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Mercury in Fish and Shark Tissues from Two Coastal Lagoons in the Gulf of California, Mexico

J. Ruelas-Inzunza,[1] F. Páez-Osuna[2]

[1] Technological Institute of the Sea, Post Office Box 757, Mazatlán 82000, Sinaloa, Mexico
[2] Institute of Marine Sciences and Limnology, National Autonomous University of Mexico, Post Office Box 811, Mazatlán 82000, Sinaloa, Mexico

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After the Minamata disaster in the 1950´s, studies related to the occurrence of toxic substances in fish and other aquatic resources have been conducted throughout the world, specially in coastal areas where fishery products are extensively consumed. In tropical and subtropical areas, studies on the presence of Hg compounds in biota are scarce. Contaminated fish products that are consumed by people can cause diverse damages, from headaches to difficulties in learning since this mercury reaches and alters the central nervous system (Lacerda and Salomons 1998).

Guaymas harbor (GUH) is located in the middle part of the Gulf of California (27° 54' and 27° 59' N; 110° 48' and 110° 55' W), the system has an average area of 28 km^2 and an average depth of 2.3 m. Potential sources of Hg pollution include domestic effluents from Guaymas city (>150,000 inhabitants), oil residues from transport operations, effluents from a cement industry and cooling waters from a thermo electrical plant (Green-Ruiz 2000). Altata-Ensenada del Pabellón (AEP) system is located in the central part of Sinaloa state (24° 20' and 24° 40' N; 107° 30' and 107 58' W). The major source of pollution is represented by the waste effluents from the intensive agriculture (140,000 ha) which border the lagoon system and consists mostly of vegetables, grains and sugar cane; in this context, recently, some Hg compounds have been used in agriculture principally as fungicides (Boening, 2000). Another source of pollution is the urban sewage from the towns (pop. 100,000) and the cities of Culiacán (pop. 750,000) and Navolato (pop. 50,000) which are located 40 and 20 km away from the main lagoon, respectively, on the margin of the Culiacán River (Páez-Osuna et al. 1998). In addition, from December to June the effluents of a sugar-cane industry called Ingenio La Primavera are discharged directly into the Ensenada del Pabellón lagoon portion (Fig. 1).

With the aim of knowing the degree of Hg accumulation in biota from two coastal systems, levels of Hg in muscle, liver, gills and viscera of 7 species of fish and 2 species of sharks from Altata-Ensenada del Pabellón and Guaymas (Gulf of California) were determined. Additionally, Hg

Correspondence to: F. Páez-Osuna

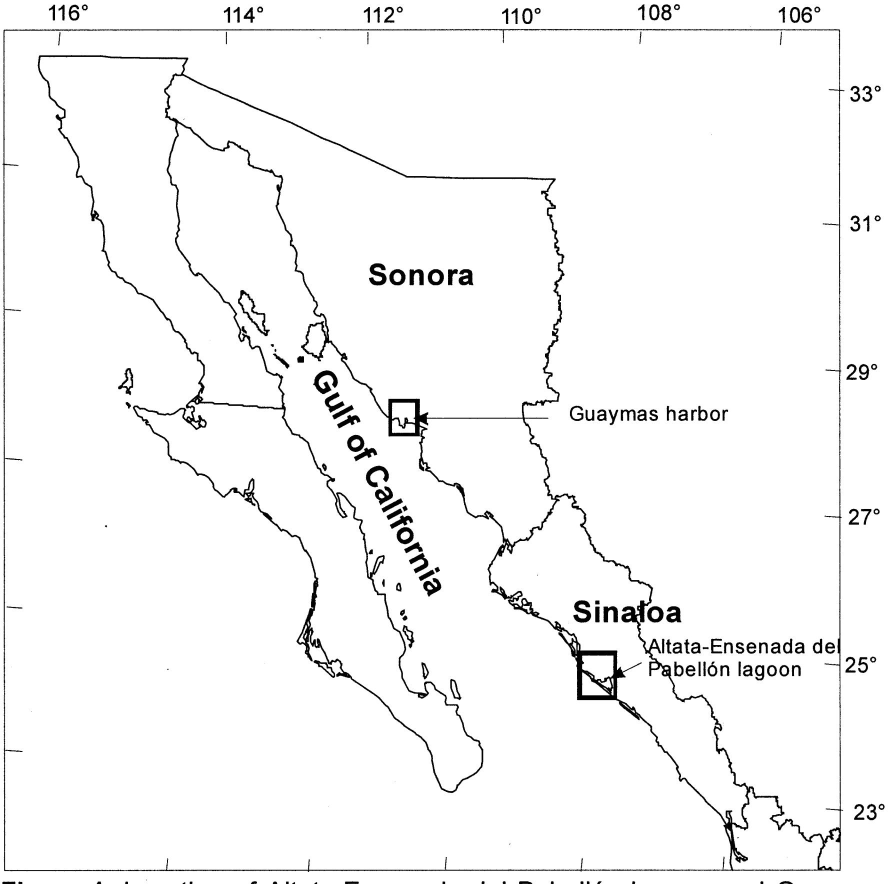

Figure 1. Location of Altata-Ensenada del Pabellón lagoon and Guaymas harbor (Gulf of California) where fishes and sharks were collected.

concentration in the edible portion of analyzed specimens was compared with maximum permissible levels in fish by international legislation.

MATERIALS AND METHODS

A limited number of specimens were collected over an 8-month period (April 1998-January 1999) obtained directly from local fishermen; all specimens collected were commercially sold for human consumption. Samples were placed in polyethylene bags and transported in iced coolers, in the laboratory, samples were identified, measured and weighed prior to dissection. Depending on the availability and size of specimens, individual or pooled samples of 3-4 organisms were used (Table 1). In order to avoid contamination of samples from manipulation and storage, glassware and other plastic utensils were previously washed according to Moody and Lindstrom (1977); samples were freeze-dried for 72 hours (-49°C and $133x10^{-3}$ mBar) then ground in an automatic agate mortar (Retsch) for 10 min. Powdered samples were acid digested (5 ml of quartz distilled concentrated nitric acid) using a microwave digestion unit (CEM MDS-2000) under the following conditions (MESL 1997): step 1, 20 psi for 10 min; step 2, 40 psi for 10 min; step 3, 90 psi for 30 min. Digested samples were stored in polyethylene containers for further analysis. Two aliquots of each tissue were analyzed.

Table 1. Biological characteristics of collected organisms from Altata-Ensenada del Pabellón and Guaymas harbor in the Gulf of California.

Species	Common name	Diet	N	Length (cm)	Weight (g)	Site
Galeichthys peruvianus	catfish	C	1*	48	1428	AEP
Lutjanus colorado	colorado snapper	C	6	22-44	159-1082	AEP
Cynoscion xanthulus	orangemouth corvine	C	8	24-43	188-572	AEP
Mugil cephalus	striped mullet	O	6	29-41	256-580	AEP
Carcharhinus leucas	bull shark	C	1*	106	11000	AEP
Sphyrna lewini	scalloped hammerhead	C	1*	89	3 700	AEP
Opisthonema libertate	Pacific thread herring	H	8	21-24	111-136	GUH
Cathorops fuerthii	catfish	C	6	24-28	164-218	GUH
Mugil cephalus	striped mullet	O	6	25-27	148-183	GUH
Seriola lalandi	yellowtail	C	2*	97-101	6536-6634	GUH

Diet: C, carnivore; O, omnivore; and H, herbivore. N means the number of pools of 3 or 4 organisms. * individual samples

Analyses were carried out by reducing mercury compounds using $SnCl_2$ and detection by flameless atomic absorption spectrophotometry (Loring and Rantala 1995); measurements were made with a Hg analyzer (Buck Scientific). Hg concentrations are expressed as ng g^{-1} on a dry weight basis; precision and accuracy of the analytical method were assessed by using reference material MA-B-3/TM (IAEA 1987). A satisfactory agreement between the analytical results (0.60 ± 0.05 µg g^{-1} dry weight) and the certified values (0.54 ± 0.07 µg g^{-1} dry weight) was obtained. To check for contamination, blanks were also analyzed using this procedure after every 8 samples. The minimum detection limit was estimated in 0.01 µg g^{-1} dry weight. Normality of data was assessed by a Kolmogorov-Smirnov test (Zar, 1984); for a given tissue, average concentrations of Hg among species from the same site were compared by a one-way ANOVA ($p<0.05$). Statistical analyses were carried out using GraphPad Prism 2.1 (Graph Pad Software, San Diego, CA).

RESULTS AND DISCUSSION

It is widely recognized that trace metals accumulate preferentially in selected tissues of biota; in this sense, an overview of Hg accumulation in the studied fishes and sharks resulted in relatively high levels in muscle and liver (Fig. 2). After the statistical comparison of Hg concentrations in the same tissue among fish species (with a $n \geq 6$) from AEP system: *Lutjanus colorado* was the species with significantly ($p <0.05$) higher concentrations of Hg in gills, liver, and muscle than *C. xanthulus* and *M. cephalus; L. colorado* had significantly ($p <0.05$) higher levels of Hg in viscera than *M. cephalus*; and the liver of *C. xanthulus* showed significantly higher concentrations of Hg than *M. cephalus*. In the case of Guaymas harbor the comparisons resulted as: *Cathorops fuerthii* had significantly ($p <0.05$) higher levels of Hg than *Opisthonema libertate* in muscle and viscera; *C. fuerthii* had significantly higher Hg concentrations than *M. cephalus* in muscle; and *O. libertate* showed significantly higher Hg levels than *M. cephalus* in muscle as can be appreciated from Fig. 2.

In general, levels of Hg in the analyzed specimens from AEP were more elevated than in biota from GUH. *M. cephalus* was the only species common to both sites, and Hg concentration in gill specimens from AEP were higher (201 ± 77 ng g^{-1} dry weight) than in organisms from GUH (68 ± 3 ng g^{-1} dry weight). It might indicate that AEP is a more impacted area with Hg in comparison to GUH. From published data in muscle of fishes and sharks from other areas, it can be said that Hg levels in the catfish *G. peruvianus* (1.58 µg g^{-1} dry weight) from AEP were comparable to levels in the sardine *Sardinella punctatus* (1.39 µg g^{-1} dry weight) from an impacted site in the Philippines (Prudente *et al.*, 1997) and lower than concentrations reported in the doncella *Ageneiosus caucanus* (4.52 ± 0.42 µg g^{-1} dry weight) from a gold mining area in Colombia (Olivero et al. 1998). Concerning sharks, Hg levels in the scalloped hammerhead *Sphyrna lewini* (4.84 µg g^{-1} dry weight) from AEP were comparable to concentrations reported in the Port Jackson shark *Heterodontus portusjacksoni* (5.8 to 7.3 µg g^{-1} dry weight) from Australia (Gibbs and Miskiewicz 1995) and the blackmouth cat shark *Galeus melastomus* (4.32 ± 4.5 µg g^{-1} dry weight) from the Adriatic Sea (Storelli and Marcotrigiano 2002). Nevertheless, Hg values in other sharks species [the Gulper shark *Centrophorus granulosus* (38.6 ± 2.8 µg g^{-1} dry weight) and the smooth hammerhead *Sphyrna zygaena* (73.1 ± 0.1 µg g^{-1} dry weight) from the Adriatic sea were an order

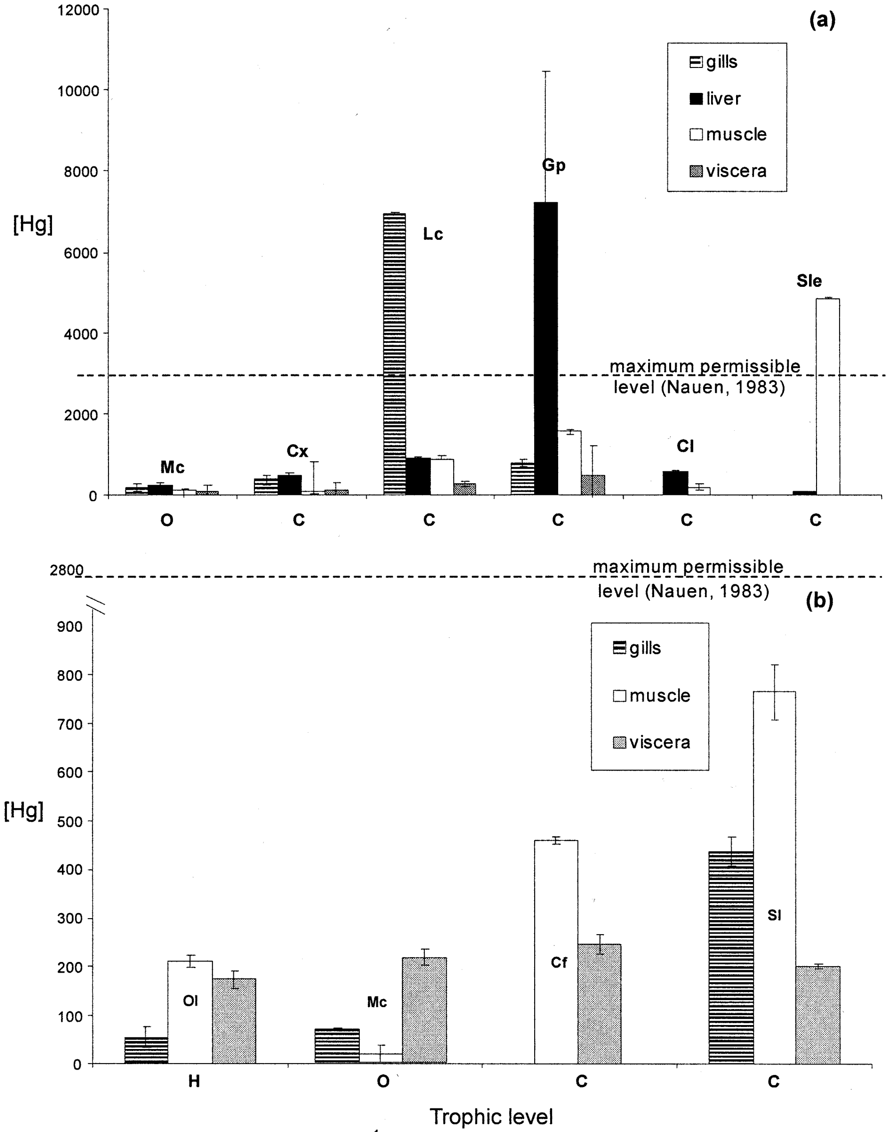

Figure 2. Mercury levels (ng g^{-1} dry weight) in tissues of fishes and sharks with different feeding habits from Altata Ensenada del Pabellón (a) and Guaymas Harbor (b). Mc, *M. cephalus*; Cx, *C. xanthulus*; Lc, *L. colorado*; Gp, *G. peruvianus*; Cl, *C. leucas*; Sle, *S. lewini*;Ol, *O. libertate*; Cf, *C. fuerthii*; Sl, *S. lalandei*, (C, carnivore; H, herbivore; O, omnivore).

of magnitude higher than concentrations reported above (Storelli et al. 2002). Considering that muscle is the portion of fish of human interest and that trophic level of specimens is an important factor related to Hg biomagnification, variations were plotted in order to have an idea of the magnitude of Hg levels in the different species (Fig. 2). In AEP, the shark *S. lewini* and the catfish *G. peruvianus* accumulated higher concentration of Hg than the rest of the species; both species feed predominantly on fish. In GUH, the carnivorous catfish *C. fuerthii* and the yellowtail *S. lalandi* had the highest Hg concentrations. Bioaccumulation of Hg during the life course of fish and elasmobranchs is well known (GESAMP 1988; Walker 1988). In this context, those species with a longer life span and of carnivorous habits would be expected to accumulate higher levels of Hg. The general trend of Hg accumulation in muscle of ichthyofauna from both sites was carnivorous>non-carnivorous. Mercury contents in muscle of one of the analyzed species (scalloped hammerhead) exceeded the established limits (<2800 ng g^{-1} dry weight) in edible fish tissues in many countries (Nauen 1983). Concerning other tissues, levels of Hg in most of the specimens were below the maximum permissible levels, with the exception of the liver of *Galeichthys peruvianus* and the gills of *L. colorado*. In this sense, it is worth mentioning that some fish species, the Pacific herring (*O. libertate*) in this region are used for flour production as a nutritious supplement in animal diets. Special attention should be placed on fish species of popular consumption and the potential risk of health problems.

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