Bull. Environ. Contam. Toxicol. (2005) 74:1098–1104

DOI: 10.1007/s00128-005-0694-z

Bulletin of Environmental Contamination and Toxicology

Heavy Metals in the Edible Muscle of Shrimp from Coastal Lagoons Located in Northwest Mexico

M. G. Frías-Espericueta, J. I. Osuna-López, F. J. Estrada-Toledo, G. López-López, G. Izaguirre-Fierro

Environmental Studies Laboratory, Faculty of Marine Sciences, Autonomous University of Sinaloa, Post Office Box 610, Mazatlán 82000, Sinaloa, Mexico

Received: 20 August 2004/Accepted: 24 February 2005

In Mexico, in spite of environmental policy efforts to reduce environmental risk to safeguard the natural environment and to protect human health, studies carried out for more than 25 years have demonstrated high concentrations of some heavy metals in lagunar and estuarine ecosystems (Villanueva and Botello 1998).

The importance of heavy metals in estuarine and coastal environments derives from both their potential effects and excessive anthropogenic sources. In this context, organisms can accumulate the metals from their food and seawater and/or sediment to concentrations that considerably exceed those found in their environment, and some species have commercial value.

The purpose of this study was to assess the concentration of seven heavy metals (Cd, Co, Cu, Fe, Ni, Pb and Zn) in the edible muscle of shrimp *Litopenaeus vannamei* and *L. stylirostris* from six coastal lagoons located in the northwest coast of México. These species are the most important resources from fisheries and aquaculture in NW of Mexico.

MATERIALS AND METHODS

In each coastal lagoon (Fig. 1), shrimp samples were obtained from local fishermen between September and October 2003 (when shrimp are extensively commercialized). The main human activities occurring in each lagoon are shown in table 1. From each lagoon, 30 shrimp were selected and they were transported in coolers (4 °C) to the laboratory to analysis. *L. vannamei* was the shrimp sampled in all lagoons, with exception of Altata-Ensenada del Pabellón lagoon, where *L. stylirostris* inhabits. Only shrimp with similar size (*L. vannamei*: 9.4-11.9 cm; *L. stylirostris*: 15.5±0.5 cm) and at the intermolt stage were used. The molt stage was determined by examining the urupoda in which partial retraction of the epidermis can be distinguished (Robertson et al. 1987).

After determination of length of shrimp, organisms were dissected to separate abdominal muscle (edible), and the other tissues were not analyzed. No sex separation was carried out.

Correspondence to: M. G. Frías-Espericueta

Figure 1. Location of sampling sites.

The edible muscle was freeze-dryed at -45°C and vacuum conditions for 72 h. Pulverization and homogenization were achieved by grinding the tissue samples in a Teflon mortar. Triplicate sub-samples were digested with a concentrated nitric acid and slowly evaporated to dryness (90 °C) and the remainder dissolved in nitric acid 2M. The multiple standard addition method was used (Miller and Miller 1988). After that, samples were centrifuged and analyzed by flame atomic absorption spectrophotometry. All material used in sampling and heavy metal treatment were acid washed (Moody and Lindstrom 1977).

The accuracy and precision of the method employed was evaluated by analyzing a shrimp tissue as a reference material MA-A-3/TM (IAEA 1987), and values were satisfactory except for Cr and Mn (27 and 68.4% of recovery, respectively) and these metals were not included. Differences in average concentrations among lagoons were assessed by an one-way analysis of variance ($p<0.05$) (Miller and Miller 1988).

RESULTS AND DISCUSSION

Several studies about metal distribution in tissues in shrimp have been carried out, and the abdominal muscle presents the lowest metal concentrations. However, the edible muscle is the major tissue consumed by Mexican people.

Table 1. Summary of the characteristics of selected coastal lagoons.

Coastal lagoon	Activities	Rivers
Altata-Ensenada del Pabellón	Fisheries, shrimp farms, agriculture, urban and industrial sewage	Yes
Verde Camacho	Fisheries, agriculture, rural communities	Yes
Huizache-Caimanero	Fisheries, shrimp farms, agriculture, rural communities	Yes
Los Laureles	Fisheries, rural communities	No
Pescadero	Fisheries, shrimp farms, rural communities	No
Mexcaltitán	Fisheries, shrimp farms, rural communities	Yes

Table 2 shows heavy metal values found in the edible muscle of the shrimp collected in the present study. All Ni values were below of limit of detection, indicating that the muscle is not a storage tissue, however some Ni concentrations could be concentrated in the hepatopancreas of shrimps analyzed, because it is the main organ for metal accumulation (Kargin et al. 2001).

Regarding Co, Fe, and Zn, the values reported in the coastal lagoons of the present study are very similar, and a discussion of differences was not carried out.

Shrimp from Altata-Ensenada del Pabellón lagoon showed the highest values for Cd and Pb (0.89, 31.4 and 4.5 μg/g, respectively). As commented in table 1, in this lagoon some human activities are observed. According to Green-Ruiz and Páez-Osuna (2003), this lagoon has a surface of 335 km^2 and the main body water is connected with three inner shallow lagoons (Bataoto, Caimanero and Chiricahueto) which directly receive agriculture and sugar cane industrial discharges. Besides, this lagoon also receives the effluents from 130 000 ha of agriculture fields where vegetables, sugar cane, corn and soybeans crops are cultivated. It could be the main source of Cd, because agricultural fertilizers are considered as important source of heavy metals, including Cd (Alloway 1990). A possible source of Pb to Altata-Ensenada del Pabellón lagoon could be the atmospheric transport from vehicle emission from cities (Culiacán city: 800 000 inhabitants) and several roads surrounding the study area. In this context, Pb discharges from various years may cause an accumulation in the sediments, where *L. stylirostris* inhabits (benthic organisms).

Ruelas-Inzunza and Páez-Osuna (2003) found levels of 1.2 and 0.9 μg/g, for Cd and Pb, respectively, in the edible muscle of *L. stylirostris* from the same coastal lagoon. With exception of Pb, Cd values are higher than those determined in the present study.

Highest value of Cu (20 ± 0.5 μg/g) was determined in the Huizache-Caimanero lagoon (Table 2), which receives agricultural effluents (Presidio and Baluarte Rivers) derived mainly from the vegetables fields which are characterized by the use of large quantities of metallic fungicides with high content of Cu (cupravit).

Table 2. Heavy metal concentrations (μg/g, d.w.) in muscle of shrimp from coastal lagoons included in the present study.

Lagoon	Cd	Co	Cu	Fe	Pb	Zn
Altata-Ens. del Pabellón	0.89±0.02	1.1±0.05	15.3±0.7	4.5±0.5	4.5±0.2	31.4±0.3
Verde Camacho	0.66±0.04	1.06±0.16	16.3±0.2	6.6±0.4	2.3±0.3	29.9±0.7
Huizache-Caimanero	0.7±0.04	1.4±0.1	20±0.5	6.3±0.6	2.4±0.9	30.4±0.2
Los Laureles	0.59±0.01	1.2±0.11	8.8±0.2	7.6±0.7	1.4±0.5	28.5±0.2
Pescadero	0.65±0.01	1.1±0.08	8.4±0.1	5±0.6	2±0.36	28.7±1
Mexcaltitán	0.62±0.04	1.3±0.1	9.3±0.2	3.9±0.3	1.5±0.2	29.4±0.3

Alloway (1990) pointed out that pesticides are an important source of heavy metals to environment. Páez-Osuna and Ruiz-Fernández (1995) and Páez-Osuna and Tron-Mayen (1996) found similar values (19.15 μg/g) in the muscle of *L. vannamei* sampled in the Huizache-Caimanero lagoon.

Regarding Cd and Pb, these authors found concentrations below the limit of detection, and in the present study, values of 0.7 (Cd) and 2.4 (Pb) μg/g are reported, indicating probably an increase of Cd and Pb in the Huizache-Caimanero lagoon. It could be due to the enclosed nature of the system together with irregular access to tidal flushing; which allows metal accumulation.

Highest values of Cu and Pb were determined in those lagoons associated to rivers (Table 1), which are intensively used for irrigation canals. It is in this segment where the rivers flow through agricultural basins and urban and rural communities. These activities affecting the quality of the rivers when irrigation channels return to rivers, which could contain traces of heavy metals and other contaminants (Gutierrez and Borrego 1999).

Regarding Verde-Camacho, Los Laureles, Pescadero and Mexcaltitán lagoons, no previous work have been carried out, and a comparison is not possible. However, Los Laureles, Pescadero and Mexcaltitán lagoons, are coastal lagoons from the state of Nayarit (Fig. 1), which is lower in agricultural fields, industries, and population than state of Sinaloa. In this context, lowest concentration of majority of metal is reported in those lagoons.

The statistical analysis reveals that Pb and Cd values found in Altata-Ensenada del Pabellón lagoon were different ($p<0.05$) than those found in the others coastal lagoons. Regarding the Laureles lagoon, Cd, Cu and Zn values were statistically different than those determined in the coastal lagoons from state of Sinaloa (Altata-Ensenada del Pabellón, Verde-Camacho, and Huizache-Caimanero lagoons), but no statistical difference was observed with the lagoons from state of Nayarit (Pescadero and Mexcaltitán lagoons). In spite of Los Laureles lagoon showed the highest Fe value, it only was different with Altata-Ensenada del Pabellón lagoon.

Table 3. Oral intake per person (in grams, wet weight) of muscle of shrimp to reach levels of concern proposed by USFDA (1993) and WHO (1998).

Metal	Shrimps from Sinaloa state	Shrimps from Nayarit state	Levels of concern μg/person/day
Cd	586.6	709.7	110
Cu	697.6	1363.6	3000
Pb	139.8	262.6	107

When comparing the metal concentration found in the present study to the levels of concern showed in table 3 (Cd, Cu and Pb), it can seen that the greatest concern would be from Pb exposure. People would have to consume 139.9 g (wet wt.) of edible muscle of shrimp from coastal lagoons from Sinaloa state to reach the daily limit for Pb. Besides, in areas where whole shrimps are consumed, the potential for increase metal uptake is much greater.

Table 4. Comparative heavy metal concentrations (μg/g, dry weight) in muscle of shrimp from other areas of the world.

Site	Species	Cd	Cu	Pb	Zn	Reference
Sunderban, India	*P. monodon*	0.74		32.1	1184	Guhathakurta and Kaviraj (2000)
British Columbia Coast, Canada	*P. borealis*	0.25	13.7	0.94	45.7	Harding and Goyette (1989)
Gulf of Fonseca, Nicaragua	*P. vannamei*	0.13*	21.9*	0.85*	103*	Carbonell et al. (1998)
Three Mile Creek, Australia	*P. merguiensis*	<0.05	40.9*		56.7*	Darmono and Denton (1990)
Iskenderun Gulf, Turkey	*P. semiculatus*	1.3	33.9	6.82	74.9	Kargin et al. (2001)
Gulf of Mexico	*P. setiferus*	6.11	17.3	7.73	107	Vazquez et al. (2001)
Coastal lagoons, NW of Mexico	*L. vannamei*	0.68	13.01	2.35	29.7	This study

*Transformed to dry weight from the original publication assuming a wet:dry ratio of 4.5 (Darmono and Denton 1990).

In spite of ecological concern by Pb, the mean value of the present study is lower than those determined in *Penaeus monodon*, *Penaeus semiculatus* and *Penaeus setiferus* from Sunderban, India; Iskenderun Gulf, Turkey; and Gulf of Mexico, respectively (Table 4). Regarding Cd, a similar behavior is observed. Besides, Cu and Zn concentrations determined in the coastal lagoons from NW coast of Mexico, are lower than those values reported in table 4.

In conclusion, the observed differences between coastal lagoons may be a consequence of different concentrations of metals in the sediments and the environment, and/or by different metal bioavailability in those environments. This is of ecological concern, because metal levels in organisms depend mainly of their environmental levels and it may affect fisheries in terms of environmental/biological conservation.

Acknowledgments. This work was partially supported by the CECyT and PAFI-UAS projects. We thank to H.M. Zazueta-Padilla for technical assistance.

REFERENCES

Alloway BJ (1990) Heavy metals in soils. Blackie and Son. Glasgow, Scotland

Carbonell G, Ramos C, Tarazona JV (1998) Heavy metals in shrimp culture areas from the Gulf of Fonseca, Central America. II. Cultured shrimps. Bull Environ Contam Toxicol 60: 260-265

Darmono D, Denton RW (1990) Heavy metal concentrations in the banana prawn, *Penaeus merguiensis*, and leader prawn *P. monodon*, in the Townsville region of Australia. Bull Environ Contam Toxicol 44:479-486

Green-Ruiz C, Páez-Osuna F (2003) Heavy metal distribution in surface sediments from a subtropical coastal lagoon system associated with an agricultural basin. Bull Environ Contam Toxicol 71:52-59

Guhathakurta H, Kaviraj A (2000) Heavy metal concentration in water, sediment, shrimp (*Penaeus monodon*) and mullet (*Liza parsia*) in some brackish water ponds of Subdweban, India. Mar Pollut Bull 40:914-920

Gutierrez M, Borrego P (1999) Water quality assessment of the rio Conchos, Chihuahua, Mexico. Environ Int 25:573-583

Harding L, Goyette D (1989) Metals in Northeast Pacific coastal sediments and fish, shrimp and prawn tissues. Mar Pollut Bull 20:187-189

IAEA (1987) International Atomic Energy Agency. Intercalibration of analytical methods on marine environmental samples: Trace elements measurements on shrimp homogenate. Report No 34, Monaco

Kargin F, Donmez A, Cogun HY (2001) Distribution of heavy metals in different tissues of the shrimp *Penaeus semiculatus* and *Metapenaeus monocerus* from the Iskenderun Gulf, Turkey: seasonal variations. Bull Environ Contam Toxicol 66:102-109

Miller JC, Miller JN (1988) Statistics for analytical chemistry. John Wiley & Sons, New York,NY

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

Páez-Osuna F, Ruiz-Fernández AC (1995) Trace metals in the Mexican shrimp *Penaeus vannamei* from estuarine and marine environments. Environ Pollut 87: 243-247

Páez-Osuna F, Tron-Mayen L (1996) Concentration and distribution of heavy metals in tissues of wild and farmed shrimp *Penaeus vannamei* from the northwest coast of Mexico. Environ Int 22: 443-450

Robertson L, Bray W, Leung-Trujillo J, Lawrence A (1987) Practical molt staging of *Penaeus setiferus* and *Penaeus stylirostris*. J World Aquaculture Soc 18:180-185

Ruelas-Inzunza J, Páez-Osuna F (2003) Distribution and concentration of trace metals in tissues of three shrimp species from Altata-Ensenada del Pabellón lagoon (S.E. Gulf of California). Bull Environ Contam Toxicol 72:452-459
USFDA (1993) Guidance documents for trace elements in seafood. FDA Centre for Food Safety and Applied Nutrition, Washington, DC
Vazquez FG, Sharma VK, Mendoza QA, Hernandez R (2001) Metals in fish and shrimp of the Campeche sound, Gulf of Mexico. Bull Environ Contam Toxicol 67:756-762
Villanueva S, Botello AV (1998) Metal pollution in coastal areas of Mexico. Rev Environ Contam Toxicol 157:53-94
WHO (1998) International programme on chemical safety (IPCS) environmental health criteria 200: Copper. World Health Organization, Geneva