Bioaccumulation, Fate and Toxicity of Two Heavy Metals Common in Industrial Wastes in Two Aquatic Molluscs

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Abstract: Accumulation of chromium (Cr) and cadmium (Cd) by the bivalve *Caelatura (Caelatura) companyoi* and the gastropod snail *Cleopatra bulimoides* was determined. The fate of these metals through soft parts and shells of the molluscs was investigated. Toxicity studies of different concentrations of Cr and Cd on the survival of these organisms were performed. Results showed that both molluscs could accumulate both metals to a large extent and could tolerate their toxicity to high limits, as these metals were accumulated mainly in their soft parts, while small amounts were absorbed by their shells. It could be concluded that the investigated molluscs can be used as bioindicators for pollution of aquatic ecosystems by such heavy metals.
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1. Introduction:

The term, trace metal, identifies a large group of metallic elements which are present in limited amounts in nature as well as in living organisms. Heavy metals are among the major concerns in waste water treatment (Salchi *et al.,* 2008). They are often derived from heavy industry, such as electroplating, battery factories and mining operations. The problems associated with trace metals contamination were highlighted in industry because of their large discharges and because chromium and cadmium are especially dangerous to aquatic organisms and can be bioaccumulated in the food chain (Medina *et al*., 1986; Brown and Louma, 1995; Pip, 1995). Also chromium and cadmium are metallic contaminants that have known essential function in human physiology (Barak and Mason, 1990). Moreover, fishes and bivalves are known to accumulate metals in their bodies .Since they constitute an important human food (Lopez-Artiguez *et al.,* 1989; El-Deek *et al.,* 1994; Schuhmacher and Domingo, 1996; Zyadah, 1996; Sidoumou *et al.*, 1997), they are potentially an indirect source of metals entering the human body, but they may also suffer from a wide range of metabolic, physiological and ecological factors. As the concentration of metal increases, the accumulation of metal and its damage effect increase (Cain and Louma, 1986; Buschiazzoa *et al.*, 2004). Cumulative effects of metals or chronic poisoning may occur as a result of long term exposure**.**

Reports on the occurrence and accumulation of heavy metals in bivalve molluscs have led to the concern about contamination of commercial mussel. They have generally been limited to salt water forms (Pentreath, 1973; Valiela *et al.,* 1974).

Hemelraad *et al.* (1986, 1987 and 1988) have published a series of papers concerned with the effect of cadmium on freshwater clams.

Hemelraad *et al.* (1990) studied the effects of cadmium on freshwater clams *Anodonta cygnea* and the interaction of Cd with the essential elements Na^{+}, K^{+}, Ca^{2+}, Hg^{2+}, Fe^{2+} and Zinc.

Abdel Moati and Farag (1991) studied the rate of bioaccumulation in Edku lake and El-Fayomy (1994) found that the marine clam *Cardium edula* in lake Manzala accumulated more heavy metals than the examined fishes.

The freshwater bivalve *Caelatura (Caelatura) companyoi* and the snail *Cleopatra bulimoides* were chosen for the present study as they are widely distributed along the River Nile from Assiut (Upper Egypt) to Damietta branches (Lower Egypt).

These species were chosen to determine their ability for the accumulation of Cr^{3+} and Cd^{2+} in their soft parts and to show the extent of their tolerance towards these pollutants in the freshwater ecosystems. It also aimed to examine the possibility of using these organisms as bioindicators for heavy metals pollution. This study might provide basic information for detecting the current status of heavy metal pollution in freshwater ecosystems.

2. Materials and Methods

Collection of the investigated mollusc samples

Samples of molluscs were collected from Ismailia canal at the industrial area of Abu-Zabal, El-Kalyubia Governorate during autumn 2008, in polyethylene bags filled with water from the same habitats and brought alive to the laboratory. Specimens were cleaned before being placed in glass aquaria (30x25x20 cm). They were left for two weeks in dechlorenated tap water that was changed twice per week.

From the same habitat, water samples were collected in polyethylene bottles, preserved by adding 2.0 ml of concentrated nitric acid and stored in a refrigerator till analysis. Bivalves and snails were labeled and frozen until analysis (FAO, 1983; UNEP, 1984).

Bioaccumulation and fate of the investigated heavy metals in the sampled molluscs

To study the bioaccumulation of each heavy metal, 60 specimens of each mollusc species were immersed in chromium and cadmium solutions of different concentrations. Twice per week, 3 specimens were taken randomly from each mollusc species for the analysis of the metal accumulation in their soft parts and shells.

Toxicity

Adult specimens of *C. companyoi* and *C. bulimoides* were divided into groups (10 each) to determine the LC_{50} of cadmium and chromium of different concentrations which kill 50% of the specimens in a certain time. Three replicates of each experiment were used.

The samples were then digested with nitric acid and perchloric acid (Saki *et al,* 1995) and finally diluted with double-distilled water. The digested solutions were analysed by Flame Atomic Absorption Spectrophotometer (Varian Spectra AA-300 plus). Data were expressed in mg/g weight and the concentration factor (C.F) values were calculated according to the equation:

$$C.F. = \frac{\text{Concentration of metal/g wet weight of animal}}{\text{Concentration of metal/g water}}$$

3. Results

Cadmium and chromium levels in field samples

Table (1) shows the concentrations of Cd and Cr in soft parts of the molluscs under investigation and in water from the field. The concentration factor of chromium was higher than that of cadmium.

Table 1: Concentration of chromium and cadmium in soft parts and shells of molluscs and water from the field.

Molluscs	Heavy metals	Conc. in Water (mg/l)	Conc. in Soft parts (mg/g wet wt)	C.F.	Conc. in Shells (mg/g wet wt)	C.F.
Caelatura (Caelatura) companyoi	Chromium (Cr)	0.022	1.520	69.0	0.20	9
	Cadmium (Cd)	0.012	0.576	48.0	0.084	7
Cleopatra bulimoides	Chromium (Cr)	0.022	1.100	50.0	0.13	6
	Cadmium (Cd)	0.012	0.504	42.0	0.06	5

C.F.: Concentration Factor

Bioaccumulation of cadmium and chromium in the investigated molluscs

Tables 2 – 5 and Figures 1-2 show the measured concentrations of Cr and Cd in the soft parts and shells of *C. companyoi* and *C. bulimoides*, as well as the concentration factor values. Results showed that cadmium is much more toxic than chromium. Therefore, the bioaccumulation studies were continued with a lower concentration of cadmium than that of chromium. The concentration factor values for chromium reached 325 and 278 for the investigated bivalve and snail, respectively after 20 days at 20 mg/l, while in the case of cadmium it increased to reach 88 and 72 for the bivalve and the snail at a low concentration of 3 mg/l. Higher concentrations of cadmium (10-20 mg/l) showed great toxicity.

Table 2: Mean bioaccumulation of chromium (20 mg/l) in the soft parts and shells of the bivalve *Caelatura (Caelatura) companyoi* as a function of time.

Immersion time (days)	1	2	5	10	15	20
Concentration in soft parts (mg/g)	3.4	8.4	16.8	28.2	42.4	65.0
Concentration factor (C.F.)	17	42	84	142	212	325
S D	0.095	0.261	0.144	0.227	0.178	0.180
Concentration in shells (mg/g)	1.6	1.6	2.2	2.2	2.0	2.2
Concentration factor (C.F.)	8	8	11	11	10	11
S D	0.325	0.298	0.413	0.206	0.342	0.200

Table 3: Mean bioaccumulation of chromium (20 mg/l) in the soft parts and shells of the gastropod snail *Cleopatra bulimoides* as a function of time.

Immersion time (days)	1	2	5	10	15	20
Concentration in soft parts (mg/g)	1.6	3.8	13.4	20.4	37.2	55.6
Concentration factor (C.F.)	8	19	67	102	186	278
S D	0.255	0.344	0.261	0.254	0.276	0.172
Concentration in shells (mg/g)	1.0	1.2	1.6	1.4	1.6	1.6
Concentration factor (C.F.)	5	6	8	7	8	8
S D	0.104	0.096	0.072	0.055	0.070	0.092

Table 4: Mean bioaccumulation of Cadmium (3 mg/l) in the soft parts and shells of the bivalve *Caelatura (Caelatura) companyoi* as a function of time.

Immersion time (days)	1	2	5	10	15	20
Concentration in soft parts (mg/g)	0.33	0.96	1.56	2.64	2.58	2.64
Concentration factor (C.F.)	11	32	52	188	86	88
S D	0.085	0.076	0.114	0.062	0.140	0.137
Concentration in shells (mg/g)	0.21	0.24	0.3	0.3	0.27	0.3
Concentration factor (C.F.)	7	8	10	10	9	10
S D	0.306	0.144	0.092	0.315	0.023	0.602

Table 5: Mean bioaccumulation of Cadmium (3 mg/l) in the soft parts and shells of the gastropod snail *Cleopatra bulimoides* as a function of time.

Immersion time (days)	1	2	5	10	15	20
Concentration in soft parts (mg/g)	0.27	0.84	1.44	2.16	2.19	2.16
Concentration factor (C.F.)	9	28	48	72	73	72
S D	0.115	0.179	0.380	0.605	0.378	0.713
Concentration in shells (mg/g)	0.15	0.15	0.18	0.18	0.21	0.21
Concentration factor (C.F.)	5	5	6	7	7	7
S D	0.323	0.356	0.405	0.793	1.117	1.503

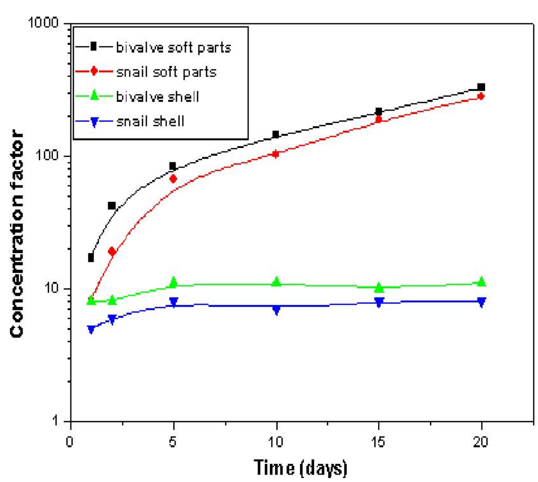

Fig.1: Mean concenteration factor of Chromium in soft parts and shell of the bivalve *Caelatura (Caelatura) companyoi* and the snail *Cleopatra bulimoides* as a function of time.

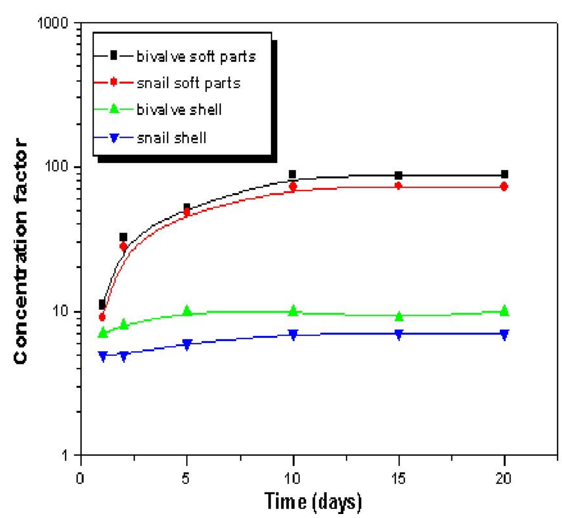

Fig. 2: Mean concenteration factor of Cadmium in soft parts and shell of the bivalve *Caelatura (Caelatura) companyoi* and the snail *Cleopatra bulimoides* as a function of time.

Fate of Cd and Cr

The toxic metals were accumulated mainly in the soft parts (more than 90%) while a small amount was adsorbed in the shells which was immediately released when the shells were immersed in 0.1M HCl for 5 minutes.

Toxicity of Cd and Cr (Figures 3-6)

Specimens of both bivalves and snails were subjected to different concentrations, from 1 to 20 mg/l in the case of cadmium and from 5 to 40 mg/l in the case of chromium. The estimated LC_{50} of Cd was 8.0 and 7.5 mg/l in the bivalve and snail, respectively. The corresponding values were 32.5 and 30.0 mg/l in the case of chromium. It could be concluded that cadmium is more toxic than chromium and that both investigated molluscs can tolerate higher concentrations of chromium than those of Cd.

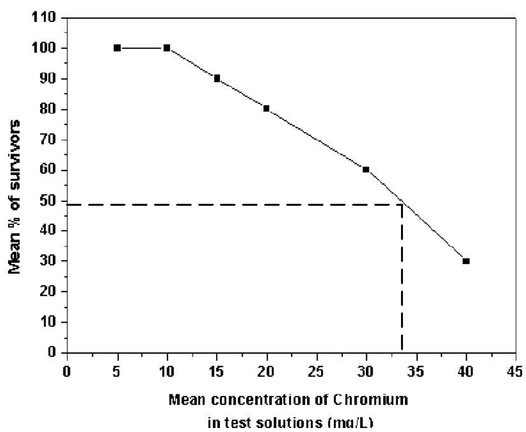

Fig.3: The mean estimated 7 days LC_{50} of Chromium for the mean percentage survivors of the bivalve *Caelatura (Caelatura) companyoi.*

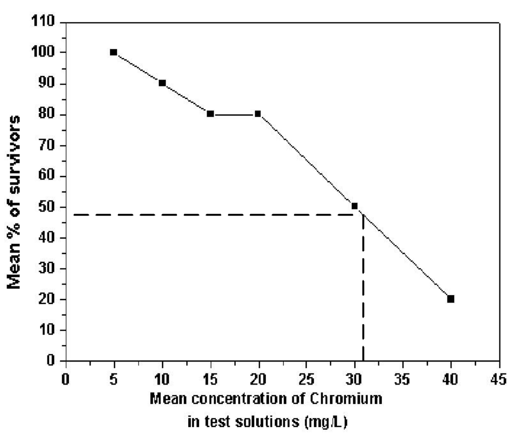

Fig.4: The mean estimated 7 days LC_{50} of Chromium for the mean percentage survivors of the snail *Cleopatra bulimoides*.

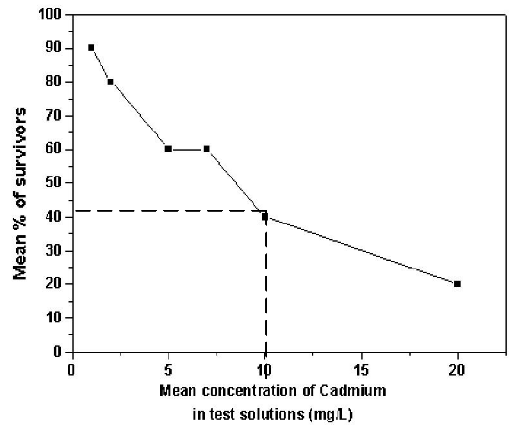

Fig.5: The mean estimated 7 days LC_{50} of Cadmium for the mean percentage survivors of the bivalve *Caelatura (Caelatura) companyoi.*

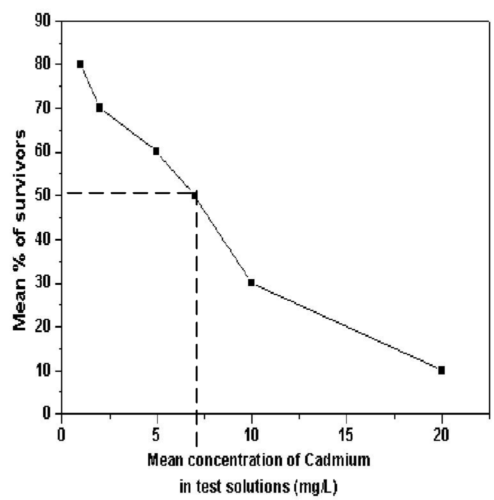

Fig. 6: The mean estimated 7 days LC_{50} of Cadmium for the mean percentage survivors of the snail *Cleopatra bulimoides.*

4. Discussion

In the present study, the freshwater molluscs *Caelatura (Caelatura) companyoi* and *Cleopatra bulimoides* were exposed to different concentrations of chromium and cadmium for twenty days in the laboratory to examine the effects of these heavy metals on their survival and their fate through their soft parts and shells. From the obtained results it is clear that the analysis of water and the investigated molluscs (soft parts and shells) from the field indicated that these organisms can accumulate Cd and Cr in high concentrations in their bodies, so they can be used as bioindicators for heavy metals pollution in aquatic ecosystems. This is in agreement with the studies of Lopez-Artiguez *et al.* (1989), Brown and Louma (1995) and Burgos and Rainbow (2001) on some bivalves. Results showed that cadmium is much more toxic than chromium. This agrees with the finding of Shivaraj and Patil (1985) on the freshwater fish *Lepidocephalichthys guntea* and of Cain and Louma (1986) and Ibrahim *et al.* (1997) on some bivalves.

The present work indicates that accumulations of Cd and Cr in the soft parts of the examined molluscs increase as their concentrations in their medium increase at various immersion time intervals. This is in agreement with the findings of EL-Deek *et al.* (1994) on fishes, Hook and Fisher (2002) on copepods and Buschiazzoa *et al.* (2004) on oysters. Moreover, Hemelraad *et al.* (1986, 1990) reported that mortality of *Anodonta cygnea* due to Cd was low and not differing from a control group, for up to fifteen weeks, but strongly increased after the period.

Cadmium and chromium are very toxic (FAO, 1983; UNEP, 1984). The investigated bivalves and snails can tolerate and accumulate them to a great extent. Similar observations were given for other molluscs (Hemelraad and Zandee (1986); Hemelraad *et al*. (1990) and Brown and Louma, 1995).

Many workers found that the accumulation patterns of heavy metals are dependent on both uptake and elimination rates (Hakanson, 1984, Gomaa *et al.,* 1995). The pattern of both heavy metals accumulation in the present test animals was nearly similar. Some workers demonstrated that bivalves accumulate more cadmium than crustaceans and much more than fish (Howard and Nickless, 1977). Moreover, bivalves and other molluscs were found to be critical groups in the biological transport (Engel and Fowler, 1979, Frazier, 1979). Bivalve molluscs were also reported to withstand remarkably high metal concentrations in their environment. Cadmium, Zinc, Nickel, Copper, Lead and Mercury are accumulated to high tissue levels in both freshwater and marine mussels (Zadory, 1984; Hemelraad *et al.,* 1986 and 1987).

Conclusion

It could be concluded that the bivalve *Caelatura (Caelatura) companyoi* and the snail *Cleopatra bulimoides* could be considered as good bioindicators for pollution of heavy metals in aquatic ecosystems.

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