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Short Communication

Heavy metals in sediment and fish from two coastal lagoons of the Mexican Central Pacific

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ABSTRACT. The present work analyzed the concentration of As, Cd, Pb, and Hg in sediment and the Hg concentration in fish muscle from two coastal lagoons in the states of Jalisco (Barra de Navidad Lagoon) and Colima (Cuyutlán Lagoon), Mexico. Both lagoons showed relatively low levels of metal contamination and potential health risk compared to other Mexican areas. A non-carcinogenic hazard quotient (HQ) was determined. As (10.7 ± 1.3 - 25.4 ± 3.1 µg g^{-1}) and Pb (42.7 ± 4.2 - 123.9 ± 14.7 µg g^{-1}) concentrations exceeded the permissible levels, otherwise for Hg and Cd were below the limits. The highest total mercury concentration was found in *Haemulopsis* sp. and *Lutjanus* sp. with 0.23 and 0.1 µg g^{-1} (wet weight) respectively, out of 14 species of fish analyzed that are frequently consumed locally. HQ based on the national daily *per capita* consumption of fish in Mexico and the consumption of fish associated with fishing communities in Mexico showed an HQs >2, which manifests the vulnerability of these communities to persistent toxic and bioaccumulative contaminants.

Keywords: heavy metals; sediment; non-carcinogenic hazard quotient; fish intake; coastal lagoon; Mexico

Chemical pollution of aquatic ecosystems, particularly caused by heavy metals, is one of the most serious problems facing modern society. Both due to its significant contribution to the general degradation of aquatic ecosystems and the loss of biodiversity, as well as the immediate risk that it presents in terms of public health and food security (Reyes et al. 2016). This pollution presents a growing and multidimensional problem that is expected to worsen with population growth and the rapid increase in industrial areas worldwide, especially in countries with emerging economies (Ramírez-Ayala et al. 2018). Mexico is a prominent member of the mega-diverse countries, which has a considerable extension/surface of aquatic ecosystems of international importance. It is the second country with more wetlands registered in the RAMSAR

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agreement (RAMSAR Convention 2020). It also holds one of the largest human populations globally, being the 10th most populous country on the planet (UN 2019). Industrial developments include mining, oil, textile, and agricultural industries, cause a complicated balance between economic development and environmental protection. This contradictory scenario represents a significant challenge in the protection and responsible management of national aquatic ecosystems. In recent decades, international conventions and treaties, laws, norms, national policies, and monitoring programs (e.g. National Monitoring Network, CONAGUA 2017) have been established for promoting the protection and conservation of the country's aquatic ecosystems. However, the complex pollution scenarios in which a large part of the country's aquatic ecosystems are found (CONAGUA 2017) require even more efforts from the competent authorities and decision-makers to meliorate the problem (McCulligh 2014).

Mexico has a great wealth of aquatic ecosystems; however, many of these present considerable pollution levels. Although notable efforts have been made to monitor aquatic contamination, much remains to be done, especially in monitoring persistent toxic and bioaccumulative contaminants (PTBCs), as with heavy metals (e.g. mercury, Hg; cadmium, Cd; lead, Pb; or arsenic, As). Monitoring PTBCs such as toxic metals, particularly Hg, is crucial in the various environmental matrices because it estimates the potential health risk for aquatic ecosystems and humans. Heavy metals toxicity is a topic of increasing interest due to the high potential for bioaccumulation and biomagnification, mainly of Hg, considered one of the most dangerous elements, species-wise in its organic form as methyl mercury (MeHg) (Manavi & Mazumder 2018). MeHg appears in aquatic ecosystems mainly through bacterial biotransformation of inorganic Hg principally in the sediments, through methylation (Paranjape & Hall 2017). On the other hand, the main source of human exposure to MeHg is through the consumption of fish (Fuentes-Gandara et al. 2018), given that of the total Hg contained in the fish muscle of 75 to >90%, it is found as MeHg (Ruelas-Insunza et al. 2008, Hong et al. 2012, Ehnert-Russo & Gelsleichter 2020, Le Croizier et al. 2020). MeHg exposure has been shown to have neurotoxic, immunotoxic, or carcinogenic effects and reproductive and embryonic developmental disorders, primarily in the development of the nervous system (Hong et al. 2012, Paranjape & Hall 2017).

Tens of tons of heavy metals are generated in Mexico as waste from various activities and industries. For example, it produces about 1.8 million tons of mining products, being considered one of the main producers of this sector (Franco-Hernández et al. 2010, INECC 2017, SGM 2018). Likewise, thousands of tons of electronic waste are generated (OINCyTU 2018). Other important sources of heavy metals are domestic and industrial wastewater; only 50% of the wastewater generated in the country receives some level of treatment (CONAGUA 2017). This discharge results in the release of huge amounts of toxic metals throughout the Mexican territory.

In Mexico, researchers in recent decades have been monitoring the concentration of heavy metals in various environmental matrices (water, sediment, air, and biota) of aquatic ecosystems. They are generating valuable information that can serve as a basis for decision-making in environmental and public health matters to favor the protection and responsible management of the ecosystems. However, despite the great effort, there are still areas with little information about persistent pollutants in different environmental matrices, such as the central part of the Mexican Pacific coast. Therefore, this work aims to evaluate the possible risk of Hg, Pb, Cd, and Cr concentrations in sediments and Hg in fish from two Mexican coastal lagoons (Barra de Navidad Lagoon-BNL and Cuyutlán Lagoon-CL). These objectives were reached by comparing them against international environmental guidance values for the ecotoxicological risk of trace metals in sediments and maximum metal ingestion allowances for humans.

The BNL is located in the coastal area of the state of Jalisco in the municipality of Cihuatlán (19°11'N, 104°39'W), a municipality that has about 40 thousand inhabitants and whose economic activity is mainly oriented to tourism, agriculture, and coastal fishing (INEGI, 2017a). BNL has a surface area of 334 ha and freshwater inlets from two river sources, the Arroyo Seco River and the Marabasco River, and water exchanges with the sea through a mouth of 100 m wide (Aguilar-Betancourt et al. 2016). On the other hand, the CL is located in the municipality of Manzanillo in the state of Colima (19°03'N, 104°19'W), which has about 184,000 inhabitants, and whose economy is mainly oriented to industry (port, electrical, mining sector), tourism and coastal fishing (INEGI 2017b). This aquatic body, with an area of 38,884 ha, has a distinctive geographical feature: the separation into four reservoirs called "vasos", delimited by natural and artificial barriers that regulate the exchange of water and the drag of sediments between one compartment and another (Torres & Quintanilla-Montoya 2014). This lagoon receives limited contributions of freshwater from the Coahuayana River and the Armería River.

The concentrations of metals in sediments were compared against international reference values for adverse biological effects for aquatic biota. Threshold effects level (TEL), low range effect level (ERL), and probable effects level (PEL) guidelines were used, according to the Canadian Council of Minister of the Environment and the National Oceanic and Atmospheric Administration, USA (Table 1). Fish sampling was carried out in March 2018 by local fishermen's assistance, sampling for three days (one per week). The organisms were collected near the sampling points established for sediment collection by traditional fishing gear (cast fishing net and trammel). Once the specimens were collected, they were put on ice and transported to the laboratory, where biometric data (weight and total height) were measured and subsequently individually packed in airtight plastic bags and kept frozen at -20°C until further analysis.

The determination of heavy metals in sediment was performed by mass spectrometry with inductively coupled plasma (ICP-MS, Agilent 7900 ICP-MS). Before determining heavy metals, the sediment samples were dried at room temperature in the shade for seven days. Sediments were crushed/pulverized in an agate mortar and passed through a #20 (840 µm) sieve, the samples were homogenized, and subsequently, three sub-samples of 1 g were taken. The sub-samples were subjected to acid digestion with concentrated HNO_3 (JT Beiker) on a hot plate (100°C) as described in Pérez-Rodríguez et al. (2017) with some modifications. Five grams of muscle were digested with HNO_3 and H_2SO_4 to determine Hg in fish muscle, with their respective reagent blanks and standard solutions as control of quality and processed following the NMX-AA-051-SCFI-2016 standard, using an Agilent 240FS AA atomic absorption spectrophotometer coupled to a hydride generator. A reagent blank (2% HNO_3) and a multi-elemental NIST standard were routinely measured after every 10 experimental samples to verify the reliability of the analysis. Similarly, the experimental samples, blanks, and reference materials (NIST-RM8704 and NIST-SRM1577 for sediment and fish, respectively) were added with 100 µg mL^{-1} of Agilent internal calibration standard of Li, Sc, Ge, Y, In, Tb, and Bi (p/n 5183-4681, Agilent, USES). The recoveries for certified reference materials were 95 ± 15% for As, Cd, Pb, and Hg in sediments and 100 ± 9.8% for Hg in tissue. The detection limits were as follow: As (0.1 µg g^{-1}), Cd (0.005 µg g^{-1}), Hg (0.05 µg g^{-1}) and Pb (0.005 µg g^{-1}), respectively.

The potential health risk from Hg ingestion associated with fish consumption was evaluated considering the non-carcinogenic risk ratio by calculating hazard quotient (HQ) as an indicator. The equation: HQ = E / RfD was used as reference dose for oral exposure (Newman & Unger 2002), where RfD is the reference dose (µg kg^{-1} kg^{-1} of body weight d^{-1}), E is the level of exposure or consumption of the contaminant and is calculated using the equation E = C × I / W, where C: concentration of the contaminant (µg g^{-1} wet weight: ww), I: *per capita* ingestion rate (g d^{-1}), and W: weight consumer average (kg), and RfD of 0.1 µg kg^{-1}, ww was considered for MeHg (USEPA 2010), I of 36 g d^{-1} (CONAPESCA 2017), and W of 70 kg (Walpole et al. 2012). One-way analysis of variance (ANOVA) was performed to assess significant differences between the data, using the SPSS statistical package (Ver.16) with a $P < 0.05$. The biota-sediment accumulation factor (BSAF) can be calculated using the expression BSAF = C_{org} / C_{sed} (Thomann et al. 1995), where C_{org} is the metal concentration in the organism and C_{sed} is the concentration of the metal in the sediment. Fish can be classified according to their BSAF value into: macro-concentrators (BSAF >2), micro-concentrator (1 < BSAF <2) and as non-concentrators (BSAF <1) (Ziyaadini et al. 2017).

Table 1. Environmental guidelines (µg g^{-1} dry weight) for metal concentrations in sediment for biological effects. As: arsenic, Cd: cadmium, Hg: mercury, Pb: lead, TEL: threshold effects level, ERL: low range effect level, PEL: probable effects level, ^{C}CCME (Canadian Council of Minister of the Environment), ^{N}NOAA (2008).

	As	Cd	Hg	Pb
TEL	7.24^{N}	0.68^{N}	0.13^{C}	30.2^{C}
ERL	8.20^{N}	1.2^{N}	0.15^{N}	46.7^{N}
PEL	41.20^{N}	4.21^{N}	0.71^{C}	112^{C}

In the case of Hg, no concentrations were found that exceeded the detection limit (DL <0.05 µg g^{-1}). Although no sediment sample showed mercury above the detection limit, it is known that the concentration in sediments is not sufficient for the prediction of the bioaccumulation process of mercury in aquatic food chains (Lawrence & Mason 2001). Therefore, any presence of mercury below the present study's detection limit might be accumulating at lower levels of the food chain. This process should mainly include benthic invertebrates or animal diets associated with the estuarine cycle of organic matter (Lawrence & Mason 2001). This metal will eventually contribute to the presence of mercury detected in fish.

Cd concentrations (from 0.02 ± 0.01 to 0.42 ± 0.23 µg g^{-1}) were found below the threshold effects level (TEL: 0.68 µg g^{-1}) (Fig. 2). On the other hand, the concentrations of As (from 10.7 ± 1.3 to 25.4 ± 3.1 µg g^{-1}) in both lagoons exceeded the TEL (7.24 µg g^{-1}) and low range effect level (ERM: 8.20 µg g^{-1}), likewise in the case of Pb the probable effects level (PEL: 112 µg

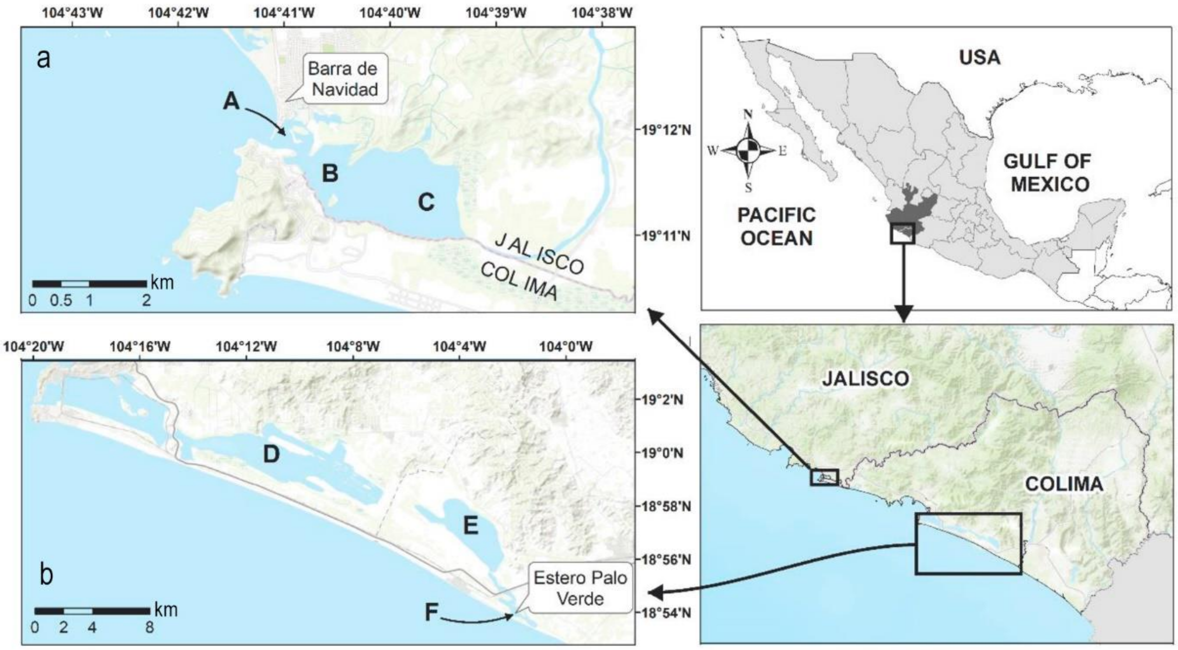

Figure 1. Location of the sampling areas. a) Barra de Navidad Lagoon, b) Cuyutlán Lagoon. A, B, C, D and E are sampling points.

g^{-1}) was exceeded (from 42.7 ± 4.2 to 123.9 ± 14.7 µg g^{-1}) (Fig. 2). In general, Barra de Navidad and Cuyutlán coastal lagoons showed similar conditions concerning the pollutants here analyzed. In both lagoons, differences were found between the sampling sites, mainly for Pb, registering the highest concentrations in the areas closest to the mouth of both coastal lagoons (Fig. 2).

Concerning total mercury (THg) concentration, 14 species of fish were analyzed. The highest concentration was found in *Haemulopsis* sp. and *Lutjanus* sp. with 0.23 and 0.1 µg g^{-1} ww and BSAF equal to 4.6 and 2.0. On the other hand, it is observed that in each one of the cases, the cogeneration of THg in fish muscle does not exceed the maximum permissible limits of 1 µg g^{-1} ww proposed by USA (USFDA 2017), the European Community (EU 2006), or Mexico (DOF, 2009) (Table 2). Regarding the non-carcinogenic risk ratio (HQ), the results show that for our study area, the national *per capita* consumption rate of fish showed that the HQ value was maintained in all cases <1, except in the case of *Haemulopsis* sp. with an HQ = 1.12 (Table 2). However, in the estimates set on fish consumption rate from some fishing communities in Mexico (400 g d^{-1}), HQ values >3 were observed. Table 3 shows the HQ values associated with the national *per capita* fish consumption rate and the consumption rate associated with fishing communities, which showed similarities to other cases previously reported in other coastal areas of Mexico.

The differences found among the sampling sites (mainly in Pb, which recorded the highest concentrations in the area closest to the mouth of both lagoons, Figs. 1-2) are probably due to its proximity to human settlements. Multiple fishing boats with outboard motors have been related as important sources of Pb in coastal sediments (Soto-Jiménez et al. 2008). In the case of the BNL, the result is also consistent with Marmolejo-Rodríguez et al. (2007), who found maximum values of 18 µg g^{-1} dry weight (dw) of Pb (Fig. 2) related to a terrigenous origin (labile fraction <1%). It could indicate a possible recent anthropic origin of the high concentrations of Pb (>100 µg g^{-1} dw) as here founded. Rapid enrichment with Pb has also been observed in other coastal ecosystems of Mexico, mainly in port areas. For example, González-Lozano et al. (2006), reported concentrations of Pb that ranged between 14-43 µg g^{-1} dw in 1998 and 43-123 µg g^{-1} dw in 2002 in Salina Cruz, Oaxaca, Mexico. These can be related to the sedimentation processes of suspended particulate materials. For example, Soto-Jiménez et al. (2008) indicate that suspended particulate matter can contribute to >98% of the Pb present, suggesting that this factor could also be involved in the presence of lead in BNL. Other significant Pb sources could be related to air transportation, such as the atmospheric deposition

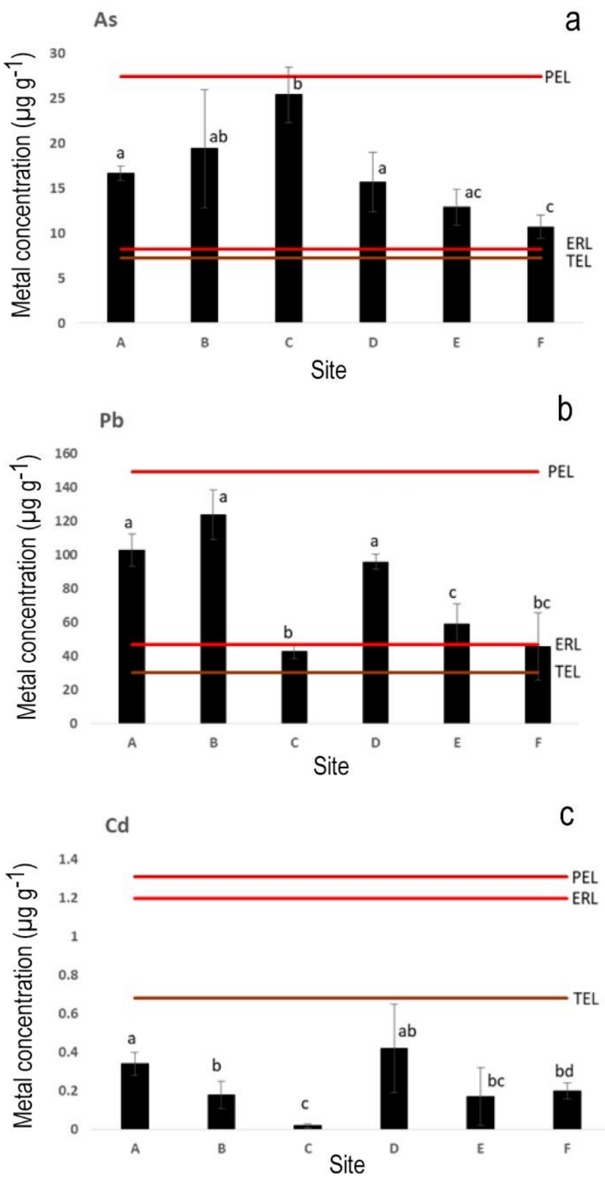

Figure 2. Metal concentrations (mean ± standard deviation, µg g^{-1} dry weight) in sediment from Barra de Navidad Lagoon (Jalisco: A, B, and C) and Cuyutlán Lagoon (Colima: D, E, and F). As: arsenic (a), Pb: lead (b), Cd: cadmium (c), TEL: threshold effects level, ERL: low range effect level, PEL: probable effects level. [a,b,c,d]Different superscript letters denote significant differences (P < 0.05).

of vehicular emissions and the thermoelectric plant emissions located next to the CL in the municipality of Manzanillo as urban wastewater discharges. These emissions have been increased in recent years in this region, which could explain the high concentrations of Pb found in both lagoons. On the other hand, only previously reported Cd values were found for the BNL. Marmolejo-Rodríguez et al. (2007) reported values of 0.05-0.34 µg g^{-1} dw in 2005, which are similar to those found in the present study (Fig. 2). There are no previous reports of As and Hg concentrations in sediment from the BNL and the CL. Similarly, it is observed that As and Pb concentrations found, both for the BNL and the CL, significantly exceed the TEL and the ERL levels (Fig. 2). They represent a potential risk for organisms associated with these ecosystems and the local population that consumes them (Enuneku et al. 2018, Ali et al. 2019).

It is unclear why the mean As concentration found in site C (the furthest from the BNL mouth) was higher than the other sites near the urbanized areas (Fig. 2). Further studies are needed to clarify the origin and accumulation of arsenic in that geographical zone, especially considering that this metalloid has already been reported in local fish (Aguilar-Bentacourt et al. 2016). The exposure of aquatic organisms to toxic environmental pollutants, such as STPBs, even in low concentrations, represents a potential risk of toxicity to be considered. It can affect the wildlife ecological balance of affected ecosystems and directly people's health belonging to communities heavily dependent on these resources and the population in general. Very little is known about the pathological outcome of chronic exposure to environmental pollutants in trace amounts in the region. The presence and bioaccumulation of some heavy metals (mainly Hg in its organic form MeHg) in the trophic networks of aquatic ecosystems may constitute a risk to human health (Mendoza-Carranza et al. 2016).

On the other hand, the bioaccumulation processes are influenced by various processes, such as the different routes of exposure and the ecological niche of each monitored species. In general, monitoring the concentration of metals in aquatic organisms can reflect the contamination of these ecosystems. Furthermore, it can help understand the potential risk they present for consumers (Wang et al. 2013). The BSAF describes the bioaccumulation of compounds, such as heavy metals associated with sediments in the tissues of organisms (Burkhard 2009). In other words, it reflects the efficiency of the accumulation of heavy metals in an organism, allowing assessing the potential toxicity of contaminated sediments. In the present study, most organisms analyzed can be considered as micro-concentrators (Table 2). However, this may be because the coastal lagoons act as a hatchery for large predators (Aguilar-Betancourt et al. 2016). Only juvenile organisms of *C. caninus* could be collected (*Lutjanus* sp. and *A. mazatlanus*), explaining the relatively low BSAF values. At the same time, they are considered top predators in their respective ecological niches in their adult stages, so they are one of the final receptors for the Hg available in the trophic web. It is essential to highlight that the highest BSAF observed was in

Table 2. Total mercury (THg) concentration (mean ± standard deviation, μg g^{-1} wet weight) and sediment-biota accumulation factor (BSAF) in fish muscle from the Barra de Navidad Lagoon and the Cuyutlán Lagoon. LD: detection limits: Hg (0.05 μg g^{-1}). Maximum permissible limits of Hg in fish: USFDA (1 μg g^{-1} wet weight); European Community (1 μg g^{-1} wet weight); NOM-242-SSA1-2009 (1 μg g^{-1} wet weight). Sample size by species N = 6. *A single organism.

Site	Species	Common name	Size (cm)	THg	BSAF
Cuyutlán Lagoon	*Mugil* sp.	Lisa	25 ± 3	0.08 ± 0.04	1.6
	Sciades guatemalensis	Bagre	20 ± 4	0.06 ± 0.02	1.2
	Polydactylus approximans	Bonito	16 ± 1	<LD	-
	Centropomus sp.	Constantino	25 ± 5	<LD	-
	Caranx caninus	Jurel	15 ± 2	0.09 ± 0.04	1.8
	Lutjanus sp.	Pargo	16 ± 2	0.07 ± 0.05	1.4
	Elops affinis	Machete	25 ± 2	0.06 ± 0.03	1.2
Barra de Navidad Lagoon	*Chanos chanos*	Sábalo	30*	0.05	1
	Mugil sp.	Lisa	33 ± 9	0.06 ± 0.05	1.2
	Acanthurus xanthopterus	Navajero	30 ± 4	0.07 ± 0.11	1.4
	Diapterus peruvianus	Mojarra	17 ± 5	<LD	-
	Sciades guatemalensis	Bagre	34 ± 6	0.06 ± 0.04	1.2
	Haemulopsis sp.	Ronco	23 ± 8	0.23 ± 0.16	4.6
	Selene sp.	Tostón	25 ± 3	<LD	-
	Achirus mazatlanus	Lenguado	15 ± 2	0.09 ± 0.06	1
	Caranx caninus	Jurel	18 ± 1	0.08 ± 0.05	1.6
	Peprilus snyderi	Gavilán	16 ± 1	0.05 ± 0.03	1
	Lutjanus sp.	Pargo	21 ± 3	0.10 ± 0.09	2

Haemulopsis sp. (Table 2), a commercial species from BNL. Although the mean THg concentration was below the maximum permissible limit of 1 μg g^{-1} ww, it is crucial to analyze the effects at a subcellular level due to this exposure, inducing antioxidant response changes at the molecular level.

On the other hand, the potential risk to human health due to exposure to Hg associated with the consumption of contaminated fish is a matter of global concern. Various diseases have been related to exposure to low concentrations of this pollutant, such as cancer, neuro-toxicity, cardiovascular diseases, endocrine disruption, and neurological defects in the developing fetus when exposed to MeHg (Dórea 2008, García-Hernández et al. 2018). The HQ is the relationship between the potential exposure to a substance and the level at which no adverse effects are expected. An HQ less than or equal to 1 indicates that adverse effects are not likely to occur. Therefore, it can be considered to have a statistically significant probability of no risk. However, HQs >1 are not statistical probabilities of damage occurring but a simple quantitative statement of whether an exposure concentration exceeds the RfD. In the present work, the concentration of Hg was transformed to MeHg form by a conversion factor of 0.95, considering that more than 90% of THg in fish muscle is present as MeHg (García-Hernández et al. 2018). Likewise, the RfD of 0.1 μg kg^{-1} d^{-1} proposed by the EPA was used (USEPA 2010). Consumption of fish of 36 g d^{-1} was considered, representing the national average (CONAPESCA 2017) and a consumption of 300 g d^{-1} associated with fishing communities (Zamora-Arellano et al. 2017, Astorga-Rodríguez et al. 2018, García-Hernández et al. 2018). Table 3 shows the different HQs for MeHg associated with the consumption of collected fish.

Based on the national average fish consumption rate, about 13.2 kg y^{-1} or 36 g d^{-1} (CONAPESCA 2017), it is possible to consider that the studied area has a relatively low-risk potential with an HQ <1 in all cases, compared to other national coastal areas showing HQs <2. However, this situation represents a potential risk for the general population of those regions (Table 2). This risk remains considerably low, compared to vulnerable communities, such as coastal fishing communities, which have a high rate of fish consump-tion associated with 400 g d^{-1} (Zamora-Arellano et al. 2017, Astorga-Rodríguez et al. 2018), which puts them in a situation of evident vulnerability especially to children and women in reproductive age. Generally, a considerable increase in HQ's value is associated with fishing communities, based on their high consumption of fishery products, representing some risk for these communities.

Table 3. Methyl mercury (MeHg) concentration µg g^{-1} wet weight (considered as 95% of total mercury concentration), non-carcinogenic risk ratio (hazard quotient, HQ) associated with the most consumed fish in fishing communities in Mexico. RfD = 0.1 µg kg^{-1} d^{-1}; average adult weight in México 70 kg. HQN: calculated based on the national average fish intake of 36 g d^{-1}. HQP: calculated based on fish consumption reported in some fishing communities in México of 400 g d^{-1}.

Species	MeHg	HQN	HQP	Location	Reference
Mugil sp.	0.06	0.34	3.80	Cuyutlán Lagoon, Colima	This study
	0.05	0.25	2.70	Barra de Navidad Lagoon, Jalisco	This study
	< 0.01	< 0.1	0.33	Barra de Navidad Lagoon, Jalisco	Aguilar-Betancourt et al. (2016)
	0.02	0.10	1.09	Alvarado Lagoon, Veracruz	Elliott et al. (2015)
	0.08	0.44	4.89	Kino Bay, Sonora	García-Hernández et al. (2018)
	0.03	0.10	1.34	Estero de Urias, Sinaloa	Frías-Espericueta et al. (2016)
	0.04	0.20	2.28	Coastal lagoons of the Mexican northeast, Sinaloa	Delgado-Alvarez et al. (2017)
	0.04	0.20	2.71	Alvarado Lagoon, Veracruz	Guentzel et al. (2007)
	0.36	1.86	20.63	Altata-Ensenada del Pabellón, Sinaloa	Ruelas-Inzunza et al. (2011)
Elops affinis	0.06	0.24	2.44	Cuyutlán Lagoon, Colima	This study
	0.37	1.90	21.27	Santamar-La Reforma Lagoon, Sinaloa	Ruelas-Inzunza et al. (2011)
	0.15	0.78	8.69	Topolobampo Bay, Sonora	Ruelas-Inzunza et al. (2011)
	0.38	1.63	16.29	Topolobampo Bay, Sinaloa	Ruelas-Inzunza et al. (2011)
	0.17	0.87	90.66	Coastal lagoons of the Mexican northeast, Sinaloa	Ruelas-Inzunza et al. (2008)
Lutjanus sp.	0.08	0.39	40.34	Barra de Navidad Lagoon, Jalisco	This study
	0.06	0.29	30.26	Cuyutlán Lagoon, Colima	This study
	0.25	1.27	14.11	Altata-Ensenada del Pabellón, Sinaloa	Ruelas-Inzunza et al. (2011)
	0.17	0.87	90.66	Altata-Ensenada del Pabellón, Sinaloa	Ruelas-Inzunza & Páez-Ozuna (2005)
	0.10	0.52	50.75	Coastal lagoons of the Mexican northeast, Sinaloa	Ruelas-Inzunza & Páez-Ozuna (2005)
Centropomus sp.	0.03	0.15	10.63	Cuyutlan Lagoon, Colima	This study
	0.29	1.47	16.29	Tecuala, Nayarit	Elliott et al. (2015)
	0.17	0.88	90.77	Alvarado Lagoon, Veracruz	Elliott et al. (2015)
	0.42	2.15	23.89	Topolobampo Bay, Sonora	Ruelas-Inzunza et al. (2011)
Caranx caninus	0.08	0.39	40.34	Barra de Navidad Lagoon, Jalisco	This study
	0.09	0.44	40.89	Cuyutlan Lagoon, Colima	This study
	0.95	4.89	54.29	Topolobampo Bay, Sonora	Ruelas-Inzunza et al. (2011)
	0.18	0.93	10.31	Estero de Urias, Sinaloa	Martínez-Salcido et al. (2018)
	0.18	0.94	10.50	Estero Huizache, Sinaloa	Martínez-Salcido et al. (2018)
Acanthurus xanthopterus	0.07	0.34	30.80	Barra de Navidad Lagoon, Jalisco	This study
Sciades guatemalensis	0.06	0.29	30.26	Barra de Navidad Lagoon, Jalisco	This study
	0.06	0.29	3.26	Cuyutlan Lagoon, Colima	This study
	0.51	2.64	29.31	Barra de Navidad Lagoon, Jalisco	Aguilar-Betancourt et al. (2016)
Haemulopsis sp.	0.21	1.12	12.48	Barra de Navidad Lagoon, Jalisco	This study
	0.14	0.73	8.14	Guerrero coast, Guerrero	Spanopoulos-Zarco et al. (2014)

In general, the data obtained indicate that both BNL and CL show relatively low levels of metal contamination and potential health risk compared to other Mexican areas. However, the presence of toxic metals like As, Cd, Pb, and Hg are undeniable. As and Pb from BNL and CL significantly exceed the TEL and the ERL levels, representing possible biological effects and risk for local biota. Ronco fish (*Haemolupsis* sp.) from BNL showed the species with the highest BSAF with 4.6 for THg, suggesting the need to analyze this species for antioxidant response at the subcellular level. In addition, HQ was determined. As (10.7 ±1.3 - 25.4 ± 3.1 µg g^{-1}) and Pb (42.7 ± 4.2 - 123.9 ± 14.7 µg g^{-1}) concentrations exceeded the permissible levels, otherwise for Hg and Cd were below the limits. However, a non-complex risk analysis, such as the calculation of HQs, can give a consistent perspective to dimensional the problem, at least in vulnerable populations or communities.

On the other hand, constant monitoring of pollutant levels present in the different environmental matrices is a fundamental tool in responsibly managing aquatic resources, mainly in Mexico, where aquatic ecosystems play an important role both ecologically and for socio-economic development.

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