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Metal Contents of Four Commercial Fish Species of NW Mexico

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Abstract The metal contents in tissues of fish species: *M. cephalus*, *Diapterus* sp., *Scomberomorus sierra* and *Oreochromis aureus*, were determined in order to evaluate if their consumption might become a health risk. The liver and gills of *M. cephalus* and *Diapterus* sp. had the highest values of Cu, Fe and Pb. In the muscle, there were no interspecific differences in the Cd, Cu and Pb contents (0.27–0.32, 0.96–1.30 and 2.12–2.80 μg/g dw, respectively). Cd and Pb may be of concern, since their mean contents in the edible muscle of the four species are higher than the limits of the European Community.

Keywords Metal pollution · Fish consumption · NW Mexico

The state of Sinaloa (NW Mexico) has >600,000 ha dedicated to intensive, highly mechanized agriculture. Since crops are grown under irrigation because of the local dry climate, the excess water as well as other effluents generated through human activities, drain into continental and coastal marine water bodies and are significant sources of anthropogenic metal inputs (Frías-Espericueta et al. 2005).

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Fish is important for a healthy diet, because it is low in fat, high in protein and rich in essential nutrients. However, fish tissues may accumulate metals to concentrations that exceed the safety levels; for this reason, fish consumption could become a significant pathway to metal exposure and a consequent risk for human health (Uluözlü et al. 2007; Türkmen et al. 2008).

Numerous studies have indicated that aquatic organisms may be good indicators of metal pollution of aquatic systems, but there is little information on the heavy metal content of fish of the coastal waters of NW Mexico. In this study we determined the contents of Cd, Cu, Fe, Pb and Zn of the muscle, gills and liver of four commercial species, which are popular in the fish markets of NW Mexico, and evaluated if the consumption of these species might become a health risk.

Materials and Methods

From August 2004 through June 2005, samples (15 adult specimens of similar size of each species) were obtained every second month from the commercial fishermen of El Salto reservoir (24°07′N and 106°45′W) (*Oreochromis aureus*), and of Mazatlán Harbour (23°09′ to 23°12′N and 106°18′ to 106°25′W) (the coastal/estuarine *Mugil cephalus* and *Diapterus* sp. and the marine species *Scomberomorus sierra*). However, since the fishery of *S. sierra* is seasonal, samples of this species were available only from October through February.

All samples were kept in ice boxes in separate, prewashed plastic bags. In the laboratory, the organisms were dissected and approximately 100 g of muscle (6–7 g of each specimen), and the entire gills and liver were separated, freeze-dried, ground and homogenized in a Teflon mortar.

Triplicate 1 g subsamples of the tissues of each sample, spiked with known amounts of the four metals, were digested in 25 ml concentrated HNO_3 (trace metal analysis), evaporated slowly to dryness (90°C) and the solid residue was redissolved in 2 M HNO_3. Finally, the samples were centrifuged and the supernatant was used for metal analysis by flame atomic absorption spectrophotometry. The detection limits for the four metals were 0.01 μg/g.

The possible presence of contaminants was determined with one blank for each set of five-six samples, using the same procedure used for the samples. Metal-free deionized water was used throughout the study and all the materials used for sample handling and for metal analysis were acid-washed. The accuracy of the method was assessed using DOLT-4 dogfish certified reference material (National Research Council Canada), and the percentages of metal recovery in the fortified samples were 91.5% (Cu), 96.2% (Cd), 105.6% (Pb) and 105.6% (Zn). The metal concentrations, corrected for these percentages, are reported on a dry weight basis.

To determine interspecific differences, the mean metal contents of each tissue of the four species were compared by one-way analysis of variance. When the data were not normal or homoscedastic (Lilliefors' and Bartlett's tests), the data were compared with the equivalent nonparametric tests and the different means were separated with Tukey's or Dunn's tests. In all cases the level of significance was $\alpha = 0.05$.

Because of the seasonality of some human activities, there are indications of seasonal differences in the metal contents of fish tissues. Since the liver is the organ involved in metal storage and detoxification, we pooled the data of the liver samples of the species available in both seasons (*M. cephalus*, *Diapterus* sp. and *O. aureus*), and compared the mean values of the five metals calculated for the dry season, to the corresponding values of the rainy season, using in this case Student's t tests, with $\alpha = 0.05$.

Results and Discussion

There were several interspecific differences in the ranges of concentrations, as well as in the mean values of the metal contents of the four species, but there were discrepancies between different tissues: for instance, the mean Cd and Cu contents of the muscle of all species were similar, but the gills and livers of *O. aureus* had lower values of Cd than all marine species. The liver of *M. cephalus* had a content of Cd similar to that of *O. aureus*, but the content of Cu was two orders of magnitude higher than the values found in *M. cephalus* and *Diapterus* sp. (Table 1a, b).

The muscle of *O. aureus* had a significantly lower Fe content than *M. cephalus*, and the remaining two species had intermediate values; in the case of gills and liver, *O. aureus* had the lowest values, but there was no difference between the liver content of this species and that of *S. sierra* (Table 1 c).

The muscle and liver of the four species had similar Pb contents, but Pb was significantly lower in the gills of *Diapterus* sp. and *O. aureus* than in *M. cephalus*, and *S. sierra* had intermediate values (Table 1d).

As to Zn, the highest and lowest contents of the muscle were those of *Diapterus* sp. and *M. cephalus*, respectively. The gills of *S. sierra* had the highest value and those of *O. aureus* had the lowest. *Diapterus* sp. had the highest liver content of Zn, and there were no differences between the remaining three species (Table 1e).

Irrespective of the species, the most abundant metal in the three tissues was Fe, which in most cases was followed by Zn, although Cu had higher values than Zn in the liver of *M. cephalus* and *O. aureus*. As a general rule, Cd had the lowest mean values, with the exception of Pb in the liver of *S. sierra* and *Diapterus* sp.

In agreement with most literature, metals were generally higher in livers than in gills and muscle, since metals are not actively accumulated in the muscle (Türkmen et al. 2008) and gill concentrations are mostly related to waterborne metals, whereas metals from all sources (food and water) are stored in the liver prior to their mobilization and/or detoxification (Türkmen et al. 2008). However, as observed in *M. cephalus* by Dural et al. (2007), Pb was higher in the gills, possibly because it may accumulate through complexation or adsorption on the gill lamellae, and desorption and uptake in the gill microenvironment.

The liver and gills of *M. cephalus* and *Diapterus* sp. had the highest values of Cu, Fe and Pb (Table 1): both species were caught in Urias lagoon, which receives the discharges of a thermoelectric power plant, as well as the wastewaters of the city of Mazatlán, of its commercial and fishing harbour and of different food-processing industries (Frías-Espericueta et al. 2005). Additional sources of metals are the antifouling paints used in the shipping industry, and all these inputs, as well as the limited water exchanges and long flushing time of this ecosystem (Montaño-Ley et al. 2008), could explain the high metal levels of these two species.

Seasonal variations of metal concentrations have been related to the seasonality of human activities such as agriculture (Çoğun et al. 2006; Dural et al. 2006) rather than to the variability of natural inputs. During this research, only the mean value of the Fe liver contents of the three species used for this comparison was slightly higher in the dry than in the rainy season (561.2 ± 354.2 and 496.0 ± 325.0 μg/g, respectively). With this exception, there was a general tendency to higher values in the rainy season (Cd: 2.07 ± 1.4 and 1.35 ± 0.80; Cu:

Table 1 Ranges and mean metal concentrations in the tissues of the fish species studied

Tissue	*M. cephalus*	*Diapterus* sp.	*O. aureus*	*S. sierra*
A	Cd			
Muscle*	0.27–0.33	0.30–0.35	0.25–0.33	0.02–0.47
	0.31 ± 0.02a	0.32 ± 0.02a	0.28 ± 0.03a	0.27 ± 0.23a
Gills	0.47–0.82	0.63–0.81	0.01–0.61	0.79–0.87
	0.67 ± 0.17b	0.71 ± 0.07b	0.36 ± 0.21a	0.82 ± 0.04b
Liver	0.69–1.65	2.11–4.30	0.54–1.34	2.87–5.47
	1.23 ± 0.31a	2.82 ± 0.84b	0.71 ± 0.31a	4.04 ± 1.31c
B	Cu			
Muscle*	1.18–1.57	1.07–1.92	0.21–1.86	0.13–1.42
	1.30 ± 0.15a	1.25 ± 0.33a	0.98 ± 0.53a	0.96 ± 0.72a
Gills	2.10–4.60	2.35-5.94	0.12–2.19	3.27–4.07
	3.01 ± 0.85b	3.62 ± 1.77b	1.31 ± 0.69a	3.74 ± 0.42b
Liver*	183.3–308.9	5.44–11.64	101.86–279.17	6.97–7.60
	231.5 ± 52.5c	7.92 ± 2.36a	146.6 ± 66.8b	7.28 ± 0.32a
C	Fe			
Muscle*	9.20–27.58	9.39–14.79	4.35–10.43	7.63–39.73
	19.47 ± 6.73b	11.29 ± 1.96ab	7.53 ± 2.26a	20.66 ± 14.7ab
Gills	176.02–215.60	147.49–236.39	52.13–144.21	150.36–201.17
	200.9 ± 19.7b	172.4 ± 32.7b	106.5 ± 31.6a	179.2 ± 97.0b
Liver	196.40–1177.26	517.93–987.81	124.58–598.48	201.78–287.16
	595.9 ± 354.0b	795.03 ± 164.62b	227.6 ± 182.6a	234.0 ± 129.7a
D	Pb			
Muscle	2.07–3.05	0.61–3.78	0.89–4.91	0.10–3.96
	2.62 ± 0.43a	2.80 ± 1.07a	2.12 ± 1.58a	2.34 ± 2.70a
Gills	5.97–7.56	3.12–4.60	2.22–6.78	4.66–8.66
	6.68 ± 0.67b	3.62 ± 0.55a	4.34 ± 1.67a	6.26 ± 2.83ab
Liver	0.47–3.02	1.83–3.39	2.83–4.59	0.10–3.77
	2.10 ± 0.93a	2.38 ± 0.59a	3.56 ± 0.61a	1.94 ± 1.27a
E	Zn			
Muscle*	9.64–11.73	13.58–20.61	8.41–15.32	11.07–11.73
	10.78 ± 0.76a	17.18 ± 2.91b	12.08 ± 2.63 ab	11.47 ± 0.36ab
Gills	29.21–46.61	33.58–46.84	15.11–36.10	41.49–53.89
	33.67 ± 6.63b	38.50 ± 5.87b	25.23 ± 6.96a	48.42 ± 6.33c
Liver	30.60–47.77	42.79–97.22	20.08–53.61	34.62–43.86
	38.67 ± 6.56a	64.5 ± 17.86b	38.93 ± 12.11a	38.04 ± 5.06a

Concentrations in μg/g, dry weight. Different letters indicate significant differences between the same tissue of different species (one-way ANOVA, $\alpha = 0.05$). a ≤ ab ≤ a and a < b

*, Nonparametric test

156.8 ± 128.4, and 114.6 ± 95.1; Zn: 55.2 ± 23.2 and 43.4 ± 13.2 μg/g for the rainy and dry season, respectively), but the only significant difference was that of Pb (3.33 ± 0.70 and 2.43 ± 0.88 μg/g). This tendency could be due to increased metal discharges through surface runoff and storm drains from the nearby agricultural areas of El Salto Reservoir or, in the case of *M. cephalus* and *Diapterus* sp., from the metal-contaminated soils of the industrial zone of Mazatlán harbor.

The muscle concentrations of Cd and Pb, as well as the Zn content of the liver of *M. cephalus* of this study are lower than those reported in *Mugil* sp. from Fayum Egypt, and in *Liza saliens* from Paramos lagoon, Portugal (Table 2), whereas the Cu contents of the liver of *S. sierra* are lower than those reported in other studies with taxonomically related species of other regions. With the exception of the value determined by Mansour and Sidky (2002) in *Tilapia* sp. from Fayoum, Egypt, all the values

Table 2 Metal concentrations (μg/g, dry weight) in the tissues of taxonomically related fish species from different regions

Species	Site	Tissue	Cd	Cu	Fe	Pb	Zn
Mugilidae							
Liza saliens[a]	Paramos lagoon,	Liver	–	262 ± 140	–	<LD	88.6 ± 32
	Portugal	Muscle	–	<2.6	–	<LD	25.7 ± 10.1
Mugil cephalus[b]	Aegean Sea	Liver	–	–	–	–	–
		Muscle	0.45 ± 0.03	1.26 ± 0.10	82.7 ± 5.6	0.61 ± 0.04	40.2 ± 3.3
Mugil sp.[c,*]	Fayoum, Egypt	Liver	1.82	17.10	952	17.46	30.94
		Muscle	1.38	7.40	72.08	16.6	22.88
Mugil cephalus[d]	Tuzla lagoon,	Liver	0.02–0.35	4.77–12.03	87.7–384	1.85–3.12	26.7–49.7
	Portugal	Muscle	0.08–0.11	0.47–0.62	7.15–11.12	0.49–1.19	8.27–60.8
Mugil cephalus[e]	NW Mexico	Liver	0.69–1.65	183–309	196–1177	0.47–3.02	30.6–47.7
		Muscle	0.27–0.33	1.18–1.57	9.2–27.6	2.07–3.05	9.64–11.7
Scombridae							
Scomber japonicus[f,*]	Turkey	Liver	0.91	33.37	936	3.44	101.4
		Muscle	0.2	10.88	200.25	1.52	55.06
Scomberomorus maculatus[g,*]	Saudi Arabia	Liver	–	–	–	–	–
	markets	Muscle	0.013	–	–	0.16	21.1
Scomberomorus commersoni[h,*]	El-Mex Bay	Liver	3.65	24.6	489	7.3	237
	Egipt	Muscle	0.65	7.3	40.5	3.2	26.2
Scomberomorus sierra[e]	NW Mexico	Liver	2.87–5.47	6.97–7.28	202–287	0.10–3.77	34.6–43.8
		Muscle	0.02–0.47	0.13–1.42	7.63–39.7	0.10-3.96	11.1–11.7
Cichlidae							
Tilapia sp.[c,*]	Fayoum, Egypt	Liver	0.88	4.70	217.6	6.92	16.41
		Muscle	0.79	1.43	49.20	8.26	7.10
Tilapia mossambica[i]	SW Nigeria	Liver	0.90	<LD	10.10	1.00	2.01
		Muscle	0.51	<LD	2.21	<LD	1.02
Oreochromis aureus[e]	NW Mexico	Liver	0.54–1.34	102–279	125–598	2.83–4.59	20.1–53.6
		Muscle	0.25–0.33	0.21–1.86	4.35–10.43	0.89–4.91	8.41–15.3

* Converted to dry weight from the original data using a conversion factor of 0.2 (Dural et al. 2006)

[a] Fernandes et al. (2008)

[b] Uluözlü et al. (2007)

[c] Mansour and Sidky (2002)

[d] Dural et al. (2007)

[e] This study

[f] Türkmen et al. (2009)

[g] Al-Bader (2008)

[h] Khaled (2004)

[i] Adefemi et al. (2008)

found in the liver of *O. aureus* are lower than those of our study.

In comparison to other studies in NW Mexico, the Cu and Zn mean values in the muscle of *O. aureus* determined in this study (0.98 ± 0.53 and 12.08 ± 2.63 μg/g) are lower than those reported in *Tilapia* sp. (2.56 and 26.97 μg/g) and *Tilapia mossambica* (5.6 and 17.33 μg/g), by Gutiérrez-Galindo et al. (1989), Izaguirre-Fierro et al. (1992), respectively. However, with the exception of Pb, all the mean values determined in *M. cephalus* were lower than those reported by Izaguirre-Fierro et al. (1992) in the Culiacán Valley, Sinaloa, Mexico.

Because of their toxicity, Cd and Pb are of ecological concern to health-related agencies. To determine the risk level for human consumption of these fish species, the reference values for Cd (0.05 μg/g fresh weight) and Pb (0.30 μg/g fresh weight) (GUCE 2006) were compared to the mean values of this study, corrected for fresh weight assuming 80% water content (Dural et al. 2006) (Cd = 0.054 to 0.064; Pb = 0.424 to 0.560), showing that the ingestion of these species may be of concern for the Mexican public health.

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