Pakistan J. Zool., vol. 47(3), pp. 671-677, 2015.

Heavy Metal Concentrations in Tissues of the Shrimp *Penaeus semisulcatus* (De Haan, 1844) From Jazan, Southern Red Sea Coast of Saudi Arabia

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Abstract.- The aim of the present study was to determine levels of zinc, nickel, copper, lead, cobalt and cadmium, in gills, muscle tissue and exoskeleton of the shrimp *Penaeus semisulcatus*, caught from Jazan, southern Red Sea coast of Saudi Arabia, and to assess whether these metals are within permissible limits for human consumption. The analysis showed that occurrence of heavy metals were in the order Zn > Pb > Cd > Cu > Ni > Co in gills, Zn > Cu > Pb > Cd > Ni > Co in muscles and Zn > Pb > Cu > Ni > Cd > Co in exoskeleton. An overall ranking of average trace metal levels in the analyzed tissues resulted as gills > exoskeleton > muscles for Zn, Pb and Cd and; in case of Ni, Cu and Co the sequence was exoskeleton > muscle > gills. The highest mean Pb, Cd and Zn concentrations (21.33, 6.33 and 24.0 $\mu g\ g^{-1}$ wet weight, respectively) were found in gills samples, but the highest level of Ni, Cu and Co (3.0, 11.67 and 1. 36 $\mu g\ g^{-1}$, respectively) was observed in exoskeleton. The results revealed that the heavy metal concentrations (except Pb and Cd) in the shrimp *Penaeus semisulcatus* are below the threshold levels associated with the toxicological effects and the regulatory limits. This study is the first on the shrimp *Penaeus semisulcatus* in this area and data are important as a background for the estimation of the future impact of metal concentrations in this area.

Keywords: Heavy metals, *Penaeus semisulcatus*, Jazan, Red Sea, Saudi Arabia.

INTRODUCTION

Environmental pollution has increased substantially in the last decades due to a great number of industrial, agricultural, commercial and domestic waste, effluents and emissions as well as hazardous substances. Some heavy metals such as Hg, Cr, Cd, Ni, Cu, Pb etc. introduced into environmental water system may pose high toxicities on the aquatic organisms (Wu and Zhao, 2006; Ambreen *et al*., 2015). In order to evaluate the environmental impact of these pollutants on the marine ecosystem it has become important for a rapid assessment of their toxic effects on the marine organisms.

Shellfish is a major part of food, which supplies all essential elements required for life processes in a balanced manner (Iyengar, 1991). In Saudi Arabia, shrimp is a preferred food of numerous marine species including fish and other shellfish. Hence, it is important to investigate the levels of heavy metals in these organisms to assess whether the concentration is within the permissible level and will not pose any hazard to the consumers (Krishnamurti and Nair, 1999). The prawn *Penaeus semisulcatus* is one of the most common and commercially important shrimp in Jazan, Red sea. This species inhabits mud, sandy-mud or sandy- grit substrates on the continental shelf from the coastline to depths of about 130 m, but is most abundant in waters shallower than 60 m (Yu and Chan, 1986; Hayashi, 1992). *Penaeus semisulcatus* can form small shoals and is predominantly nocturnal, burying in the substrate in daytime. It is mostly fished at night-time, but is also fished by daytime in some areas (Holthuis, 1980).

The accumulation of metals in specific organs of marine shellfish has been proposed as a more sensitive and specific indicator of environmental contamination than whole body burdens (Ahn *et al*., 2001; Yap *et al*., 2006; Kavun and Podgurskaya, 2009). The goal of this study was to determine concentrations of zinc, nickel, copper, lead, cobalt

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0030-9923/2015/0003-0671 $ 8.00/0

and cadmium, in gills, exoskeleton and muscle tissue of the shrimp *Penaeus semisulcatus*, caught from Jazan, southern Red Sea coast of Saudi Arabia, and to assess whether the these concentrations are within the permissible level and will not pose any hazard to the consumers.

MATERIALS AND METHODS

Study area

Jazan is one of the seven sea ports of the Saudi Arabia, situated in the southwestern region of the Saudi Arabia (16° 53' N and 42° 33' E). It is one of the largest fishing ports along the Saudi Arabian Red Sea. The city receives different types of pollutants from commercial trawling and motor boat engines. A free of cost ferry ride runs twice a day from Jazan Port, for which two ships are engaged. In addition, it receives different pollutants from shipping, operational spills of cargoes and fuel during loading and unloading of ships; accidental spills, dredging and construction, modification of coastline, intensive human activities and accumulation of shipwrecks and other garbage (Al Farraj, 2014). Moreover, Jazan is one of the Kingdom's richest agricultural regions. Consequently, its marine water receives a considerable amount of pollutants from agricultural land runoffs.

Sampling

Specimens of the shrimp species *Penaeus semisulcatus* (length of 12.84± 2.02 cm) were captured in depth 41-42 m from the study area using cast nets during a 1-week cruise in December 2013. Immediately after capture, specimens were stored at -18°C in clean polyethylene recipients and transferred to the laboratory and frozen -20°C until analyzed. The plastic materials used for storing and treating the samples were cleaned to avoid contamination of the samples with traces of any metal.

Laboratory and statistical analyses

Ten samples from the study prawn species were dissected to separate exoskeleton, gill and muscle tissues. Tissue samples were dried at 110°C for 48 h. Samples were transferred into a digestion flask containing 2 ml nitric acid and 1 ml perchloric acid (Merck) and digested at 120°C for 3 h. The digestion was diluted with distilled water appropriately in the range of standards which were prepared from stock standard solution of the metals (Merck). After dilution, metals concentrations were measured using a PerkinElmer AS 3100 flame atomic absorption spectrophotometer.

Concentrations of zinc (Zn), nickel (Ni), cobalt (Co), copper (Cu), cadmium (Cd) and lead (Pb) in muscle, exoskeleton and gills tissue samples of each prawn specimen were analyzed in triplicate. One-way Analysis of Variance (SNK test) was applied to investigate differences in metal concentrations in tissues.

RESULTS AND DISCUSSION

Based on the results presented in Table I and Figure 1, an overall ranking of average trace metal levels in the analyzed tissues resulted as gills > exoskeleton > muscles for Zn, Pb and Cd and; in case of Ni, Cu and Co the sequence was exoskeleton > muscle > gills.

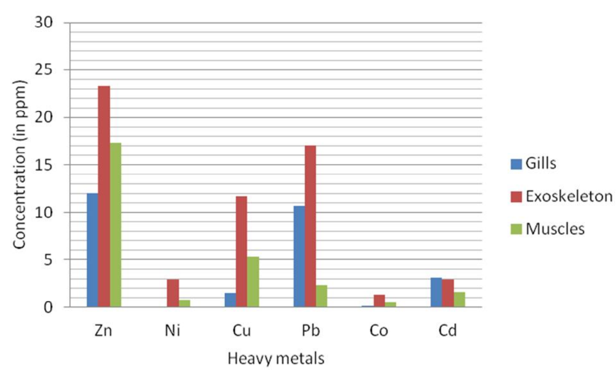

Fig. 1. Heavy metal concentrations (in ppm) in tissues of *P. semisulcatus* caught in December, 2013, from Jazan, Saudi Arabia.

Zn

Zinc is a naturally abundant element present as a common contaminant in agricultural, food wastes, manufacturing of pesticides as well as antifouling paints. Zinc plays an important role as an essential trace element in all living systems (Merian, 1991). However, it is an USEPA (United States Environmental Protection Agency) priority

Table I.- **Comparison of heavy metal concentrations in tissues of the prawn *Penaeus semisulcatus* collected from Persian Gulf, Iran, Iskenderun Bays Turkey, Qatar, Arabian Gulf, Dammam, Saudi Arabian Gulf and Jazan, Red Sea, Saudi Arabia.**

Metals	Iran, Persian Gulf (Heidarieh (*et al*., 2013)	Iskenderun Bay, Turkey (Firat *et al*., 2008)		Iran, Persian Gulf (Pourang *et al*., 2005)		Qatar, Arabian Gulf (Kureisy, 1993)	Dammam, Saudi Arabia, Arabian Gulf (Sadiq *et al*., 1982)	Jazan, Red Sea, Saudi Arabia (Present study)		
	Whole body	Muscles	Gills	Muscles	Exoskeleton	Muscles	Whole body	Muscles	Exoskeleton	Gills
Zn	68.73	27.75	576.1	8.977	8.559	-	148.89	17.33±2.08	23.33±5.03	24±7.81
Ni	-	ND	ND	-	-	0.97	-	0.8±0.26	3.1±1.0	0.67±0.32
Cu	-	34.24	665.3	3.418	12.130	2.4	-	5.33±0.58	11.67±2.05	3±1.0
Pb	-	-	-	-	-	1.10	-	2.33±0.57	17±4.0	21.33±2.08
Co	0.4	-	-	-	-	0.20	4.56	0.5±0.22	1.36±0.35	0.33±0.10
Cd	-	16.72	70.93	0.103	0.790	0.68	-	1.57±0.066	3±1.0	6.33±2.08

pollutant (Keith and Telliard, 1979). High levels of zinc concentration in water are particularly toxic to many species of algae, crustaceans, and salmonids (Leland and Kuwabara, 1985) and have especially strong effects on macroinvertebrates such as molluscs, crustaceans, odonates, and ephemeropterans (Gore and Bryant, 1986).

In the current study, the mean concentration of Zn in gills, exoskeleton and muscles (Fig.1) were 24.00, 23.33 and 17.33 ppm, respectively. In their study on green tiger shrimp of the northwestern of the Persian Gulf, Pourang *et al*. (2005) recorded the highest mean of Zn concentration (43.39 ppm/fresh weight) in hepatopancreas. They found the Zn levels in exoskeleton and muscle were 8.56 and 8.98 ppm/ wet weight, respectively.

However, the concentrations of Zn in the studied organism were below the risk international standards (40-100 with median 50 wet weight) given by United Nations Food and Agriculture Organization for Reference Dose (risk-based); United States Environmental Protection Agency (USEPA, 2004). Also, Zn levels in this study are below the maximum limits for prawn (1000 ppm) (FAO, 1992) and marine sea food (100 ppm) (WHO, 1989).On the other hand, Sadiq *et al*. (1982) recorded a level of Zn is148 ppm/dry shrimp whole body of the Arabian Gulf. This value is markedly higher than level obtained in the current study.

Ni

Nickel, which is quite abundant in the Earth's crust, enters surface waters from the dissolution of rocks and soils, from biological cycles, atmospheric fallout, and especially from industrial processes and waste disposal (Prego *et al*., 1999). De Carlo and Spencer (1995) showed that Ni and Co do not display trends indicative of large anthropogenic contribution to the sediments.

In the present study, it was found that concentrations of Ni (Fig. 1) were 0.76, 3.1 and 0.8 ppm in gills, exoskeleton and muscles, respectively. Ni concentrations in gills and muscles are well within the toxic limit of 70-80 mg kg^{-1} set by USFDA (1993) and the limit (1.00 µg g^{-1}) set by USEPA (2000). However, the present concentrations are within the permissible level of Ni in sea food, which is 0.5-1.0 ppm prescribed by WHO (1989) and will not pose any hazard to the consumers. Most striking is the relatively higher level of Ni (3 ppm) in exoskeleton. Moulting may influence metal concentrations and the distribution between soft tissues and exoskeleton (Pourang *et al*., 2004). It could be an effective way to eliminate the accumulated Ni from the body (Safahieh, 2007).

Cu

Copper plays a biological important role in the growth and life of most aquatic organisms. However, it may become toxic to the marine organisms if exceeds a specific threshold (Kennish, 1992). The input of copper into marine environment comes from different sources, including mining, smelting, domestic and industrial activities and from algaecides and antifouling paint on boat hulls (Fabrizio and Rodolfo, 2012). Copper is highly toxic in aquatic environments and has effects in fish, invertebrates, and amphibians, with all three groups equally sensitive to chronic toxicity (USEPA, 1993; Horne and Dunson, 1995).

Crustaceans, such as shrimp, lobster and crab, are in particularly need of Cu because its serves as an oxygen carrier in their blood (Rose and Bodansky, 1920). Everaarts and Nieuwenhuize (1995) noticed that Cu concentrations in crustaceans may be elevated (60 and 140 µg g-1) compared with other groups (polychaetes and molluscs) since many crustaceans use Cu in a blood pigment.

In the present study, values of Zn (Fig. 1) were 3 and 5.33 ppm in gills and muscles, respectively. These values were found below the permissible limit as prescribed by (30 ppm) WHO (1989) and (10 ppm) by FAO (1992) maximum limits for prawn. On the other hand, concentration of Cu in exoskeleton (11.67 ppm) is relatively higher than the permissible limit given by WHO (1989) and FAO (1992).

Pb

The high Pb concentration in the marine environment is attributed to several sources such as boat exhaust systems, oil spill, and other petroleum compounds from mechanized boats employed for fishing and sewage effluents discharged into water (Laxen, 1983), all of these sources exist in the studied areas. Atmospheric input of Pb that generated from the automobile exhaust emission also recorded in Jeddah area, Red Sea, which situated close to the high way and the cities roads (Badr *et al*., 2009). The atmospheric input is considered responsible for the introduction of Cd, Pb and Zn to the marine environment (Frignani *et al*., 1997).

In the present study, Pb levels (Fig. 1) were 21.33, 17.00 and 2.33 ppm in gills, exoskeleton and muscles, respectively. The lead levels recorded in the three organs exceeded the permissible limits of WHO (1984) which mentioned that lead level should not be more than 2 mg/Kg. Moreover, the concentration of Pb in the studied prawn were above the risk international standards (0.5-10.0 with median 2.0µg/g, wet weight) given by United Nations Food and Agriculture Organization for Reference Dose (risk-based); United States Environmental Protection Agency (USEPA, 2004). Jazan Port serves as a free travel lane to the Island of Farasan twice a day. This type of domestic transportation has caused considerable increase in Pd concentrations in sea water. This confirmed with the work of Al Farraj (2014) who stated that this type of domestic transportation has caused considerable increase in pollution level. In addition, antifouling paints of fishing boats also contain Pb as an important component.

Co

Cobalt is a natural element found throughout the environment. Anthropogenic sources to the environment include burning of fossil fuels, sewage sludge, phosphate fertilizers, mining and smelting of cobalt-containing ores and industrial processes that use cobalt compounds (Hodge and Dominey, 2001; IPCS, 2006). Cobalt has both beneficial and harmful effects on human health. It is beneficial for humans because it is a part of vitamin B_{12}, which is essential for human health. On the other hand, bioaccumulation of this metal may pose great hazard to health of humans. In shallow waters, up to 98% of the metal can be found in the sediments and in suspended particulate matter (Robertson *et al*., 1973).

In the present work, the mean values of cobalt in gills, exoskeleton and muscles of the prawn *Penaeus semisulcatus* (Fig. 1) were found to be 0.33, 1.36 and 0.50 ppm, respectively. Except in exoskeleton, the Co concentrations are similar to those reported for the Saudi Arabian Gulf *Penaeus semisulcatus* (4.411 µg g^{-1}; Sadiq *et al*., 1982).

Level of Cobalt in exoskeleton was found to be relatively higher than in gills and muscles. Much of the cobalt taken up by molluscs and crustaceans from water or sediment is adsorbed to the shell or exoskeleton; very little cobalt is generally accumulated in the edible parts (Amiard and Amiard-Triquet, 1979; Smith and Carson, 1981).

Cd

Cadmium is considerably toxic for both vertebrates and invertebrates alike (Elinder, 1983; Taylor, 1983). The International Agency for

Research on Cancer (IARC, 1993) classified cadmium as a human carcinogen. In particular, crustaceans appear to be more sensitive to cadmium than fish and mollusks (Sadiq, 1992). Cadmium which is a transition element conduct in the environment as a cumulative poison (Roy, 1997). Cd is listed by USEPA as one of 129 priority pollutants and among the 25 hazardous substances (Kong *et al*., 1995). It should not to be dumped into the sea, since it is included in the black list (Clark *et al*., 1997). The main source of Cd to the marine environment is mainly anthropogenic through the refinement and use of Cd, Cu and Ni smelting and atmospheric input (Kennish, 1996) in which most of these metals are deposited in bottom sediments (Clark *et al*., 1997). Cadmium in agriculture and industry has been identified as a major source of wide dispersion into the environment (Şireli *et al*., 2006).

In the present study, the levels of Cd (Fig. 1) were 6.33, 3.0 and 1.57 ppm in gills, exoskeleton and muscles, respectively. These values were found above the permissible limit (1.0 ppm) as prescribed by WHO (1989) and (0.2 ppm) by FAO (1992) maximum limits for prawn. In addition, the concentrations of Cd in the studied organisms were above the risk international standards (0.05-2.0 with median 0.3 wet weight) given by United Nations Food and Agriculture Organization for Reference Dose (risk-based); United States Environmental Protection Agency (USEPA, 2004). Agricultural activities (as in the study area) are likely to add important amounts of Cd to the natural levels. Fertilizers are important sources of Cd based agrochemicals which are widely used in intensive agriculture (Alloway, 1990).

The presence of substantial concentrations of cadmium in the exoskeleton of some decapod crustaceans (*e.g.*, the crayfish *Cambarus bartoni*) can be attributed to the involvement of this tissue in the excretion of these metals (Keenan and Alikhan, 1991).

CONCLUSIONS

The findings of this study suggest that metal concentrations were in the following descending order: Zn > Pb > Cd > Cu > Ni > Co in gills, Zn > Cu > Pb> Cd > Ni > Co in muscles and Zn > Pb > Cu > Ni > Cd > Co in exoskeleton. The highest mean Pb, Cd and Zn concentrations (21.33, 6.33 and 24.0 $\mu g\ g^{-1}$ wet weight, respectively) were found in gills, but the highest level of Ni, Cu and Co (3.0, 11.67 and 1.36 μg g-1 wet weight, respectively) was observed in exoskeleton. The results obtained revealed that the heavy metal concentrations (except Pb and Cd) in the shrimp *Penaeus semisulcatus* are below the threshold levels associated with the toxicological effects and the regulatory limits. Agricultural activities may be the reason of high level of Cd in Jazan; while the domestic transportation between Jazan Port and Farasan Island has caused considerable increase in Pd concentrations in sea water.

ACKNOWLEDGMENT

The authors wish to express their appreciation to the Deanship of Scientific Research at King Saud University for funding the work through the Research Group Program No. RG 1435-018.

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(Received 7 January 2015, revised 30 March 2015)