Bull. Environ. Contam. Toxicol. (1998) 61: 182-187

Bulletin of Environmental Contamination and Toxicology

Total Mercury in Muscle of Fish from Two Marshes in Goldfields, Colombia

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Received: 21 March 1998/Accepted: 16 June 1998

Among Au producing countries in Latin America, Colombia has increased the mining of the metal exponentially in recent years. However, this mining activity is concomitant with extensive damage to the environment. The lack of technological processes in gold extraction leads to the unmanageable introduction of considerable amounts of Hg into the food chain. Significant Hg concentrations have been detected in hair samples of fishermen living in gold mining areas (Olivero et al. 1995). Most of the Au mines in Colombia are located in the watersheds of the Magdalena and Cauca rivers. This paper addresses the distribution of Hg in fish from two marshes influenced by Au mining in the North of Colombia. In addition, these data were compared to that obtained in a relatively uncontaminated marsh downstream from the extraction areas. All three marshes provide fishmeal not only for the fishing village population but also for other parts of Colombia.

MATERIALS AND METHODS

The study area was three marshes located in Northwestern Colombia. The marshes were chosen because of their different geographic characteristics in the gold mining area, and because they are extensively used for fishing. Simiti marsh, found in the Magdalena River watershed (7°56'-8°1' N and 73°55'-73°58' W) and Grande marsh, situated in the Cauca River watershed (8°19'-8°22''N and 74°29'-74°32' W), both receive direct influence of gold mining activities, with Grande marsh being affected the most. Capote marsh (10°18'-10°23' N and 75°5'-75°9' W), located approximately 290 km downstream from the gold mining area served as a control. Monitoring of Hg in fish was carried out during two different periods of 1997: April-May and August-September, with monthly mean precipitation between 167.6-284.0 and 347.7-267.7 mm, for the first and second period respectively (IDEAN 1997).

Fish collected for this study belonged to different trophic levels, including the phytoplanktonic Prochilodus reticulatus magdalenae (Bocachico) and Curimata mivartii (Vizcaina); detritivorus with tendency to zooplanktonic Triportheus magdalenae (Arenca) and Curimata magdalenae (Pincho); the detritivorous-carnivorous Pimelodus clarias (Barbudo), and the carnivorous Petenia kraussii (Mojarra amarilla), Plagioscion surinamensis (Pacora), Ageneiosus caucanus (Doncella), Sorubin lima (Blanquillo), Pseudoplatystoma fasciatum (Bagre Pintado), and Hoplias malabaricus (Moncholo).

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Fish were caught by fishermen from local areas. The body length and weight of these fish were measured. Fish were transported to the lab, eviscerated, and frozen at -20°C. Thawed fish were dissected with plastic knives and dorsal muscle was used for total Hg analysis by cold vapor atomic absorption spectroscopy after acid digestion with sulfuric and nitric acids at temperatures between 100-110 °C (Sadiq et al. 1991) for three hours. All determinations were made in duplicate and analytical quality was ensured by using both certified material (Tort-1, National Research Council Canada) and recovery of Hg in spiked samples. The analysis of Tort-1 provided a mean value of 280±20 µg/Kg (certified value 330±60 µg/Kg). The recovery for spiked samples ranged from 84.5 to 112.5% (n=6). Mean coefficient of variation from duplicate samples with values higher than the detection limit was 7.04±0.45%, n=151.

Data were expressed as mean ± standard error of the mean for duplicate determinations. In samples below the detection limit (7.4 µg/Kg), a mean value equal to half of the detection limit value was used for statistical analysis. In order to perform multiple comparisons, normality was tested according to the Kolmogorov-Smirnov test. Interspecies differences in tissue Hg concentration were analyzed using one-way ANOVA and Tukey's Test at $p<0.05$ significance level.

RESULTS AND DISCUSSION

Table 1 summarizes Hg concentrations in muscles of different fish species caught from marshes monitored during the two sampling periods.

Hg concentrations in fish from Grande marsh vary considerably with the species; Prochilodus reticulatus magdalenae (primary consumer) contains the lowest while Ageneiosus caucanus (tertiary consumer) the highest. For samples collected from this marsh, Petenia kraussii Hoplias malabaricus and Ageneiosus caucanus showed relatively higher Hg concentrations than the internationally accepted limit of 0.5 mg Hg/Kg for fish consumption (WHO 1991). In all samples, species belonging to different trophic levels showed significant statistical differences ($p<0.001$). Significant differences between specimens caught in different sampling periods were detected for the carnivorous Ageneiosus caucanus.

Fish from Simiti marsh had Hg concentrations lower than that observed in those from Grande marsh. Nevertheless, some of these fish exhibited values close to 50% the guideline limit. There were not significant differences between Hg concentrations for the species collected in different sampling periods ($p=0.228$). However, significant differences ($p=0.015$) were observed between the carnivorous Blanquillo and Moncholo and the phytoplanktonic species Bocachico during the second sampling period.

As expected, the lowest Hg mercury concentrations were found in fish from Capote Marsh, with the carnivorous species Plagioscion surinamensis showing the highest values. This species had Hg concentrations significantly different

Table 1. Hg concentrations in muscle of fish caught from marshes within gold mining area and control marsh.

Species	Mean ± SE* µg Hg/g, wet wt	
	Sample 1 (Apr-May)	Sample 2 (Aug-Sep)
Grande Marsh		
Prochilodus reticulatus magdalenae	0.086±0.030 [5] (0.025-0.201)	0.080±0.018 [11] (0.019-0.226)
Curimata mivartii	0.114±0.046 [4] (0.028-0.195)	0.027±0.006 [4] (0.017-0.044)
Pimelodus clarias	0.197 [2] (0.152-0.241)	0.118±0.018 [8] (0.046-0.206)
Petenia kraussii	0.946 [2] (0.835-1.057)	0.570±0.094 [4] (0.359-0.805)
Ageneiosus caucanus	1.130±0.105 [3] (0.920-1.236)	0.694±0.159 [5] (0.231-1.187)
Other Species		
Triportheus magdalenae		(0.353±0.095) [9] (0.044-0.766)
Curimata magdalenae		(0.129±0.016) [9] (0.082-0.240)
Hoplias malabaricus	(0.899±0.115) [3] (0.740-1.122)	
Simiti Marsh		
Pimelodus clarias	0.050±0.016 [4] (0.027-0.097)	0.071±0.018 [3] (0.037-0.095)
Petenia kraussii	0.248±0.144 [3] (0.022-0.516)	0.159±0.041 [3] (0.099-0.237)
Sorubin lima	0.192 [2] (0.150-0.233)	0.214±0.039 [4] (0.118-0.292)
Hoplias malabaricus	0.235±0.059 [5] (0.081-0.391)	0.239 [2] (0.155-0.324)
Other Species		
Prochilodus reticulatus magdalenae		0.044±0.030 [6] (DL-0.194)
Pseudoplatystoma fasciatum		0.137±0.036 [3] (0.065-0.180)

Capote Marsh	Sample 1	Sample 2
Prochilodus reticulatus magdalenae	0.015±0.004 [5] (DL-0.029)	0.029±0.004 [5] (0.022-0.045)
Plagioscion surinamensis	0.125±0.027 [5] (0.037-0.187)	0.117±0.011 [4] (0.085-0.128)
Other Species		
Triportheus magdalenae		0.094±0.024 [4] (0.030-0.135)
Pimelodus clarias	0.065±0.024 [4] (0.017-0.121)	
Petenia kraussii	0.098±0.026 [5] (0.033-0.174)	
Ageneiosus caucanus	0.076±0.018 [3] (0.045-0.107)	
Sorubin lima		0.083±0.016 [4] (0.059-0.112)
Pseudoplatystoma fasciatum	0.086±0.009 [5] (0.060-0.110)	
Hoplias malabaricus	0.079±0.020 [3] (0.052-0.119)	

* Standard error of the mean. Range of data is given under the means. Number of samples are given within brackets. DL = Detection limit: 7.4 µg/Kg.

from Prochilodus reticulatus magdalenae ($p<0.001$) during the two sampling periods. As a comparison, the observed value for Plagioscion surinamensis was similar to that detected for the primary consumer Curimata mivartii during the first sampling period in Grande Marsh.

From Table 1 it is evident that Hg in fish from the monitored marshes increases in the order Capote<Simiti<Grande. This spatial distribution is directly related to the link between those waterbodies and gold mining.

It is important to mention that there are many similarities between our data and those reported for gold mining areas in Brazil (Nriagu et al. 1992; Palheta and Taylor 1995; Boshio and Henshel 1995; Bidone et al. 1997) especially for mercury distribution in fish from Grande marsh. However, for this particular waterbody, our data showed that the carnivorous Hoplias malabaricus had 50% higher concentrations than those reported by Palheta and Taylor (1995) within the Gurupi gold field in the Brazilian State of Para.

Despite the low Hg concentrations detected in Simiti marsh, a difference is evident between carnivorous and phytoplanktonic species from both gold mining-affected marshes. This suggests that a biomagnification process is taking place in the trophic chain for those waterbodies, particularly in Grande marsh. Figure 1 summarizes the sequential increase in Hg concentration with the trophic position of the species. Although Triportheus magdalenae is considered a lower trophic level than Pimelodus clarias, it showed a high Hg

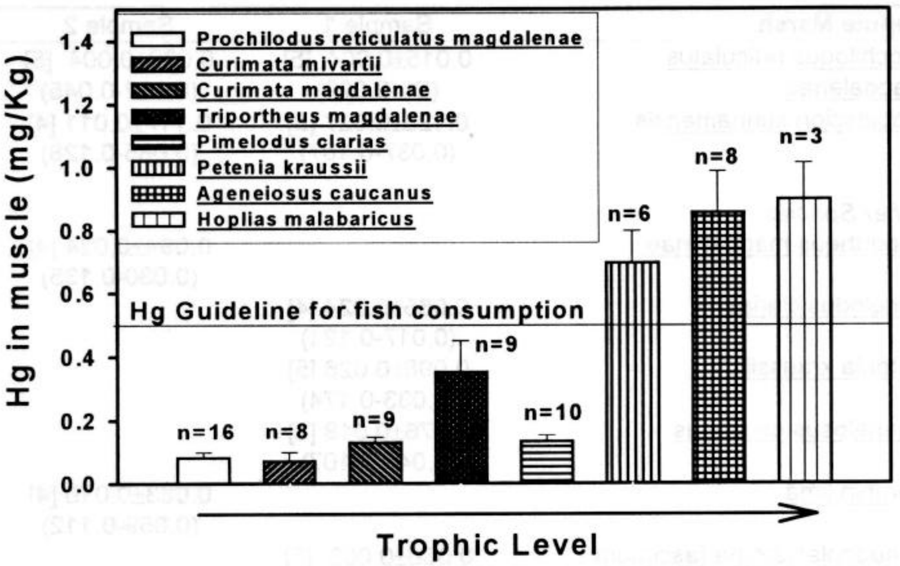

Figure 1. Distribution of mercury in fish from different trophic levels in Grande Marsh. Bars on columns represent SE of the means.

concentration. This was probably due to direct bioaccumulation as observed in low-contaminated places (Olivero et al. 1997).

Correlations between the concentration of Hg in muscle and the fish length ($r=0.995$, $p<0.001$) and weight ($r=0.984$, $p=0.002$, $n=5$) were observed in Prochilodus reticulatus magdalenae during the first sampling period in Grande Marsh. This suggests the possibility of bioaccumulation of Hg in this primary consumer species.

Given the fact that Prochilodus reticulatus magdalenae is the most popular and economically important fish in Colombia and given the concentration of Hg found in this species, consumption of this species may prove less risky. However, the reality may be different. Frequent fish consumption may increase the overall Hg intake to dangerous levels, particularly in fish caught from Grande marsh. This may lead to neurotoxicity, previously observed even at low level exposure (Cranmer et al. 1996; Lebel et al. 1996).

These results have shown that consuming fish from Grande marsh may result in a high risk of Hg contamination for fishermen who depend only on this ecosystem as their protein source.

Acknowledgments. We thank “Fondo para la Proteccion del Medio Ambiente Jose Celestino Mutis, FEN Colombia” for financial assistance, fishermen from the study area for providing fish samples, and also to Claudia Mendoza and Rafael Olivero for technical assistance.

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