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Seasonal variations of some heavy metal concentrations in seawater, sediment, and the surf clam, *Mactra olorina* (Philippi, 1846) in the Great Bitter Lake, Suez Canal, Egypt

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ABSTRACT

Molluscs, owing to their filtrate ability, can accumulate metals that may contaminate food, causing a negative impact on the health of the consumers. Thus, the main objective of the present study was to investigate the heavy metal concentrations in one of the widest broad and consumed surf clams *Mactra olorina* available in the Great Bitter Lake, Egypt. The concentrations of the heavy metals (Pb, Cd, Cu, and Zn) were seasonally evaluated in water, sediment, and the soft flesh of *M. olorina*. The specimens were monthly collected from the Egyptian Great Bitter Lake near Fayed City (Ismailia Governorate) for one year , from April 2009 to March 2010. Results revealed that, the annual mean concentrations of heavy metals in water were 1.376±0.562, 0.267±0.329, 2.256±2.909 and 3.355±2.731 µg/l for Pb, Cd, Cu and Zn, respectively. The corresponding concentration values in the sediment were 0.398±0.355, 0.307±0.244, 1.753±0.464 and 8.643±1.821 for Pb, Cd, Cu and Zn µg/g, respectively. While, the annual mean concentrations of heavy metals in soft tissues were 0.538±1.130, 0.262±0.283, 5.395±3.115 and 13.043±5.743 for Pb, Cd, Cu, and Zn µg/g, respectively. Interestingly, heavy metals deposited in the tissues of *M. olorina* and their environment (water and sediments) recorded a close relationship ($0.05 \geq p \leq 0.01$) in the current research. In conclusion, though no apparent risk was detected on bivalve consumers from being exposed to a single metal, yet there is a risk from being exposed to the 4 studied metals combined together, especially for high bivalve-consuming groups such as fishermen. Furthermore, environmental parameters need to consider when to use bivalves as indicators of heavy metal pollution since seasonality could affect the absorption of heavy metals.

INTRODUCTION

Phylum Mollusca constitute the second most diverse groups in the animal kingdom with ~ 120,000 living species. It contains many well-known organisms of economic importance including clams, mussels, snails, squids, and octopuses, most of which are marine (**Koulouri *et al.*, 2006; Antit *et al.*, 2013)**. Imenently, mollusca requires special attention since its water filtering mechanism makes it capable of concentrating pollutants in quantities higher than those of the environment where this species lives **(Vázquez, 2002)**. Depending on certain factors, some intrinsic to the organism itself (age, height, activity reproductive), other abiotic (salinity, temperature, presence of other elements) and even speciation chemistry **(Gobert *et al.*, 1992; Wang, 2001)** can bioaccumulate high concentrations of pollutant metals in the digestive gland (hepatopancreas) as in the kidney. From a toxicological point of view, metals such as zinc and copper being essential micronutrients, can cause harmful effects only at high concentrations **(Pereira *et al.*, 2002)**. However, other metals such as cadmium and lead are toxic to living organisms at minimum doses **(Mas & Azcue, 1993)**.

For the recorded edible bivalve species in Egypt, which are most common to the consumers in coastal area, the marine surf clams (Bivalvia: Mactridae) *M. olorina* are found in the Great Bitter Lake, Ismailia. This site is characterized by low tide, sandy bottom and is scantily covered with vegetation. The water in this area is almost turbid due to agricultural land, human activities and domestic drainage. Moreover, this area is considered a transit area for ships passing through the Suez Canal. The eastern side of the lake is mostly a sandy desert. These clams are found in the surf zone of the exposed sandy beaches and occur in densities that would support significant fisheries. They are locally consumed in areas where pollution is minimal. Interestingly, this edible species has attracted scientific and commercial interest and is the main point of several investigations **(Cranfield *et al.*, 1992)**. Remarkably, marine bivalves or molluscs are food for humans, fish, other marine creatures and even birds, yet controlling pollution with poisonous elements is of great importance **(Brown *et al.*, 1991)**. Thus, it is reasonable that, these toxic elements can be transferred to the molluscs by feeding on phytoplankton or by filter-feeding of bottom sediments which may contain high levels of pollutants **(Luoma & Jenne, 1976)**. Several studies have shown that living molluscs have the ability to store many heavy metals in their tissues at high concentrations and can adapt to these environmental conditions **(Amiard *et al.*, 1986; Usero *et al.*, 1997; Joiris & Azokwu, 1999; Ananthan *et al.*, 2006; Kesavan *et al.*, 2013)**. Therefore, marine bivalves are usually used as bio-indicator for heavy metals contamination in marine environment **(Azizi *et al.*, 2018)**. In addition, heavy metal concentrations in shells and organisms can be used as a tool to monitor pollution **(Huanxin *et al.*, 2000; Hamed & Emara, 2006a; El-Sorogy *et al.*, 2013)**. Notably, a weaker defensive system in the human body is due to an increase in the accumulation of heavy metals, including Cu, Pb and Cd **(Xue *et al.*, 2017)**. Therefore, a rising attention has been witnessed with respect to food safety since marine molluscs are commercially used as seafood products. Consequently, an additional information is required to achieve a better risk assessment regarding the shellfish consumption caught from the Great Bitter Lake in Ismailia, which represent a geographical area with an increased touristic attractive and fishing activity. The investigated *M. olorina* was found inhabiting sandy shore of the Suez Canal, and was chosen for two reasons: its familiarity to the consumers as a sea food and its wide abundance. Toxic heavy metals, such as cadmium and lead have been found at high concentrations in bivalve mollusk fresh weight. Thus, the current study was organized to monitor water quality and evaluate the concentrations of heavy metals (Pb, Cu, Cd, and

Zn) in the soft flesh of *M. olorina* in relation to their levels in the water and the sediments on which these organisms live.

MATERIALS AND METHODS

Study area and sample collection

Specimens of *M. olorina* were collected monthly for one year (April 2009 to March 2010) from the Great Bitter Lake, Ismailia, Egypt (Fig. 1). They were selected from sediment in labeled plastic bags, freeze-dried in isothermal boxes, and transported to the laboratory for further examination. At the sampling site, monthly measurements of the surface water temperature, salinity and pH were carried out in the field by using HORBIA Water Quality Checker Type U -10.

Heavy metal concentrations in water, sediment, and the soft tissues of *M. olorina*

The concentrations of four metals [lead (Pb), cadmium (Cd), copper (Cu) and zinc (Zn)] were seasonally determined in water, sediment, and the whole tissue of the collected *M. olorina.*

For water, following the methods of **Ravera (2001)**, **Abdallah and Moustafa (2002)** and **Ravera *et al.* (2007)**, heavy metals were measured using a Perkin-Elmer spectrometer, with a specific-hollow cathode lamp for each metal. They were expressed as µg/l for water.

Samples of sediments were collected in plastic zipper bag (0.5-1 kg) using a grab sampler with a top of 5cm and a depth of 20cm and were then transported to the laboratory in ice pack in the cooler. For digestion of sediment, the samples were first dried in a room temperature. The dried samples were then ground into fine powder, sieved with a sieving hole<2mm and stored in polyethylene bags based on method of **Romic and Romic (2003)** for further analysis. Before the determination of heavy metals, the samples were digested using aqua regia digestion. Approximately, an amount of 2g of each sample was digested with 15 ml of aqua regia acid mixture of HCl: HNO_3, with a ratio of 3:1 for 2h in a boiling water bath at 120ºC. After cooling, the digested samples were filtered and kept in plastic bottles before analysis. Heavy metals were determined using a Perkin-Elmer spectrometer, with a specific-hollow cathode lamp for each metal.

For analysis, heavy metals were seasonally determined in the whole tissue of the collected *M. olorina* according to the methods of **Hare *et al.* (1989)**. Samples were prepared for metal analysis stepping the methods of **Bryan and Hummerstone (1971)**, **McDaniel (1991)**, **Abdallah and Moustafa (2002)** and **AbdAllah (2006)** with some modifications. Prior to analysis, the specimens were thawed, rinsed and weighed. Special care was taken to eliminate sediment particles adhering to the animals. Digestion of soft tissues was performed with analar nitric acid in a water bath till complete digestion. An amount of 5ml concentrated nitric acid was added to each tissue sample of the frozen tissue. The tissue was then gently heated in a water bath till boiling and vortexed to help the tissue solubilization. The dissolved tissue was cooled at room temperature, and an additional amount of 0.25 ml of the concentrated nitric acid was added. Then, the solution was heated until it started to turn brown. The solubilized tissue was cooled. A third addition of 0.1 ml nitric acid was done, and the volume was reduced to approximately 0.5 ml. The addition of 0.1 ml concentrated nitric acid was repeatedly appended until the solution turned clear. The digested tissue was diluted with bi-distilled water to 10 ml and analyzed for the determination of heavy metals using the graphite furnace. Heavy metals were determined by a Perkin-Elmer spectrometer, with a specific-hollow cathode lamp for each metal. The metal concentration was calculated according to the methods of **McDaniel (1991)**, **Pip (1992)** and **Kraak *et al.* (1993)**.

Statistical analysis

All experiments were conducted three times. Data were represented as mean ± standard error (SE). One-way ANOVA followed by least significant differences (Tukey's HSD) post hoc test were conducted for heavy metals concentration in water, metals, and tissue of *M. orolina* during the four seasons.

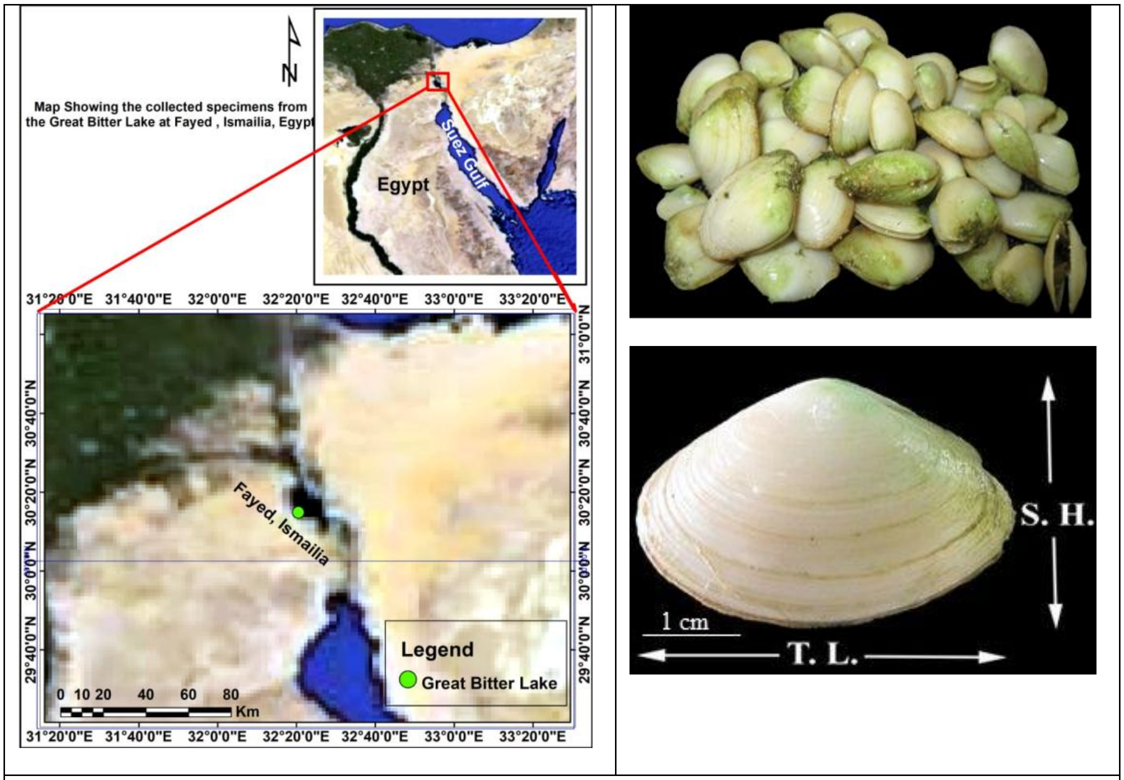

Fig 1. A. Map showing the sampling site: Great Bitter Lake. **B**. A Photograph of *M. olorina*; C, *M. olorina* shell dimensions.

RESULTS

In the present study, four selected trace metals were detected in the tissue of *M. olorina* and corresponding water and sediment samples; lead (Pb), cadmium (Cd) copper (Cu), and zinc (Zn) (Table 1 & Fig. 2) represented some of the essential and non-essential elements for humans.

Table 1. Seasonal means ±SD of heavy metal concentrations (µg/l) in water, sediments (µg/gm) and tissues (µg/gm) from spring 2009 till winter 2010

Season	In water µg/l			
	Pb	Cd	Cu	Zn
Winter	0.54±0.02	0.004±0.001	0.675±0.075	1.72±0.081
Spring	1.44±0.09	0.779±0.035	0.003±0.001	1.8±0.083
Summer	1.482±0.04	0.284±0.011	1.286±0.237	2.617±0.19
Autumn	2.042±0.01	0.001±0.0006	7.06±0.049	8.082±0.11
	In sediments µg/gm			
Winter	0.009±0.003	0.004±0.0025	1.57±0.098	7.783±0.0289
Spring	0.489±0.024	0.624±0.035	1±0.005	10.164±0.139
Summer	0.182±0.02	0.42±0.013	1.193±0.123	6.263±0.230
Autumn	0.912±0.027	0.181±0.011	2.245±0.209	10.362±0.427
	In tissues µg/gm			
Winter	1.459±1.17	0.226±0.11	8.088±3.375	15.04±3.024
Spring	0.6825±0.32	0.587±0.12	4.844±0.586	15.831±5.904
Summer	0.003±0.002	0.006±0.001	4.376±0.075	9.921±0.303
Autumn	0.009±0.004	0.22±0.15	4.273±0.229	11.382±0.318

Heavy metals in water

A remarkable increase in the mean of lead (Pb) was gradually observed during the four seasons. The recorded value started with 0.540 ±0.040µg/l in winter, 1.440±0.172µg/l in spring, 1.482±0.078µg/l in summer and peaked in autumn (2.042±0.023µg/l), and this was statistically significant (F= 124.103, df=3, P=0.000). Cadmium (Cd) showed narrow fluctuation between winter (0.004±0.003 µg/l) and autumn (0.001±0.001 µg/l); however, high levels were monitored between spring (0.779±0.068 µg/l) and summer (0.284±0.020 µg/l), and this was statistically significant (F= 391.925, df=3, P=0.000). The lowest mean value of copper (Cu) (0.003±0.003 µg/l) was measured in spring samples, while the highest (7.06±0.081 µg/l) was reached during autumn. On the other hand, in winter, it reached the value of 0.675±0.136µg/l and in summer, it was 1.286±0.413µg/l. Remarkably, this was statistically significant (F= 654.429, df=3, P=0.000). Fairly, the mean concentration of zinc (Zn) was recorded between winter (1.720±0.141µg/l) and spring (1.800±0.144µg/l). In contrast, it increased from 2.617±0.339µg/l in summer to 8.082±0.207µg/l in autumn, showing a statistical significance (F= 581.136, df=3, P=0.000) (Fig. 2).

Heavy metals in sediments

According to the data represented in Table (1) and Fig. (2), the minimum mean of Pb (0.009±0.003 µg/g) concentration was recorded in winter, while the highest mean value was observed in autumn (0.912±0.027 µg/g), then it declined from 0.489±0.024 µg/g to 0.182±0.02 µg/g from spring to summer, respectively. As well as Pb, the minimum value of Cd concentration was 0.004±0.002 µg/g in winter, whereas the maximum mean was recorded through the next spring season (0.624±0.035 µg/g). Moreover, it was 0.420±0.013 µg/g in summer, while in autumn, the recorded value was 0.181±0.011µg/g. The minimum concentration mean of Cu in sediment was recorded in spring (1.000±0.011 µg/g), and the maximum mean value was recorded in autumn (2.245±0.209 µg/g). Zinc is the only metal that achieved high concentrations during the four seasons; these measurements were recorded (6.263±0.0.230 µg/g) in summer, (7.783±0.289 µg/g) in winter, (10.164±0.139 µg/g) in spring and (10.362±0.427) in autumn (Fig. 4). Statistically, ANOVA test has revealed the significant differences between the means of metal concentrations [Pb (F= 355.404, df=3, P=0.000), Cd (F= 188.183, df=3, P=0.000), Cu (F= 17.456, df=3, P=0.001), Zn (F= 45.824, df=3, P=0.000)] in sediments during the four seasons.

Heavy metals in tissues

Table (1) and Fig. (2) show that the minimum concentration mean of Pb in tissue was recorded in summer (0.003±0.003 µg/g), and the maximum mean value was recorded in winter (1.459±21.173 µg/g). During the seasons of winter and autumn, the mean concentration of Cd gave the same value (0.226 µg/g), increased to (0.587±0.128 µg/g) in spring, then rapidly declined in summer to record a value of 0.006±0.001 µg/g. A steady status was observed for Cu concentration throughout the year, except in winter which gave the twice mean concentration (8.088±3.37 µg/g). In comparison, zinc was assessed as the only metal recording the highest levels in both sediments and tissues. In tissues, the observed increase in Zn was 9.921±0.3032 µg/g in summer; then it continued increasing to record a value of 15.831±10.22 µg/g in spring, with an annual mean concentration of 13.043±3.023 µg/g. Furthermore, the concentrations of Pb, Cu, and Zn recorded no significant differences among the seasons [Pb (F= 1.290, df=3, P=0.342), Cu (F= 1.113, df=3, P=0.399), Zn (F= 0.732, df=3, P=0.561)]; however, the concentration of Cd showed significant difference among the seasons (F= 4.214, df=3, P=0.046).

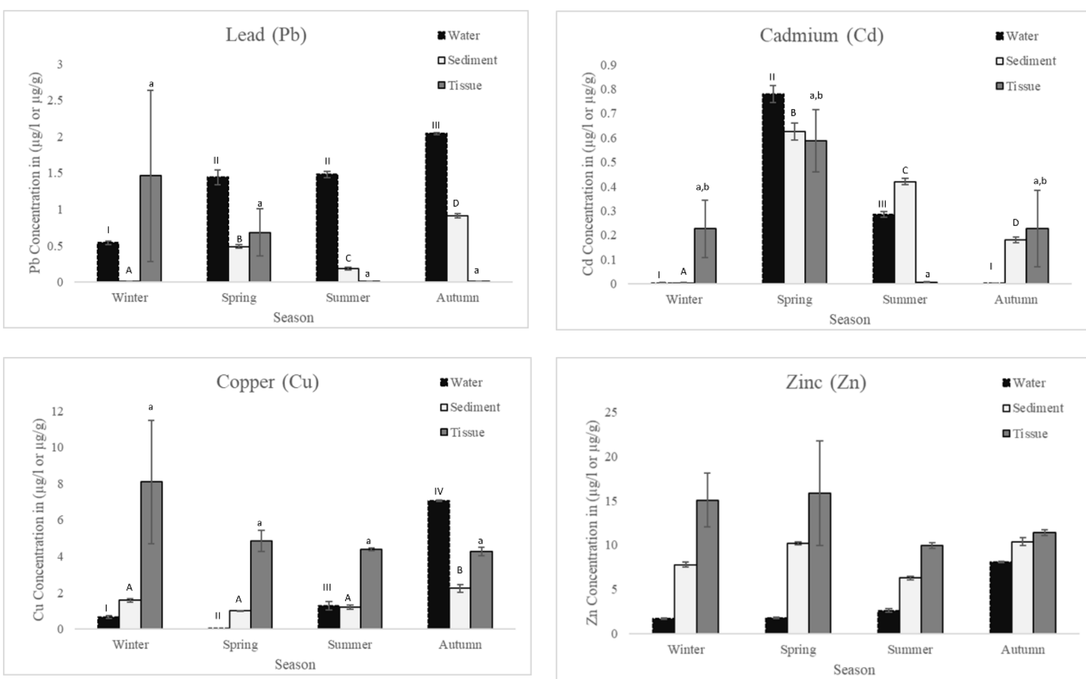

Fig 2. Seasonal means of heavy metal concentrations in water, sediment and tissue of *M. olorina*. **A**, Lead (Pb); **B**, Cadmium (Cd); **C**, Copper (Cu) and **D**, Zinc (Zn).

Roman number (water) and capital letters (tissue) and small letters (sediment) indicate significant differences between the seasons, significance assessed at $P < 0.05$)

DISCUSSION

The present study provides very important information about the monitoring of some heavy metals' concentration in the Great Bitter Lake. It was found that, the minimum concentration mean of Pb in tissue was recorded in summer (0.003±0.003 µg/g), and the maximum mean value was recorded in winter (1.459±2.037 µg/g) with total annual mean (0.538±1.130 µg/g). During winter and autumn, the mean concentration of Cd recorded the same value (0.22 µg/g), increased to 0.587±0.224 µg/g in spring, then rapidly declined in summer (0.006±0.005 µg/g).

A steady status was observed for Cu concentration throughout the year, except in winter which showed a twice mean concentration (8.088±5.848 µg/g), with total seasonal mean (5.395±3.115 µg/g).

In comparison, zinc was the only metal with the highest levels in both sediments and tissues. In tissues, the increase in Zn started with a value of (9.921 ±0.522 µg/g) in summer; then it continued increasing to a level of (15.831±10.22 µg/g) in spring, recording an annual mean concentration (13.043±5.743 µg/g).

It can be concluded that different factors can affect the accumulation of metals and their relationships with the studied bivalve species, such as land-based activities which influence the ambient concentrations of metals, seasonal variations of metals content, food supply for the species population, growth rate, uptake and excretion rates of the metals, and biological and gonadal development of the animal.

The present study was carried out to reveal the seasonal levels of four heavy metals (Zn, Cu, Pb and Cd) in the edible marine bivalve *M. olorina* collected from the Great Bitter Lake. Results revealed that significant seasonal variations were detected in the concentrations of heavy metals in water, sediment, and the soft tissues of *M. olorina* collected from the Great Bitter Lake, Ismailia, Egypt.

Generally, in aquatic environments, sediments are the major compartments for metal storage **(Amiard *et al.*, 2007)**. Since the bivalve Mactra lives in the superficial sediment (which is the fraction always collected for the present work); thus, sediment enters the diet of filter-feeders. In addition, from the large volume of water they filter, mollusks uptake and accumulate in their body's toxic metals without noxious effects **(Lobel *et al.*, 1990; Metcalfe-Smith *et al.*, 1992; Byrne & Vesk, 2000)**. The seasonal variation monitoring of element concentrations in tissues provides information on element metabolism over the year which would facilitate the measurements of actual mean concentration of the elements **(Ravera *et al.*, 2007)**.

Data of the present study showed that the lead concentration during the period of investigation recorded a minimum value of Pb (0.003±0.003µg/g) in summer while it reached the highest concentration (1.459±1.17µg/g) in winter, with a mean value of (0.538±1.130µg/g). In comparison, **Hamed (1996)** and **Hamed and Emara (2006a)** determined higher concentrations of Pb in different bivalves and gastropods molluscan species (Table 2). In addition, the data observed previously on the concentration of Pb from the bivalve *Austrovenus stutchburyi* and *Macomona liliana* from the Auckland, New Zealand (0.1–4.8µg/g) and (0.8–34µg/g), respectively by **Fukunaga and Anderson (2011)** were close to the present observations. On the other hand, the concentrations of Pb reported from Pekan, Pahang and Malaysia in the study of **Kamaruzzaman *et al.* (2011)** on *Perna viridis* are higher than the present findings of Mactra tissue. Moreover, the concentration of Pb reported from Lake Temsah in the study of **EL-Moselhy and Yassien (2005)** on clams; namely, *Paphia undulata* and *Gafrarium pectinatum* are lower in the case of *Paphia undulata* and higher in the case of *Gafrarium pectinatum* compared to the present finding. On the other hand, **Schulz-Baldes (1974)** reported a decrease in the rates of accumulation and depuration of lead with an increase in the size of *M. edulis*.

Considering the seasonal variation in physicochemical factors of the marine ecosystem, and from the ecotoxicological point of view; the bioavailability of some heavy metals is affected by factors such as temperature and water acidity. Consequently, the presence of significant and insignificant differences among seasons in Cd concentration may be explained as ecological factors – dependant. In addition to Pb, the values tabulated in the works of **Hamed (1996)**, **Emara (1999)** and **Hamed and Emara (2006a)** on the bivalve and gastropod mollusks are higher than the current records of Cd measured in their relative Mactra. Moreover, the concentrations of Cd reported from Atlantic Coastal line of South Eastern Nigeria in the work of **Ndome *et al.* (2010)** on *Mactra nitida*, *Donax rugosus* and *Tympanotonus fuscatus* are higher than those in the present study. Recently, **Kamaruzzaman *et al.* (2011)** reported higher concentrations of Cd from the Pekan, Pahang and Malaysia from *Perna viridis* tissues. On the other hand, concentration of Cd reported from Lake Timsah by **EL-Moselhy and Yassien (2005)** for clams, *Paphia undulata* and *Gafrarium pectinatum* are lower than the present finding. In the current investigation, Cu recorded from Mactra tissues exhibited in accordance with the opposite *Barbatus barbatus* and *Patella caerulea* measured by **Hamed and Emara (2006a)**. On the other hand, the present accumulator Mactra showed lower concentration of Cu in comparison with the Cu from the tissues of bivalves *Brachidontes variabilis* and *Modiolus auriculatus* recorded in the study of **Emara (1999)** and *Barbatus barbatus* in the work of **Hamed (1996)**. In contrast, *Pinctada radiate* tissues obtained low concentrations of Cu compared to current data of Mactra in the investigation of **Hamed (1996)**. A lower concentration of Zn was reported in **Emara (1999)** study on the tissues of the bivalve mollusks *Brachidontes variabilis* and Modiolus auriculatus compared to those resulted from Mactra tissues.

Harris *et al.* (1979) recorded an increase in the concentration of Zn with an increase in shell length of the mussle *Mytilus edulis planulatus*. To assess the possible carcinogenic risk of eating sea food, **Friberg (1988)** considered shellfish with cadmium concentrations exceeding 1mg/kg fresh weight. **Magos (1989)** gave the median concentration in mollusks as 1.6 mg/kg. While, **Gil *et al.* (1988)** and **Hutagalung (1989)** determined a mean concentration up to 5 mg/kg cadmium in mollusks and bivalves. The present levels of cadmium in the surf clam *M. olorina* in the Great Bitter Lake do not exceed the above-mentioned concentrations.

Copper concentration ranged from (4.273±0.396µg/g) in autumn and (8.088±3.115µg/g) in winter, with a mean value of (5.395±3.115µg/g). No significant differences were detected between the mean concentrations of Cu among the four seasons. The concentrations of Cu reported from Lake Timsah in the work of **EL-Moselhy and Yassien (2005)** for clams *Paphia undulata* and *Gafrarium pectinatum* are lower than the present finding. In addition, the present results are higher than the concentration of Cu reported from the Atlantic Coastalline of Southeastern Nigeria in the study of **Ndome *et al.* (2010)** on *Tympanotonus fuscatus*, *Mactra nitida* and *Donax rugosus*, recording (0.4, 3.7 and 1.4), respectively. On the other hand, the concentrations of Cu reported from the Pekan, Pahang and Malaysia in the study of **Kamaruzzaman *et al.* (2011)** conducted on *Perna viridis* are higher than the present findings of Mactra tissue. Additionally, the concentrations of Cu reported from the Auckland, New Zealand with respect to the bivalve *Austrovenus stutchburyi* and *Macomona liliana* in the study of **Fukunaga and Anderson (2011)** were (1–18µg/g) and (8–180µg/g), respectively.

The lowest value of zinc concentration was (9.921±0.522µg/ g) in summer and the highest (15.83±10.22µg/g) was recorded in spring, with a mean value of 13.043±5.743µg/g. Except for winter & spring (insignificant), the mean concentration of zinc exhibited the maximum level of significant differences ($p<0.01$) among seasons. The Zn concentration detected from the Lake Temsah in the investigation of **EL-Moselhy and Yassien (2005)** on clams *Paphia undulata* and *Gafrarium pectinatum* is lower than the present finding.

Furthermore, the concentration of Zn of Mactra *nitida* recorded in the work of **Ndome *et al.* (2010)** coincides relatively with the present result. On the other hand, the concentrations of Zn reported from the Pekan, Pahang, and Malaysia in the study of **Kamaruzzaman *et al.* (2011)** on *Perna viridis* are higher than the present findings of Mactra tissue. **Harris *et al.* (1979)** recorded an increase in the concentration of Zn with the increase in shell length of the mussle *Mytilus edulis planulatus*. Moreover, the concentrations of Zn reported in the Auckland, New Zealand on the bivalve *Austrovenus stutchburyi* and *Macomona liliana* in the studies of **Ndome *et al.* (2010)** and **Fukunaga and Anderson (2011)** were (20–290µg/g) and (50–170µg/g), respectively.

Brereton *et al.* (1973) studied the effect of Zn on the growth and the development of larvae of the pacific oyster *Crassostrea gigas* and observed that, increasing of Zn concentration over the range of 125 to 500 ppb resulted in decreasing the growth and increasing the incidence of abnormality, and hence, led to larval mortality.

The calculated data above revealed that, the mean seasonal concentration of heavy metals in Mactra tissue could be ranked as Zn> Cu > Pb > Cd. Heavy metals will accumulate either directly (e.g., in the case of macroalgae) or through the food chain, eventually posing a serious health risk to inhabitants of an ecosystem, including humans **(Galloway *et al.*, 1982; Angelone and Bini, 1992; Chan *et al.*, 2003)**. The ecotoxicological risk posed by contaminated sediment would depend on metal mobility leading to solution, as well as the ability of living organisms to assimilate metals directly from ingested sedimentary particles **(Amiard *et al.*, 2007)**. In response to metal pollution, many aquatic animals produce metal-binding metallothionein proteins that appear to function in detoxification **(Roesijadi, 1992; Couillard *et al.*, 1993; Mason & Jenkins, 1995)**.

In comparing metals' concentrations in the present bivalve species with those found in other Egyptian waters (Table 2) and other environments (Table 3), it can be observed that, most metals are comparable to the literature levels. This variation is mainly attributed to bioavailability of different species to accumulate specific metal. In addition, the present concentrations are within the WHO limits for safety consumption of marine organisms **(FAO, 1992)**.

Table 2. Heavy metal concentrations in tissues of some molluscan species (µg/g wet wt.) in the current study relative to those found in other Egyptian sites.

Location - Species	**Cd**	**Pb**	**Cu**	**Zn**	**Reference**
Lake Timsah - *Gafrarium pictinatum*	0.03-0.18	0.10-1.28	0.79-5.20	2.81-17.7	**(Mourad, 1996)**
Gulf of Suez - *Barbatus barbatus*	0.05-0.13	0.84-1.08	9.90-32.40	12.20-40.80	**(Hamed, 1996a**)
El Mex Bay - Bivalves	0.47	0.07-0.09	2.00-2.11	17.7-20.7	**(El-Rayis *et al.*, 1997)**
Lake Timsah - *Ruditapes decussate*	0.02-0.09	0.06-2.29	0.23-0.071	2.09-5.73	**(Attwa, 1997)**
Suez Bay - *Pinctada radiate*	0.16-0.75	0.33-0.84	0.51-1.89	67.8-135.5	**(Yassien, 1998)**
Gulf of Suez *Brachidontes variabilis*	1.34-2.28	5.63-10.76	17.47-38.38	0.61-0.85	**(Emara, 1999)**
Gulf of Suez - *Modiolus auriculatus*	0.96-2.18	5.20-10.66	26.83-35.16	0.73-1.92	**(Emara, 1999)**
Gulf of Suez - *Pinctada radiata*	0.14-1.21	0.14-3.60	0.46-3.34	48.88-202.45	**(Emara, 1999)**
Lake Timsah - *Periglyta reticulate*	0.27	0.66	1.18	1.69	**(Abdel-Azim, 2002)**
Lake Timsah - *Paphia undulate*	0.08-0.36	0.23-0.78	0.51-1.64	6.22-12.66	**(EL-Moselhy & Yassien, 2005)**
LakeTimsah - *Gafrarium pectinatum*	0.10-0.63	0.35-1.08	0.81-2.47	6.24-12.47	**(EL-Moselhy & Yassien, 2005)**
Gulf of Suez - *Barbatus barbatus*	0.69-2.37	6.92-37.81	3.69-10.07	69.54-163.69	**(Hamed & Emara, 2006b)**
Alexandria - *Mactra spp*	0.03-0.19	0.03-0.17	0.5-2.1	18-35	**(Ahdy *et al.*, 2007)**
Alexandria - *Mytillus spp*	0.031-0.18	0.06-1.80	0.7-2.5	17-20	**(Ahdy *et al.*, 2007)**
Present work	0.006 - 0. 587	0.003 - 1.459	4.273 -8.88	9.921 - 15.831	…….

Table 3. Concentrations of heavy metals in dried soft tissue of various molluscan species in previous researches from various habitats.

Location - Species	Cd	Pb	Cu	Zn	Reference
Jiaozhou Bay - *R. philippinarum*	0.2-2.3	0.33-1.66	0.6-23	8-120	**(Liu et al., 1983)**
Moroccan estuarines - *S. plana*	0.2-1.6	ND	16-20	242-222	**(Cheggour *et al.*, 2005)**
EdoMirandaVenezuela - *T.mactroidea*	1-1.9	1.5-4.9	11-49	55-166	**(LaBrecque *et al.*, 2004)**
Ras Al nouf Qatar - *C. callipyga*	1.17	1.45	8.35	69.1	**(de Mora *et al.*, 2004)**
Bohai Sea - *R. philippinarum*	0.1-0.6	0.1-0.3	1.2-4.3	9.9-20	**(Yassien, 1998)**
Gulf of California - *V. gigas*	115.2	2.89	8.26	844.8	**(Ruelas-Inzunza *et al.*, 2003)**
Rio dela plata Argentina *C. fluminea*	0.5-1.9	ND	28-89	118-316	**(Bilos *et al.*, 1998)**
Atlantic coast of Spain and Portugal *Cardium*	1.5	32	15	210	**(Stenner & Nickless, 1975)**
Han and De estuaries *Corbicula* sp		1.67-2.1	0.37-0.51		**(Khanh *et al.*,**

					2013)
Nam O, Da nang coast - *O. rivulasis*		10.35	1.35		**(EL-Moselhy & Yassien, 2005)**
Nam O, Da nang coast- *C. sinensis*		14.72	1.85		**(Mui, 2008)**
Nam O, Da nang coast *A. subcrennata*		16.52	2.12		**(Mui, 2008)**
Nam O, Da nang coast - *Perna viridis*		12.23	1.65		**(Mui, 2008)**
Xuan Trieu, Danang Coast - *M. guadragular*		7.15	1.13		**(Mui, 2008)**
Xuan Trieu, Danang Coast - *A. subcrennata*		12.21	1.87		**(Mui, 2008)**
Son Tra, Danang Coast - *C. sumatrensis*		10.15	1.39		**(Mui, 2008)**
Son Tra, Danang Coast - *P. undulata*		9.17	1.23		**(Mui, 2008)**
Son Tra, Danang Coast - *Perna viridis*		8.75	1.15		**(Mui, 2008)**
Bizerte Bay- *L. lithophaga*	ND	1.81	3.43	54.15	**(Jaafar Kefi & Mleiki, 2016)**
Izmir Bay- *L. lithophaga*	2.23	9.48	64.65	293.16	**(Ozsuer & Sunlu, 2013)**
Spain (Menorca)- *L. lithophaga*	2.21	9.2	14.9	212.2	**(Deudero *et al.*, 2007)**
Spain (Menorca)- *L. lithophaga*	1.73	7.9	18.4	341.9	**(Deudero *et al.*, 2007)**
Indonesia- *L. obesa*	ND	35.98	8.99	539.76	**(Marasabessy, 2002)**
Bizerte Lagoon- *M. galloprovincialis*	1.79	0.65	3.32	299	**(Mzoughi & Chouba, 2012)**
Morocco- *M. galloprovincialis*	7.2	9.6	26.8	292	**(Maanan, 2008)**

CONCLUSION

In conclusion, temporal variation may affect heavy metals accumulation in the soft tissue of *M. olorina.* Moreover, the accumulation of heavy metals in *M. olorina* may not only depend on the amount of the heavy metals in the environment. Therefore, as the results showed a significant influence of seasons on the variation of heavy metals' contamination in molluscs, the environmental parameters need to consider when to use bivalves as bioindicators of heavy metal pollution in food safety monitoring program of fisheries product.

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