Impact assessment of some heavy metals on tilapia fish, *Oreochromis niloticus*, in Burullus Lake, Egypt. The Journal of Basic and Applied Zoology, **79:**13

EMI (2012). Egyptian Ministry of Irrigation, the amount of agricultural drainage water which entered the Lake Burullus during 2010. Organization of Mechanic and Electricity, Central Administration of the Central Delta stations, Kafr El- Sheikh, Egypt.

EOS (1993). Egyptian standard, maximum levels for heavy metal concentrations in food., 546-815.

Farag, M.A.; Abib, B.; Tawfik, S.; Shafik, N. and **Khattab, A.R. (2021).** Caviar and fish roe substitutes: Current status of their nutritive value, bio-chemical diversity, authenticity and quality control methods with future perspectives. Trends Food Sci. Tech., **110:** 405–417.

Farouk A.E.; Enas M.G.; Mansour and **Mekawy M.T. (2020)** Assessment of some heavy metals contamination and their pollution indices in water and fish organs of (*Oreochromis niloticus*and *Clarias gariepinus*) in Burullus and Edku lakes, (A comparative study). Egyptian Journal of Aquatic Biology & Fisheries, **24(**5**):** 609 – 637

Fernandes, C.; Fonta´ınhas-Fernandes, A.; Peixoto, F. and **Salgado, M.A. (2007).** Bioaccumulation of heavy metals in *Liza saliens* from the Esmoriz-Paramos coastal lagoon, Portugal. Ecotoxicology and Environmental Safety, **663**: 426–431.

Foladifard, R. and **Ebrahimi, A.A. (2010).** Efficiency study of nickel (II) and cadmium (II) biosorption by powder of waste activated sludge from aqueous solutions. Iranian Journal of Health and Environment, **3(**4**):** 419-430. (In Persian).

GAFRD (2015). General Authority for Fishery Resources Development. Year-Book of Fishery: Statistics, Cairo, Egypt

Ghannam, H.E. (2021). Risk assessment of pollution with heavy metals in water and fish from River Nile, Egypt. Applied Water Science, **11**: 125

Gobas, F.A.P.C.; Wolf, D.; Burkhard, W.; Verbruggen, L.P. and **Plotzke, K.,** ***et al.*** **(2009).** Revisiting bioaccumulation criteria for POPs and PBT assessments. Integrated Environmental Assessment and Management, **5:** 624–637.

Golovanova, I.L. (2008). Effects of heavy metals on the physiological and biochemical status of fishes and aquatic invertebrates. Inland Water Biol., **1(**1**):** 93-101.

Hakanson, L. (1984). Metals in fish and sediment from the River Kolbacksan water system, Sweden. Archives of Hydrobiology, **101:** 373-400.

Hayward, J. (1969) Studies on the growth of *Rhaeodactylum*. V. The relationship to iron, manganese and zinc. J. Mar. Biol. Assoc. *UK,* **49:** 439–446.

Huang, C.F.; Hsu, C.J.; Liu, S.H.; Lin-Shiauand **S.Y. (2008).** Neurotoxicological mechanism of methylmercury induced by low-dose and long-term exposure in mice: Oxidative stress and down-regulated Na+/K+-ATPase involved. Toxicology Letters, **176:** 188–197.

Jabeen, G.; Javed, M. and **Azmat, H. (2012).** Assessment of heavy metals in the fish collected from the river Ravi. Pakistan. Vet. J., **32**(1)**:**107-111.

Jagakumar, P. and **Paul, V. (2006).** Patterns of cadmium accumulation in selected tissues of the cat fish *Clarius batruchus* exposed to sub lethal concentration of cadmium chloride. Veterinarski.Arhiv., **76:** 167-177.

Jaishankar, M.; Tseten, T.; Anbalagan, N.; Mathew, B.B. and **Beeregowda, K.N. (2014).** Toxicity, mechanism and health effects of some heavy metals. Toxicol., **7:** 60–72.

Kamaruzzaman, B. Y.; Ong, M.C. and **Rina, S.Z. (2010).** Concentration of Zn, Cu and Pb in some selected marine fishes of the Pahang coastal waters, Malaysia. The American Journal of Applied Sciences**, 7(3):** 309–314.

Javed, M. and **Usmani, N. (2016).** Accumulation of heavy metals and human health risk assessment via the consumption of freshwater fish *Mastacembelus armatus* inhabiting thermal power plant effluent loaded canal. Springer Plus., **5(**776**):**1-8.

Khan, M.S. ; Javed, M.; abishRehman, M.T.; Urooj, M. and **Ahmad, M.I. (2020).** Heavy metal pollution and risk assessment by the battery of toxicity tests. Scientific Reports, **10:** 16593.

Landis, W.; Sofield, R.; Yu, M.H.; Landis, W.G. and **Sofield, R.M. (2011).** Introduction to Environmental Toxicology: Molecular Substructures to Ecological Landscapes. 4th ed. Boca Raton, Florida: CRC Press. ISBN 9781439804100.

Mahmoud, H. and **Mazrouh, M.M. (2008).** Biology and fisheries management of Tilapia species in Rosetta branch of the Nile River, Egypt. Egyptian journal of aquatic research, **34:** 273-284**.**

Malakootian, M. ;Mortazavi, M.S. and **Ahmadi, A. (2016).** Heavy metals bioaccumulation in fish of southern Iran and risk assessment of fish consumption. Environmental Health Engineering and Management Journal, **3(**2**):** 61–68.

Malassa, H.; Al-Qutob, M.; Al-Khatib, M. and **Al-Rimawi, F. (2013).** Determination of different trace heavy metals in ground water of South West Bank/Palestine by ICP/MS. J. Environ. Prot. Sci., **4:** 720–726.

Maleki, A.; Azadi, N.A.; Mansouri, B.; Majnoni, F.; Rezaei, Z. and **Gharibi, F. (2015).** Health risk assessment of trace elements in two fish species of Sanandaj Gheshlagh Reservoir, Iran. Toxicol. Environ. Health. Sci., **7:** 43–49.

Malik, N.; Biswas, A.K. ;Qureshi, T.A. ; Borana, K. and **Virha, R. (2010).** Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal, Environmental Monitoring and Assessment, **160 (**1–4**):** 267–276.

Masoud, M.S.; Mohamed, E.A. (2005). Distribution of some metal concentration in water and sediments of lake. Afr. J. Environ. Sci. Technol., **4:** 280–298.

Ministry of Agriculture and Land Reclamation (2017). In Fish Statistics Yearbook. Cairo, Egypt. Gen Authority Fish Resour. Dev. https:// www. gafrd. Org

Mohammadnabizadeh, S.; Pourkhabbaz, A. and **Afshari, R. (2014).** Analysis and determination of trace metals (nickel, cadmium, chromium, and lead) in tissues of *Pampus argenteus* and *Platycephalus indicus* in the Hara Reserve, Iran. Journal of Toxicology, Volume 2014, Article ID 576496, 6 pages.

NYSDOH (New York State Department of Health) (2007). Hopewell Precision Area Contamination: Appendix C-NYS DOH. Procedure for Evaluating Potential Health Risks for Contaminants of Concern.

Orata, F. and **Birgen, F. (2016).** Fish tissue bio-concentration and interspecies uptake of heavy metals from waste water lagoons. J. of Pollution Effects & Control., **4(2):** 157.

Pokorska-Niewiada, K.; Witczak, A.; Protasowicki, M. and **Cybulski, J. (2022)**. Estimation of target hazard quotients and potential health risks for toxic metals and other trace elements by consumption of female fish gonads and testicles. Int. J. Environ. Res. Public Health, **19**: 2762. https:// doi.org/10.3390/ijerph19052762

Ravanbakhsh, M.; Javid, A.Z.; Hadi, M. and **Fard, N.J.H. (2020).** Heavy metals risk assessment in fish species (*Johnius belangerii* (C) and *Cynoglossus arel*) in Musa Estuary, Persian Gulf. Environ. Res.**, 188**: 109560.

Shaltout, K.H. and **Al-Sodany, Y.M. (2008).** Vegetation analysis of Burullus wetland: A Ramsar site in Egypt. Wetl. Ecol. Manag., **16:** 421–439.

Sorenson, E.M. (1991). Metal Poisoning in Fish. CRC Press, Inc. Boca Raton, Florida, 119-174.

US EPA, United States Environmental Protection Agency (2000). Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume II. Risk Assessment and Fish Consumption Limits; EPA 823-B-00-008; USEPA: Washington, DC, USA.

US EPA, United States Environmental Protection Agency (2012). Regional Screening Level (RSL) Summary Table (TR=1E-06, HQ=1), United States Environmental Protection Agency: Washington, DC, USA, 2019. Available online: http:// www. epa. gov/ regshwmd/ risk/ human/ Index. htm. Accessed 10 Feb 2002

US EPA, United States Environmental Protection Agency (2013). Technical report EPA/100/R11/001: Recommended use of BW3/4 as the default method in derivation of the oral reference dose. 1-50
https://www.epa.gov/sites/default/files/2013-09/documents/recommended-use-of-bw34.pdf

US EPA, United States Environmental Protection Agency (2019). Risk Based Concentration Table. United States Environmental Protection Agency, Philadelphia, Washington

Uysal (2008). The determination of heavy metals accumulation ratio in muscle, skin and gills of some migratory fish species by inductively coupled plasma-optical emission spectrometry in Beymelek lagoon Antalya / Turkey. Microchem. J., **90:** 67-70.

Yacoub, A. (2007). Study on some heavy metals accumulated in some organs of three river Nile fishes from Cairo and Kalubia Governorates. African. J. Biol. Sci., **3:** 9-21.

Yi, Y.; Tang, C.; Yi, T.; Yang, Z. and **Zhang, S. (2017)**. Health risk assessment of heavy metals in fish and accumulation patterns in food web in the upper Yangtze River, China. *Ecotoxicology and Environmental Safety,* **14**5: 295–302.

Zhang, H.; Huang, B.; Dong, L.; Hu, W.; Akhtar, M.S. and **Qu, M. (2017)**. Accumulation, sources and health risks of trace metals in elevated geochemical background soils used for greenhouse vegetable production in southwestern China. Ecotoxicology and Environmental Safety, **137:** 233–239.