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Cadmium and Lead Levels Along the Estuarine Ecosystem of Tigre River-San Andres Lagoon, Tamaulipas, Mexico

María de la Luz Vázquez-Sauceda · Roberto Pérez-Castañeda · Jesús Genaro Sánchez-Martínez · Gabriel Aguirre-Guzmán

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Abstract Cadmium and lead levels were evaluated in water and sediment along the estuarine ecosystem of Tigre River-San Andres Lagoon (Gulf of Mexico) during September to December 2009. Significant highest metal concentration in water (0.45 mg L^{-1} Cd and 3.94 mg L^{-1} Pb) and sediment (2.83 mg kg^{-1} Cd and 6.61 mg kg^{-1} Pb) were found at the mouth of the Tigre River, where the fishing town of El Moron is located. Cadmium levels in sediment were above limits associated with adverse biological effects on aquatic fauna, so negative impacts on natural populations of aquatic organisms would be expected to occur. This in turn could affect the fishery resources inhabiting this ecosystem.

Keywords Cadmium · Lead · Estuary · Gulf of Mexico

Estuaries and coastal lagoons are essential habitats for resident and estuarine-dependent species of fishes and invertebrates, some of which support valuable commercial fisheries. However, contamination of estuarine ecosystems may affect the organisms living in them at different levels of ecological organization (Dauvin 2008; Gillet et al. 2008). Estuarine ecosystems are extremely fragile and, in some regions, they have undergone major transformations caused by the dams on rivers, the closure of tidal inlets, and the dumping of municipal and industrial discharges from adjacent populations, which contain various pollutants including heavy metals such as Hg, Cd, Pb and Cr (Villanueva and Botello 1998).

The study of pollutants in coastal habitats is necessary to evaluate the presence of anthropogenic contamination. Particularly, the evaluation of heavy metal levels in estuarine ecosystems is of utmost importance as these pollutants can affect the life of the organisms inhabiting them. Heavy metals may have negative effects on different phases of the life cycle (from embryos to adults) of fishes, mollusks and crustaceans, affecting their survival and reproductive fitness (Sheehan 1984; Lawrence and Hemingway 2003).

Heavy metals are present naturally in the Earth's crust and in living organisms taking part in metabolic processes. Their toxicity in marine and estuarine habitats is influenced by physical and biological factors, often resulting in adverse biological effects at high concentrations (Long et al. 1995).

The presence of anthropogenic contamination by heavy metals has been reported in several coastal ecosystems along the Gulf of Mexico (Villanueva and Botello 1998). In the case of San Andres Lagoon (Tamaulipas, Mexico), it is a semi closed coastal lagoon that communicates to the Gulf of Mexico through a narrow tidal inlet. It receives freshwater inputs from the Tigre River, thus creating an important estuarine ecosystem between the river and the lagoon where fishing and aquaculture activities are carried out. This estuarine ecosystem is subject to several water discharges and runoffs from different sources (urban, agricultural and livestock). Because of this, heavy metal levels monitoring in water and sediment of this ecosystem, especially those originated from anthropogenic activities is

M. L. Vázquez-Sauceda (✉) · R. Pérez-Castañeda · J. G. Sánchez-Martínez · G. Aguirre-Guzmán
Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Tamaulipas, Carretera Victoria-Mante km 5, 87000 Cd. Victoria, Tamaulipas, Mexico
e-mail: mvazquez@uat.edu.mx

M. L. Vázquez-Sauceda
Instituto de Ecología Aplicada, Universidad Autónoma de Tamaulipas, División del Golfo No. 356, Col. Libertad, 87019 Cd. Victoria, Tamaulipas, Mexico

essential for the safety of the fishery resources. To address this, an analysis of the concentration of two heavy metals (Cd and Pb) in water and sediment of the estuarine ecosystem of Tigre River-San Andres Lagoon was performed during September to December 2009.

Materials and Methods

Sixteen sampling sites were situated along the estuarine ecosystem of Tigre River-San Andres Lagoon, located in the Gulf of Mexico (22°39′–22°51′N, 97°49′–97°57′W) (Fig. 1). At each site water and sediment samples were taken during September to December 2009. Water was collected in polyethylene bottles submerged approximately 15 cm below the surface, taking a sample of 1 L; whereas sediment was obtained with the help of a PVC pipe (1.5 m long and 7.5 cm in diameter) collecting the first 10–15 cm of the sediment surface ensuring a 500 g mass in each site. Samples were placed in ice for posterior analysis in laboratory.

Cadmium and Lead levels in water were determined by photometric analysis using a Merck SQ118 photometer and the corresponding Spectroquant® kits. A recovery rate of 95 % was obtained for cadmium and 93 % for lead,

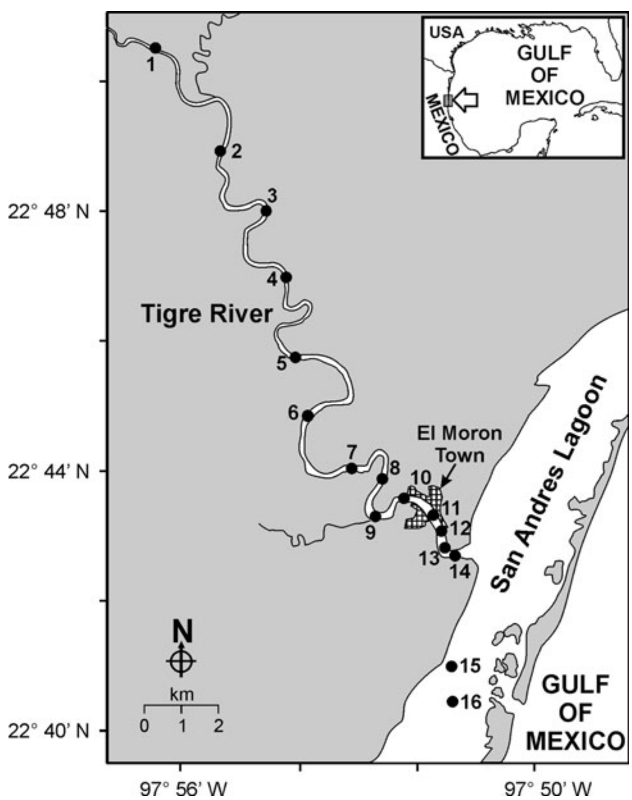

Fig. 1 Location of sampling sites in the estuarine ecosystem of Tigre River-San Andres Lagoon

whereas the limits of detection were 0.025 and 0.1 mg L^{-1} for Cd and Pb, respectively. Sediment samples were analyzed by atomic absorption spectrometry under the NMX-AA-051-SCFI-2000 standard, using a Buck Scientific 200 atomic absorption spectrometer. Marine sediment reference material for trace metals (HISS-1) was used to validate this analytical procedure. The recoveries obtained for sediment were 93 % Cd and 89 % Pb. The limits of detection were 0.2 mg kg^{-1} for Cd and 0.1 mg kg^{-1} for Pb. Concentrations of cadmium and lead in water and sediment were compared between sites using one way ANOVAs.

Results and Discussion

The study area showed significant differences in water salinity (ANOVA, $F_{15,48} = 44.2$, $p < 0.05$) among the 16 sampling sites, exhibiting an increasing trend in mean salinity from site 1 (2.8 ± 0.7 ‰, located upstream) to site 16 (31.1 ± 0.8 ‰, located in the coastal lagoon) (Fig. 2). In the case of the temperature no significant differences were observed along the sampling sites (ANOVA, $F_{15,48} = 0.11$, $p > 0.05$) (Fig. 2).

Significant differences ($p < 0.05$) in cadmium levels were found in both water and sediment along the estuarine ecosystem with highest values occurring downstream. The highest water cadmium concentrations were found in sites 13 and 14 (0.41 ± 0.14 and 0.45 ± 0.17 mg L^{-1}, respectively) and the lowest were found in sites 1–9, and site 11, which were below the lower limit of detection, i.e. <0.025 mg L^{-1} (Fig. 3). The average cadmium content in sediment was significantly greater ($p < 0.05$) in sites 10–14, with the highest concentration in site 11 (2.83 ± 0.1 mg kg^{-1}), while the lowest levels were found in sites 4–6 (Fig. 3).

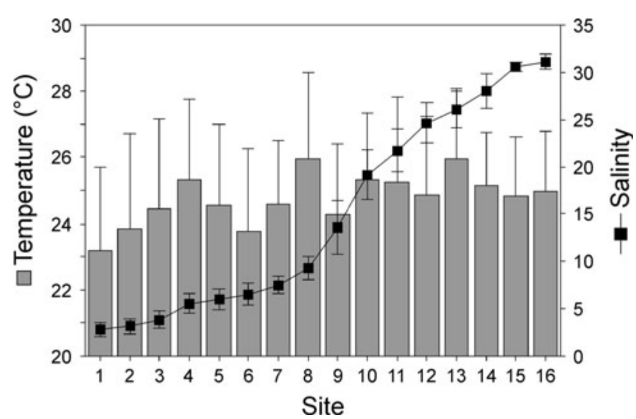

Fig. 2 Spatial variation (mean ± SE) in temperature and salinity at 16 sampling sites located along the estuarine ecosystem of Tigre River-San Andres Lagoon

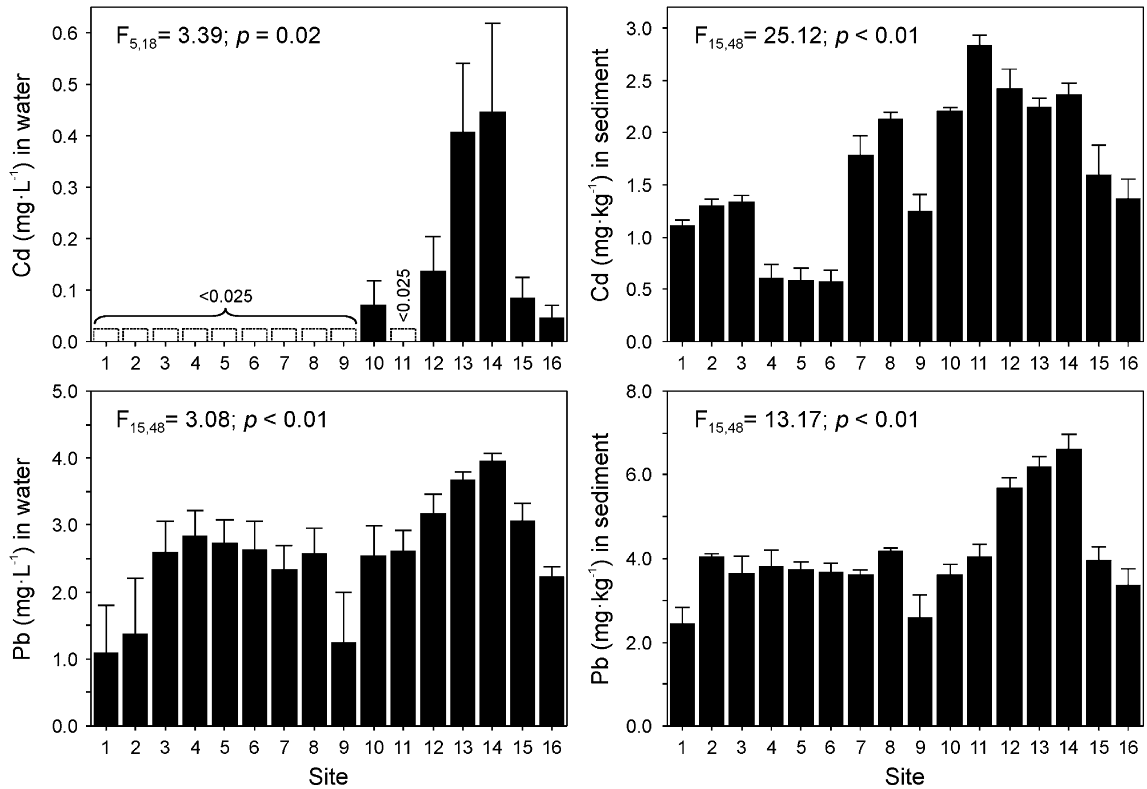

Fig. 3 Mean (±SE) heavy metal concentrations in water (mg L^{-1}) and sediment (mg kg^{-1}) at different sampling sites along the estuarine ecosystem of Tigre River-San Andres Lagoon

The highest water cadmium concentration found in sites 13 and 14 (mouth of the river) is probably due to their proximity to the discharges of domestic wastewater from the fishing town of El Moron, coupled with the lack of sufficient natural tributaries. Furthermore, the cadmium levels found in this study at the mouth of the Tigre River, are slightly greater than those previously reported (0.33 mg L^{-1}) by Vázquez-Sauceda et al. (2011) within San Andres Lagoon in the area contiguous to the mouth of this river.

Cadmium enters the soil by aerial deposition, landslides, manure and the application of phosphates in fertilizer, which contain between 10 and 200 µg g^{-1} of cadmium (Cook and Morrow 1995); therefore water runoff from these soils may be an important cause of the accumulation of this metal in sediment. Studies on cadmium levels in different types of sediment, have determined that its concentration in unpolluted surface sediment should not exceed 1.00 µg g^{-1} (Sadiq 1992). However, in this study cadmium concentrations were much higher (1.62–3.69 mg kg^{-1}); and exceeded concentrations associated with adverse biological effects on aquatic organisms (Long et al. 1995).

Lead concentration in water and sediment showed significant differences between sites, with highest values towards the mouth of the Tigre River, primarily in sites 13 and 14 (Fig. 3). Water lead levels in sites 13 and 14 were 3.68 ± 0.12 mg L^{-1} and 3.94 ± 0.14 mg L^{-1}, respectively; whereas for sediment, the lead concentrations were 6.17 ± 0.27 mg kg^{-1} and 6.61 ± 0.37 mg kg^{-1}. On the other hand, sites 1, 2 and 9 showed the lowest lead concentrations in water (from 1.09 ± 0.70 mg L^{-1} to 1.36 ± 0.85 mg L^{-1}); whereas lowest lead levels in sediment were observed in sites 1 and 9 (2.42 ± 0.42 mg kg^{-1} and 2.59 ± 0.55 mg kg^{-1}, respectively) (Fig. 3).

Lead levels reported in our study are much higher than those previously reported in San Andres Lagoon (0.39–0.70 mg L^{-1} in water and 0.89–1.01 µg g^{-1} in sediment) by Vázquez-Sauceda et al. (2011), indicating a substantial increase in lead levels probably associated with an increased magnitude of lead inputs from diverse sources.

High lead levels in water and sediment, like those observed in this study, may be due to the emissions from vehicles and boats with outboard motors in the area of study or by atmospheric transport from the industrial cities of Altamira and Tampico, located 35 and 50 km southward, respectively. Another possible source would be the wastewater discharges from the fishing town of El Moron. Lead pollution in this estuarine ecosystem could be closely related to these anthropogenic influences, as documented in other coastal lagoons from the Gulf of Mexico where leaded gasoline has been indicated as an important source of lead (Sharma et al. 1999; Green-Ruiz and Páez-Osuna 2003; Vazquez and Sharma 2004).

The levels for cadmium and lead tended to be higher at the mouth of the Tigre River, where anthropogenic activities are concentrated, such as urbanization as well as boating, fishing and shrimp aquaculture. This is in agreement with results obtained in a previous study in San Andres Lagoon, where the highest concentrations of cadmium and lead in water samples were found at sites located close to the mouth of the Tigre River (Vázquez-Sauceda et al. 2011).

Undoubtedly, anthropogenic pressure has an important impact in coastal pollution; indeed, it has been recognized that aggressive industrialization and urbanization of coastal areas along the Gulf of Mexico from several decades ago, resulted in an increase in metal concentrations in coastal lagoons from this region (Villanueva and Botello 1998). However, other human activities like animal husbandry and agriculture developed in the coastal basin of this region could also be additional sources of heavy metals to the estuarine ecosystem, because of the use of pesticides and fertilizers, as occurs in other coastal lagoons (Frías-Espericueta et al. 2009). In this regard, runoff regime in the coastal basin has an important role.

Since cadmium levels in sediment (up to 2.83 mg kg^{-1}) were usually above limits (1.2 mg kg^{-1}, ERL: effects range-low) associated with adverse biological effects on aquatic fauna (Long et al. 1995), negative impacts on natural populations of aquatic organisms are expected to occur. However, at present these potential effects have not been evaluated. The knowledge of these aspects would be of relevance for conservation and management of marine resources inhabiting the estuarine ecosystem.

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References

Cook ME, Morrow H (1995) Anthropogenic sources of cadmium in Canada. National workshop on cadmium transport into plants. Canadian Network of Toxicology Centres, Ottawa

Dauvin JC (2008) Effects of heavy metal contamination on the macrobenthic fauna in estuaries: the case of the Seine estuary. Mar Pollut Bull 57:160–169

Frías-Espericueta MG, Osuna-López I, Bañuelos-Vargas I, López-López G, Muy-Rangel MD, Izaguirre-Fierro G, Rubio-Carrasco W, Meza-Guerrero PC, Voltolina D (2009) Cadmium, copper, lead and zinc contents of the mangrove oyster, *Crassostrea corteziensis*, of seven coastal lagoons of NW Mexico. Bull Environ Contam Toxicol 83:595–599

Gillet P, Mouloud M, Durou C, Deutsch B (2008) Response of *Nereis diversicolor* population (Polychaeta, Nereididae) to the pollution impact—Authie and Seine estuaries (France). Estuar Coast Shelf Sci 76:201–210

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

Lawrence A, Hemingway K (2003) Effects of pollution on fish. Molecular effects and population responses. Blackwell Science Ltd, Iowa

Long ER, Macdonald DD, Smith SL, Calder FD (1995) Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environ Manage 19:81–97

Sadiq M (1992) Cadmium in the marine environment. In: Sadiq M (ed) Toxic metal chemistry in marine environments. Marcel Dekker, New York, p 390

Sharma VK, Rhudy KV, Koening R, Vazquez FG (1999) Metals in sediments of the upper Laguna Madre. Mar Pollut Bull 38:1221–1226

Sheehan PJ (1984) Effects on individuals and populations. In: Sheehan PJ, Miller DR, Butler GC, Bourdeau P (eds) Effects of pollutants at the ecosystem level. Wiley, New York, p 443

Vazquez FG, Sharma VK (2004) Major and trace elements in sediments of the Campeche Sound, southeast Gulf of Mexico. Mar Pollut Bull 48:87–90

Vázquez-Sauceda ML, Aguirre-Guzmán G, Sánchez-Martínez JG, Pérez-Castañeda R (2011) Cadmium, lead and zinc concentrations in water, sediment and oyster (*Crassostrea virginica*) of San Andres Lagoon, Mexico. Bull Environ Contam Toxicol 86:410–414

Villanueva FS, Botello AV (1998) Metal pollution in coastal areas of Mexico. Rev Environ Contam Toxicol 157:53–94