Bull Environ Contam Toxicol (2014) 93:339–343
DOI 10.1007/s00128-014-1334-2

Evaluation of the Bioaccumulation of Heavy Metals in White Shrimp (*Litopenaeus vannamei*) Along the Persian Gulf Coast

Maryam Dadar · Rahim Peyghan · Hamid Rajabi Memari

Received: 24 July 2013 / Accepted: 8 July 2014 / Published online: 17 July 2014

Abstract The concentrations of heavy metals in Persian Gulf are low, but petrochemical and refinery activities have caused an increase in heavy metal wastes, especially in coastal regions. The present study was done to determine the bioaccumulation of heavy metals in the muscle of white shrimp (*Litopenaeus vannamei*) using flame atomic absorption spectrophotometry. The experiment was conducted in four important coastal regions of the Persian Gulf: Bushehr, Deylam, Mahshahr, and Abadan. Amounts of seven heavy metals such as Copper (Cu), Iron (Fe), Lead (Pb), Zinc (Zn), Nickel (Ni), Cadmium (Cd), and Cobalt (Co), were measured as µg/g heavy metal in dry weight in the muscle of white shrimp from the afore-mentioned regions during 2011. This study revealed information that the primary risk for human health and the marine life chain was lead in the muscles of white shrimp in Mahshahr, where intense petrochemical and refinery activities are conducted. Concentrations of other heavy metals were lower than world standards.

Keywords Bioaccumulation · Heavy metals · White shrimp · Spectrophotometry

Persian Gulf (26°54′17.00″N, 51°32′51.00″E) is a body of water in the Middle East which bordered by Iran, Iraq, Kuwait, Saudi Arabia, Bahrain, Qatar, United Arab Emirates, and Oman. It is surrounded by the greatest oil reserves and has long been an important part of the global economy. Because of a variety of operations, such as oil exploration and industrial and agricultural activities, the marine environment has become contaminated with a wide range of pollutants, causing much concern over the last few decades (Amoozadeh et al. 2014). Because of petrochemical and oil industries which are the major sources of pollution, the matter of heavy metal contamination of aquatic organisms has become a field of study in environmental studies and toxicology (Hellou et al. 1992; Rahmanpour et al. 2014). Heavy metals enter the aquatic environment through sources such as anthropogenic activities which cause industrial effluents, domestic sewage, and mining wastes (Reddy and Chinthamreddy 1999; Wan Ngah and Hanafiah 2008). The discharge of these wastes without suitable treatment often contaminates the marine biota in fish, shrimp, oysters, and crabs (Mitra et al. 2010). In addition to the anthropogenic input, the largest natural sources of heavy metal are rock and solid elements (Soegianto and Irawan 2009). This is a vital requirement to adopt an environmentally maintainable management system to estimate the biological availability of environmental pollutants (Krishnamurti and Nair 1999; Dökmeci et al. 2014; Salahshur et al. 2014). The purpose of this study was to document the concentration of metals in the tissue of commercially valuable shrimp from the Persian Gulf. This survey also presents the distribution pattern and bioaccumulation of heavy metals in the Persian Gulf. Furthermore, hazardous heavy metal levels were compared to available certified safety guidelines proposed by the Food and Drug Administration (FDA), the National Academy of Science (NAS), the National Health Research Council (NHMRC), the Tasmania Public Health Regulation (TPHR), the Ministry of Agriculture Fisheries and Food (MAFF), the Food Standards Committee (FSC), the World Health

M. Dadar (✉) · R. Peyghan
Department of Aquatic Animal Health, College of Veterinary Medicine, Shahid Chamran University, Ahvaz, Iran
e-mail: dadar.m77@gmail.com

H. R. Memari
Center of Biotechnology Research, College of Agriculture, Shahid Chamran University, Ahvaz, Iran

Fig. 1 Shrimp collection sites in the Persian Gulf. *Black arrows* show Bushehr, Deylam, Mahshahr and Abadan in border line ports of Persian Gulf

Organization (WHO), and the Food and Agricultural Organization (FAO).

Materials and Methods

Four different stations along the coast of the Persian Gulf (Fig. 1) were selected, namely Bushehr (28.9833° N, 50.8167° E), Deylam (30.0539° N, 50.1572° E), Mahshahr (30.5500° N, 49.1833° E), and Abadan (30.3472° N, 48.2917° E). Up to twenty individual shrimp of commercial size (20–23 g) were collected in each sampling to analyze the concentrations of heavy metals in their muscles. The collected samples were stored in crushed ice and brought to the laboratory where they were rinsed with distilled water. The shells and legs were removed and the abdomens were separated from the cephalothorax and tail and stored at −20°C until processing for metal analysis. Similarly sized specimens of each group were analyzed for heavy metal content in the muscles.

All samples were washed with HCL(Moody and Lindstrom 1977). Then, the muscles of white shrimp were dried in an oven at 105°C and finely ground separately. The tissue was measured using Walkey-Black titration (Walkley and Black 1934), and heavy metal concentrations were measured with the standard addition method (Frías-Espericueta et al. 2006; Paez-Osuna and Tron-Mayen 1995). 100 mg dried ground sample was digested in 5 mL concentrated nitric acid at 135°C for 4 h. Subsequently, 1 mL hydrogen peroxide (30 %) and 1 mL concentrated perchloric acid were added to previous solution, and the solution was incubated at 150°C (6 h) until clear and all particles had turned white color (Wu and Yang 2011; Zhou et al. 1998). Digested samples were filtered and diluted with high purity deionized water at a ratio of 1:5 prior to being analyzed with flame atomic absorption spectrophotometry. Samples were analyzed in triplicate, and the results were collected on a dry weight basis using an atomic absorption spectrometer (Perkin-Elmer Model-Analyste 300) equipped with a microcomputer-controlled acetylene flame.

Analysis of variance (ANOVA) was used to identify any significant differences between the various parameters. Statistical significance was defined as $p < 0.05$. The data was analyzed using SPSS software version 13.0.

Result and Discussion

The concentrations of heavy metal in the muscle of white shrimp are shown in Table 1. The results of this study indicated that concentrations of Copper, Zinc and Lead in Mahshahr and Iron in Abadan and Nickel in Deylam had the highest concentrations in heavy metal. Cadmium and cobalt in all the locations had very negligible concentrations. Nickel in Mahshahr, lead in Deylam, and copper in Abadan and Bushehr had the lowest concentrations (Table 1).

In Mahshahr station, the concentrations of copper and lead were significantly higher than in those from the other places ($p < 0.05$). Also, the concentrations of Iron were significantly higher in Abadan than in other regions ($p < 0.05$). Other heavy metals in another ports had no significant differences ($p < 0.05$). All heavy metal concentrations in shrimp muscle from different areas were below standard levels except the concentration of lead in the Mahshahr. A comparison of heavy metal concentrations in different ports of the Persian Gulf is shown in Fig. 1. The order of heavy metal concentrations in shrimp muscles were Cu > Pb > Fe > Zn > Ni > Cd, Co respectively

Table 1 Level and standard deviation of heavy metals in seawater from different marine ecosystems in the Persian Gulf (μg/g)

Different ports in Persian gulf	Copper mean ± SE	Iron mean ± SE	Nickel mean ± SE	Lead mean ± SE	Zinc mean ± SE	Cadmium	Cobalt
Mahshahr	4.14 ± 0.65	0.95 ± 0.1	0.29 ± 0.17	2.54 ± 0.32	0.48 ± 0.1	NS	NS
Deylam	0.95 ± 0.24	1.48 ± 0.10	0.39 ± 0.10	0.01 ± 0.02	0.46 ± 0.12	NS	NS
Abadan	0.19 ± 0. 1	1.98 ± 0.2	0.31 ± 0.01	0.59 ± 0. 2	0.47 ± 0.1	NS	NS
Bushehr	0.06 ± 0.01	0.62 ± 0.10	0.38 ± 0.01	0.33 ± 0.10	0.34 ± 0.14	NS	NS

NS below detection limit, Limits of detection of measurements are 0.09 mg kg d.w. for Cd, 0.3 mg kg^{-1} d.w. for Pb and 0.09 mg kg^{-1} d.w. for Co

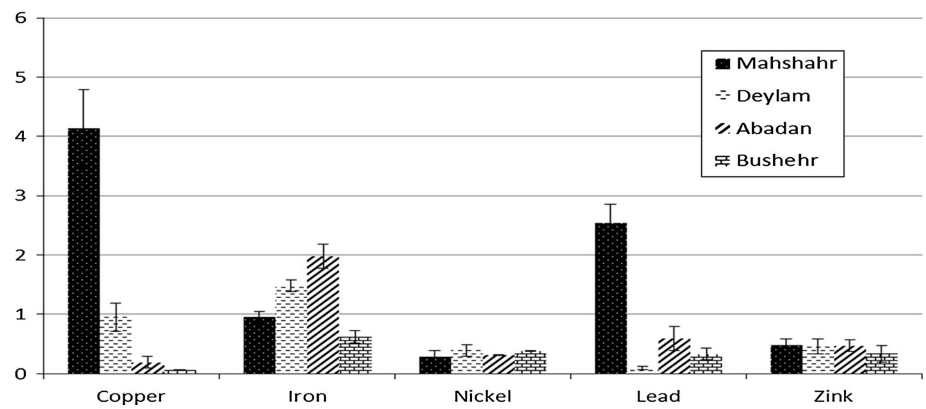

Fig. 2 Comparison of heavy metals in shrimp muscles in different ports of Persian Gulf

(Figs. 1 and 2), and the records of concentrations are summarized in Table 1. These heavy metal concentrations were compared to seafood standards set by world organizations, including the FDA, the WHO, and the FAO (Huang 2003; Kumar et al. 2012).

The lead (Pb) concentration in Mahshahr was much higher than that in other regions, and it was above seafood standards set by world organizations. Despite the importance of marine life and seafood resources in the Persian Gulf, relatively little data is available on the flux and distribution of environmental marine pollutants and their effects on marine organisms. The contamination of aquatic systems with a wide range of pollutants has become a matter of concern over the last few decades (Vutukuru 2005). Aquatic animals, part of the food chain, can be contaminated by heavy metals (Perugini et al. 2014). The toxicity and capacity of heavy metal accumulation in the biota are serious problems for human health and ecosystem safety. We found that the concentrations of Cu are higher than other metals (Pb, Fe, Zn, Ni, Cd, and Co) in shrimp, which these results are similar to (Sadiq et al. 1982). Different aquatic organisms from other marine environments of the world have also been exposed to heavy (Paez-Osuna and Tron-Mayen 1995; Carbonell et al. 1998; Hossain and Khan 2001; Kádár et al. 2006; Badejo et al. 2010; Wu and Yang 2011; Dökmeci et al. 2014). The levels of heavy metals in shrimp muscles in this report were relatively lower than those of other regions in the world except the lead concentration, which had the highest concentration in Mahshahr. Mahshahr Industrial Zone has one of the biggest petrochemical complexes in the Middle East (Nabavi et al. 2013). Variations in heavy metal concentrations among the samples could have been dependent on factors such as size categories, ecological zones, and trophic levels (Rainbow 1995; Canli and Atli 2003; Soegianto and Irawan 2009; Nabavi et al. 2013). The concentrations of heavy metal may be dependent on species, feeding habits, the bioconcentration capacity of each species, or ecological zone(Kwok et al. 2014). In many studies, increasing amounts of heavy metal accumulation in aquatic organisms have been linked to urbanization, agriculture, oil activities, and anthropogenic sources. The lowest Pb concentration was found in Deylam station. There is no industrial activity near this region. Which is relatively remote area compared to other station. Thus, it seems reasonable that Abadan and Mahshahr, both of which have intense industrial activity, would have more heavy metal pollution. The concentrations of other metals in shrimp muscle were generally lower than those in current world standards (Huang 2003; Kumar et al. 2012). This study found that the white shrimp (*Litopenaeus vannamei)* from Bushehr, Deylam, and Abadan are safe for human consumption. Significant variations were found between locations for Fe, Cu, and Pb ($p < 0.05$). Fe and Cu are classified as essential elements and can be toxic when the amounts ingested increase (Uluozlu et al. 2007), but they are lower than the recommended standard maximum levels. This study shows new information on the distribution of metals in white shrimp along Persian Gulf. The results showed different results of metals rather than previous studies in these areas(Nabavi et al. 2013; Heidari et al. 2013). According to other reviews, the measurement of heavy metals in aquatic organism tissue as a water quality indicator could be more reliable than water chemical analysis (Teodorovic et al. 2000; Abdullah et al. 2007; Türkmen et al. 2008; Mokhtar et al. 2009; Hendriks et al. 1995). The shrimp market in Iran is dependent upon shrimp farming and harvesting from these regions. Therefore, it is strongly recommended that a monitoring system be deployed, especially in polluted areas. Stricter regulations for shrimp harvesting and farming could satisfy health and safety considerations in the shrimp market. The high, hazardous levels of lead pollution in the shrimp of Mahshahr are alarming for authorities, since lead in the human body tend to cause deadly diseases.

Acknowledgments Authors are highly thankful to Petroleum University of Omidiyeh and University of Shahid Chamram for support to conduct this study.

References

Abdullah M, Sidi J, Aris AZ (2007) Heavy metals (Cd, Cu, Cr, Pb and Zn) in meretrix roding, water and sediments from estuaries in Sabah, North Borneo. Int J Environ Sci Edu 2(3):69–74

Amoozadeh E, Malek M, Rashidinejad R, Nabavi S, Karbassi M, Ghayoumi R, Ghorbanzadeh-Zafarani G, Salehi H, Sures B (2014) Marine organisms as heavy metal bioindicators in the Persian Gulf and the Gulf of Oman. Environ Sci Pollut Res 21(3):2386–2395

Badejo A, Adeyemo O, Ojo S (2010) Seasonal levels of essential metals in fresh and fried marine shrimp and fishes from lagos lagoon, Nigeria. Int J Environ Sci 1(4):454–461

Canli M, Atli G (2003) The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. Environ Pollut 121(1):129–136

Carbonell G, Ramos C, Tarazona J (1998) Metals in shrimp culture areas from the Gulf of Fonseca, Central America. I. Sediments. Bull Environ Contam Toxicol 60(2):252–259

Dökmeci A, Yildiz T, Ongen A, Sivri N (2014) Heavy metal concentration in deepwater rose shrimp species (Parapenaeus longirostris, Lucas, 1846) collected from the Marmara Sea Coast in Tekirdağ. Environ Monit Assess 186(4): 2449–2454

Frías-Espericueta M, Osuna-López J, Voltolina D, Correa-González E, Armenta-Monje M, López-López G, Izaguirre-Fierro G (2006) Metals in shrimp farm sediments, sinaloa, northwest Mexico. Bull Environ Contam Toxicol 77(6):912–917

Heidari B, Riyahi Bakhtiari A, Shirneshan G (2013) Concentrations of Cd, Cu, Pb and Zn in soft tissue of oyster (*Saccostrea cucullata*) collected from the Lengeh Port coast, Persian Gulf, Iran: a comparison with the permissible limits for public health. Food Chem 141(3):3014–3019

Hellou J, Warren W, Payne J, Belkhode S, Lobel P (1992) Heavy metals and other elements in three tissues of cod, *Gadus morhua* from the Northwest Atlantic. Mar Pollut Bull 24(9):452–458

Hendriks A, Ma W-C, Brouns JD, de Ruiter-Dijkman E, Gast R (1995) Modelling and monitoring organochlorine and heavy metal accumulation in soils, earthworms, and shrews in Rhine-delta floodplains. Arch Environ Contam Toxicol 29(1):115–127

Hossain MS, Khan YSA (2001) Trace metals in penaeid shrimp and spiny lobster from the Bay of Bengal. Sci Asia 27:165–168

Huang W (2003) Heavy metal concentrations in the common benthic fishes caught from the coastal waters of eastern Taiwan. J Food Drug Anal 11(4):324–330

Kádár E, Costa V, Santos RS (2006) Distribution of micro-essential (Fe, Cu, Zn) and toxic (Hg) metals in tissues of two nutritionally distinct hydrothermal shrimps. Sci Total Environ 358(1): 143–150

Krishnamurti AJ, Nair VR (1999) Concentration of metals in fishes from Thane and Bassein creeks of Bombay, India. Indian J Mar Sci 28:39–44p

Kumar B, Sajwan K, Mukherjee D (2012) Distribution of heavy metals in valuable coastal fishes from north east coast of India. Turk J Fish Aquat Sci 12:81–88

Kwok C, Liang Y, Wang H, Dong Y, Leung S, Wong M (2014) Bioaccumulation of heavy metals in fish and Ardeid at Pearl River Estuary, China. Ecotoxicol Environ Saf 106:62–67

Mitra A, Mondal K, Banerjee K (2010) Concentration of heavy metals in fish Juveniles of Gangetic Delta of West Bengal, India. J Fish Hydrobiol 5(1):21–26

Mokhtar MB, Aris AZ, Munusamy V, Praveena SM (2009) Assessment level of heavy metals in *Penaeus monodon* and Oreochromis spp in selected aquaculture ponds of high densities development area. Eur J Sci Res 30:348–360

Moody JR, Lindstrom RM (1977) Selection and cleaning of plastic containers for storage of trace element samples. Anal Chem 49(14):2264–2267

Nabavi SMB, Parsa Y, Hosseini M, Nabavi SN (2013) Assessment of heavy metal concentration (Fe, Ni, Cu and Hg) in sediment from North of Persian Gulf, Mahshahr Coast. World Appl Sci J 28(5):718–721

Paez-Osuna F, Tron-Mayen L (1995) Distribution of heavy metals in tissues of the shrimp Penaeus Californiensis from the northwest coast of Mexico. Bull Environ Contam Toxicol 55(2):209–215

Perugini M, Visciano P, Manera M, Zaccaroni A, Olivieri V, Amorena M (2014) Heavy metal (As, Cd, Hg, Pb, Cu, Zn, Se) concentrations in muscle and bone of four commercial fish caught in the central Adriatic Sea, Italy. Environ Monit Assess 186(4):2205–2213

Rahmanpour S, Ghorghani NF, Ashtiyani SML (2014) Heavy metal in water and aquatic organisms from different intertidal ecosystems, Persian Gulf. Environ Monit Assess 1–9. doi:10.1007/s10661-014-3788-4

Rainbow PS (1995) Biomonitoring of heavy metal availability in the marine environment. Mar Pollut Bull 31(4):183–192

Reddy KR, Chinthamreddy S (1999) Electrokinetic remediation of heavy metal-contaminated soils under reducing environments. Waste Manag 19(4):269–282

Sadiq M, Zaidi TH, Mian AA (1982) Heavy metal concentrations in shrimp, crab, and sediment obtained from Ad-Dammam sewage outfall area. Bull Environ Contam Toxicol 29(3):313–319

Salahshur S, Yousefi Z, Bakhtiari A (2014) Bioaccumulation of Cd, Pb and Zn in the Oyster Saccostrea cucullata and Surface Sediments of Hendourabi Island-Persian Gulf. Iran J Mar Biol Oceanogr 3(2):2

Soegianto A, Irawan B (2009) Bioaccumulation of heavy metals in aquatic animals collected from coastal waters of gresik, Indonesia. Asian J Water Environ Pollut 6(2):95–100

Teodorovic I, Djukic N, Maletin S, Miljanovic B, Jugovac N (2000) Metal pollution index: proposal for freshwater monitoring based on trace metal accumulation in fish. Tiscia 32:55–60

Türkmen M, Türkmen A, Tepe Y, Ateş A, Gökkuş K (2008) Determination of metal contaminations in sea foods from Marmara, Aegean and Mediterranean seas: twelve fish species. Food Chem 108(2):794–800

Uluozlu OD, Tuzen M, Mendil D, Soylak M (2007) Trace metal content in nine species of fish from the black and Aegean Seas Turkey. Food Chem 104(2):835–840

Vutukuru S (2005) Acute effects of Hexavalent chromium on survival, oxygen consumption, Hematological parameters and some biochemical profiles of the Indian Major Carp, Labeo rohita. Int J Environ Res Public Health 2(3):456–462

Walkley A, Black IA (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci 37(1):29–38

Wan Ngah W, Hanafiah MAKM (2008) Removal of heavy metal ions from wastewater by chemically modified plant wastes as adsorbents: a review. Bioresour Technol 99(10):3935–3948

Wu X-Y, Yang Y-F (2011) Heavy metal (Pb Co, Cd, Cr, Cu, Fe, Mn and Zn) concentrations in harvest-size white shrimp *Litopenaeus vannamei* tissues from aquaculture and wild source. J Food Compos Anal 24(1):62–65

Zhou H, Cheung R, Chan K, Wong M (1998) Metal concentrations in sediments and Tilapia collected from inland waters of Hong Kong. Water Res 32(11):3331–3340