ASSESSMENT OF CADMIUM AND LEAD IN WATER, SEDIMENT AND DIFFERENT ORGANS OF *PROCAMBARUS CLARKII* (GIRARD, 1852) IN THE RIVER NILE

K. EL-SHAIKH*
A. S. NADA**
Z. A. YOUSIEF*

SUMMARY: Cadmium and lead were assessed in water, sediment and some organs (exoskeleton, gills, digestive glands and muscles) of crayfish, Procambarus clarkii (Girard, 1852), in four areas (I: Gezyrat El-Warrak, II: Manial Sheeha, III: Al-Hawamdia and IV: Helwan) along the River Nile at Great Cairo, Egypt. Samples of water, sediment and P. clarkii collected and analyzed by atomic absorption spectrophotometer. The present results showed that the concentration of Cd was markedly lower in water while the concentration of Pb was higher in areas II, III and IV, respectively (p< 0.001), in comparison to area I (control area). The concentration of Cd in sediment increased while it decreased in case of Pb in the three studied areas in comparison to control. The highest bioconcentration factor (BCF) of Cd in four organs observed in area IV while the highest BCF of Pb observed in area I. This study shows that the lowest concentrations of Cd and Pb were in the crayfish muscles in comparison to the exoskeleton, gills, and digestive gland. Also, these results indicate that the analysis of Cd and Pb in different organs of P. clarkii might be a useful as a bioindicator for trace metals pollution in the freshwater system, due to their ability to rapidly accumulate and retain them in their tissues for long periods of time.

Key words: Procambarus clarkii, cadmium, lead, water, sediment, body organs.

INTRODUCTION

Procambarus clarkii is one of the most abundant and commercial crustacean species allover the world (22). Since the introduction of the red swamp crayfish *P. clarkii* in the early 1980s, from the United States of America into the Egyptian freshwater systems for aquaculture, it has been rapidly expanded in all aquatic ecosystems including streams, ponds, and marshes with polluted or clean waters.

The River Nile exposed to many kinds of chemical and biological pollutants in addition to the remains of agriculture wastes and dead animals that are deposited in it. Along the Nile course, it receives about 37 main drains discharging municipal agricultural and industrial waste water (3). The primary source of heavy metals in irrigation and drainage canals is the discharge of domestic waste waters which contain fairly high concentrations of metals such as copper, iron, lead and zinc, which are derived from household products such as cleaning materials, toothpaste, cosmetics and human faeces (40). Also, there are additional quantities introduced from industrial wastes illegally into

*From Department of Zoology, Faculty of Science, Helwan University, Ain Helwan, Cairo, Egypt.
**From Atomic Energy Authority, National Center for Radiation and Technology, Ain Helwan, Cairo, Egypt.

canals (4) and washings of herbicides and pesticides of the agricultural land.

Some heavy metals such as zinc, copper, manganese, and iron are essential for the growth and well being of living organisms including man. However, they are likely to show toxic effects when organisms are exposed to levels higher than normally required. Other elements such as lead and cadmium are not essential for metabolic activities and exhibit toxic properties. Thus, the aim of the present study was conducted to assess the accumulation of Cd and Pb in the Nile water and sediment, and different animal tissues like exoskeleton, digestive glands, muscles and gills of crayfish, *P. clarkii* collected from different areas along the River Nile.

MATERIALS AND METHODS

Sample collection

Samples of the crayfish *P. clarkii*, water, and sediments were collected from four different areas of the River Nile. Gezyrat El-Warrak (Area-I), Manial Sheeha (Area-II), Al-Hawamdia (Area-III) and Helwan (Area-IV) at Great Cairo, Egypt, were the areas selected for this study. The specimens were collected during the period from May to September 2001.

Water was sampled using Ruttner-sampler at a depth of 0.5 meter. Sediment samples were taken with core sampler (diameter, 6.4 cm). Three sediment replicate samples from each site were combined. Water and sediment samples were collected from the same location where the crayfish were collected.

Experimental design

Samples of *P. clarkii* were collected and transported immediately alive to the laboratory, where they were dissected. Exoskeleton, digestive glands, muscles, and gills were removed and refrigerated at -20°C till analyzed by atomic absorption spectrophotometer.

Different samples were weighed and then digested in concentrated pure nitric acid (65%, S.G. 1.42) and hydrogen peroxide in 4:1 ratio (23). Sample digestion was carried out with acids, at elevated temperature and pressures by using Microwave Sample Preparation Lab station, MLS-1200 MEGA. The selected elements were estimated quantitatively by using SOLAR System Unicam 939 (AAS), equipped with a deuterium background correction, fitted with GFTV accessory, a SOLAR GF 90, Graphite Furnace and SOLAR FS 90 plus Furnace Autosampler (Atomic Energy Authority, National Center for Radiation and Technology, Atomic Absorption Lab, Central Labs).

Bioconcentration Factor (BCF) calculated as the ratio of the concentration of the metal in the selected tissue to the concentration in water (39).

RESULTS

Cadmium (Cd)

The results obtained from the water analysis showed that the concentration of Cd was markedly lower by 53.57, 55.87, and 64.98% in areas II, III and IV, respectively ($p< 0.001$), in comparison to area I, which considered as a control area (Figure 1a). Significant increases (76.18, 77.89 and 182.2%) in the concentration of Cd in the Nile sediment were observed in areas II, III and IV, respectively as compared to area I (Figure 1b).

The concentration of Cd in exoskeleton increased significantly (27.2 and 62.4%) in areas II and IV respectively while it very slightly decreased (4.95 %) in area III as compared to area I (0.202 ng/g fresh tissue) (Figure 1c). The concentration of Cd in gills increased significantly (194.5%) in area IV while it decreased in area II (17.9%) and area III (42.9%) as compared to area I (0.273 ng/g fresh tissue) (Figure 1d). The lowest percentages of decrease (40.2 and 50.7%) in Cd concentration in hepatopancreas observed in areas II and III respectively in comparison to control area (0.306 ng/g fresh tissue) (Figure 1e). The concentration of Cd in muscles decreased insignificantly in all studied areas in comparison to area I (0.239 ng/g fresh tissue) (Figure 1f).

The bioconcentration factor of Cd in the different organs of the animal are shown in Figure 2a-d. The exoskeleton of the animal showed the highest BCF value in area IV followed by areas II, III and I, respectively. The highest BCF value in the gills was observed in area IV followed by areas II, III and I, respectively. The hepatopancreatic BCF value decreased in the following order: Area IV > II > III > I, respectively. As regards the concentrations of Cd in the muscles of *P. clarkii*, the BCF of muscles was in the following order: Area IV > II > III > I, respectively.

Lead (Pb)

Water analysis showed that the concentrations of Pb were markedly higher by 146.1, 300.1 and 218.8% in areas II, III and IV, respectively ($p<0.001$) in comparison to area I (Figure 1a). Highly significant decreases (81.5 and 74.35%, $p<0.001$) in the concentration of Pb in the Nile sediment were observed in areas III and IV, respectively, whereas the concentration of Pb in area II was more or less, the same as that of area I (Figure 1b).

Figure 1: Cadmium and Lead concentrations expressed as ng/ml in water (a), ng/g in sediment (b) and ng/g wet tissue in each of exoskeleton (c), gills (d), digestive glands (e) and muscles (f) of *P. clarkii* in the different areas of the investigation. All levels of significance are calculated as compared to area-I (control area). (*p<0.05 ,**p< 0.01 and ***p<0.001).

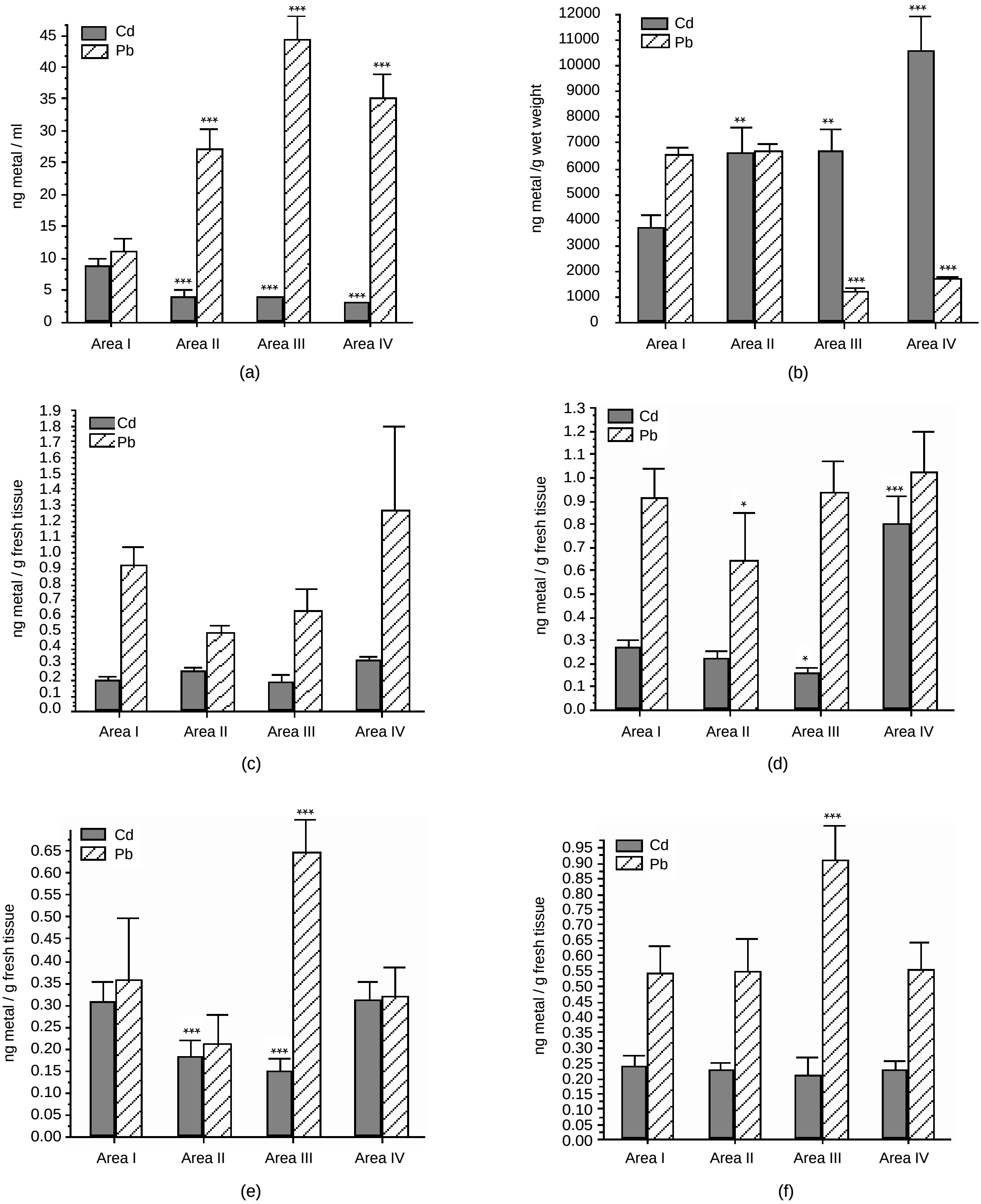
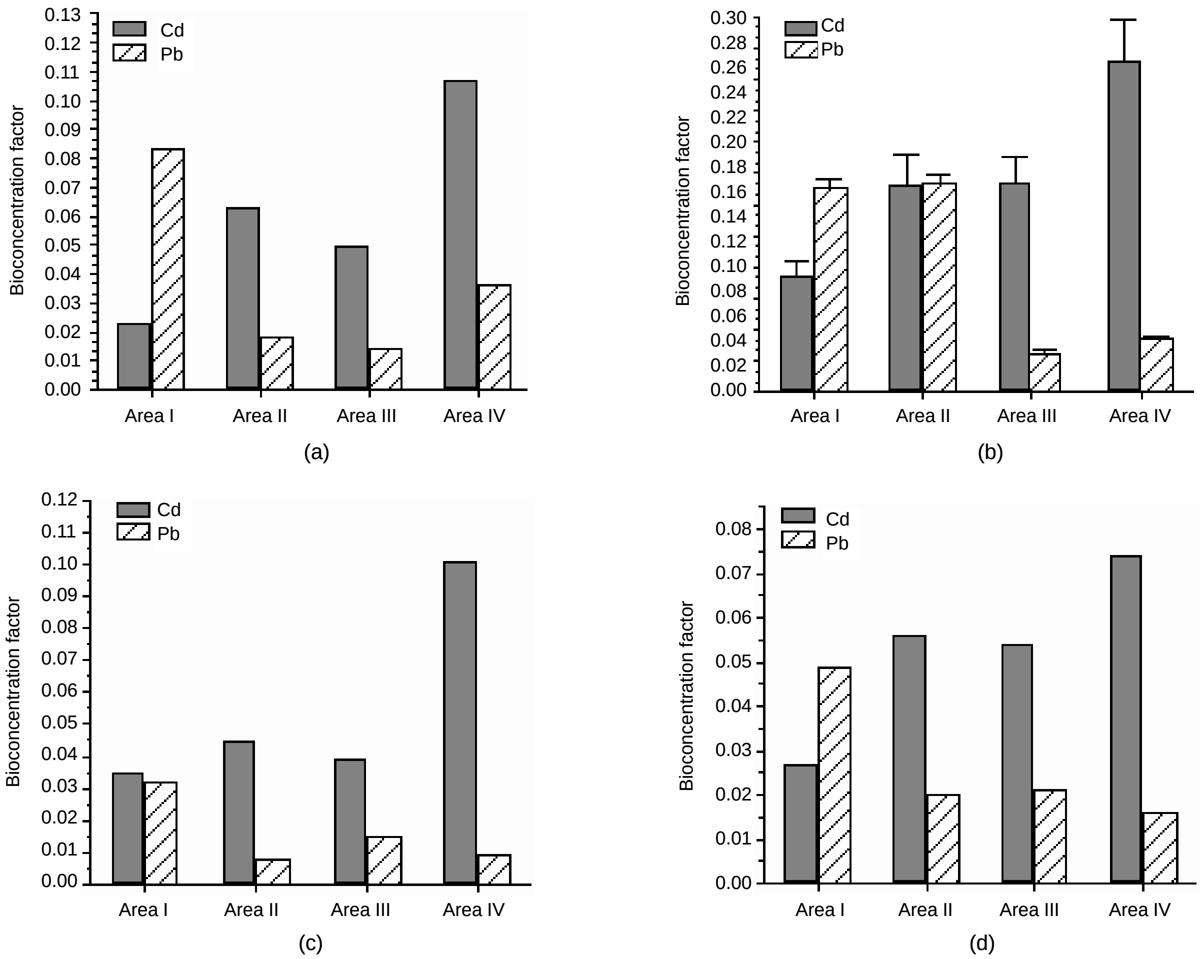


Figure 2: Bioconcentration factor of Cadmium and Lead in each of exoskeleton (a), gills (b), digestive glands (c) and muscles (d) of *P. clarkii* in the different areas of the investigation (Area I: Gezyrat El-Warrak, area II: Manial Sheeha, area III: Al-Hawamdia and area IV: Helwan).



The present study showed that the concentration of Pb in exoskeleton decreased insignificantly (45.5 and 30.6%) in areas II and III while slightly increased (37.1%) in area IV as compared to area I (0.921 ng/g fresh tissue) (Figure 1c). The concentration of Pb in gills decreased significantly (29.1%) in area II while it very slightly increased in areas III and IV respectively as compared to area I (0.911 ng/g fresh tissue) (Figure 1d). A slight decrease (40.9 and 10.3%) in Pb concentration observed in areas II and IV while a marked increase (80.5%) observed in area III as compared to area I (0.359 ng/g fresh tissue) (Figure 1e). A marked increase (68.2%) in the concentration of Pb observed in area III while area II and IV showed no change in Pb concentration as compared to area I (0.541 ng/g fresh tissue) (Figure 1f).

The bioconcentration factor of Pb in the different organs of the animal are given in Figure 2a-d. The exoskeleton of the animal revealed the highest BCF of Pb in area I followed by areas IV, II and III, respectively. The highest BCF value in the gills was observed in area I then followed by areas IV, II and III, respectively. The hepatopancreatic BCF was in the following order: Area I > III > IV > II, respectively. The BCF of muscles showed the following order: Area I > III > II > IV, respectively.

DISCUSSION

The maximum mean values expressed as μg/ml of the measured metals in the Nile water were as follows: 0.009 for Cd and 0.044 for Pb. It is obvious that the levels of Cd and Pb are within the permissible limits (Cd: 0.01

mg/l and Pb: 0.05 mg/l) according to USEPA (43) and the Egyptian Laws (24).

It was found that the concentrations of Cd and Pb in the current study showed higher values than those reported by El-Rayis and Saad (16). Many authors estimated the concentrations of variant heavy metals along the River Nile in Egypt (15,33) and concluded that the differential concentrations of metals in water depend on the seasonal variations and the types of discharges.

Moreover, the obtained results in the present investigation indicate that the concentration of metals in the River Nile sediment reveal different patterns of concentrations according to their abundance in water. Hamed (20) reported that the sediment acts as a reservoir for all the contaminants and dead organic matter descending from the ecosystem above. Abdel-Baky *et al.* (2) found a correlation between the concentration of heavy metals and the abundance of organic matter. Hickling (21) reported that the broken-down organic matter exists as "humus" which behaves like an organic compound of high molecular weight. Humus acts as a weak acid and a weak base. Sediment with large amounts of humus has high colloidal content and has a very high adsorption capacity. It can strongly adsorb phosphate and different anions and cations.

When compared to other results obtained from other aquatic environments in Egypt, the present data show that the concentrations of Pb and Cd in the sediment of the studied areas are higher than those reported by Zyadah (46) in different locations of the River Nile at Damietta Governorate, Zyadah (47) in areas with intensive fish culture at Damietta Province and Abdel-Baky *et al.* (2) in different sites of the middle, western and eastern regions of Lake Manzala. Zyadah (48) reported very high levels of Cd (47.8 ppm dry wt.) and Pb (24.1 ppm dry wt.) in comparison with the results of the present investigation on the sediment taken from El-Borg and Hamido regions of the River Nile at Damietta city.

Generally, crustaceans accumulate some metals in direct proportion to the increase in the bioavailability from water and food chains (34). Many decapods can regulate their tissue and body burdens of heavy metals effectively (35). Naqvi and Howell (28) reported that the crayfish could accumulate cadmium, lead, and arsenic rapidly.

The gills are in contact with the external medium and are considered responsible for metal transfer to organism and this therefore could explain the high metal concentration in this organ. Accordingly, Anderson (6) found that gills were the most important site of lead accumulation when *Oreconectes virilis* was exposed to several concentrations of lead. It was found that the highest lead concentration was in the gills and antennal glands of *P. clarkii* and the lowest was in the hepatopancreas and muscles (13,32). Tulasi *et al.* (42) showed that the lead content in the gills was much higher than that in muscles and midgut gland of crabs after four days of lead exposure.

Significant bioaccumulation of lead was observed in the hepatopancreas and gills of 7-day-exposed *P. clarkii*, whereas chromium accumulated the most in the gills and blood (5). Meyer *et al.* (27) reported that lead accumulated in high amounts of the crayfish *Astacus astacus*, especially in the digestive gland, carapace, and gills, whereas the hindgut and musculature exhibited very low lead levels, while cadmium accumulated particularly in the digestive gland and gills.

The digestive gland plays an important role in heavy metal metabolism and contributes to their detoxification (44). Granules of pyrophosphate containing metals were reported in digestive glands of many invertebrates, including bivalves (19) and cirripeds (45). In the garden snail *Helix adspersa* these pyrophosphate granules have been described to scavenge metals and detoxify them (38).

Pastor *et al.* (32) reported that the highest percentage of Pb accumulation (90%) was present in the gills of *P. clarkii* whereas the lead content in other tissues such as hepatopancreas and muscle was less than 1%. Lead and Cd were accumulated in high amounts especially in digestive gland and gills after exposure of the crayfish *Astacus astacus* to low-level of Pb and Cd (27). The accumulation of Cd in crayfish could be attributed to the presence of Cd-binding proteins in the mid-gut gland of *P. clarkii* and *Austropotamobius pallipes* (12,25).

It has been shown that lobster *Homarus americanus* can accumulate high concentrations of heavy metals (Cu, Cd, Zn and Ag) in the digestive gland and thus is a good indicator for monitoring changes in environmental metal levels (11,29).

The present study shows that the lowest concentrations of Cd and Pb were in the crayfish muscles in comparison to the exoskeleton, gills, and digestive gland. These findings are in agreement with other studies on the freshwater and marine decapods and other crustaceans (9,32,42). Anderson *et al.* (5) reported no metal accumulation in the abdominal muscle of the crayfish after placing it, for 7-days, in water receiving petroleum-laden effluents.

Abdel-Baky and Zyadah (1) reported that the liver and gills of marine fishes collected from Lake Manzala in Egypt had higher tendency to accumulate heavy metals more than muscles. Several authors reported that fish muscle tissue is generally low in trace metal content (14,24,30,36).

The recommended permissible levels of Cd and Pb in fish tissues for human consumption were 0.5 mg/kg dry wt. for Cd (17,26,31) and 0.5-2.0 mg/kg dry wt. for Pb (8,10,17). Also, the permissible levels of Cd and Pb in the shellfish *Macrobrachium sp.* were <0.10 mg/kg fresh weight for Cd and 4.36 mg/kg fresh weight for Pb (17). These results indicate that the analysis of Cd and Pb in various body parts of *P. clarkii* might be a useful as a bioindicator of trace metals pollution in the freshwater system, due to their ability to rapidly accumulate and retain them in their tissues for long periods of time. Similar findings were reported by many authors (7,28,37,41).

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Correspondence:
Zakaria A. Yousief
Zoology Department,
Faculty of Science,
Helwan University,
Ain Helwan, Cairo, EGYPT.
e-mail: zico_youssef@yahoo.com