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Accumulation of heavy metals in freshwater molluscs with special emphasis on utilizing them as biomonitors in the aquatic environments

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ABSTRACT

A field study was conducted to evaluate the potential of using some of the freshwater moluscan species as a bioindicator for the heavy metals in Mit Yazid Canal and Belay Drain, Gharbia Governorate. Based on the field visit, six of moluscan species were collected from Mit Yazid Canal, namely; *Mutela sp*., *Coelatura aegyptiaca* and *Corbicula fluminea* (filter feeder bivalves) and *Melanoides tuberculata*, *Bellamya unicolor* and *Lanistes carinatus* (bottom feeder gastropod snails). On the other hand, only one species of *L. carinatus* was collected from the polluted drain (Belly Drain).

In the unpolluted canal (Mit Yazid Canal), the present result showed that there were statistical differences between concentrations of the heavy metals (aluminum, barium, cadmium, cobalt, copper, iron, manganese and vanadium) among the soft tissues of moulscan species. But, the heavy metals (chromium, lead, nickel and zinc) were uniformly distributed. Also, the present result showed that aluminum, copper, nickel, zinc, iron and lead were highly accumulated in the soft tissues more than the other metals. In addition, the present result showed that the bioaccumulation of all trace metals in both adult and juvenile, *Bellamya unicolor* was statistically the same except for vanadium. In the polluted drain, the bioaccumulation of the investigated heavy metals in the soft tissues of *L. carinatus* tended to be high when it compared with their bioaccumulation in the soft tissues of the same species in the unpolluted canal except for the vanadium. Furthermore, the present result showed a positive correlation between the accumulations of trace metals in different moluscan species with their concentration in the sediments.

Key words: Moluscan species, heavy metals, bioaccumulation, pollution.

INTRODUCTION

The term 'heavy metal' is synonymously used with 'trace metal' which includes both essential and non-essential trace metal. All trace metals are potentially toxic at a threshold bioavailability. They are often introduced into the terrestrial and aquatic ecosystems and they have long been recognized as a serious environmental concern because they cannot be biologically or chemically degraded, and thus may either accumulate locally or be transported over long distances (Cheng, 2008). The heavy metals have a tendency to accumulate in the soil, the water sediments and the food chain as well as the tissues of both plants and animals (Onyari *et al*., 2003). Heavy metals bioaccumulation is a major route through which increased levels of the pollutants are transferred across food chains/web creating an environmental concern. Most of the aquatic habitats are fouled by water pollution and the most important heavy metals are zinc, copper, lead, cadmium, nickel and chromium (Marshall, 2005). Some of these metals are essential trace metals to living organisms. Zinc, for example, is an essential component of at least 150 enzymes; copper is essential for the normal function of cytochrome oxidase; iron is part of the haemoglobin in red blood cells; boron is required exclusively by plants (Walker *et* *al.*, 2006; Shuhaimi-Othman *et al.*, 2012). Such metals become toxic at higher concentrations like other toxic heavy metals such as lead and cadmium (Čelechovská *et al*., 2008). Therefore, it is important to determine the bio-accumulation capacity for heavy metals by organisms, in order to assess potential risk to the aquatic environmental health.

In this respect, bottom sediments, fish, aquatic macrophytes and invertebrates are very important links for metal cycles in the aquatic environment and they are commonly used in the biomonitoring of heavy metals. Generally, sediments can accumulate large amounts of heavy metals and become their main reservoir in the wetlands (Dickman *et al.*, 1990). Invertebrates accumulate the pollutants and these are further transported to and accumulated in carnivores. This transport of toxicants in the nutrition web causes the concentrations of toxicants to increase from one nutrition level to the next, thereby causing chain effects in ecosystems. The magnification in each step is considered to be 3-5 times in an aquatic nutrition web.

Several authors have reported the importance of molluscans as good indicators for monitoring heavy metal pollution because they are abundant in many aquatic ecosystems, being easily available for collection and highly tolerant to many pollutants and exhibit high accumulations of them (Gardenfors *et al.*, 1988; Lau *et al.*, 1998; Ogeleka *et al*., 2016). Beaby and Eaves (1983) mentioned that molluscs can accumulate higher concentration of metal ions than other groups of invertebrates. Also, such benthic organisms offer advantages to water quality surveys because (a) they inhabit all kinds of waters, (b) they are sedentary, unable to avoid environmental disturbances, (c) they have long life cycles compared to planktonic groups, (d) their responses to different environmental conditions are known, and (e) they are in the middle of the aquatic food web, reflecting the productivity of trophic levels below and above (Milbrink, 1983; Dickman *et al.*, 1990; Amyot *et al.*, 1994; Bu-Olayan and Subrahmanyam, 1997; AbdAllah and Moustafa, 2002; Yap and Cheng, 2008).

Compared to the sediments, the molluscs exhibit greater spatial sensitivity and therefore, are the most reliable tool for identifying sources of biologically available heavy metal contamination (Lau *et al.* 1998). Generally, molluscs accumulate the heavy metals in their tissues in proportion to the degree of environmental contamination which signifies their importance as biomonitors of heavy metal pollution (Presing *et al*., 1993; Bu-Olayan and Subrahmanyam, 1997; Tanhan *et al*., 2005; Ogeleka *et al*., 2016).

There have been some uncertainties regarding the importance of difference on feeding habits as source of heavy metals for the aquatic molluscs. However, it is generally assumed that food is more effective than direct uptake of soluble metal from water in gastropods as well as bivalves (Ogeleka *et al*., 2016).

The objectives of present study were to:

1- evaluate in field conditions, the bioaccumulation of twelve heavy metals (aluminum, barium, cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, vanadium and zinc) within the soft tissues of the bivalves (*Mutela sp., Coelatura aegyptiaca and Corbicula fluminea*)) and the gastropods (*Melanoides tuberculata*, *Bellamya unicolor* and *Lanistes carinatus*) that were collected from Mit Yazid Canal and Belay Drain in Gharbia Governorate.
2- study the potential use of the molluscan species as a biomonitor of such heavy metals based on correlation analysis of heavy metals concentration between species, juvenile and adult species, water and sediments,

3- evaluate the potential use of such species as a biomonitoring material for the investigated heavy metals.

MATERIALS AND METHODS

A field visit was conducted in Mit Yazid Canal and Belay Drain, Gharbia Governorate to collect surface water, sediments and molluscan species samples for evaluating the potential use of molluscs as bioindicator of accumulation of heavy metals.

Sampling procedure:

1- Water quality analysis

Surface water sampling was carried out according to standard methods for examination of water. Polyethylene containers of two-liter capacity were used for most chemical analysis. Heavy metal analysis (aluminum, barium, cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, vanadium and zinc) for the surface water was carried out, using the standard methods (APHA, 2005). Heavy metals were determined by aspirating the samples in an inductively coupled plasma-optical emission spectrometer (ICP-OES) Perkin-Elmer optima 3000 coupled with an ultra sonic nubulizer.

2- Sediment analysis

To describe the chemical characteristics of the sediments, the surface sediments were carefully collected. The samples were collected by Ekman-Grab sampler with an area of 225cm^2 (15 x 15cm) and were kept cool in an icebox during transportation to the laboratory. The samples were air-dried, homogenized using pestle and mortar, passed through a 2-mm mesh screen and stored in polyethylene bags. Heavy metals (aluminum, barium, cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, vanadium and zinc) were analyzed by digesting 0.5gm of each sample with 10ml of aqua-regia (1:3 $HCl:HNO_3$) in a Teflon bomb for 2h at 120^{o}C. After cooling, the digested samples were filtered and measured on ICP-OES Perkin-Elmer optima 3000 coupled with an ultra sonic nubulizer (APHA, 2005).

3- Bioaccumulation of heavy metals analysis

Five samples each of the freshwater molluscs used in this study were freshly harvested mechanically. The five samples were nearly uniform in size. It was placed in the ice and brought to the laboratory.

The soft tissue was dissected out of shell pieces by using a fine small scissors and dried at 60ºC. The dried tissue was homogenized and stored in dessicator for analysis. Ten milliliters of nitric acid-perchloric acid (10:4) mixture were added to the sample, covered and left overnight at room temperature. The samples were digested, allowed to cool to room temperature, filtered (glass wool) and made up to 50ml. The concentration of twelve investigated were determined using the standard method (APHA, 2005), and aspirating the samples in an inductively coupled plasma-optical emission spectrometer (ICP-OES) Perkin-Elmer optima 3000 coupled with an ultra Sonic Nebulizer. All concentrations were expressed in mg/kg.

4- Statistical analysis

All data were estimated by SPSS VERSION 17 PROGRAM. The relationships between the bioaccumulation of the heavy metals in the soft tissues from different molluscs collected from Mit Yazid Canal were tested using Friedman test with confidence level 95% ($p<0.05$). Also, the relationships were tested using classify-Hierarchical Cluster Analysis (Dendogram).

The relationships of the bioaccumualtion of each heavy metal for soft tissue in adult and juvinle of the snail, *Bellamya unicolor* were evaluated by using t-test (two tailed, p=0.05).

The relationships between the the bioaccumulaion of heavy metals in the soft tissues of the moluscan species that collected from the unpolluted area and polluted area were tested using classify-Hierarchical Cluster Analysis (Dendogram).

Pearson Correlation Statistics and the significant difference of the heavy metals content in moluscan species and their relationships with the heavy metals content in surface water and the sediment were evaluated by using t-test (two tailed, p=0.05 & p=0.01).

RESULTS AND DISCUSSION

Most of the trace metals play an essential role in the life processes of aquatic organisms, however at high concentrations they become toxic and may cause drastic environmental impact on the aquatic organisms. Table (1) shows the analyses of surface water and sediment samples taken from Mit Yazid Canal and Belly Drain. The obtained result indicated that the concentrations of the heavy metals in both water and sediments in the drain were higher than that in the canal. These wide variations may be related to many sources of pollutants including agricultural wastes and untreated domestic wastes.

Table (1): The concentrations of heavy metals in the surface water and the sediment samples taken from Mit Yazid Canal and Belly Drain.

Heavy metals	Mit YAzid		Belly Drain	
	Sediments (mg/kg)	Water (ml/l)	Sediments (mg/kg)	Water (ml/l)
Aluminum (Al)	15.57	0.005	22.96	0.120
Barium (Ba)	0.075	0.044	0.136	0.052
Cadmium (Cd)	0.000	0.001	0.000	0.001
Chromium (Cr)	0.150	0.001	0.075	0.001
Cobalt (Co)	0.015	0.005	0.025	0.005
Copper (Cu)	0.147	0.039	0.683	0.001
Iron (Fe)	30.64	0.048	51.05	0.021
Lead (Pb)	0.008	0.001	0.026	0.001
Manganese (Mn)	0.847	0.354	1.207	0.061
Nickel (Ni)	0.047	0.001	0.065	0.001
Vanadium (V)	0.088	0.013	0.141	0.006
Zinc (Zn)	0.137	0.019	0.395	0.011

Based on the field visit, 6 of moluscan species were observed and collected from Mit Yazid Canal, namely; *Mutela* sp., *Coelatura aegyptiaca* and *Corbicula fluminea* (filter feeder bivalves) and *Melanoides tuberculata*, *Bellamya unicolor*, and *Lanistes carinatus* (bottom feeder snails) as shown in Table (2). But in case of Belly Drain, only one species of *Lanistes carinatus* was observed and collected. This obtained result suggests that mechanisms other than mortality resulting from a direct poisoning may be responsible for the extinction of molluscs in highly polluted areas. One such possibility is the rejection of food with high concentrations of metals. In this case, the prolonged decrease in food consumption could cause increased mortality due to starvation rather than poisoning. This suggestion is confined with the finding of Russell *et al*. (1981) and Askowski and Hopkin (1996) who mentioned that in the contaminated water, the snails are endangered by a prolonged decrease in consumption rate that eventually may lead to death by starvation rather than contamination. The other explanation for the absence of molluscan species in polluted environments could be the effects of metals on their life history (Askowski and Hopkin, 1996).

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Table (2). Species composition of molluscs.

Taxa and Species
Class: Gastropoda
Family: Thiaridae
Genus: *Melanoides*
Melanoides tuberculata (O. F. Müller, 1774)
Family: Viviparidae
Genus: *Bellamya*
Bellamya unicolor (Olivier, 1804)
Family: **Ampullariidae**
Genus: *Lanistes*
Lanistes carinatus (Olivier, 1804)
Class: Bivalves
Family: **Iridinidae**
Genus: *Mutela*
Mutela sp. (Scopoli, 1777)
Family: **Unionidae**
Genus: *Coelatura*
Coelatura aegyptiaca (Cailliaud, 1827)
Family: **Cyrenidae**
Genus: *Corbicula*
Corbicula fluminea (Megerle von Mühlfeld, 1811)

Concerning, the molluscs, they have been widely used as indicator organisms for obtaining a qualitative picture of water pollution caused by heavy metals contamination because of their excellent bio-absorbent and high accumulation capacity (Milbrink, 1983; Dickman *et al.*, 1990; Amyot *et al.*, 1994; Bu-Olayan and Subrahmanyam, 1997; AbdAllah and Moustafa, 2002; Yap and Cheng, 2008). Similarly, the present results revealed that the molluscan species absorbed heavy metals from the effluent and they had a tendency to accumulate trace metals in their soft tissues as shown in Table (3).

Regarding to the heavy metal contents in the molluscan species, the result of the statistical analysis showed that there were significant differences between concentrations of the metals (aluminum, barium, cadmium, cobalt, copper, iron, manganese and vanadium) among the investigated species. On the other hand, the statistical analyses revealed that some trace metals were uniformly distributed among the moluscan species like chromium, lead, nickel and zinc. The different patterns of heavy metals distribution in the soft tissues of different species are shown in Table (3). These variations between species may due to different rates of meta-accumulation or due to their different feeding, growth, reproduction, maturity and behavior. This result was in agreement with findings of (Russell *et al*. 1981; Sunila and Lindstrom, 1985) and coincides with that obtained by Mahmoud and Abu Taleb (2013) and Ogeleka, *et al*. (2016) who mentioned that the absorption did not based on the water quality but based mainly on the selectivity of the molluscs and the physiological behaviour and biological factors of the molluscs; age, sex, sexual maturity and stage.

Table (3). Concentrations of heavy metal bioaccumulation in different molluscan species and their statistical values.

Species		Al	Ba	Cd	Cr	Co	Cu	Fe	Pb	Mn	Ni	V	Zn
***Mutela* sp**	**Mean**	10.2	0.59	0.03	0.06	0.26	1.18	22.4	18.6	0.25	8.29	0	9.91
	St. dev.	6.77	0.33	0.02	0.76	0.19	0.73	12.8	9.81	0.13	4.67	0	5.61
Melanoides tuberculata	**Mean**	78.3	3.25	1.94	0.87	5.99	16.2	79.0	10.5	1.21	70.4	2.65	8.16
	St. dev.	45.2	2.08	2.47	0.65	4.83	13.1	19.1	4.53	0.69	27.4	2.26	3.67
Bellamya unicolor	**Mean**	28.3	0.86	0.16	0.07	1.62	5.37	27.7	9.38	0.32	11.7	0.68	19.2
	St. dev.	12.1	0.85	0.08	0.02	1.63	1.51	12.0	5.34	0.15	6.82	0.48	11.8
Caelature aegyptiaca	**Mean**	12.8	0.58	0.01	0.04	0.62	0.65	11.0	9.09	0.16	4.67	0.29	10.3
	St. dev.	9.34	0.32	0.1	0.03	0.28	0.10	2.58	6.68	0.06	4.52	0.23	2.52
Lanistes carinatus	**Mean**	10.5	0.30	0.10	0.03	1.07	5.19	6.89	2.78	0.24	2.73	0.11	3.38
	St. dev.	3.17	0.12	0.13	0.00	0.86	1.1	1.73	1.59	0.07	0.94	0.14	4.21
Corbicula conobrina	**Mean**	44.5	2.33	0.25	0.13	0.54	2.89	31.2	3.26	1.72	12.3	0	9.79
	St. dev.	24.7	0.56	0.14	0.10	0.18	1.72	13.6	1.56	1.42	12.5	0	3.09
N		4	4	4	4	4	4	4	4	4	4	4	4
Chi-Square		14.7	13.9	15.9	10.3	11.9	12.0	15.3	7.4	16.7	9.57	16.5	4.71
df		5	5	5	5	5	5	5	5	5	5	5	5
Asymp. Sig.		**0.012**	**0.01**	**0.0**	*.068*	**0.04**	**.017**	**.001**	*.191*	**.005**	*0.09*	**0.01**	*.452*

Bold Value (P) <0.05 = significance difference
Italic Value (P) >0.05 = non- significance difference

Also, the present result showed that the concentrations of aluminum, copper, nickel, zinc, iron and lead in the soft tissues of studied molluscan species were characterized by distinct patterns, which varied between species. Such metals were highly accumulated in the soft tissues more than the other metals such as barium, cadmium, chrome, cobalt, manganese and vanadium as shown in Figures (1 & 2).

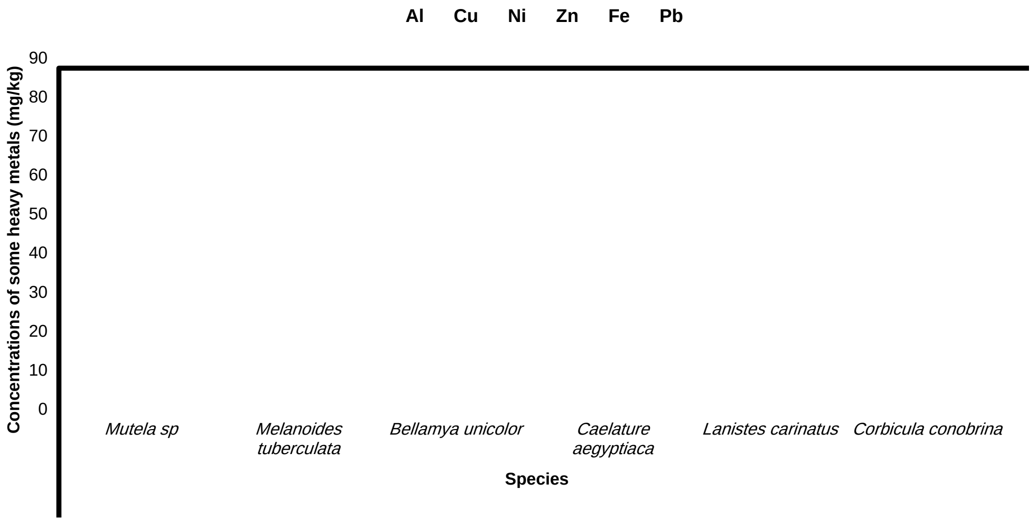

Fig. (1). The concentrations of the dominated heavy metals within the soft tissues of different molluscan species.

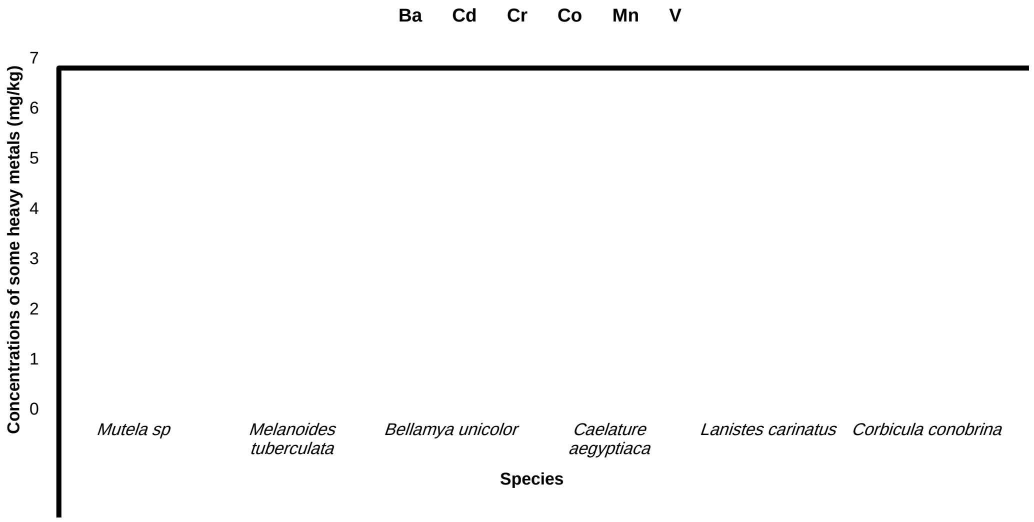

Fig. (2). The concentrations of non-dominated heavy metals within the soft tissues of different molluscan species.

To complete the picture and support the suggestion of dissimilarity of the bioaccumulation of the heavy metals within the soft tissues of moluscs, the total concentrations of the heavy metals (the dominated and not dominated one) in each species were subjected to Hierarchical Cluster Analysis to indicate the linkage between them. Interestingly, the obtained result as shown in Figures (3 & 4) indicated that species could be clustered into groups based on the total content of heavy metals in each species.

In case of the dominated heavy metals, the Hierarchical Cluster Analysis divided the species into two groups. The first group with the maximum determined total trace metals in the soft tissues was recorded in the species of *Melanoides tuberculata*. The second group contained the snails, *Bellamya unicolor*, *Lanistes carinatus*, and the bivalves, *Mutela sp.*, *Coelatura aegyptiaca and Corbicula fluminea*. *Corbicula conobrina* and *Bellamya unicolor* revealed high total content of trace metals in their soft tissues. *Mutela sp.* revealed moderate total content. However, *Lanistes carinatus* and *Coelatura aegyptiaca* revealed the lowest total content of heavy metals in their soft tissues as shown in Figure (3). Based on this result, it is suggested that there are smaller and lighter individuals that were found to contain significantly higher concentrations of heavy metals than larger and heavier individuals.

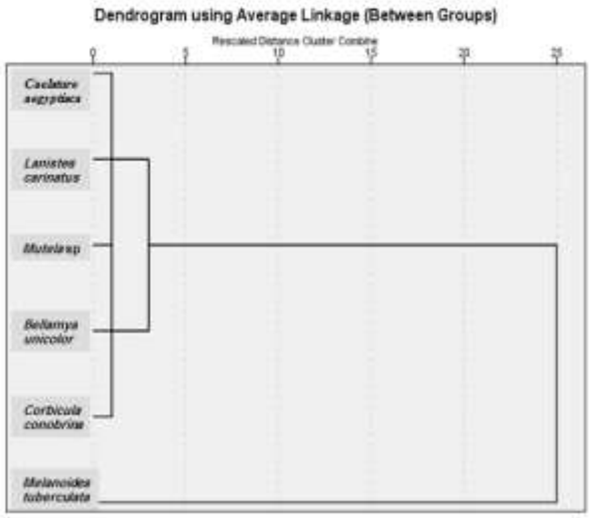

Fig. (3). Hierarchical Cluster Analysis for different molluscan species that having ability to bioaccumulate the dominated heavy metals.

In case of non-dominated heavy metals, the Hierarchical Cluster Analysis divided the species into two groups. In the first group, a similar trend was observed with a maximum recorded total trace metals in the soft tissues in the species of

Melanoides tuberculata which indicates that this species has the highest accumulation ability of heavy metal. The second group was divided into three sub-groups. The first sub-group, involved *Corbicula conobrina* that contained high bioaccumulation of the total traces metals in the soft tissues. The second sub-group involved *Lanistes carinatus* and *Bellamya unicolor* that contained moderate bioaccumulation of the total trace metals in the soft tissues. The third sub-group involved the lowest bioaccumulation of the total trace metals in the soft tissues of *Mutela sp.* and *Coelatura aegyptiaca* as shown in Figure (4).

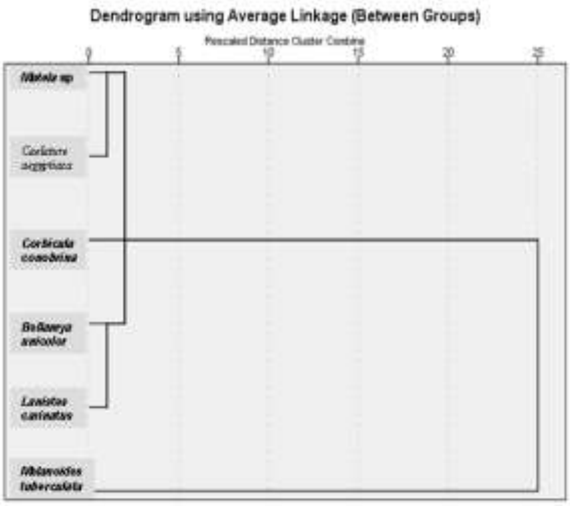

Fig. (4). Hierarchical Cluster Analysis for different molluscan species that having ability to bioaccumulate non-dominated heavy metals.

Concerning the result of the bioaccumulation of the heavy metals in the juvenile and adult organisms, the available sample collection was achieved for only the snail, *Bellamya unicolor*. The statistical analyses as shown in Table (4) revealed that the bioaccumulation of all trace metals in both adult and juvenile, *Bellamya unicolor* was statistically the same except for vanadium where its concentration tended to be zero in the juvenile snail. The present finding is parallel with the finding of Adu (2010) who mentioned that the heavy metals in the tissue of the calm *Galatea paradoxa* were almost identical and did not vary significantly in both small and large size. However, it is opposite to the finding of Kihlström (1992) who mentioned that heavy metal concentrations in an organism is increasing with increasing age, notwithstanding the ability of the organism to regulate metals concentrations (Kihlström, 1992).

In case of the species, *Lanistes carinatusin* that was only collected from Belly Drain, the Hierarchical Cluster Analysis in the present result showed very strong positive correlations between bioaccumulation of the heavy metals in the soft tissues and the locations (polluted or unpolluted area). In the polluted drain, the bioaccumulation of the heavy metals in the soft tissues "mg/kg" tended to be high (aluminum "59.6", barium "2.72", cadmium "0.06" , chromium "0.03" , cobalt "0.36", copper "9.08", iron "33.5", lead "9.5", manganese "0.53", nickel "18" and zinc, 35.7) when it was compared with the bioaccumulation of the same heavy metals in the soft tissues of the same species in the unpolluted Mit Yazid Canal except for the vanadium which recorded zero mg/kg in the soft tissues of the snail within the polluted drain as shown in Table (3).

Also, the Hierarchical Cluster Analysis divided the snail, *L. carinatusin* into only two groups. The first group contained the snails that were locating in the unpolluted canal and the second group contained the snail that stored more heavy metals in its soft tissue within the polluted drain despite the fact that *L. carinatusin* reveals no intra-specific shell variation among them. Similar finding of Adu, (2010) showed that snails in Trepca region (Ghana) were highly contaminated with heavy metals compared with snails from unpolluted area.

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Table (4). Concentrations of heavy metal bioaccumulation in both adult and juvenile *Bellamya unicolor* and their statistical values.

Parameters	N	Adult (*Bellamya unicolor*)		Juvenile (*Bellamya unicolor*)		Sig. (2-tailed)
		Mean	Std. Deviation	Mean	Std. Deviation	
Aluminum	5	28.3	12	35	16	*0.466*
Barium	5	0.86	0.85	1.4	1.3	*0.532*
Cadmium	5	0.16	0.079	0.066	0.05	*0.085*
Chromium	5	0.069	0.022	0.1	0.11	*0.597*
Cobalt	5	1.6	1.63	0.09	0.038	*0.106*
Copper	5	5.37	1.51	7.24	4	*0.450*
Iron	5	27.7	11.95	40.8	23.45	*0.288*
Lead	5	9.38	5.34	6.18	5.84	*0.372*
Manganese	5	0.32	0.15	0.48	0.23	*0.363*
Nickel	5	11.68	6.8	15.24	26.48	*0.668*
Vanadium	5	0.68	0.48	0	0	**0.034**
Zinc	5	19.22	11.8	9.59	1.3	*0.153*

Bold Value (P) <0.05 = significance difference
Italic Value (P) >0.05 = non- significance difference

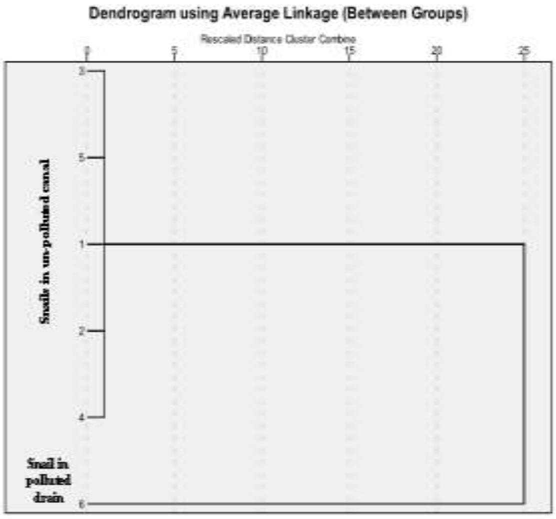

Fig. (5). Hierarchical Cluster Analysis for the snail, *L. carinatusin* **that has ability to bioaccumulate dominated heavy metals in polluted drain and unpolluted canal**

As a continuation for evaluating the absorption of heavy metals by the moluscan species, several previous studies showed that aquatic organisms are sensitive biological indicators for continuously monitoring trace quantities of toxic metals in their aquatic environment. Also, some findings showed that all aquatic organisms concentrate heavy metals from their surrounding water, sediments or food. In addition, many organisms are able to regulate the concentrations of metals in their tissues (and hence regulate toxic effects) by controlling absorption, excretion, and depuration rates or by detoxification either by changing the metal to a less toxic form or by storage at sites in the body where the metal does not have an adverse effect (Presing *et al*., 1993; Tanhan *et al*., 2005; Adedeji *et al*., 2011). In case of the present study, the obtained result showed that the soft tissues of the molluscan species could be used as target organs for heavy metals since their concentrations exceeded environmental concentration which indicated the occurrence of bioaccumulation process. In addition, the Pearson Correlation Statistic Analysis in the present result showed positive correlation between the accumulations of trace metal in different moluscan species with the concentration of such metal in the sediment (Table 4).

On the other hand, bioaccumulation of heavy metals did not show any match correlation with the concentration of such heavy metals in the surface water even in the polluted water.

Table (5). Pearson Correlation Statistics and the significant difference of the heavy metals content in moluscan species and their relationships with the heavy metals content in surface water and the sediments.

Species in un-polluted canal	Sediments		Surface water	
	Pearson correlation	Sig. (2-tailed)	Pearson correlation	Sig. (2-tailed)
***Mutela* sp.**	0.679*	0.015	-0.193	0.547
Melanoides tuberculata	0.757**	0.004	-0.189	0.555
Bellamya unicolor	0.779**	0.003	-0.207	0.518
Caelature aegyptiaca	0.635*	0.026	-0.235	0.463
Lanistes carinatus	0.706*	0.010	-0.198	0.537
Corbicula conobrina	0.818**	0.001	-0.133	0.680
Juvenile (*Bellamya unicolor*)	0.917**	0.0	-0.024	0.941
Species in polluted drain *L. carinatusin*	0.616*	0.033	0.579*	0.49

* Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Based on the results obtained from the moluscan species, the metal enrichment in the soft tissues could be classified into macroconcentrators and microconcentrators as proposed by Dallinger (1993). In the case of un-polluted canal, the soft tissues of all the moluscan species could be classified as macroconcentrators for barium, cobalt, copper, nickel, lead and zinc because their concentration in the soft tissues were higher than that in the surface sediment. On the other hand, aluminum, cadmium, chromium, iron and manganese in all the soft tissues of the moluscan species represented microconcentrators because their concentration were lower than that in the surface sediment except for the concentrations of aluminum in the soft tissues of *Melanoides tuberculata*, *Bellamya unicolor* and *Corbicula conobrina*; chromium in the soft tissues of *Melanoides tuberculata* and manganese in the soft tissues of *Melanoides tuberculata* and *Corbicula conobrina* as shown in Tables (1 & 3).

In case of the polluted drain, the concentrations of aluminum, barium, cadmium, cobalt, copper, nickel, lead and zinc in the soft tissues of the snail *L. carinatusin*, represented macro-concentrators, while the concentrations of chromium, iron, manganese and vanadium represented microconcentrators.

These obtained results indicated that sediments play a vital role for the moluscan species where they live above the sediment and the soft tissues for many moluscan species are macroconcentrators thus provide a further claim that the soft tissues of some species such as *Melanoides tuberculata* are good biomonitors. Therefore the sedemint and the moluscan species can be utilized for assessing sources and distribution of the heavy metals in aquatic environments. Similar results were emphasized by several investigators (Abel, 1996; Laskowski and Hopkin, 1996; Pihan and de Vaulfleury, 2000; Swaileh *et al.*, 2001; Mandaville, 2002; Gadzała-Kopciuch *et al.*, 2004; Ibrahim, 2006; Moolman *et al.*, 2007) who mentioned that the moluscan species are considered as a suitable diagnostic organisms for examination of pollutant in tissues, because they are able to accumulate large quantities of metals in their tissues. Also, the present result is parallel with the findings of Ho and Hui (2001) and Black and Williams (2001) who mentioned that the monitoring of the sediment with the determination of heavy metals is fundamental to the realization of toxic pollutants in the river sediment.

Conclusion

The present study concludes the following:

1. As long as water and sediments are not polluted with heavy metals, it will not affect moluscan species. But in case of polluted area, the extinction of moluscan may highly occur.
2. In the field condition, the heavy metal uptake in the moluscan species does not follow the concentration of such metals in the surface water but it is mainly regulated by the characteristic of heavy metals in the sediment.
3. The moluscan and the sediment can be therefore utilized for assessing sources and distribution of the heavy metals in aquatic environments.

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تراكم المعادن الثقيلة في رخويات المياه العذبة مع التركيز بشكل خاص على استخدامها كمؤشرات بيولوجية في البيئات المائية

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المستخلص

من منطلق تقييم مدي إمكانات إستخدام الحيوانات القاعية كمؤشرات بيولوجية للمعادن الثقيلة في قناة ميت يزيد ومصرف بيلاي بمحافظة الغربية، تم رصد ستة أنواع بقناة ميت يزيد، وهي: موتيلا، كولاتورا إيجيبتياكا و كوربيكولا فلومينا (ذات مصرعين – متغذيات بالترشيح) و ميلانويدس توبيركولاتا، بيلاميا ونيكولور و لانيستس كاريناتوس (قواقع – متغذيات القاع). علاوة علي ذلك، تم رصد نوع واحد فقط من القاعيات وهو لانيستس كاريناتوس بمصرف بيلي (صرف صحي وزراعي). أظهرت النتائج الحالية وجود فروق ذات دلالة إحصائية بين تركيزات المعادن الثقيلة (الألمنيوم والباريوم والكادميوم والكوبالت والنحاس والحديد والمنجنيز والفاناديوم) بأنسجة القاعيات التي تم رصدها بقناة ميت يزيد (قناة ري غير ملوثة) ولقد توزعت تركيزات عناصر (الكروم والرصاص والنيكل والزنك) بشكل غير منتظم. أيضاً، تراكمت عناصر (الألمنيوم، النحاس، النيكل، الزنك، الحديد و الرصاص) بشكل كبير بأنسجة القواقع أكثر من المعادن الأخرى.

أظهرت النتائج الحالية أن هناك تشابة إحصائي لتراكم جميع العناصر الثقيلة بأنسجة الطور البالغ وغير البالغ لقوقع (بلاميا يونيكولور) بإستثناء عنصر الفاناديوم. فيما يخص مصرف بيلي، فقد تراكمت العناصر الثقيله بأنسجة قوقع (لانيستس كاريناتوس) مقارنة بنفس العناصر بنفس القوقع بترعة ميت يزيد (الغير ملوثة) بإستثناء عنصر الفاناديوم. وعلاوة على ذلك، أظهرت النتائج الإحصائية إرتباط إيجابي بين تركيزات العناصر الثقيلة بأنسجة القواقع المختلفة وتركيزات نفس العناصر بالرسوبيات بمنطقة الدراسة.