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The occurrence of some carcinogenic metals in sediments and their effluences on some edible bivalves at Great Bitter and Timsah lakes, Egypt

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ABSTRACT

The occurrence of some carcinogenic metals; Cu, Ni, Pb and Cd was investigated in sediment samples collected from 12 stations at Great Bitter and Timsah lakes. In the same time, two of the most famous edible bivalve species (*Ruditapes decussatus* and *Paratapes undulatus*) live buried in these sediments were chosen for measuring the same metals within their edible tissues in order to investigate the permissibility limits for human consumption. The bio-available forms of these metals were measured in the bulk sediments and the finest fractions (Ø_3, Ø_4 and Ø_5) and in the edible tissues (flesh) of the selected bivalve individuals using a flame atomic absorption spectrophotometer (AAS). The finest fraction (Ø_5) recorded the highest averages of most carcinogenic metals at Great Bitter and Timsah lakes with significant occurrences of Cd at both lakes. Carcinogenic Cd in the edible tissues of *P. undulates* and *R. decussatus* showed neglected low contents at the Great Bitter and Timsah lakes in spite of its very high contents in the surrounding sediment layer. Ni, Cu, and Pb averages in the edible tissues of *P. undulates* at the Great Bitter lake were 1.32, 0.23 and 0.37 µg/g wet wt. respectively. The averages of Ni, Cu and Pb *in R. decussatus* at Timsah Lake, were; 1.30, 0.24 and 0.95 µg/g wet wt. and in *P. undulates* were; 0.79, 0.14, and 1.15 µg/g wet wt. respectively. Bio-sediment accumulation factor (BSAF) in the different bivalve species at the Great Bitter and Timsah lakes were much lower than unity (<<<1.0) indicating that the bivalves tend to accumulate their needs only from the surrounding environment. Finally, the investigated metals in the edible tissues of the different bivalve species are within the permissible safe limits for human consumption except for Pb that exceeds these limits and showed a slight hazard to health risk.

INTRODUCTION

Lake sediments act as major repositories of heavy metals and serve as a source of the contaminants for biota and the overlying water. The bottom sediments are critical to heavy metal assessments because they are mid and/or longterm integrators of metal inputs. Horizontal distribution of metals illustrated lateral variations in the chemical composition of surface sediments and act as a guide to local pollution. Overpopulation, industrialization, rapid urbanization, overuse of pesticides and herbicides, detergents and agricultural chemicals, sewage treatment plants, garbage dumps and the discharging of municipal wastes are the main contaminant sources of heavy metals in the natural water resources (Baruah *et al.* 2011). The discharge of different types of the anthropogenic pollutants; industrial and agriculture drainages into the closed and semi closed lakes were resulted in much high concentrations of heavy metals and other contaminants in the bottom sediments and benthos. The high capacities of metals and metallic compounds accumulated in the natural water resources pose risks to human health through consumption the contaminated edible tissues of seafood (Chan *et al.* 1999). Some heavy metals may be accumulated in the target tissues such as brain, liver, bones, and kidneys in the human body resulting in serious health hazards, depending on the element and its chemical form. Carcinogenic metals can potentially enhance the risk of cancer in humans, however, the long-term of exposure to low amounts of these metals could result in many types of cancers (Mohammadi *et al.* 2019). Carcinogenic metals can be accumulated by the marine organisms and their concentrations provide a time-integrated measure of metal supply, over long periods of time (weeks, months or even years) depending on the accumulative species (Rainbow, 1995). Some metals are essential in small quantities for organism growing up and metabolic operations, but they can be toxic above certain threshold concentrations. For protecting the aquatic biota, it is very important preserve these limits low(Brown and Depledge, 1998). Amongst the filter and deposit feeders; mollusks are seeming to be more suitable for reflecting the heavy metal contents in the seawater and surrounding sediments, they are among the most used organisms as bio-monitors for the heavy metal accumulation (Conti and Finoia, 2010). Mollusks at the same location showed differential concentrations of heavy metals between different species and individuals due to species-specific ability/capacity to regulate or accumulate these metals within their organs (Otchere, 2003). The levels of the accumulated carcinogenic metals in mollusks are function of many factors such as; temperature, diet, spawning, salinity and the seasonal variations, metal bioavailability, hydrodynamics of the environment, size, sex, changes in tissue composition and reproductive cycle (Boyden and Phillips, 1981; Conti, 2008). The present work aims to evaluate the accumulation limits of carcinogenic metals in the edible tissues of two bivalve species (*P. undulatus* and *R. decussatus*) at two famous bivalve fisheries in Egypt (Timsah and Great Bitter lakes) in order to determine the permissibility as sea food. Also the study targets to illustrate the differential tendencies of these bivalve species to accumulate certain metals within their edible tissues.

MATERIALS AND METHODS

The Study area

Bitter Lakes are the central and the most important water body of the Suez Canal. It contains about 85% of the water of the Suez Canal System. The Great and Small Bitter Lakes are separated by a narrow and saline connection. The lakes suffer from various types of pollution as; domestic sewage from; the surrounding human settlements, industrial wastes and agricultural drains from the cultivated lands along the west bank of the lakes (El-Bassat, 2008). Timsah Lake lies adjacent to Ismailia City at the middle district of the Suez Canal about 80 km south of Port Said. the lake occupies about 16 sq. km with about 90×10^6 cubic water. The lake has unique ecosystem due to the interference between fresh and seawater. The western side of the lake is connected to a small and shallow embayment that receiving about 833,000m^3/day of treated and untreated domestic and agricultural wastewaters throughout many drains (Gabr and Gab-Alla, 2008).

Field work

Twelve sediment samples and 12 lake water samples were collected from each of Timsah and Great Bitter lakes using handled boat, Grab Sampler and Sterile One-liter Bottle of Polypropylene Sampler (Fig., 1). About 40 to 60 individual of each of the selected edible bivalve species; *Ruditapes decussatus* and *Paratapes undulatus* were collected using trawl sampler from the same sediment samples sites. Bosch (1982), Bosch *et al.* (1995) and Sharabati (1984) were used to identify the selected species**.**

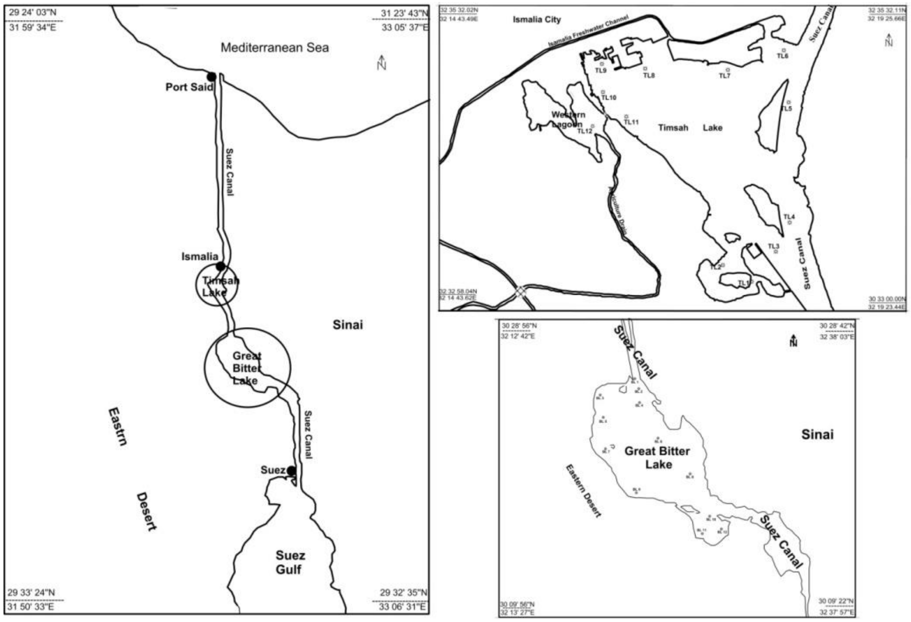


Fig. 1. Location and sampling distribution maps of Great Bitter and Timsah lakes.

Sediment analyses

The collected sediment samples were air dried, disaggregated then sieved through a stainless sieving each one phi (Ø) interval according to Went Worth Scale (Folk 1974). Seven sediment fractions were obtained; Gravel ($Ø_{-1}$), very coarse sand ($Ø_0$), coarse sand

($Ø_1$), medium sand ($Ø_2$), Fine sand ($Ø_3$), very fine sand ($Ø_4$) and mud fraction ($Ø_5$<0.063mm).

Determination the carcinogenic heavy metals in the finest sediment fractions:

About 0.5g of the pre-powdered bulk samples and 0.5 of each of separated fractions ($Ø_3$, $Ø_4$ and $Ø_5$) were digested with a mixture of conc. HNO_3 and Conc. $HClO_3$ (3:1) to near dryness (El-Metwally *et al.* 2021), diluted then filtered with deionized distilled water (DDW) to 25 ml. The bio-available forms of the selected carcinogenic metals: Cu, Ni, Pb and Cd were determined as (µg/g) in the extracts using flame Atomic Absorption Spectrophotometer (AAS, GBC-932) at the National Institute of Oceanography and Fisheries (NIOF), Red Sea Branch, Hurghada, Egypt.

Bivalve measurements

Individual weights

The collected bivalves were sorted and screened, about 40 to 60 of the live individuals were chosen for the chemical analyses. The edible tissues (flesh) of the selected individuals were separated from their shells then weighted.

Determination carcinogenic metals in edible tissues of bivalve species

The pre-weighted wet edible tissues of the selected individuals were digested with a mixture of conc. HNO_3 and conc. $HClO_3$ (3:1) to near dryness (Belal and Dar, 2020) then filtered and diluted with DDW to 25ml.The selected carcinogenic metals were measured using AAS at NIOF-Hurghada and expressed as (µg/g wet wt.).

Statistical analysis

Correlation Coefficients

Pearson's correlation was used to illustrate the relationships between the weight of individuals and the bio-accumulated metals. The data were estimated using Microsoft Excel 7.00 and were plotted using Wingraph Prism 8.00.

Bio-sediment Accumulation Factor (BSAF)

To illustrate the bioaccumulation efficiency of carcinogenic metals in the studied bivalve species, Bio-sediment Accumulation Factor (BSAF) was calculated as ratio of the average concentration of metal determined in the bivalves to the average concentration determined in the associated sediment at a given time (Zhao *et al.*, 2012).

$$BSAF = C_x/C_s$$

Where C_x and C_s are the average concentrations of a given metal in the organism and the associated sediment (< 0.063mm), respectively.

RESULTS

1. Sediment characteristics

As shown in Tables (1 and 2), sand was the dominant sediment category at Great Bitter Lake (av. 94.36%) supported by the high average $Ø_2$ (34.39% respectively) with significantly low gravel and mud percentages. At Timsah Lake, sand showed very high average percentage (Fig. 2), gravel was low percentage at all stations except TL1, TL6 and TL11; it recorded 10.47%, 16.7% and 18.75%, respectively with significantly high percentages of $Ø_2$ and $Ø_3$ (31.84% and 30.53%). The finest fraction $Ø_5$ that may consumed by benthic organisms showed very low percentage at Great Bitter Lake between 0.05 and 7.65% with average of 2.28%and at Timsah Lake between 0.30 and 6.37% averaging of 1.56%.

Table 1. Max., min. and averages of the Gravel, sand, mud and the different sediment groups at the Great Bitter and Timsah lakes:

	S. No.	**Gravel%**	**Sand%**	**Mud%**	**C. Sed.**	**M. Sed.**	**F. Sed.**
G. Bitter Lake	Max.	3.97	98.94	7.65	25.44	79.86	79.02
	Min.	0.41	88.08	0.05	1.16	19.83	8.05
	Av.	2.52	94.36	2.28	10.39	52.31	36.46
Timsah Lake	Max.	18.75	97.67	6.37	29.49	69.97	86.66
	Min.	0.57	70.21	0.30	1.21	10.59	11.17
	Av.	6.02	86.77	1.56	11.67	45.24	43.09

Table 2. Max., min. and averages of the different sediment fractions at the Great Bitter and Timsah lakes:

	S. No.	$Ø_{-1}$	$Ø_0$	$Ø_1$	$Ø_2$	$Ø_3$	$Ø_4$	$Ø_5$
G. Bitter Lake	Max.	3.97	24.35	42.70	57.13	63.04	27.19	7.65
	Min.	0.41	0.75	3.45	12.02	6.07	0.20	0.05
	Av.	2.52	7.87	17.92	34.39	24.16	10.02	2.28
Timsah Lake	Max.	18.75	11.95	30.08	57.79	68.46	32.07	6.37
	Min.	0.57	0.64	1.16	8.82	8.93	1.94	0.30
	Av.	6.02	5.65	13.39	31.84	30.53	11.01	1.56

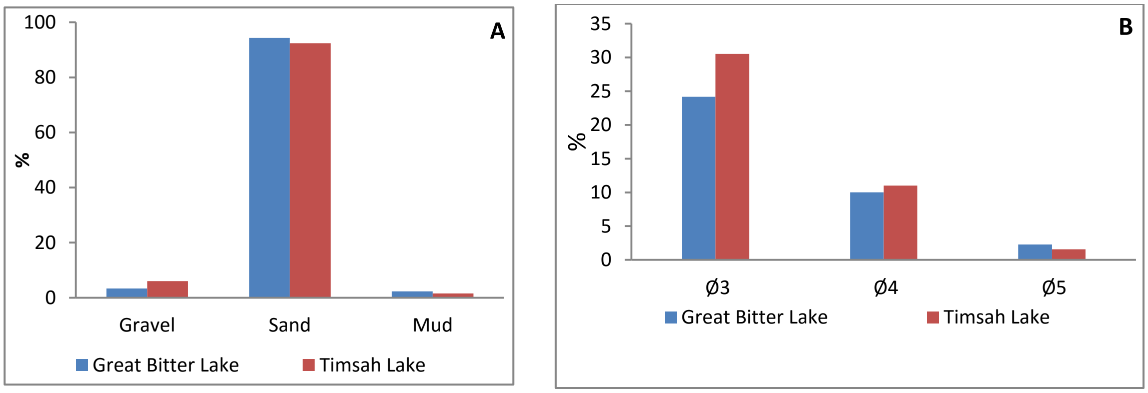


Fig. 2. The averages of A(gravel, sand and mud) and the fine fractions B($Ø_3$, $Ø_4$ and $Ø_5$) at the studied lakes

2. Carcinogenic metals in Sediments

At the Great Bitter Lake, the carcinogenic Cd recorded the averages of; 5.87, 9.73, 8.93 and 10.30 µg/g in the bulk sediment and the finest fractions $Ø_3$, $Ø_4$ and $Ø_5$, Ni recorded 11.26, 12.03, 15.85 and 21.93 µg/g, Cu showed the values of 13.94, 15.60, 31.26 and 51.88 µg/g however, Pb recorded 11.81, 10.74, 9.67 and 15.21 µg/g in the bulk, $Ø_3$, $Ø_4$ and $Ø_5$ respectively (Table 3). Cd showed significantly high contents at St. BL1 (21.73 µg/g) in the bulk sediments, St. BL2 (45.10 and 26.43 µg/g) in $Ø_3$ and $Ø_4$, meanwhile the absolute highest Cd value was recorded at St. BL3 (73.00 µg/g) in the finest fraction $Ø_5$. St. BL9 recorded the highest Ni content in the bulk sediments and $Ø_3$ (22.80 and 51.80 µg/g) meanwhile St. BL3 recorded significantly high Ni in $Ø_4$ and $Ø_5$ (73.57 and 66.63µg/g) respectively. BL10 recorded the highest contents of Cu (22.97 µg/g) in the bulk sediments, meanwhile BL10, BL3 and BL8 showed the highest Cu contents in $Ø_3$, $Ø_4$ and $Ø_5$ (24.72, 55.56 and 84.36 µg/g respectively). Pb showed its high contents in the bulk sediments at BL 6 (28.14 µg/g), BL3 recorded the highest Pb in $Ø_4$ and $Ø_5$ (24.34 and 40.65 µg/g respectively) meanwhile the highest content in $Ø_3$ (34.22 µg/g) was observed at St. BL9.

At Timsah Lake, Cd showed the averages of; 7.80, 2.14, 5.04 and 5.07 µg/g in the bulk sediment and the finest fractions $Ø_3$, $Ø_4$ and $Ø_5$, the averages of Ni were; 7.99, 10.23, 13.18 and 20.91µg/g, Cu has 15.16, 17.52, 35.23 and 62.14 µg/g meanwhile Pb recorded 17.50, 22.16, 23.32 and 26.56 µg/g in the bulk, $Ø_3$, $Ø_4$ and $Ø_5$ respectively (Table 3). The highest value of carcinogenic Cd in the bulk sediments (39.73 µg/g) was observed in St. TL12, in fraction $Ø_3$ (15.23 µg/g) was at St. TL7 and in the fractions $Ø_4$ and $Ø_5$ (39.98 and 31.54 µg/g) were recorded St. TL2. Ni showed the highest content in the bulk sediments (20.97 µg/g) at St. TL8, in $Ø_3$ and $Ø_4$ (21.76 and 28.31 µg/g) at St. TL11, and in $Ø_5$ recorded (45.22 µg/g) at St. TL4. St. TL10 recorded the highest values of Cu in the bulk sediments, $Ø_3$ and $Ø_5$ (36.84, 34.26 and 107.02 µg/g respectively), meanwhile St. TL9 recorded the highest value of Cu in $Ø_4$ (82.30 µg/g). Pb recorded the highest content in the bulk sediments (35.24 µg/g) at St TL8, in $Ø_3$ (50.16 µg/g) at St. TL11, in $Ø_4$ (54.28 µg/g) at St. TL10 and the highest value in $Ø_5$ (69.40 µg/g) was observed at TL12. The recorded averages of the carcinogenic metals; Cd, Ni, Cu and Pb in the bulk and the finest sediment fractions at Great Bitter and Timsah lakes are shown in (Fig. 3).

Table 3. Max., min. and averages of carcinogenic metals in the bulk sediments and the finest fractions ($Ø_3$, $Ø_4$ and $Ø_5$) fractions at the Great Bitter and Timsah Lake expressed as (µg/g):

			Cd	**Ni**	**Cu**	**Pb**
Great Bitter Lake	Bulk	Max.	21.73	22.8	22.97	28.14
		Min.	1.85	2.98	6.5	1.77
		Av.	5.87	11.26	13.94	11.81
	$Ø_3$	Max.	45.1	51.8	24.72	34.22
		Min.	1.55	0.89	4.24	0.99
		Av.	9.73	12.03	15.6	10.74
	$Ø_4$	Max.	26.43	73.57	55.56	24.34
		Min.	1.12	2.18	11.51	0.63
		Av.	8.93	15.85	31.26	9.67
	$Ø_5$	Max.	73	66.63	84.36	40.65
		Min.	1.18	2.11	14.37	4.67
		Av.	10.3	21.93	51.88	15.21
Timsah Lake	Bulk	Max.	39.73	20.97	36.84	35.24
		Min.	2.54	0.01	5.5	3.2
		Av.	7.8	7.99	15.16	17.5
	$Ø_3$	Max.	15.23	21.76	34.26	50.16
		Min.	0.01	4.32	6.01	0.01
		Av.	2.14	10.23	17.52	22.16
	$Ø_4$	Max.	39.98	28.31	82.3	54.28
		Min.	0.56	0.82	13.65	2.86
		Av.	5.04	13.18	35.23	23.32
	$Ø_5$	Max.	31.54	45.22	107.02	69.4
		Min.	0.77	6.43	41.11	4.31
		Av.	5.07	20.91	62.14	26.56

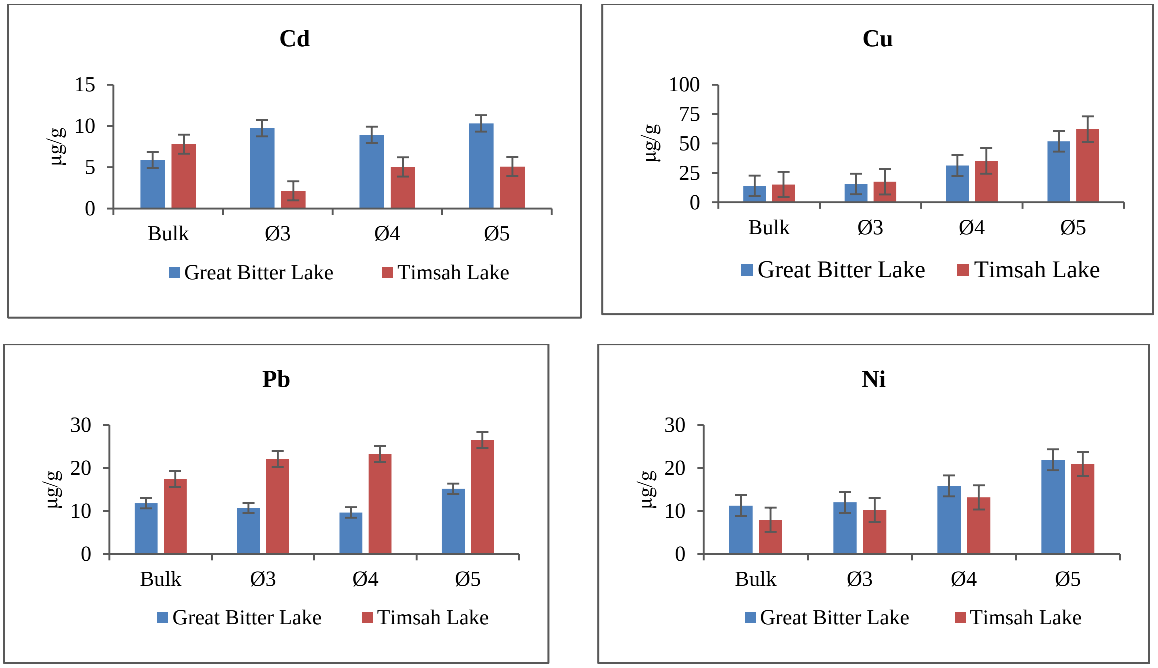


Fig. 3. The averages carcinogenic metals Cd, Cu, Pb and Ni in the bulk and different fractions ($\O_3$, $\O_4$ and $\O_5$) at the studied lakes.

3. Carcinogenic metals in edible tissues of bivalves

One bivalve species (*P. undulates*) was the dominant in the Great Bitter Lake. 60 individuals were collected with weight variation between 1.72gm wet wt. and 7.32gm wet wt. with average of 3.93gm wet weight. The carcinogenic Cd in the edible tissues of *P. undulates* was varied between below the detection limit (BDL<0.001) and 0.008 µg/g wet wt. with average of 0.002µg/g wet wt. Ni was fluctuated between 0.06 and 2.87 µg/g wet wt. with an average of 1.32 µg/g wet wt., Cu was changed between 0.10 and 0.38 µg/g wet wt. and the average was 0.23 µg/g wet wt. meanwhile Pb was varied from BDL to about 3.14 µg/g wet wt. with an average of 0.37 µg/g wet wt (Table 4).

Two bivalve species were collected from Timsah Lake (*P. undulates* and *R. decussatus*). 60 individuals were collected from *R. decussatus* and 40 individuals were collected from *P. undulates.* The individuals wet weight of *R. decussatus* was fluctuated between 0.51 gm and 2.67 gm with average of 1.20 gm, whereas the individuals wet weight of *P. undulates* was changed from 0.85 gm to 2.66 gm averaging of 1.64 gm. Cd contents in the edible tissues of *R. decussatus* and *P. undulates* were significantly low. Ni content in the edible tissues *R. decussatus* was fluctuated between BDL to 5.63 µg/g wet wt. with the average of 1.30 µg/g wet wt., Cu from 0.08 to 5.55 µg/g wet wt. averaging of 0.24 µg/g wet wt. and Pb was varied from BDL to 11.97 µg/g wet wt. and the average was 0.95 µg/g wet wt.. In edible tissues of *P. undulates*; Ni was changed from BDL to 2.63 µg/g wet wt. with average of 0.79 µg/g wet wt., Cu was varied between 0.05 to 0.31

averaging of 0.14 µg/g wet wt., meanwhile, Pb was varied from BDL to 4.52 µg/g wet wt. with average of 1.15 µg/g wet wt. (Table 4).

Table 4. Max, min. and average concentrations of the carcinogenic metals measured in the soft tissues of the studied bivalves at the Great Bitter and Timsah lakes expressed as (µg/g wet wt.):

Site	**Species**		**Soft tissue wet wt. (gm)**	**Cd**	**Ni**	**Cu**	**Pb**
Great Bitter Lake	***P. undulatus***	Max.	7.32	0.008	2.87	0.38	3.14
		Min.	1.72	BDL	0.06	0.10	BDL
		Av.	3.93	0.002	1.32	0.23	0.37
Timsah Lake	***R. decussatus***	Max.	2.67	0.002	5.63	5.55	11.97
		Min.	0.51	0.001	BDL	0.08	BDL
		Av.	1.20	BDL	1.30	0.24	0.95
	P. undulatus	Max.	2.66	0.004	2.63	0.31	4.52
		Min.	0.85	0.001	BDL	0.05	BDL
		Av.	1.64	0.001	0.79	0.14	1.15

BDL: Below Detection Limit (DL of Cd =0.001), (DL of Cu, Ni and Pb =0.05)

DISCUSSION

The observed high percentages of coarse sediments at stations BL9 and BL10 of the Great Bitter Lake were due to the effect of the natural wave actions and ship-generated waves that disperse the fine particles near these stations as well as the biological production, meanwhile, the very high average percentages of coarse sediments at TL1, TL6 and TL11of Timsah Lake were attributed to the continuous leaching of fine particles by waves and currents at these locations. Generally, the significant high average percentages of medium and fine sediment fractions in the two lakes especially near the sheltered and protected stations contributed to the stagnant conditions inside these basins (semi closed) that minimize the wave action and prevent the fine sediment dispersion. Dar *et al.* (2015) reported that the discharged fine and particulate sediments to both lakes (Great Bitter and Timsah lakes) from the different discharge sources are much higher than the recorded percentages in the collected seafloor sediments, it is clear that most of these fine and particulate fractions were dispersed by the waves and currents of Suez Canal.

Sediment quality is a good indicator of pollution in the marine environment, since sediments have great tendency to accumulate metals and other organic pollutants, subsequently metal concentrations in the sediments were much higher than those in the water column and in the benthic organisms. Cd is an immensely toxic heavy metal, and it is associated with significant health implications as an environmental contaminant and human exposure typically occurs from inhalation, smoking and ingesting contaminated food and water (Bertin and Averbeck 2006; Chunhabundit 2016). Cadmium (Cd), and nickel (Ni) are category 1 heavy metals according to the International agency for Research on Cancer (Kim *et al.* 2015). Exposure to Cd has been associated with carcinogenesis in multiple tissues including breast, esophagus, stomach, intestines, prostate, lungs and testes (Bishak *et al.* 2015).The observed very high values of Cd in the Great Bitter Lake was certainly attributed to the improvidence in fertilizing. Kim *et al.* (2015) reported that some fertilizers which contain Cd cause an increase of Cd concentration in sediments. They added, Itai-itai, bone pain, osteomalacia, osteoporosis are caused by Cd throughout food intake. Increasing the Cd concentration in the kidney means high excretion of calcium in the urine and is significantly causes bone damage. Ni can produce toxic effects upon exposure in an environmental or occupational setting. Pollution of Ni can enter the environment and bioaccumulate in organisms that enter the human food chain (Plavan *et al.* 2017). There are a variety of cancers that have been associated with nickel exposure; carcinogenesis in lung, nasal and sinus tissues (Pavela *et al.* 2016). Nickel and Ni compounds are considered Class I human carcinogens (Chen *et al.* 2019). Oral exposure to Ni induces skin and oral epithelium damage. Kim *et al.* (2015) discovered a various toxicities induced by Ni in lung, nose, skin, kidney and human liver. Ni-induced hypoxia like state under normal oxygen tension may be a mechanism for promoting cancer development as well as Ni may preferentially exert its carcinogenic effect through epigenetic changes, rather than mutation (Chen *et al.* 2019).

Leone *et al.* (2006) suggested that Cu is involved in carcinogenesis and atherogenesis. Copper (Cu) serves as enzymes that are essential for intracellular processes of the organisms and have DNA-binding domains but almost it induces various cancers and diseases (Kim *et al.* 2015). Cu ions play an important role in biological systems and working as essential co-factors for many biochemical reactions but they become toxic to organisms when their concentrations surpass the natural levels and produce damage by breaking the DNA strands leading to carcinogenesis (Theophanides and Anastassopoulou, 2002). The excess Cu can introduce human body and may cause abdominal pain, vomiting, diarrhea, hemolysis, hepatic necrosis, hematuria, proteinuria, hypotension, tachycardia, convulsions and coma (U.S. AF, 1990). Pb is a toxic heavy metal that has significant risks to health, which can enter the human food cycle through contaminated products (Mc Cumber and Strevett, 2017). Silbergeld *et al.* (2000) pointed out that recent epidemiological and experimental work confirms that inorganic lead compounds are associated with increased risks of tumorigenesis. The possible mechanism of lead carcinogenicity include direct DNA damage, clastogenicity, or inhibition of DNA synthesis or repair (Steenland and Boffetta, 2000).

Fig. (4) shows the distribution patterns of the different metals at the Great Bitter Lake, the carcinogenic Cd has relatively uniform high distribution pattern with slight increase to eastward and northward of the lake, Cu showed definitely elevated distribution pattern in the middle and southern tissues of the lake, Ni was increased in its distribution towards the western bank of the lake assured the fertilizer and reclamation sources of contaminations, meanwhile Pb tends to increase the eastward of the lake may be due to the navigation operations inside the lake and Suez Canal. The carcinogenic Cd, Ni, Cu and Pb as a major sources of environmental contamination and accumulation in the human body due to their chemical and physiological properties pose health risk for sea food consumers especially those of daily diet. The elevated levels of these carcinogenic metals and other heavy metals in the sediments of the Great Bitter Lake are certainly attributed to the agriculture drains with wastewater enriched by chemical fertilizers and land reclamation.

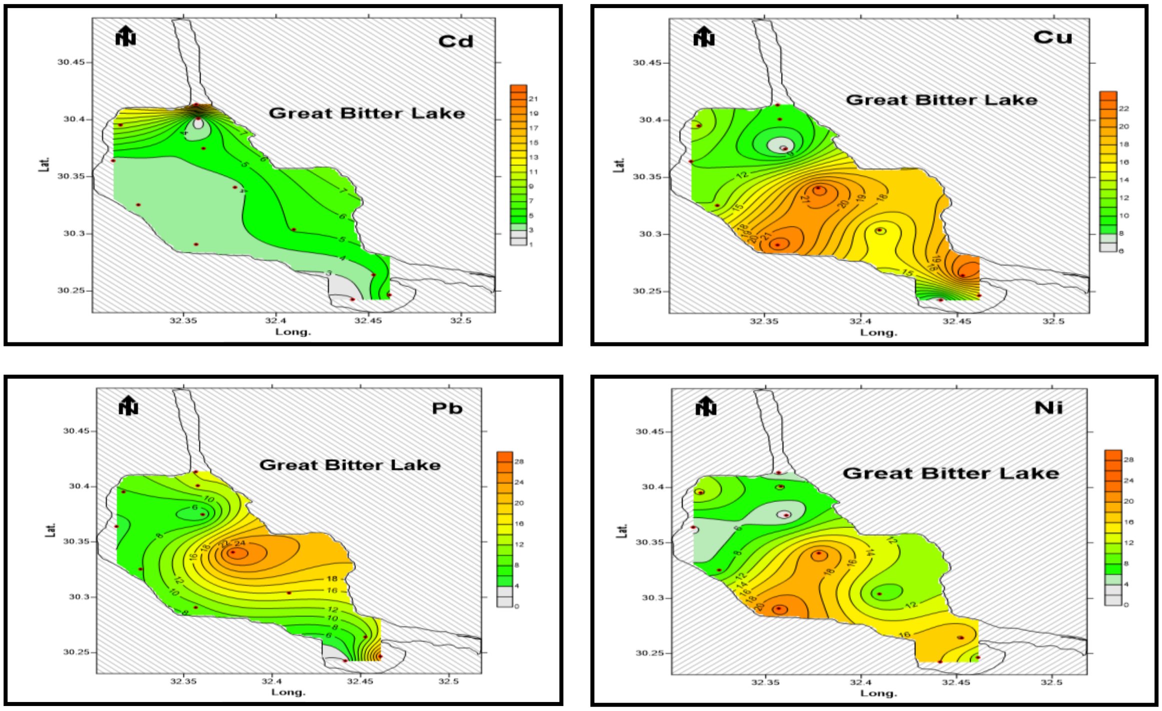


Fig. 4. Distribution patterns of the carcinogenic metals (Cd, Cu, Pb and Ni) in bulk sediments of Great Bitter Lake

Fig., (5) shows the distribution pattern of the carcinogenic metals at Timsah Lake. The distribution pattern of carcinogenic Cd showed uniform distribution increased eastward to the direction of Suez Canal with small hot spot were observed in the western embayment at the stream flow of the main agriculture drainage system. Ni and Cu showed abrupt changes in distribution, significant high occurrences were observed in the north and northeastern sides of the lake with small hot spot at the western bay connection with the lake indicating to two accumulation sources one of them came from the treated and untreated industrial wastes from the western bay and the other may be from the Hugh ship yard at the northern side of Timsah Lake. Pb distribution was spread over most the eastern and south tissues of the lake with two hot spots; one of them northern the lake near the shipyard and the other south of the lake indicated that the essential sources of the metal in the lake was due to ship maintaining and repairing, ship waiting area, land reclamation and the human activities along the coast.

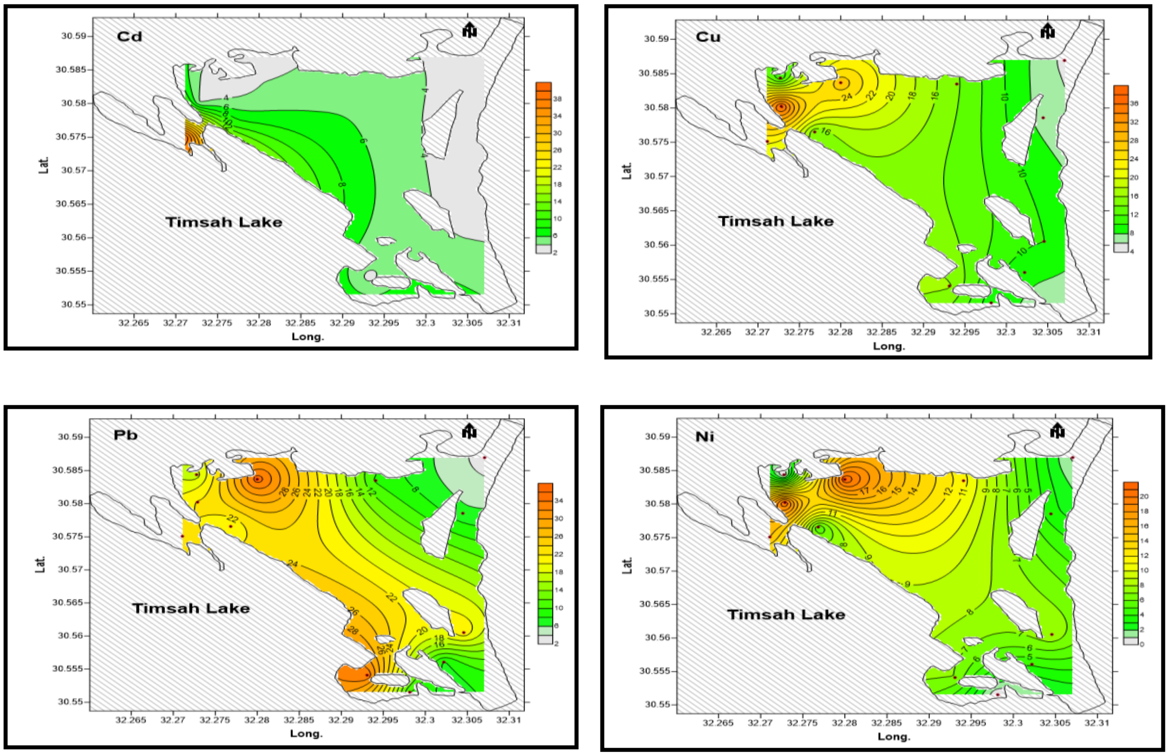


Fig. 5. Distribution pattern of the carcinogenic metals (Cd, Cu, Pb and Ni) in bulk sediments of Timsah Lake.

Correlation coefficient illustrated only fair positive correlation between the individuals weight with Cu accumulation (Table 5, Fig., 6). *P. undulates* showed fair positive correlation between the individual weight and Cd, slight negative with Ni and slight positive with Cu (Table 5; Fig., 7). The same correlations of *R. decussatus* at Timsah Lake showed slight positive correlations with Cd (r = 0.34) and Cu and fair negative with Ni (Table 5; Fig., 8). The data of correlation coefficients illustrated the presence of miss to weak relationships between the individual weights and metal bioaccumulation in the edible tissues of the studied species at both lakes. Sami *et al.*, (2020) found negative correlations between Cd, Cu and Zn with mussel size of the studied species; *Ruditapes decussatus*, *Venerupis pullastra* and *Paphia undulata* at Timsah Lake. Abd El Ghany (2017) pointed out, negative relationship was between the bivalve size and metal concentration in *Venerupis decussata* at the Mediterranean Sea coast of Port Said, Egypt. Yap *et al.* (2009) and Abd El Ghany (2017) illustrated that the smallest individuals contained the highest concentrations of metals meanwhile, the large and aged mussels tended to pump less water through their bodies per unit of body weight, then the uptake of metals was lower than that in smallest ones. Inversely; Szefer *et al.*(1999) observed strong positive correlation between the accumulated metals and mussel size of the mollusk species collected from the Gulf of Aden, Yemen. Strong and Luoma (1981) found both strongly positive and strongly negative relationships between the bio-accumulated metals and mussel size of the clam *Macoma balthica*.

Table 5. The Correlation coefficient relationships between individual weights of the studied bivalve species and the carcinogenic metals at the Great Bitter and Timsah Lakes:

Location	sp.	Cd	Ni	Cu	Pb
Great Bitter Lake	*P. undulatus* Wt.	-0.04	-0.19	0.52**	-0.22
Timsah Lake	*R. decussatus* Wt.	0.34*	-0.51**	0.33*	-0.03
	P. undulatus Wt.	0.51**	-0.41*	0.44*	0.14

*** Slight positive/negative, ** Fair positive/negative**

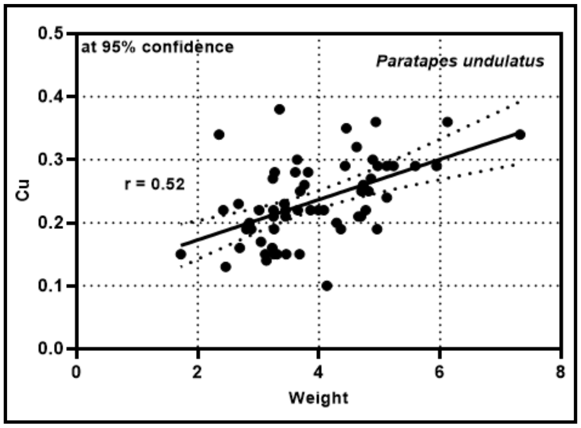
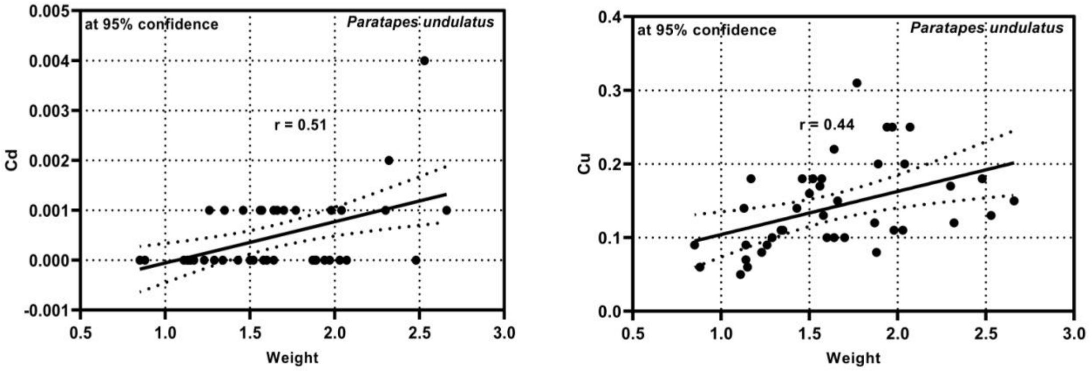


Fig. 6. Relationships between edible tissues and Cu in *P. undulatus* at the Great Bitter Lake.



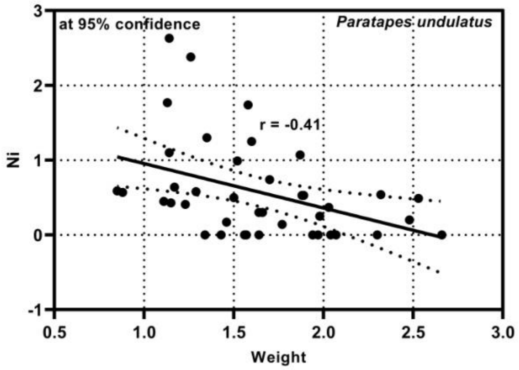


Fig. 7. Relationships edible tissues with Cd, Cu and Ni in *P. undulatus* at Timsah Lake

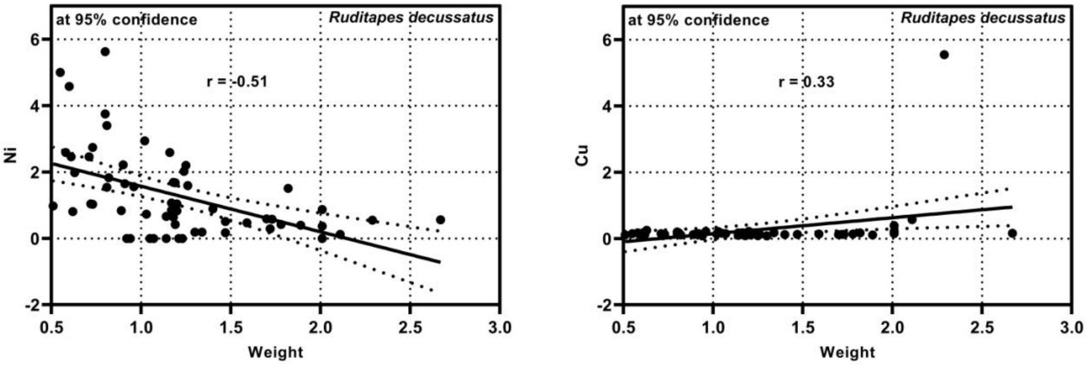


Fig. (8) Relationships of edible tissues with Ni and Cu in *R. decussatus* at Timsah Lake.

Bio-sediment accumulation factor (BSAF)

Bioaccumulation is the process through which deposit feeder organisms assimilate metals from the surrounding sediment layer. Thoma *et al.*, (1995) defined the BSAF as the ratio of the average bivalve metal to average sediment concentration at a given station/year. To evaluate the differential abilities of bivalves to bioaccumulation within their edible tissues; bio-sediment accumulation factor (BSAF) was estimated. BSAF values for all the studied metals in the different bivalve species at the Great Bitter and Timsah lakes were much lower than unity (<<<1.0) (Table 6), indicating that these species just accumulated their needs from the surrounding environment then release the rest into the water column. The same results were demonstrated by Rzymski *et al.*, (2014), they were suggested that the accumulation of metals in the soft tissues of the studied bivalve species were lower than in sediment samples, thus BSAF values did not exceed unity. Thoma *et al.*, (1995) found that the median of BSAF across stations was varied by about three orders of magnitude for Zn, Cd, and Cu at the highest levels of BSAF = 1 to 10. They added, the variability in the median BSAF for studied metals was due to the variations from site to site, primarily in the sediment to water partitioning, a function of sediment deposition, resuspension, and metal diffusive exchange.

Table 6. The recorded bio-sediments accumulation factor (BSAF) in the different studied bivalve species at the studied lakes:

Metal	**BSAF**		
	P. undulates G. Bitter Lake	*R. decussatus* Timsah Lake	*P. undulates* Timsah Lake
Cd	5.55×10^{-5}	7.73×10^{-5}	1.58×10^{-5}
Ni	0.60×10^{-2}	2.75×10^{-2}	6.19×10^{-2}
Cu	4.52×10^{-3}	2.28×10^{-3}	3.94×10^{-3}
Pb	2.45×10^{-2}	1.95×10^{-2}	3.57×10^{-2}

Permissibility of the studied species for human consuming

The human health hazards related to the consumption of the edible bivalve was evaluated through comparing the heavy metals concentrations in the edible tissues of all the studied bivalves and the permissible maximum carcinogenic metals limits determined by many authorized organizations as; the World Health Organization and Food and Agriculture Organization (WHO/FAO, 2000), Food and Drug Administration (FDA, 2001) and (EC Regulation No. 1881/2006). WHO was determined the permissible rate of Cd for human consumption by 0.07 µg/g weakly, EU limited Cd by 0.05 µg/g and EUROPA (2004) delineated permissibility rate of Cd by 0.100 µg/g (Tabinda *et al.* 2010). The safe limit of Ni for human consumption was certificated by WHO 0.35µg/g, U.S. Food and Drug Administration (USFDA) 70-80 µg/g and it was set by USEPA as 1.00 µg/g. The certified permissible limit of Cu (µg/g) by Canadian Food Standards (CFS) in marine fish is 100 µg/g, by FAO (1983) and WHO (Kakulu *et al.* 1987) was 30 µg/g. EU (2001) and TFC (2002) were ranged the international standard the permissible limits of Pb in marine fish between 0.5 and 10µg/g, according USEPA (2000) is 0.491, WHO (Kakulu *et al.* 1987) is 0.200µg/g, and its toxic limit set by Food and Agriculture Organization (FAO, 1983) is 0.5 µg/g. As shown in Table (4), the average contents of the carcinogenic Cd, Ni and Cu in the edible tissues of the different species at both lakes showed low concentrations that are within the permissible safe zone for the human consuming, whilst Pb is showing a sign of human risk if consumed diurnally.

CONCLUSION

- Studying the lakes sediments illustrated that sand was the dominant category at the Great Bitter Lake and Timsah lakes. The high percentages of coarse sediment at the Great Bitter Lake were attributed to the effect of the natural wave actions and ship-generated waves that disperse the fine particles and the biological productions.

- The high percentages of medium and fine sediments at the two lakes were concentrated in the sheltered and protected stations contributed to the stagnant conditions that prevent the fine sediments dispersion.
- At the Great Bitter Lake, Cd showed significantly unexpected high contents relative to other metals in the bulk sediments at St. BL1, in $Ø_3$ and $Ø_4$ at St. BL2, and in $Ø_5$ at St. BL3. At Timsah Lake Cd was considerably high in the bulk sediments and all fractions.
- The distribution patterns of the studied metals at both lakes show remarkable variations depending upon the source and location of the anthropogenic effluents.
- The accumulated carcinogenic metals; Cd, Ni, Cu and Pb in the edible tissues of the studied bivalves showed very low concentrations relative to their contents in the surrounding sediments with descending sequences of; Ni>Pb>Cu>Cd in *P. undulates* at the Great Bitter Lake, Ni>Pb>Cu in *R. decussatus* and Pb>Ni>Cu>Cd in *P. undulates* at Timsah Lake.
- BSAF values for all the studied metals in the different bivalve species at the Great Bitter and Timsah lakes were much lower than unity indicating that these species have the ability to reject excess metals into the water column.
- The recorded carcinogenic metals in the edible tissues of the different bivalves are within the permissible safe zone for the human consuming except Pb.

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