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The Metal Content of Bivalve Molluscs of a Coastal Lagoon of NW Mexico

Martín G. Frías-Espericueta · José I. Osuna-López · Domenico Voltolina · Gabriel López-López · Gildardo Izaguirre-Fierro · María D. Muy-Rangel

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Abstract The lagoonal system Altata-Ensenada del Pabellón supports important traditional fisheries and mollusc cultures and receives urban and agricultural effluents. The annual mean Cd contents of the oyster and mussel *Crassostrea gigas* and *Mytella strigata* of the inner mangrove swamps were higher than that of the clam *Megapitaria squalida*, which lives in areas under marine influence. *Crassostrea corteziensis* had the highest Cu and Zn contents, showing that it is a strong accumulator of both metals and especially of Zn, and there were no significant differences in the Pb content of the three species.

Keywords *Crassostrea corteziensis* · *Mytella strigata* · *Megapitaria squalida* · Soft tissues · Heavy metals · Coastal lagoons

The lagoonal system Altata-Ensenada del Pabellón (total surface: 335 km^2) is located in the central part of the state of Sinaloa. It receives the untreated industrial and municipal sewage of the more than 900,000 inhabitants of the cities of Culiacán and Navolato, as well as the effluents of the smaller towns and villages of the nearby areas, where the main activities are a highly mechanized, intensive agriculture and a rapidly developing tourism industry.

Other activities are traditional fisheries, semi-intensive shrimp farming and suspended oyster cultures, but the concentrations of some metals in the sediments of this system might be of concern, because they could be reflected in the metal content of the surrounding biota (Green-Ruiz and Páez-Osuna 2003; Apeti et al. 2005).

This study concerns the Cd, Cu, Pb and Zn contents of the tissues of the oysters and mussels *Crassostrea corteziensis* and *Mytella strigata* living on mangrove roots in the inner areas of the system, and of the clam *Megapitaria squalida*, which lives predominantly in sandy sediments in areas under direct marine influence through tidal exchanges. The three species are exploited for human consumption and oysters and clams command high prices in the local markets.

Materials and Methods

Samples of 30 clams were obtained every 2 months from July 2004 to May 2005 by free diving, and 80 oysters and 50 mussels were hand-collected from mangrove roots in areas representative of the habitat of each species (Fig. 1). All organisms were of commercial and similar sizes (height of *C. corteziensis*: 5.5–6.5 cm; *M. strigata*: 6–7 cm; *M. squalida*: 4.5–5 cm).

Before analysis, all specimens were kept in 1-μm filtered seawater for 24 h to allow gut clearing. After this, the organisms were measured and shucked, and the soft tissues were freeze-dried, ground and homogenized in a teflon mortar. Triplicate 1 g subsamples were digested in 25 mL concentrated HNO_3, evaporated slowly to dryness (90 °C) and the residue was dissolved in 20 mL 2 M HNO_3.

M. G. Frías-Espericueta · J. I. Osuna-López · G. López-López · G. Izaguirre-Fierro
Faculty of Marine Sciences, Environmental Studies Laboratory, Autonomous University of Sinaloa, Mazatlan 82000, Sinaloa, Mexico

D. Voltolina (✉)
UAS-CIBNOR Laboratory, Center of Biological Studies of the North West, P.O. Box 1132, Mazatlan 82000, Sinaloa, Mexico
e-mail: voltolina@mzt.megared.net.mx

M. D. Muy-Rangel
Food and Development Research Center, Culiacán Campus, Culiacan 80125, Sinaloa, Mexico

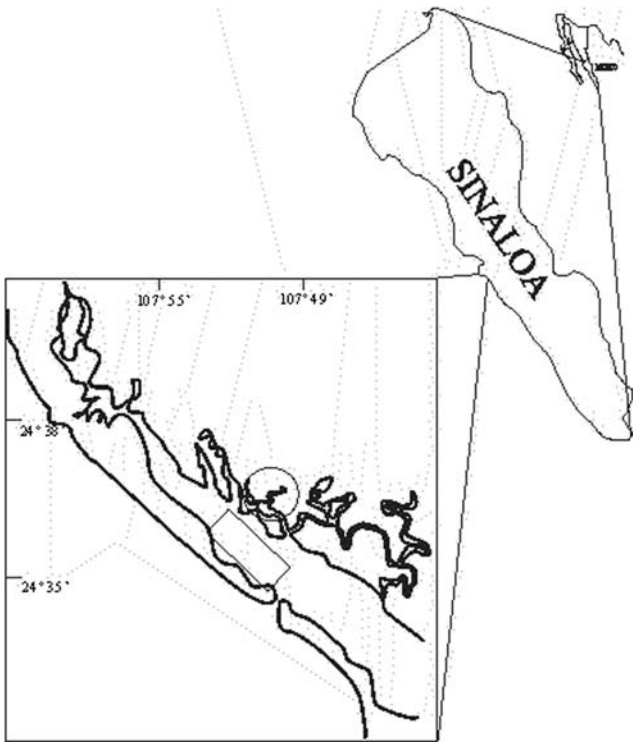

Fig. 1 Location of the sampling sites: ◯: mussels and oysters, □: clams

The samples were centrifuged and the supernatant was used for metal analysis by flame atomic absorption spectrophotometry (detection limit 0.1 μg/g) with the multiple standard addition method (Miller and Miller 1988). All glassware and equipment were acid-washed (Moody and Lindstrom 1977), and the accuracy and precision of the method were assessed using mussel homogenate MA-M-2/TM (IAEA 1987) as reference material, with percentages of recovery ranging from 89.5% to 106.5%.

Depending on the normality and equal variances of the data, the mean metal concentrations of the samples of the dry and rainy season of each species (November–May and July–October) were compared with Student's t or Mann–Whitney's tests. The mean annual values of each species were compared by one-way analysis of variance (ANOVA) or Kruskall-Wallis tests, separating the different means with Tukey's or Dunn's tests, in all cases with $\alpha = 0.05$.

Results and Discussion

The only significant seasonal difference was the Zn content of *C. corteziensis*, which was higher during the rainy season, although all the mean values of Cd, Cu and Zn tended to be higher in this season (Table 1). Since these metals are associated with fertilizers or fungicides (Alloway 1990), this trend is probably due to the increased volumes of agricultural runoff. In contrast, Pb contents tended to be higher in the dry season: the highest values were found in December and February (11.18, 5.81 and 9.23 μg/g in *C. corteziensis*, *M. strigata* and *M. squalida*), and are probably explained by the resuspension and transport of the Pb-rich sediments of this system (Green-Ruiz and Páez-Osuna 2003) caused by the strong NW winds and tidal currents typical of this season (Carbajal and Nuñez-Riboni 2002).

Table 1 Metal content* (μg/g dry weight) of three Altata-Ensenada del Pabellón bivalves

		C. corteziensis	*M. strigata*	*M. squalida*
Cd	R	7.25 ± 1.92	7.09 ± 1.96	4.13 ± 2.12
	D	5.96 ± 1.82	5.11 ± 2.52	2.59 ± 0.44
Cu	R	73.23 ± 34.30	27.83 ± 4.23	11.11 ± 4.27
	D	70.26 ± 21.71	20.45 ± 4.77	6.32 ± 3.24
Pb	R	7.70 ± 3.25	4.50 ± 1.33	6.59 ± 2.06
	D	8.79 ± 2.62	6.31 ± 1.15	8.43 ± 0.83
Zn	R	1048.5 ± 61.3[a]	69.5 ± 9.5	98.3 ± 49.1
	D	849.2 ± 119.1	63.3 ± 4.6	84.2 ± 4.1

*Mean and standard deviation; [a] Significant ($p < 0.05$; nonparametric test); R: rainy season; D: dry season

The annual mean Cd content of *C. corteziensis* and *M. strigata* were similar, and both were higher than that determined for *M. squalida* (Table 2), probably because oysters and mussels were obtained in areas close to agricultural and untreated sewage discharges, that are important sources of Cd (Landis and Yu 1999). *Crassostrea corteziensis* had also the highest Cu and Zn contents and their mean values were higher than the mean contents of the surface sediments of this lagoon (Cu: 29.3 ± 15.5 and Zn: 80.5 ± 40.0 μg/g; Green-Ruiz and Páez-Osuna 2003), showing that oysters are strong accumulators of both metals, and especially of Zn.

Clams and mussels had Cu and Zn similar or lower than the values found of surface sediments of their respective habitats (*M. squalida*: <15 μg Cu/g and <40 μg Zn/g; *M. strigata*: 15–30 and 40–80 μg Cu and Zn/g), that seems to indicate that both are weak accumulators or even partial

Table 2 Annual metal contents (μg/g dry weight) of three Altata-Ensenada del Pabellón bivalves

	C. corteziensis	*M. strigata*	*M. squalida*
Cd	6.47 ± 1.75 b	6.30 ± 2.17 b	3.20 ± 1.39 a
Cu	71.45 ± 20.63 b	24.88 ± 5.02 a	9.20 ± 4.32 a
Pb	8.36 ± 2.27 a	5.22 ± 1.37 a	7.70 ± 1.56 a
Zn[+]	928.8 ± 198.4 b	67.0 ± 7.9 a	92.7 ± 35.6 a

*Mean and standard deviation. Different letters indicate significant differences between species (one way ANOVA, $\alpha = 0.05$). *Nonparametric test regulators of these metals. In addition, the differences in content agree with the wide variability of the typical range of Zn concentrations of different bivalve species, and with the observation that oysters have higher values than mussels (Rainbow 1993).

Pb was used until recent years in Mexican gasoline, and engine emissions are likely sources of its high concentrations in the sediments of this lagoon (46–294 μg/g; Green-Ruiz and Páez-Osuna 2003) although there are other sources of this metal, such as mining sites and the natural background concentrations of the alluvial lateritic soils of the Pacific coastal plains (González-Medrano 2004).

Megapitaria squalida lives in close contact with the metal-rich sediments of this lagoon. However, its habitat is in areas under strong tidal influence, which might explain why its Cd and Pb contents are similar or lower than those of the other species.

The mean Cd content of *C. corteziensis* is within the range of 2–15 μg/g reported in a previous study in this lagoon (Páez-Osuna et al. 1993), while the content of Cu (71.4 ± 20.6 μg/g) Cu is twice as low than the 147 μg/g found in that study, which seems to indicate a tendency to decrease in the last 12 years. In contrast, the mean Zn level (929 ± 221 μg/g) is higher, although it is below the 4,000 μg/g reported for contaminated sites by Cantillo (1998).

There is no previous information on the Pb content of the bivalves of this lagoon; however, our values (5.2–8.4) are within the ranges of 5–12 and 6.4–19.4 μg/g observed in *C. corteziensis* by Frías-Espericueta et al. (2005) in Urias lagoon, which is another lagoonal system under strong anthropogenic influence.

Though relatively high, the mean concentrations of Cd, Pb, Cu and Zn found in this study are lower than the 85th percentile values reported for the Worldwide Mussel Watch (12, 16, 680 and 4,500 μg/g, respectively: Cantillo 1998), showing that the Altata-Ensenada del Pabellón lagoonal system is not yet highly impacted by anthropogenic activities.

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