CATRINA (2021), 23(1):83- 93

Heavy metals availability in sediments and their accumulation in two edible bivalves at Suez Bay, Egypt

Riham A. Nasr[1], Farouk A. Soliman[2], Saad Z. Mohamed[2], Mahmoud A. Dar[1], Aisha A. Belal[1] and Ahmed R Hassan [1]
[1] National Institute of Oceanography and Fisheries, Egypt
[2] Faculty of Science, Suez Canal University, Ismailia, Egypt

ABSTRACT

Sediment samples were collected from 23 stations in the inshore and offshore zones of Suez Bay, Egypt, along with two edible bivalve species, *Callista* sp. and *Circenita callipyga*. The grain size analyses revealed that the Suez Bay seafloor sediments were mostly made up of sand, with minor constituents of gravel and mud. The bioavailable forms of Fe, Mn, Zn, Cu, Ni, Pb, and Cd were estimated by using a flame atomic absorption spectrophotometer on the bulk sediment and the finest fractions Ø3, Ø4 and Ø5 samples (AAS). At both the inshore and offshore stations, Fe and Mn had the highest concentrations in sediment, while Ni had the lowest. In budding plants, Pb and Cd were insignificant in bulk sediments in spite of their abundance in the finest fractions. For evaluating heavy metals accumulation in their soft tissue, about 30 individuals of *Callista* sp. and *Circenita callipyga* (commonly known as the Venus Clam) were chosen. Except for Pb and Cd in *Callista* sp., all metal concentrations in soft tissues of the two bivalve species were lower than the allowed limits. The bio-sediment accumulation factor (BSAF) was calculated to assess bivalves' ability to bioaccumulate metals in their soft tissues. The data revealed that all of the analysed metals in the collected bivalve species had BSAF values less than unity (<1.0 μg/g wet weight), with the exception of Cd, which had the highest BSAF value in *Callista* sp (2.13 μg/g wet weight).

Keywords: Bioaccumulation, Bivalves, Heavy metals, Sediment characteristics, Suez Bay.

INTRODUCTION

The Suez Bay considered as an important Egyptian gate on the Red Sea since historical times. The pace of activity in this bay has led to increase the rate of urbanization in the whole region. Several industries have been established along the western coast of the Suez Bay down to Adabyia in the south. This bay receives huge amounts of wastewater and industrial effluents from different sources. Such effluents reach about 5.4×108m3/year (Suez Governate, 1998) coming from fertilizer plant, power station, oil refineries, textile company, slaughter house and domestic sewage. Such wastes contain several contaminants including heavy metals, organic and inorganic substances.

The marine sediments are highly complex and diverse as well as characterized by their capacities for associating heavy metals can be related to the parent materials (terrestrial or marine organic) and climatic conditions (Chen *et al.,* 2000). Knowing the sedimentology and chemistry (heavy metals) of the sediments deposited in marine environment is a key condition for identification of their sources and assessment of their transport-dispersion patterns. It is also of great importance for environmental studies, where it is necessary to distinguish between natural and anthropogenic conditions of particles and associated trace elements. This knowledge is required to analyze the distribution of heavy metals. Comparison of the particle size distribution of heavy metals reveals areas where microscopic sediment fractions appear to be susceptible to anthropogenic heavy metal contamination (Leoni and Sartori, 1996). The distribution pattern of the mobilized heavy metals in coastal sediments can be explained by the grain size dependence of metal concentrations. Particle size has a significant role in the accumulation and exchange processes of metals between sediments and water (Gibbs, 1977). Heavy metals can be accumulated by marine organisms and their concentrations are a measure of the time-integrated supply of the metal over long periods of time (weeks, months, or even years), depending on the species (Rainbow, 1995). Some elements are important in small quantities, can be toxic to organisms at concentrations above certain critical levels, and are important to protect aquatic biota so that these thresholds are not exceeded in the aquatic environment (Brown and Depledge, 1998). Amongst the filter and deposit feeders; mollusks appear to be better suited to reflecting heavy metals in seawater and are therefore among the most commonly used organisms as bio-monitors for heavy metal pollution (Conti and Finoia, 2010).

Bivalve mollusk has the ability to absorb contaminants from sediments, suspended particulate materials and the water column (Laffon *et al.,* 2006). They have been widely used for many years as bioindicator organisms in monitoring of chemical pollutants and biomonitoring in aquatic ecosystems due to their sedentary nature or immobility, low metabolism, filter-feeding activity, contact with sediments, wide distribution in all environments, ability to bioaccumulate pollutants and high tolerance to chemical exposure due to a remarkably active immune system (Zuykov *et al.,* 2013).

Heavy metals in mollusk at the same location are showing differential concentrations between different species and individuals due to species-specific ability/capacity to modulate or accumulate these metals (Otchere, 2003) within their organs or shells. At the same time, the contents of the accumulated heavy metals in mollusk depend several factors such as;

** Corresponding author e-mail: nasr_riham@yahoo.com* temperature, diet, spawning, salinity and seasonal variations (Conti, 2008).

The present study aims to evaluate the concentrations of the bioavailable metals in the edible parts of two bivalve species (*Callista* sp. and *Circenita callipyga*) collected from Suez Bay in order to determine their permissibility as sea food. Also, the study targets to clarify the differential abilities of these bivalve species toward certain metals in accumulation tendency within their soft tissues.

MATERIALS AND METHODS

The study area

Suez Bay represents the essential waiting area for different cargo ships and oil tankers before entering Suez Canal, Suez Bay is shallow extension of the Gulf of Suez, roughly elliptic in shape, with its major axis in the NE-SW direction. The average length along major axis is about 13.2 km, the average width along minor axis is about 8.8 km and the mean depth is nearly 10 m with horizontal surface area of about 77.13 km^2. The bay is connected with the Gulf of Suez through most of its southeastern side and it was connected to the Suez Canal through the North-eastern side of the bay. Suez city is occupied the northern part of the bay (Meshal, 1967).

Site selected and sampling techniques

Twenty three sediment samples were collected from Suez Bay using handled boat and Grab Sampler (Fig. 1). About thirty individuals of the selected edible bivalve species of *Callista* sp. and *Circenita callipyga* (Born, 1778) were also collected (Figure 2) and identified followed the criteria of Bosch (1982), Sharabati (1984) and Bosch *et al.*, (1995). The samples were collected by using trawl sampler from the same sediment samples sites.

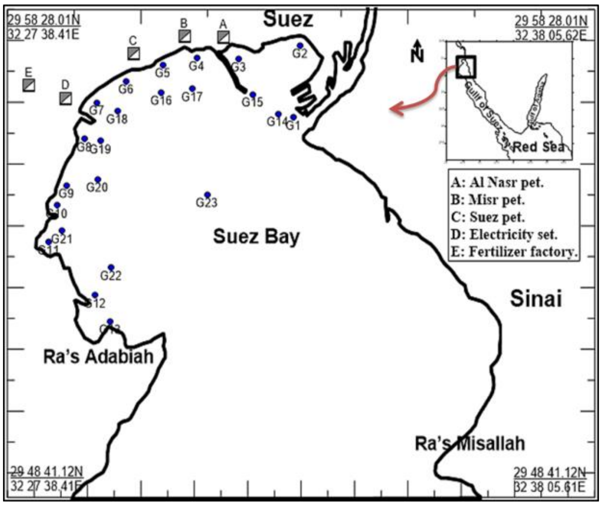

Figure (1): Suez Bay distribution map of sample sites.

Sediment analysis

Soil Texture

Samples of sediment were washed and dried. Approximately 100g of each sediment sample was sieved using a mechanical shaker at one phi (Ø) intervals to estimate the main sediment elements according to (Folk, 1974).

Figure 2. The bivalve species collected in the present study (Rusmore-Villaume, 2008). A, *Callista* sp. and B, *Circenita callipyga*.

Detection and quantification of some heavy metals

A mixture of Conc. HNO_3 and Conc. $HClO_3$ (3:1) was used to digest 0.5g of the pre-ground bulk samples and 0.5g of each of the separated fractions Ø3, Ø4, and Ø5 samples to near dryness (Chester *et al.*, 1994). Each sample's extract was filtered and diluted with deionized H_2O to a volume of 25 ml. Using a flame Atomic Absorption Spectrophotometer, the bioavailability of the selected heavy metals Fe, Mn, Ni, Pb, Cd, Cu, and Zn was measured from sample extracts (AAS, GBC-932).

Detection and quantification some heavy metals in the soft tissues of bivalve species

The pre-weighted moist soft tissue, of thirty *Callista* sp. and *Circenita callipyga*, was digested almost to dryness with a mixture of conc. HNO_3 and conc. $HClO_3$ (3:1) following the method of Chester *et al.*, 1994). Filtered sample extracts were then diluted to 25 ml with H_2O. Atomic Absorption Spectrophotometry was used to determine the concentrations of the selected heavy metals.

Determination the bio-sediment accumulation factor (BSAF)

The bio-sediment accumulation factor (BSAF) was computed as a ratio of the average metal concentration determined in the bivalves to the average concentration determined in the associated sediment at the same time to highlight the bioaccumulation efficiency metals in the analysed bivalve species (Zhao *et al.*, 2012) as follow: .

$$BSAF = Cx/Cs$$

Where Cx and Cs are the average metal concentrations in the organism and associated sediment (< 0.063mm), respectively.

Statistical analysis

The data were estimated using Microsoft Excel 7.00 and were plotted using Win-graph Prism 8.00. Experiments were run in triplicate. Pearson's correlation was applied to evaluate the correlations between bivalve soft tissues weight and bio-accumulated metals.

RESULTS

Sediment characteristics

Sediment texture

In the inshore and offshore zones, the contents of gravel, sand, and mud were recorded (Fig. 3). Gravel content in inshore stations ranged from 0.9 to 46.41 %, with an average of 17.24 %. Meanwhile, it ranged from 3.12 % up to 15.1 % at offshore stations with averaging around 7.3 percent. In the inshore zone, sand had an average percentage of 73.05 %, which increased to 84.76 % in the offshore zone, as previously recorded by Belal *et al.*, (2020). Mud contents in inshore stations ranged from 1.08 % to 26.42 %, with an average of 9.77 %. In the offshore stations, the proportion fluctuated between 2.78 % and 16.02 %, with an average of 7.95 %.

The bioavailable heavy metals in the sediments

The concentrations of the bioavailable metals (Fe, Mn, Zn, Cu, Pb, Ni and Cd) in sediment samples collected from 23 stations from the inshore and offshore areas of Suez Bay are shown in (Table 1 and Fig. 4). The bioavailable Pb and Cd were insignificant in bulk sediments although their abundant in the finest fractions in both inshore and offshore zones. In the inshore stations, the mean values of Fe, Mn, Zn, Cu and Ni in bulk sediments were (2603.35, 114.68, 34.36, 12.27 and 17.2µg/g, respectively) and (1978.21, 70.24, 30, 32.92 and 11.87µg/g, respectively) in Ø4. The mean concentration of Fe, Mn, Zn, Cu, Pb, Ni and Cd were (3268.54, 83.03, 32.6, 35.49, 16.58, 10.45 and 1.67µg/g, respectively) in Ø3 and (2350.92, 101.66, 61.73, 44.16, 31.66, 18.74 and 0.46µg/g, respectively) in Ø5. In the offshore stations, the mean values of Fe, Mn, Zn, Cu and Ni in bulk sediments were (2897.2, 114.43, 36.29, 40.18 and 29.77µg/g, respectively), while the mean concentrations of Fe, Mn, Zn, Cu, Pb, Ni and Cd were (2568.64, 104.42, 47.72, 15.74, 29.56, 13.69 and 0.30µg/g, respectively) in Ø3, (2729.2, 112.11, 50.13, 16.89, 24.39, 15.19 and 0.28µg/g, respectively) in Ø4 and (2827.79, 142.49, 72.43, 20.71, 43.89, 28.65 and 0.4528µg/g, respectively) in Ø5. The average concen-tration of metals in sediment samples decreased in the following order: Fe > Mn > Zn > Pb > Cu > Ni > Cd.

Heavy metals accumulation in the soft tissue of the bivalve species

There are 20 individuals were collected from *Callista* sp. and 10 individuals were collected from *Circenita callipyga*. The individual's wet weight of *Callista* sp. was fluctuated between 1.49g and 4.55g with average of 2.93g, whereas the individual's wet weight of *Circenita callipyga* was ranged from 1.29g to 3.81g with an average of 2.27g. Concentrations of heavy metals, expressed in µg/g wet weight, in the soft tissues of *Callista* sp. and *Circenita callipyga* showed that the values of Fe, Mn and Zn were dominant. In *Circenita callipyga*, the highest values of Fe, Zn, Cu and Ni were recorded (52.31, 17.64, 0.18 and 2.43 µg/g wet weight, respectively) within their soft tissues. Meanwhile, *Callista* sp. recorded the maximum values of three metals Mn, Pb Cd (50.46, 1.65 and 0.98 µg/g wet wt., respectively; Table 2). The concentration of the selected heavy metals in the bivalve species in Suez Bay could be arranged in the following sequence; Mn > Fe > Zn > Pb > Ni > Cd > Cu for *Callista* sp. and Fe > Zn > Mn > Ni > Cu > Pb = Cd for *Circenita callipyga*.

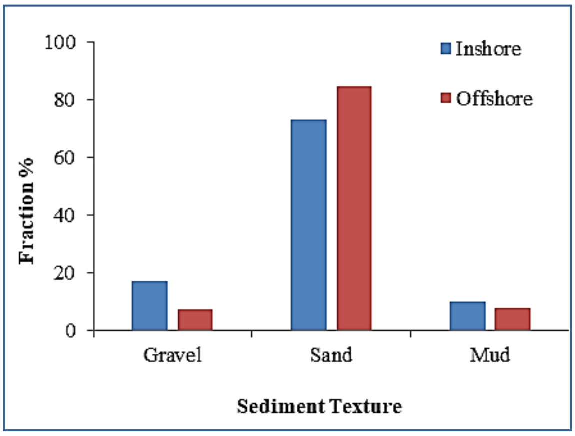

Figure (3): The fraction percent of gravel, sand and mud at the inshore and offshore areas.

Bio-sediment accumulation factor (BSAF)

The BSAF values for all studied metals in the collected bivalve species were less than unity (<1.00) except Cd in Callista sp. showed the highest BSAF (2.13) (Table 3).

DISCUSSION

Sand was the dominant sediment category at both the inshore and offshore stations of Suez Bay supported by the high averages of Ø2 and Ø3 (17.57 and 18.99%) for inshore station and Ø1 (22.72%) for offshore stations (Fig. 3b). The inshore stations G5, G10 and G13 recorded significantly high gravel percentages (36.41%, 33.27%, and 35.09%, respectively), this can be attributed to the wave winnowing for the fine particles and the chronic accumulation of coarse silicate sediments from the flash floods. Meanwhile, the offshore stations that located near Suez Harbors, G14 and G21 recorded relatively high gravel percentages that may due to the effects of the natural wave actions, eddy currants and ship-generated waves that disperse the fine particles near these stations. Mud, which may be consumed by benthic organisms, showed its highest averages at both inshore stations (G8 and G12) and offshore stations (G16, G17 and G20) that may be attributed to the fine particle accumulations under the calm conditions and the continuous feeding from the artificial and coastal activities at these stations.

Sediments are always the final destiny of both natural and anthropogenic components in the environment. Sediment quality is a good indicator of pollution in the marine environment, since sediments have the ability to accumulate metals and the organic pollutants, subsequently metals concentrated more heavily in sediments than in water. The distribution patterns of the bioavailable heavy metals in bulk sediments at Suez Bay are illustrated in (Fig. 5) these contour maps were drawn-

Table 1: Bioavailable heavy metals contents (µg/g) in the bulk sediments and different fractions, Ø3, Ø4 and Ø5, in the inshore and offshore areas of Suez Bay.

Site	Fraction	Value	Measured heavy metals (µg/g wet weight)						
			Fe	**Mn**	**Zn**	**Cu**	**Pb**	**Ni**	**Cd**
Inshore	**Bulk**	Ave.	2603.35	114.68	34.36	12.27	ND	17.20	ND
		Max.	3025.87	237.56	65.80	27.73	ND	53.58	ND
		Min.	1783.57	46.26	6.04	1.28	ND	0.99	ND
	Ø$_3$	Ave.	3268.54	83.02	32.60	35.49	16.58	10.45	1.67
		Max.	7127.50	157.45	81.23	118.00	45.85	49.05	5.05
		Min.	1279.50	15.05	2.15	1.75	2.95	1.85	0.01
	Ø$_4$	Ave.	1978.21	70.24	30.00	32.92	ND	11.87	ND
		Max.	3934.50	120.95	68.72	103.93	50.75	36.46	ND
		Min.	1027.02	24.50	7.90	0.65	ND	1.80	ND
	Ø$_5$	Ave.	2350.92	101.66	61.73	44.16	31.66	18.74	0.46
		Max.	2951.92	321.86	98.53	138.29	51.57	78.60	1.22
		Min.	1512.08	19.71	24.64	7.75	13.25	4.72	0.01
Offshore	**Bulk**	Ave.	2897.20	114.43	36.29	40.18	ND	29.77	ND
		Max.	5738.21	245.22	85.2	95.81	ND	65.04	ND
		Min.	2105.98	49.59	4.14	1.87	ND	8.24	ND
	Ø$_3$	Ave.	2568.64	104.32	47.72	15.74	29.56	13.69	0.30
		Max.	3173.68	176.20	70.15	25.24	40.86	20.98	0.52
		Min.	1431.59	37.87	27.45	9.32	8.09	6.66	0.14
	Ø$_4$	Ave.	2729.20	112.11	50.13	16.89	24.39	15.19	0.28
		Max.	3164.88	176.25	73.39	26.42	46.21	23.91	0.78
		Min.	2221.33	53.78	29.08	10.22	1.43	8.34	0.01
	Ø$_5$	Ave.	2827.79	142.49	72.43	20.71	43.89	28.65	0.45
		Max.	3058.40	191.58	99.13	31.91	70.80	46.51	0.86
		Min.	2419.51	53.04	49.49	13.61	24.68	18.41	0.04

ND, not detected.

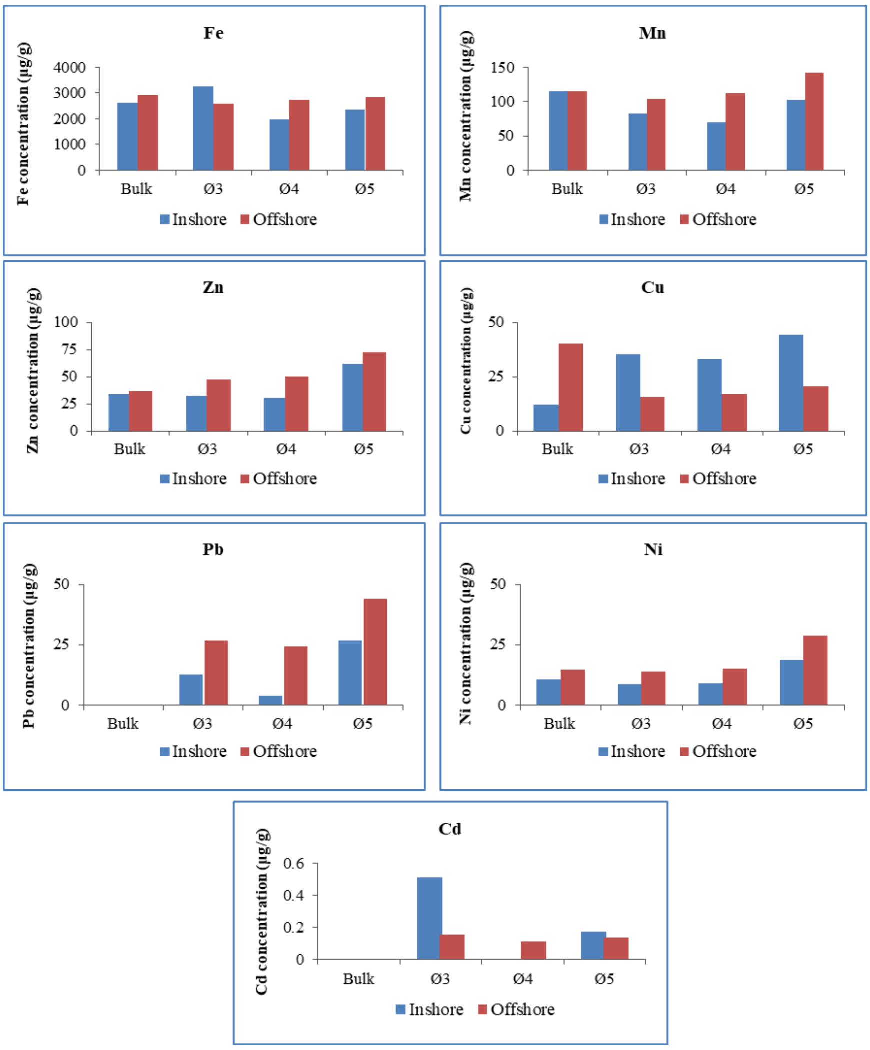

Figure (4): The average contents of the bioavailable metals in the bulk and different fractions at the inshore and offshore areas.

using Surfer ver. 13. The current results reveal that the bioavailable Fe, Mn and Zn were the dominant metals in sediment. At the offshore site, station G19 showed high concentrations of metals particularly Fe and Ni as this station located near the electric power stations, which characterized by high concentrations of Fe and Ni in their sediments due to the use of metal alloys in bombs and containers for heating the water steam to produce electricity, also it is affected by hugged sewage from the treatment station (ABB). The high concentration of the bioavailable Mn at inshore station G12 in front of Attaka Port, as well as the bioavailable Zn at the offshore station G21 could be due to the loading and unloading activities in this area, in addition to the wastes of several industries (as vegetable oil factories and chemical industries) near these stations. The high concentration of the bioavailable Cu at inshore station G3 may be due to the heavily petroleum activities of El Nasr Petroleum Company, while the offshore station G22 showed the highest concentration of Cu, this can be attributed to the effect of ships discharges which used antifouling paints containing metals such as Cu at Adabiya Port. Pb and Cd were insignificant in bulk sediments in spite of their occurrence in the finest fractions. The concentrations variability of heavy metals in bulk sediments of Suez Bay can be attributed to the effect of amount and type of contaminants arrives to it and the distinctive nature of the area (Mohapatra, 1988).

Fractions (Ø3, Ø4 and Ø5) were chosen in order to improve the impact of grain size on metals concentrations in sediments. The inshore station G10 recorded the highest concentration of the bioavailable Fe in Ø3 and station G9 showed the maximum concentration of the bioavailable Ni in Ø5 as these stations located in front of the electric power station. Ø5 showed the greatest concentration of the bioavailable Mn at inshore station G1, located in front of Tersana, while it recorded the highest Cu concentration at inshore station G12 that may be due to the variable maritime activities at Adabiya Port and the effect of ships transit and passes using antifouling paint containing Cu. The bioavailable Cd demonstrated its peak in Ø3 at inshore station G6 and this can be attributed to the wests from Suez Oil Producing Company, while Ø5 recorded the highest Cd value in the offshore area at station G19, this is may be due to the sewage from the treatment station (ABB). Station G5 at the inshore area recorded the highest bioavailable Pb concentrations in the finest fractions Ø3, Ø4 and Ø5 as this station is affected by boats maintenance and boat hulls with antifouling paints at Azaq El-Hagag village, as well as the petroleum wests from Misr Petroleum Company and the heavily oil processing at Suez Oil Producing Company. The current results revealed that the relatively high contents of Fe, Zn, Mn, Cu, Pb, Ni and Cd in the finest fractions Ø3, Ø4 and Ø5 at Suez Bay indicating to the bioavailable heavy metal forms tended to accumulate in the finest sediment fractions much more than the coarsest fractions.

Environmental pollution by heavy metals represents a serious marine problem around the world (Cajaraville *et al.,* 2000). They are dangerous due to its high toxicity and bioaccumulation ability of these metals in tissues of the living organisms (Sharaf and Shehata, 2015). The consumption of seafood contaminated by heavy metals can lead to potential human risks. From the current results, it was observed that the concentration of all analyzed metals in sediments was higher than their concentration in the studied species. However, Cd reading showed high values in *Callista* sp. compared to sediments.

From the obtained results it was notice that, some metals have significant negative correlations with soft tissue weights; Fe, Zn and Pb (r = -0.51, r= -0.61 and r= -0.54, respectively) in *Callista* sp. and Mn and Pb (r = -0.51 and r= -0.50) in *Circenita callipyga* (Fig. 6 and 7). These inverse relationships can be attributed to the dilution of the contaminants in the soft tissues of the large animals and besides, small animals can eat more than the large one which lead to accumulate pollutant in its body. These results agree with those of (Sami *et al.,* 2020) they noticed negative correlations between Cd, Cu and Zn with mussel size of the bivalve species *Ruditapes decussatus*, *Venerupis pullastra* and *Paphia undulata* at Timsah Lake. In addition, Abd ElGahny, (2017) found a negative relationship between the bivalve sizes and metal concentration, which states that the smallest individuals contained the highest concentrations of metals. Amiard *et al.,* (1986) verified inverse correlation between metal concentration and body weight in *M. edulis* and in the oyster *Crassostrea gigas*. Inverse correlations have also been reported by Bordin *et al.,* (1992) during metal uptake by smaller bivalve species, which was faster than those of big ones. Among the studied metals, only the Cu, in *Callista* sp., the excretion was equal to uptake. Some other metals have significant positive correlations with soft tissue wt; Fe and Ni (r = 0.52 and r = 0.84) as recorded in *Circenita callipyga*. These results are in agreement with those of Szefer *et al.,* (1999b).

In their study, they shown that there was strong positive correlation between trace metals and mussel size of the mollusk species collected from the Gulf of Aden, Yemen. In meantime, Strong and Luoma (1981) found strongly positive and negative relationships between metals and mussel size of the clam *Macoma balthica*. They attributed this result to the seasonal variations in growth rates and size-dependent differences in uptake rates.

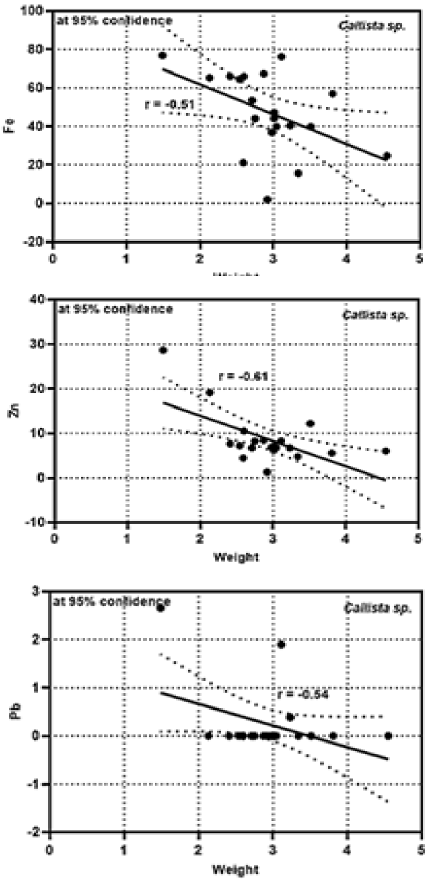

Figure (6): The relationships between soft tissue weight (g) and heavy metals bioaccumulation (µg/g) in *Callista* sp. collected from Suez Bay.

The bio-sediment accumulation factor (BSAF)

Bioaccumulation is the process through which deposit feeder organisms assimilate metals from the surrounding sediment layer. The highest BSAF value was for Cd in *Callista sp* indicating that this species has the ability to accumulate Cd within its soft tissue in a concentration much more in the surrounding sediments. In *Circenita callipyga* BSAF values for all the studied metals were less than unity (<1.00) indicating that this species takes its needs from these metals and releases the rest into the water column.

Table (2): Concentrations of heavy metals (µg/g wet wt.) in soft tissues of the bivalve species collected from Suez Bay.

Measured parameter	Bivalve species tested					
	Callista sp.			*Circenita callipyga*		
	Max.	Min.	Ave.	Max.	Min.	Ave.
Fe	76.85	1.88	47.38	92.59	0.76	52.31
Mn	90.81	10.44	50.46	32.75	0.8	7.44
Zn	28.69	1.28	8.66	43.75	2.92	17.64
Cu	0.04	0.01	0.02	0.22	0.1	0.18
Pb	2.66	0.39	1.65	0.03	0.01	0.02
Ni	3.69	0.09	1.59	3.41	1.45	2.43
Cd	1.4	0.65	0.98	0.02	0.01	0.02
Sample Wt.	4.55	1.49	2.93	3.81	1.29	2.27

Permissibility of the studied species for human consuming

The environmental health hazard related to the consumption of the edible bivalve was evaluated through comparing the heavy metals concentrations in the soft

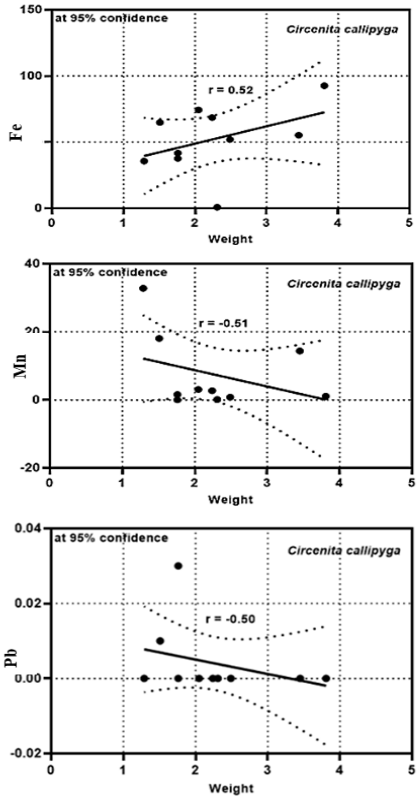

Figure (7) The relationships between soft tissue weight (g) and heavy metals bioaccumulation (µg/g) in Circenita callipyga collected from Suez Bay.

tissue of all the studied bivalves and the permissible maximum heavy metal limits determined by many authorized organizations as; the World Health Organization (WHO 2000), (FDA 2001) and (EC Regulation No. 1881/2006).

Metals such as iron, copper, manganese are essential metals as they play important roles in biological systems (Hogstrand and Haux, 2001). The concentrations of these metals in both examined species were significantly lower (Table 3) than the WHO (2000) permitted maximum levels of 109, 50, 60, 30, 0.5, 30, 0.5 for Fe, Mn, Zn, Cu, Pb, Ni, and Cd, respectively. Mn concentrations in *Callista* sp. exceeded the mollusk's lowest maximum allowed limits imposed by the EPA (WHO 2000). In parallel, the recorded Zn and Ni averages in the studied bivalve were also much lower than the corresponding permitted allowed limits. Pb and Cd are non-essential metals that are frequently harmful, causing decreased fertility, cellular and tissue damage, and cell death in a range of organs (Oliveira *et al.*, 2002). The contents of Pb and Cd in *Circenita* callipyga were lower than the allowed permissible limits, whereas their concentrations in *Callista* sp. (1.65µg/g wet wt. and 0.98 µg/g wet wt.) were higher.

CONCLUSION

The sediment characteristics are useful for improving our understanding of the current hydrodynamic circumstances and evaluating the sediment source-transport-deposition processes in Suez Bay. Heavy metals research in Suez Bay sediments found that the

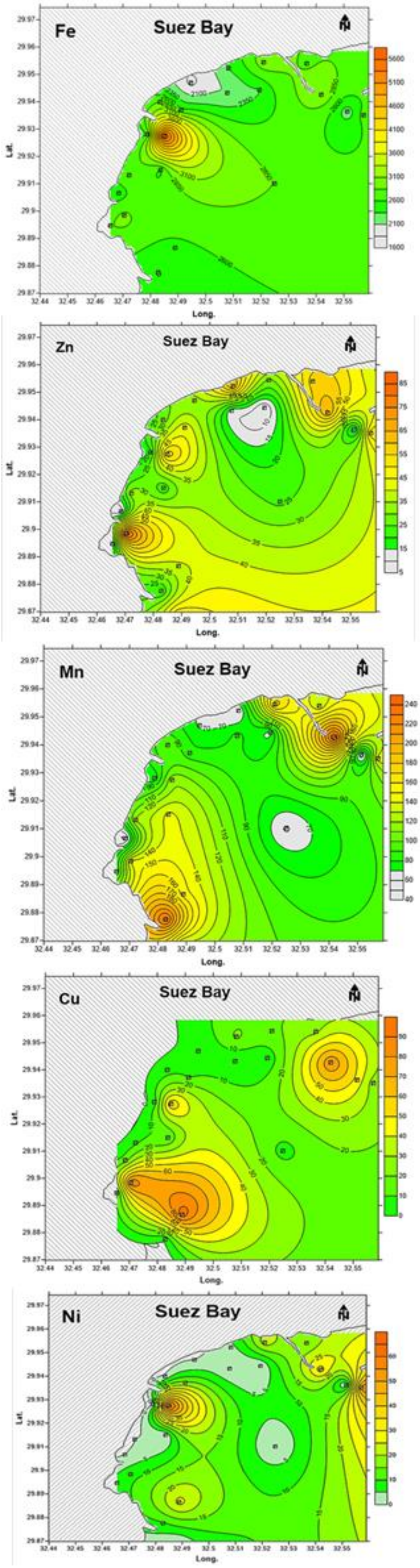

Figure (5): Distribution patterns of the bioavailable metals in bulk sediments of Suez Bay.

Table (3): The bio-sediments accumulation factor (BSAF) in the various bivalve species investigated.

Metals Investigated	BSAF	
	Callista sp.	*Circenita callipyga*
Fe	0.02	0.02
Mn	0.13	0.27
Zn	0.43	0.06
Cu	0.001	0.01
Pb	0.06	0.001
Ni	0.07	0.11
Cd	2.13	0.04

highest metal concentrations are likely due to human activity. All of the metals investigated in the different bivalve species at Suez Bay had BSAF values substantially lower than unity, with the exception of Cd, which had the greatest BSAF value in *Callista* sp. The main metals in the soft tissues of *Callista* sp. and *Circenita callipyga* were Fe, Mn, and Zn, while Cu, Pb, and Cd were the least abundant. Because the concentrations of Mn, Pb, and Cd in the soft tissue of *Callista* sp. exceed the permissible limits set by the World Health Organization (WHO), the Food and Drug Administration (FDA), and the European Commission (EC Regulation No. 1881/2006), heavy consumption of *Callista* sp. has several health implications.

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العناصر الثقيلة المتاحة بيولوجيا وتراكماها في نوعين من الصدفيات الغذائية في خليج السويس، مصر.

ريهام أحمد نصر[1], فاروق أحمد سليمان[2], سعد زكريا محمد[2] , محمود عبد الراضى دار[1], أحمد رمضان حسن[1] و عائشة أحمد بلال[1]

[1] المعهد القومى لعلوم البحار والمصايد،السويس، مصر
[2] جامعة قناة السويس، الاسماعيلية، مصر

الملخص العربــي

يعد خليج السويس بوابة مصرية مهمة على البحر الأحمر منذ العصور التاريخية. وقد أدى النشاط المتزايد لخليج السويس إلى زيادة معدل التنمية في المنطقة بأكملها حيث تم إنشاء العديد من الصناعات على امتداد الساحل الغربي وصولاً إلى الأدبية في الجنوب. واصبح الخليج السويس مستقبل لكميات كبيرة من النفايات الصناعية السائلة والناتجة من معامل تكرير البترول، مصانع الاسمدة، مصنع النسيج، مصانع الزيوت ومحطة كهرباء عتاقة الي جانب مياه الصرف الصحي المحلية. وتحتوى هذه النفايات على الكثير من الملوثات بما فى ذلك المعادن الثقيلة مما شكل خطر على صحة الانسان. ولذلك تم جمع عينات الرواسب والمياه ونوعين من ذوات الصدفتين الغذائية (**Callista sp** و **Circenita callipyga**) من 23 محطة في المناطق الشاطئية والبحرية للخليج للفحص والدراسة. أشارت تحليلات هذه الدراسة ان الرواسب تتكون بشكل رئيسي من الرمل، مع مكونات ثانوية من الحصى والطين بمتوسط نسبة 73.05٪ في المحطات الساحلية، ارتفعت إلى 84.76٪ في المحطات البحرية. ونظرا للدور الهام للرواسب في تحسين المعرفة بالظروف الهيدروديناميكية السائدة، شملت الدراسة تقييم كلا من مصادر الرواسب، تسلسل النقل، الترسيب في الخليج. و كشف تحليل المعادن الثقيلة لرواسب الخليج الي ان الرواسب الناعمة (Ø3، Ø4، Ø5) ، كان للحديد والمنغنيز أعلى تركيزات في الرواسب ، بينما كان النيكل هو الادني. كان الرصاص والكادميوم غير مهمين في الرواسب السائبة على الرغم من وفرتهما. كما سجلت معادن (الحديد, المنجنيز و الزينك) الاكبر تركيز في الأنسجة الرخوة لكلا من **Callista sp** و **Circenita callipyga** ، بينما كان النحاس، الرصاص و الكادميوم الافل تركيزا.واثبتت الدراسة ان تركيزكلا من المنجنيز، الرصاص و الكادميوم في الأنسجة الرخوة لـ **Callista sp** تتجاوز الحدود المسموح بها عالميا، وبالتالي فإن الاستهلاك المفرط لـ **Callista sp** يؤدى العديد من التأثيرات السلبية على صحة الانسان.