

Heavy Metals in Oysters, Shrimps and Crabs from Lagoon Systems in the Southern Gulf of México

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Received: November 1, 2013 Accepted: November 29, 2013 Online Published: February 15, 2014

doi:10.5539/jas.v6n3p108

URL: <http://dx.doi.org/10.5539/jas.v6n3p108>

Abstract

Lagoon systems in the southern Gulf of Mexico are highly productive. These aquatic systems have been severely negatively impacted by anthropogenic and industrial activities. The objective of this research was to estimate the concentration of heavy metals Pb, Cu, Cd and Zn in oysters, shrimp and crabs from the Carmen-Pajonal-Machona and Mecoacán lagoon systems in Tabasco, México. Samples were collected from fishing zones within these lagoon systems and included oysters *Crassostrea virginica*, and crustaceans such as *Litopenaeus setiferus* (shrimp) and *Callinectes sapidus* (crab). Concentrations of Pb, Cu, Cd and Zn were determined by atomic absorption using flame spectrophotometry. The heavy metal concentration pattern in oysters, shrimp and crab in the Carmen-Pajonal-Machona system was Cu > Pb > Cd. The maximum average concentration of Cu was 259.12 ± 12.312 in oyster; 0.516 ± 0.154 in shrimp, and in crab $0.907 \pm 0.273 \mu\text{g g}^{-1}$. Pb had a maximum concentration of 1.37 ± 0.77 in oyster, in shrimp was 0.059 ± 0.044 , and for crab was $0.0055 \mu\text{g g}^{-1}$ ($p > 0.05$), while in the Mecoacán lagoon system the pattern showed Pb > Cd > Zn. The maximum average concentration of Pb was $321.15 \pm 28.828 \mu\text{g g}^{-1}$, the minimum was $84.70 \pm 8.612 \mu\text{g g}^{-1}$. The highest concentration of Cd was $63.74 \pm 8.446 \mu\text{g g}^{-1}$, and the minimum $13.00 \pm 0.64 \mu\text{g g}^{-1}$. For Zn the maximum average concentration obtained was $24.42 \pm 2.665 \mu\text{g g}^{-1}$.

Keywords: contaminants, toxicological effects, public health, fisheries resources, bioaccumulation

1. Introduction

Lagoon systems in the southern Gulf of Mexico are key parts of agroecosystems and economic development in the country due to the diversity of habitats, dynamic interactions between water bodies, abundant fishery resources, contribution to biogeochemical cycles, and supply of minerals and products used in the pharmaceutical industry (Botello & Páez-Osuna, 1986; Contreras & Castañeda, 2004). In particular, these systems are areas of shelter, food and reproduction for many species of great importance to coastal fisheries (Toledo, 2005; Rivera & Borges, 2006). All of the above has resulted in industrial and urban development in these regions (Castañeda, Lango, & Landeros, 2011).

Among the coastal agroecosystems in the southern Gulf of México, Carmen-Pajonal-Machona, Mecoacán and Términos are known for high levels of fish production, as well as agriculture, livestock and forestry. However, these systems also contain oil wells that pose a high risk of contamination of the inherent natural resources (Contreras & Castañeda, 2004; Toledo, 2005).

Previous studies in these lagoon systems have shown environmental impacts from improper management and use of natural resources, agricultural production activities and the generation of waste pollutants. Within the latter category are included biological and chemical contaminants such as bacteria and viruses, pesticides, hydrocarbons and heavy metals (Cruz, 2011; Carrillo et al., 2012). Heavy metals are among the most studied contaminants and pollutants in the coastal environment because some are toxic (Páez, 2005). This study is focused on estimating the concentrations of the heavy metals Pb, Cd, Cu and Zn in these systems and comparing them with the permissible limits established by the Food and Drug Administration (FDA/OMS).

2. Materials and Methods

2.1 Study Area

2.1.1 Carmen-Pajonal-Machona Lagoon System

This system is located on the western edge of the coastal plain of Tabasco, between 18°14' and 18°18' N and 93°45' and 93°53' W in the municipality of Cárdenas, Tabasco (Gutiérrez & Galaviz, 1983). The system covers 8,800 ha (Carta Nacional Pesquera, 2004) (Figure 1).

2.1.2 Mecoacán Lagoon System

This system is located on the east coast of the municipality of Paraíso, Tabasco, between 18°16' and 18°26' N and 93°04' and 93°14' W (Galaviz, Gutierrez, & Castro, 1986; Carta Nacional Pesquera, 2004) and covers 5,168 ha (Figure 2).

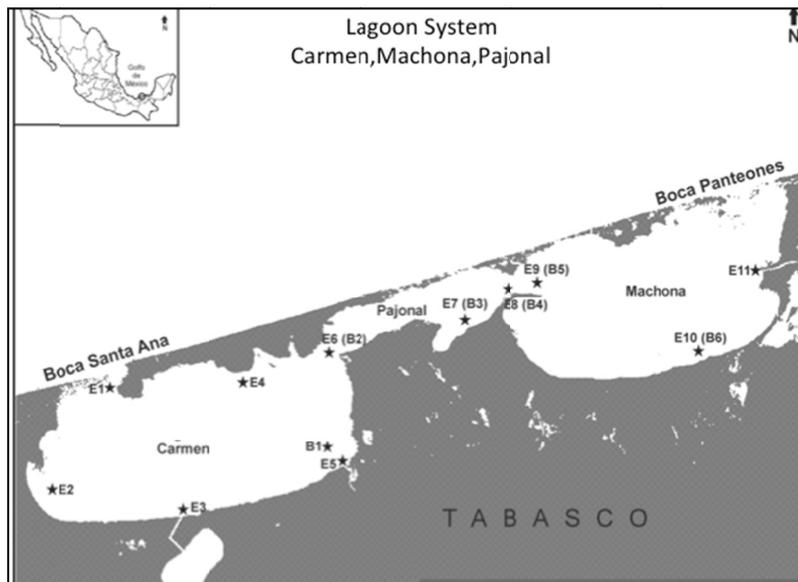


Figure 1. Location of sampling stations (E) and oyster banks (B) in the Carmen-Machona-Pajonal lagoon system

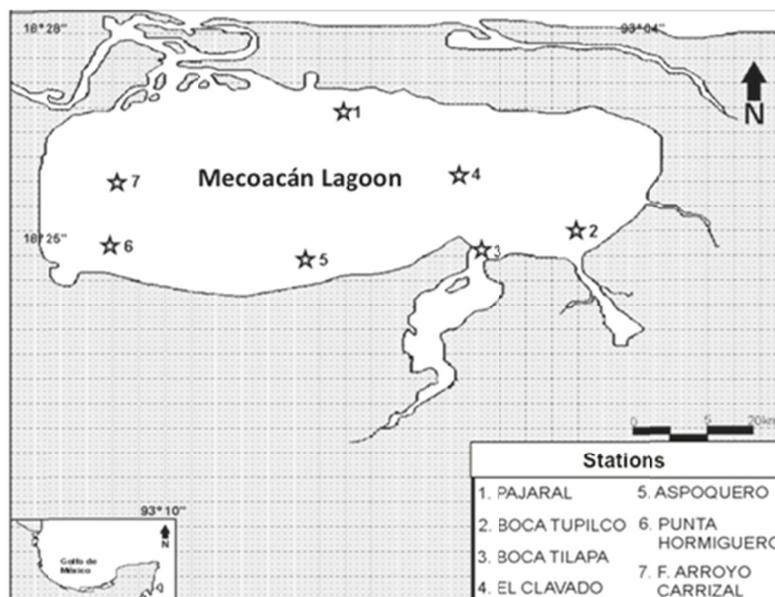


Figure 2. Location of sampling stations in the Mecoacán lagoon system

2.2 Sample Collection and Treatment

Sampling for collection of organisms was performed during the windy season (January and February), dry season (March to June) and rainy season (July to October). Oyster (*Crassostrea virginica*) samples were collected in 2007 from the Mecoacán lagoon system and in 2011 from the Carmen-Machona-Pajonal lagoon system. Samples of crab (*Callinectes sapidus*) and shrimp (*Litopenaeus setiferus*) were collected only in 2011 from the Carmen-Machona-Pajonal lagoon system.

Each oyster sample consisted of 100 oysters collected by free diving at established locations in each lagoon system, from which 30 oysters of commercial size were selected (7.0 ± 3.0 cm) to be washed and remove loose particles or bonded materials, then they were packed in Ziplock® polyethylene bags. For shrimp and crab 1 kg was collected of commercial sized individuals of 10 to 15 g each for shrimp and 100 ± 10 mm for crabs, the necessary amount to reach 1 kg of pulp per sample and they were placed in labeled Ziplock® polyethylene bags and transported to the laboratory in coolers at $5 \pm 1^\circ\text{C}$ according to the protocol established by the Mexican National Standard NOM-109-SSA1-1994 (Diario Oficial de la Federación, 1994).

2.3 Laboratory Analysis of Samples

Oysters samples were removed from their shell and the soft tissues were separated by dissection and placed in triplicate in labeled Ziploc® polyethylene bags. Each one of the samples (oyster, shrimp and crab) was frozen at -40°C in a Thermo Model 726 ultra-freezer (Thermo Fisher Scientific Inc., San Fernando, CA, USA). The frozen samples were lyophilized in a Thermo Savant MODULYOD-115 for 72 hours at -49°C and a vacuum pressure of 36×10^{-3} mbars. The samples were then ground in an Osterizer blender to obtain a fine particle size and then homogenized using a No. 30 sieve with a mesh size of $595 \mu\text{m}$. To avoid contamination with humidity the samples were then stored in hermetically sealed bags in a desiccator with silica gel. To determine heavy metal concentrations, the samples were subjected to an acid digestion process in a microwave oven CEM model Mars 5 (CEM Corporation, Matthews, NC) according to the Oyster Pure method (EPA, 1996).

2.3.1 Determination of Heavy Metals

The glassware used for the digestion process was previously washed with a 10% neutral soap solution free of phosphates to prevent ionic interference when reading the spectrophotometer. The glassware was then rinsed with potable water and immersed in a solution of distilled water with 20% nitric acid for 24 hours to ensure complete removal of the acid. The glassware was immersed in water free of heavy metals *Milli-Q* quality for 24 hours. At the end the glassware was drained and dried in a forced-air oven (Riossa CF-102) at 100°C for 24 hours. For digestion, 0.5 g of each sample were placed in a Teflon beaker (HP-500) to which was added 9 ml of 70% reagent grade nitric acid. This process was performed at 190°C . Each group of samples was accompanied by a blank sample and a control. After digestion, the samples were vacuum-filtered into a Nalgene bottle using $0.45 \mu\text{m}$ Millipore® nitrocellulose filters. The filtrate was diluted in a volumetric flask to a volume of 25 ml with water free of heavy metals *Milli-Q* quality. The diluted samples were transferred into polypropylene bottles and stored at 4°C for further reading. To ensure the quality of the data a white reference was analyzed in each matrix. Certified standards were used to prepare the standard curve for each item tested (Pb, Cu, Cd and Zn) and the reading was performed by atomic absorption through flame spectrophotometry on a Thermo Scientific 3500 Model AA Ice System (Thermo Scientific®, China). The results for each metal concentration were expressed in $\mu\text{g g}^{-1}$ dry weight.

2.4 Statistical Analysis

Single factor analyses of variance (ANOVAs) were conducted on heavy metal concentrations in oyster, crab and shrimp samples. Data of heavy metal in oyster were transformed to natural logarithms to achieve normality and homogeneity. In addition, a Tukey multiple comparisons test was performed. Data were analyzed using Statistica 7.0 software (StatSoft, Inc., Tulsa, OK, USA).

3. Results

3.1 Carmen-Pajonal-Machona Lagoon System

Crassostrea virginica showed the highest concentrations of heavy metals compared to *Litopenaeus setiferus* and *Callinectes sapidus*. The average concentration of the aquatic organisms (*Crassostrea virginica*, *Litopenaeus setiferus* and *Callinectes sapidus*) is indicated in Table 1. The concentration pattern recorded in all species analyzed was $\text{Cu} > \text{Pb} > \text{Cd}$, with the exception of Cu in crabs, where higher values were obtained with respect to shrimp.

The maximum average concentration of Cu recorded was 259.12 ± 12.312 in oysters; 0.516 ± 0.154 in shrimp, and $0.907 \pm 0.273 \mu\text{g g}^{-1}$ in crabs ($p < 0.05$), (Table 1). The maximum concentration of Cu in oysters was recorded from Bank 4 (Table 2); however, there was no significant difference among the banks. Respect to crustaceans, crabs had a higher mean concentration versus shrimp, 0.907 ± 0.273 and 0.516 ± 0.154 respectively. Cu was the metal with the highest bioaccumulation and significantly different to Pb and Cd ($p < 0.05$), (Table 1).

Pb registered a maximum concentration of 1.37 ± 0.77 in *C. virginica* ($p < 0.05$). On the other hand, shrimp had an average concentration of 0.059 ± 0.044 . Pb in *C. Sapidus* was only detected during the windy season with a concentration of $0.0055 \mu\text{g g}^{-1}$ (Table 1).

Table 1. Average concentration of heavy metals among the three species analyzed ($x \pm \text{SD}$). Different superscript indicates significant difference for the same metal (*=unique value; §=not tested due to single site presence; ND=not detected)

Species analyzed	Heavy Metals ($\mu\text{g g}^{-1}$ dry weight)		
	Pb	Cu	Cd
Oyster	1.001 ± 0.714^a	259.12 ± 12.312^a	$2.766 \pm 0.394^{\S}$
Shrimp	0.059 ± 0.044^b	0.516 ± 0.154^b	ND
Crab	0.0055^*	0.907 ± 0.273^b	ND

Cd was not detected in shrimp and crab. The maximum concentration in oysters recorded was $2.91 \pm 0.09 \mu\text{g g}^{-1}$. Comparison of the same metal between sampling sites showed no significant difference either between the contents of Pb and Cd in banks 4, 5 and 6; which was not the case of banks 1, 2 and 3 where there was a difference (Table 2).

Table 2. Average concentration of Pb, Cu and Cd ($x \pm \text{S.D.}$) in oyster muscle *C. virginica* from samples collected in the Carmen-Pajonal-Machona lagoon system, Tabasco, during the three sampling seasons

Banks	Heavy Metals in Oyster ($\mu\text{g g}^{-1}$ dry weight)		
	Pb	Cu	Cd
B1	0.56 ± 0.46^a	228.32 ± 12.519^b	2.91 ± 0.09^{ab}
B2	1.37 ± 0.77^a	277.08 ± 13.945^b	2.89 ± 0.64^{ab}
B3	1.08 ± 0.85^a	271.94 ± 15.286^b	2.50 ± 0.19^{ab}
B4	1.00 ± 0.44^a	157.09 ± 8.962^b	2.16 ± 0.54^a
B5	0.65 ± 0.12^a	136.53 ± 8.957^b	1.96 ± 0.28^a
B6	0.45 ± 0.26^a	130.25 ± 15.421^b	1.59 ± 1.38^a

3.2 Mecoacán Lagoon System

The concentration pattern in oyster *C. virginica* registered in the Mecoacán lagoon system was $\text{Pb} > \text{Cd} > \text{Zn}$. Pb showed the highest concentration among the rest of the metals. The maximum average concentration of Pb was recorded for Bank 3 with $321.15 \pm 28.828 \mu\text{g g}^{-1}$, while the lowest concentration was observed for Bank 6 with $84.70 \pm 86.12 \mu\text{g g}^{-1}$. The highest mean concentration of Cd was $63.74 \pm 84.46 \mu\text{g g}^{-1}$ recorded from Bank 5 and the lowest was $13.00 \pm 0.64 \mu\text{g g}^{-1}$ from Bank 4. For Zn, the maximum mean concentration was $24.42 \pm 26.65 \mu\text{g g}^{-1}$ recorded from Bank 2 (Table 3).

Table 3. Mean concentrations ($\bar{x} \pm SD$) of heavy metals in *Crassostrea virginica* from the Mecoacán lagoon system, Tabasco, México

Banks*	Heavy Metals in Oyster ($\mu\text{g g}^{-1}$ dry weight)		
	Pb	Cd	Zn
1	108.50 \pm 146.37	53.647 \pm 63.077	13.60 \pm 3.66
2	151.95 \pm 192.40	32.33 \pm 43.93	24.42 \pm 26.65
3	321.15 \pm 288.28	63.35 \pm 32.44	11.69 \pm 1.90
4	284.30 \pm 118.08	13.00 \pm 0.64	22.02 \pm 6.62
5	164.70 \pm 181.16	63.74 \pm 84.46	14.49 \pm 7.14
6	84.70 \pm 86.12	50.73 \pm 7.32	11.89 \pm 0.52
7	213.20 \pm 254.41	18.81 \pm 6.30	13.19 \pm 8.05

*No significant differences were observed among banks during the study.

4. Discussion

The Carmen-Pajonal-Machona and Mecoacán lagoon systems have the most important oyster banks of the area due to their contribution to the diversity of macrofauna associated with the banks (Susan & Aldana, 2008). However, the oyster, shrimp and crab fisheries are exposed to heavy metal pollution, which was evidenced by the high concentrations of heavy metals found in the muscle tissue of oyster, shrimp and crab samples. This condition may be related to the upward trend in metal pollution in coastal areas of the Gulf of México, particularly Pb and Cd. These metals can produce adverse toxicological effects on aquatic animals inhabiting these areas when exceeding natural or trace concentrations in lagoon systems such as Carmen-Pajonal-Machona (Botello, Villanueva, & Rosales, 2004). In this article all concentration data used to discuss is on dry basis.

Bivalves are considered indicators of *in situ* contamination because of their ability to bioaccumulate heavy metals (Rodríguez de la Rúa, Arellano, González, Blasco, & Sarasquete, 2005). The highest concentration of heavy metals during the study period was in oysters, confirming their bioaccumulative abilities that can have adverse effects on consumers (Vázquez, Aguirre, Pérez, Rábago y Genaro, 2005). However, according to the FDA the concentrations of Pb and Cd were found below the maximum allowable limits. In contrast, the values obtained in the Mecoacán lagoon system exceeded the limits established by the FDA, averaging 189.78 $\mu\text{g g}^{-1}$ for Pb and 42.23 $\mu\text{g g}^{-1}$, for Cd.

For crustaceans, the WHO (1989) sets a maximum allowable value of 10 $\mu\text{g g}^{-1}$ for Pb and Cd. Concentrations in the analyzed species *L. setiferus* and *C. sapidus* were lower and undetectable (ND) levels in both species (Table 1).

Cu is a metal that has no national legislation for commercially important such as molluscs, crustaceans or fish. Therefore, international laws must be used to compare the measured concentrations. The FDA provides a maximum permissible concentration 32.5 $\mu\text{g g}^{-1}$ dry weight (1993), these values were only surpassed by oysters while crustaceans obtained concentrations below the limit.

Variations in the Cu, Pb, Cd and Zn concentrations measured from the Carmen-Pajonal-Machona and Mecoacán lagoon systems are associated with a range of factors such as absorption, excretion, storage and efficiency in the regulation and detoxification of organismal systems (Bryan, 1971), although such physiological and biochemical strategies may differ among species (Gerlach, 1981). This leads to variation in the concentrations of metals among species and tissues, depending on age, sexual maturity, feeding habits, migration, metabolism, and particularly by the different affinity of the metals for specific organs (McFarlane & Franzis, 1980; Márquez et al., 2008).

Furthermore, different ecological and feeding habits among species can affect the route of uptake of metals, such as in fish (Márquez et al., 2008). In crustaceans, there is a relationship between the concentration of heavy metals and the feeding habits of omnivorous penaeid shrimp (Scelzo, 1997). Márquez et al. (2008) recorded higher levels of metals in species that feed on lagoon sludge in Unare, Venezuela.

According to Frias, Osuna, Sandoval, and López (1999), there is a relationship between the bioaccumulation of metals and their physicochemical properties, as well as with the metabolic needs of the organisms and the availability of food in the water column. Villanueva and Botello (2005) associated this bioavailability among

others, with the type of sediment and physicochemical characteristics of water. Laws (1993) reported that benthic organisms, due to their direct interaction with sediments, are among the most affected by heavy metal concentrations.

Pb showed the highest concentrations in the species analyzed, with a maximum of $525 \mu\text{g g}^{-1}$ in the Mecoacán lagoon system. The differences in the concentration of Pb between the lagoon systems can be attributed to nearby oil extraction operations in Dos Bocas. According to Botello et al. (2004), high concentrations of Pb may be related to the direct disposal of wastewater and air emissions from urban and industrial areas of Villahermosa. Due to the volatile nature of Pb, it tends to settle in areas other than its source. The values obtained from the Mecoacán lagoon system in the present study are higher than those reported by Hernández, Hernández, Botello and Villanueva (1996) for the Mandinga lagoon of $11.55 \mu\text{g g}^{-1}$, while Vázquez, Aguilera, and Sharma (1993) registered $5.81 \mu\text{g g}^{-1}$ for San Andrés lagoon. Also, these values were not in agreement with those reported by Vázquez et al. (2005), with $0.86 \mu\text{g g}^{-1}$ for the same location.

In the Carmen-Pajonal-Machona lagoon system, Pb had the highest concentration in oysters followed by Cu. The trend in concentration among species was oysters>shrimp>crab, with $1.00 \mu\text{g g}^{-1}$, $0.059 \mu\text{g g}^{-1}$ and $0.0055 \mu\text{g g}^{-1}$ values reaching the permissible limits established by national and international laws for *C. virginica* oysters. These results differ from those reported by Sosa (2005) and Lango et al. (2010) for *C. virginica* from Tamiahua lagoon with a maximum of $0.56 \pm 0.30 \mu\text{g g}^{-1}$ and $0.43 \pm 0.17 \mu\text{g g}^{-1}$ of Pb. However, the values obtained in the present study were lower than those reported by Botello (1996) who registered $51.80 \mu\text{g g}^{-1}$ for Carmen lagoon and $22.38 \mu\text{g g}^{-1}$ for Machona lagoon. All levels in oysters from the Mecoacán lagoon system exceeded the maximum permissible limit for human consumption established by the FDA (Table 4). Meanwhile, the levels obtained in the lagoon system-Carmen-Pajonal-Machona were within the limits provided by the FDA (1993).

Table 4. Permissible limits of heavy metals in aquatic organisms of commercial importance

Reference	Group	Permissible limits ($\mu\text{g g}^{-1}$ dry weight)		
		Pb ($\mu\text{g g}^{-1}$)	Cd ($\mu\text{g g}^{-1}$)	Cu ($\mu\text{g g}^{-1}$)
FDA, 1993.	Molluscs	1.7	3.7	32.5
	Molluscs			
WHO, 1989.	Crustaceans	5	0.20	32.5
	Crustaceans	2.0	5.0	-

In shrimp and crab the levels of Pb were significantly low, similar to those obtained by Mendoza (2010) for *F. aztecus*, where concentrations of Pb were not detectable (ND). However, Botello (1996) reported average concentrations of $12.13 \mu\text{g g}^{-1}$ in the crab *Callinectes rathbunae*. The low concentrations obtained in this study are for shrimp $0.05 \mu\text{g g}^{-1}$ and for crab $0.005 \mu\text{g g}^{-1}$. These concentrations are lower than those reported by Palomarez, Castañeda, Lango, and Landeros (2009) for *F. aztecus* $0.119 \mu\text{g g}^{-1}$, suggesting low bioavailability of Pb. According to Kargin, Donmez, and Cogun (2001) recorded high levels of Pb in crustaceans when there were high levels of metals in sediments.

Copper was the second most concentrated metal in oysters from the Carmen-Pajonal-Machona lagoon system with a maximum average concentration of $259.12 \mu\text{g g}^{-1}$. This value was similar to those reported by Guzman, Villanueva, and Botello (2005) in *C. virginica* for the Alvarado with $278.00 \pm 26.43 \mu\text{g g}^{-1}$, Mandinga with $165.75 \pm 13.37 \mu\text{g g}^{-1}$ and Tamiahua with $202.43 \mu\text{g g}^{-1}$. Frias et al. (2009) reported a value of Cu concentration of $166.36 \pm 38.70 \mu\text{g g}^{-1}$ in *C. corteziensis*. According to Rodríguez de la Rúa et al. (2005) the high concentrations of Cu are due to the capacity of oysters to accumulate the metal in different cellular compartments, neutralizing its effects and excreting the contaminant using different physiological strategies. Increases in the accumulation of these metals have been observed with respect to exposure time and environmental concentration. According to Laws (1981), Cu is bioaccumulated by filtering organisms reaching a concentration of several orders of magnitude compared with other macroinvertebrates. Its assimilation involves the formation of complexes with organic substances, which are not easily excreted.

In crustaceans such as shrimp, the Cu concentration showed differences according to the species analyzed. Boada, Moreno, Gil, Marcano, and Maza (2007), registered in different species of wild shrimp from the east coast of Venezuela maximum concentration of Cu of $24.00 \pm 9.48 \mu\text{g g}^{-1}$ in *F. notialis*, $18.76 \pm 8.28 \mu\text{g g}^{-1}$ in *L.*

schmitii, $16.98 \pm 10.40 \mu\text{g g}^{-1}$ in *F. subtilis* and $11.98 \pm 7.25 \mu\text{g g}^{-1}$ in *F. brasiliensis*. The present data also differed from those reported by Mendoza (2010) for *F. aztecus*, where the Cu presented a maximum concentration of $18.62 \mu\text{g g}^{-1}$. According to Scelzo (1997), there is a relationship between these values and Cu metabolism in the hepatopancreas of crustaceans, where this metal is transported and carried out through semi-permeable biological membranes such as gills and other similar epithelia using specific transport proteins. Thus, organisms such as shrimp can maintain constant levels of Cu through ionic regulatory processes in their tissues.

The highest values of Cd in oysters were from the Mecoacán lagoon system, above the limits set by the FDA with an average concentration of $42.235 \pm 3.64 \mu\text{g g}^{-1}$, while in the Carmen-Pajonal-Machona was $2.766 \pm 0.394 \mu\text{g g}^{-1}$, below the maximum limit set by the FDA. Its high concentration in oysters and lagoon systems along the Gulf of Mexico is due to increased industrial use in these areas over the past 30 years, resulting in its release into the environment; since it is not found naturally in the earth's crust (Jaramillo, 2009; Maldonado, González, & Jaramillo, 2009). The concentrations recorded in the present study from the Carmen-Pajonal-Machona lagoon system were similar to those reported by Botello (1996) $3.29 \mu\text{g g}^{-1}$ and $2.94 \mu\text{g g}^{-1}$ from the Carmen and Machona lagoons, respectively. However, the values from the Mecoacán lagoon were lower than those reported by Sosa (2005) and Lango et al. (2010), $13.54 \pm 1.96 \mu\text{g g}^{-1}$ and $11.01 \pm 4.05 \mu\text{g g}^{-1}$, respectively for oysters from the Tamiahua lagoon.

Cd was not detected in crustaceans, in contrast to Palomarez et al. (2009) who reported an average concentration of $0.03 \mu\text{g g}^{-1}$ for *F. aztecus*. However, for the same species, Mendoza (2010) reported a maximum concentration of $1.55 \mu\text{g g}^{-1}$ and Botello (1996) reported $0.71 \mu\text{g g}^{-1}$ for the crab *Callinectes rathbunae* from the Yucateca lagoon, Tabasco. Peerzada, Nojok, & Lee (1992), reported that Cd was found in low concentrations in muscle and up to 18 times more in hepatopancreas and digestive gland of decapod crustaceans. Similarly, Kargin et al. (2001) noted the hepatopancreas is the main storage and detoxification site of heavy metals in crustaceans.

National legislation does not stipulate Zn concentrations in aquatic organisms for human consumption. However, concentrations in samples from the Mecoacán lagoon were lower than concentrations recorded for other systems. Gold et al. (2007) reported that Zn, a bioessential metal, had a maximum concentration of $514.97 \mu\text{g g}^{-1}$ and a minimum of $327.16 \mu\text{g g}^{-1}$ from Terminos Lagoon. Zn is one of the most common elements in the earth's crust and can be found in the air, soil and water. It is present in all foods, although its presence can also be attributed to its wide range of use in industrial activities. Due to its high concentration in the environment there are concerns regarding health effects on consumers of oysters because it can be assimilated and accumulated by organisms from the sediment or water they process for food (ATSDR, 2005).

The differences in heavy metal concentrations reported for coastal lagoons performed by other researchers generally reflect the bioavailability of such metals in these environments (Frias et al., 2005). Other studies carried out by Vázquez et al. (1993) and Vázquez et al. (2005) associated the heavy metal content in oysters from coastal lagoons with periods of drought and the entry of river water into the sea. Galaviz, Lango and Castañeda (2013), reported that contributions of heavy metals into coastal lagoon systems during the rainy season were due to runoff associated with the hauling of sugarcane from cultivation areas, as well as pineapple, tamarind and watermelon where chemical fertilizers are used.

5. Conclusions

The pattern of concentration of heavy metals in oyster, shrimp and crab from Carmen-Pajonal-Machona was $\text{Cu} > \text{Pb} > \text{Cd}$; while Mecoacán lagoon showed $\text{Pb} > \text{Cd} > \text{Zn}$. According to the result previously mentioned, it is inferred that the highest concentrations of Pb and Cd were found in the Mecoacán Lagoon system. This is due to the presence of great industrial activity, as well as oil spills caused by the petrochemical industry. Reflecting that oyster consumption is a risk to public health. Concentrations of Pb and Cd in oysters reported in this study show that in the Carmen-Pajonal-Machona the levels are below the limits set by the FDA, which is a low risk to the health of consumers of these organisms. According to the concentrations obtained in crustaceans such as shrimp and crab, they were both within the limits stipulated by the FDA. Therefore, the consumption of these crustaceans is no risk to public health.

Acknowledgements

Thanks to Consejo Nacional de Ciencia y Tecnología (CONACYT), the Instituto Tecnológico de Boca del Rio and Colegio de Postgraduados, Campus Veracruz (LP-18 Impacto y Mitigación del Cambio Climático) for financial support.

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