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Mercury Contamination in Fish from Santarém, Pará, Brazil[1]

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This paper reports on total mercury concentrations in edible tissue from 11 fish species caught in the Municipality of Santarém, Tapajós River Basin, Pará State, which are most consumed by the local population and investigates the influence of the distance between the goldmining areas and Santarém city on fish contamination by mercury. It was found that the carnivorous species reached an average of 222.1 ng.g^{-1} ($n = 69$), higher than the herbivorous species with 31.9 ng.g^{-1} ($n = 30$) and the omnivorous species with 68.7 ng.g^{-1} ($n = 10$). Significant relationships are found between fish weight and total mercury concentrations by using descriptive statistical and regression analysis for the two species, the carnivorous *Pellona* sp. (Sarda, $r = 0.73$) and *Pseudoplatystoma* sp. (Surubim, $r = 0.63$).

Key Words: **total mercury; fish; weight; Tapajós River; Santarém.**

INTRODUCTION

During past years, the Amazon region has been subjected to enormous releases of mercury in the atmosphere. This contamination is frequently attributed to goldmining activities. Lacerda *et al.* (1991) report, based on the gold production in the region, that these discharges can reach 70 to 130 tons annually.

Mercury in the organic form, methyl mercury, is very toxic and intensely accumulated by the aquatic fauna, mainly by the predator fish whose consumption is one of the most important sources of contamination by the Indians and riverine populations (Malm *et al.*, 1995; Bidone *et al.*, 1995; Malm, 1998).

Santarém is a municipal district crossed by the Tapajós River and, in spite of being far from the direct influence of goldmining activity (Bidone *et al.*, 1995), it possesses an intense activity of commercialization and burning of its amalgam (Hg–Au). It is also responsible for approximately 25% of the fishing activities in Pará State (Bidone *et al.*, 1995).

The purpose of this work is to evaluate the contamination of the main different fish species consumed by the local population, collected in the different localities situated off the Tapajós River margin, in the Municipality of Santarém and the correlation between fish weight and total mercury concentration. The influence of goldmining areas on mercury levels found in fish caught in Santarém is also investigated.

AREA STUDY

Pará State has an area of 10 million hectares and, among the states that extract gold in the Amazon region, it has the largest area and greatest number of goldmining sites.

The municipal district of Santarém is the second most important in Pará State. It is located in the west of Pará State with an area of 26,522 km^2 and a population of 242,765 inhabitants (CPRM, 1997). Together with Belém (the capital city), it forms an important tourist center, due to its political, economical, and administrative importance.

This municipal district is crossed by six important rivers: Amazonas, Tapajós, Arapiuns, Curuá-una, Mojú, and Mojuí, and the dominant climate in the area is hot and humid—typical of areas with tropical forests—without great temperature variations.

Among the most important economic activities in the region are agriculture, cattle breeding, fishing, wild animals' skin trade, and manufacturing industries.

The main fish that greatly influence the ichthyological income of Santarém are the Pirarucu, Tambaqui,

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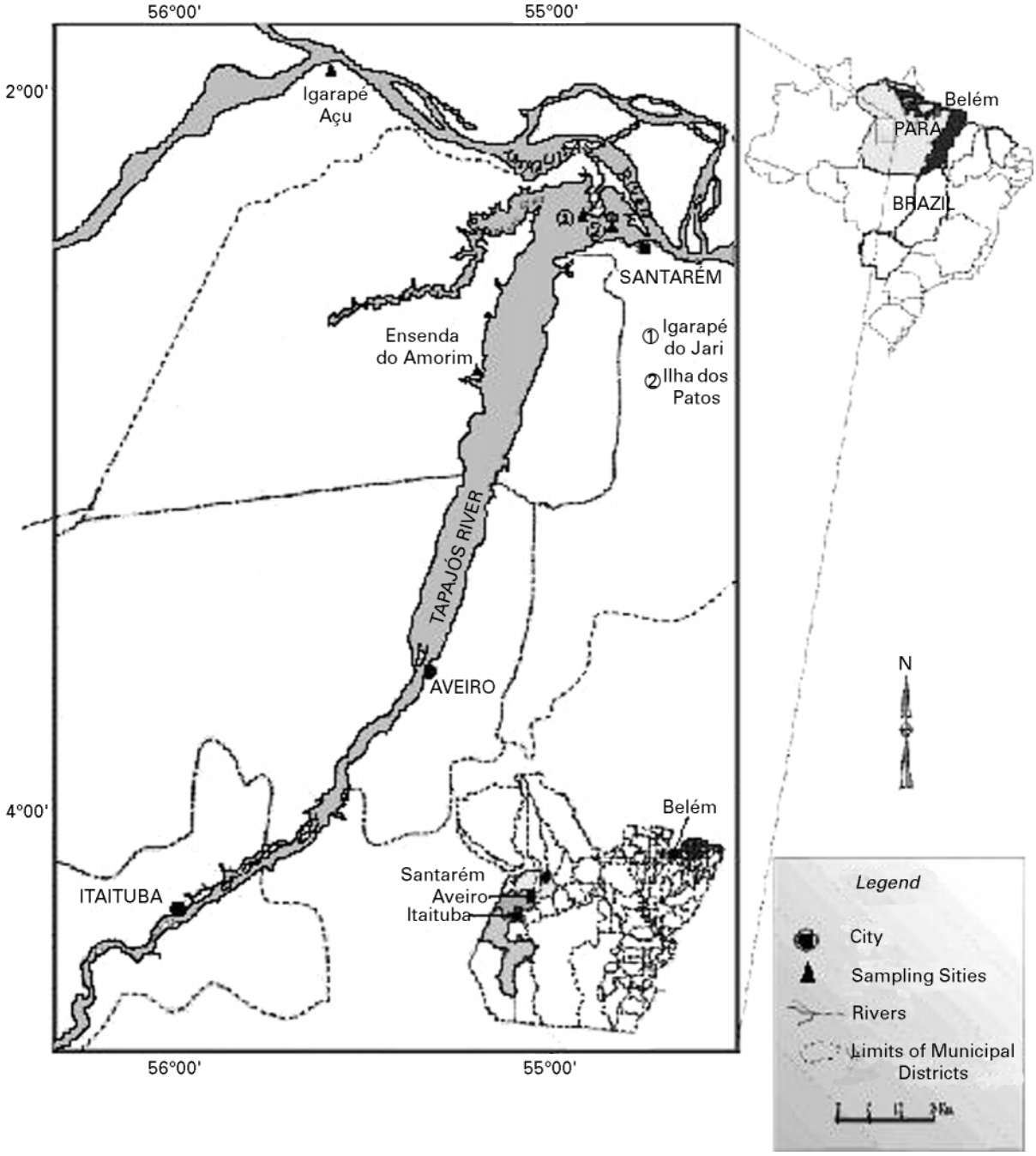

FIG. 1. Location of sampling sites along the Tapajós River, Santarém Municipality, Pará State, Amazon (Source: SEICOM).

Curimata, Acarí, Dourada, Tucunaré, and Surubim. Production is partly consumed in the municipal district; the remaining is exported to several municipal districts such as Belém, Abaetetuba, and others, as well as the cities of Fortaleza, Manaus, Brasília, and São Paulo (IDESP, 1977).

Figure 1 shows the area in the Municipality of Santarém where the fish specimens were sampled.

MATERIALS AND METHODS

Fish samples from Santarém were collected in two field trips from 1997 to 1998 by the Evandro Chagas Institute. These samples were purchased at the municipal market, Mercadão 2000, the main fish supply center. It was possible to determine fishing sites with fisherman information: Igarapé do Jari, Tapajós River,

Ilha dos Patos, and Enseada do Amorim, which are considered important areas of fishing (CPRM, 1997).

The selected species were those considered the most important in the population's diet in Santarém: *Leporinus* sp. (Aracú), *Hydrolycus* sp. (Peixe cachorro), *Plagisocion squamosissimus* (Pescada branca), *Mylossoma sp.* (Pacú), *Serrasalmus nattereri* (Piranha), *Piaractus brachypomus* (Pirapitinga), *Brachyplatystoma flavicans* (Dourada), *Colossoma macropomum* (Tambaqui), *Pellona* sp. (Sarda), *Cichla* sp. (Tucunaré), and *Pseudoplatystoma* sp. (Surubim). All samples were stored in plastic sacks and frozen for transport. A total of 109 samples were analyzed, among carnivorous and noncarnivorous species.

The analytical procedure used for determination of total mercury in the samples was that of Akagi *et al.* (1995) performed at the Human Ecology and Environment Laboratory, at Evandro Chagas Institute. All analyses were done through spectrophotometry of atomic absorption by cold vapor in a Model HG-3500 mercury automatic analyzer.

Weight (g) was measured for every fish. Variability was established by the institute. Statistical analysis was done with MINITAB 10.1 software (Ryan *et al.,* 1985).

Reproducibility and accuracy were determined by means of triplicate analysis and analysis of certified reference standards (Dorm 2). The detection limit of the methodology used was determined according to Akagi *et al.* (1995), reaching 0.5 ng Hg.

RESULTS

Total mercury concentration ranges in fish from the Santarém Municipality are shown in Table 1. A relation of carnivorous and noncarnivorous species is found, upon which the carnivorous species (n = 69) presented an average of 222.1 $ng.g^{-1}$ and ranged between 75.2 and 878.4 $ng.g^{-1}$, five times greater than the herbivorous and omnivorous species (n = 40) presenting an average of 41.1 $ng.g^{-1}$ and an interval of 1.3–140.6 $ng.g^{-1}$.

Of the total number of samples analyzed (109 samples), 10 were Tucunaré and only this species presented mercury contents of around 2% above the maximum limit of 500 $ng.g^{-1}$ established for food by Brazilian legislation (WHO, 1972; Brasil, 1975).

In Table 2, there is a significant relation between mercury concentrations and the dispersion along the river, where elevated mercury values are found in the localities in the inferior part of the Tapajós River (Fig. 1), which are closer to the goldmining areas in Itaituba (reference city due to the intense goldmining activities in the region). In Enseada do Amorim (n = 30), where local fishing is closest to the goldmining areas (377.5 km), the highest Hg levels (19.0–878.4 $ng.g^{-1}$) were found.

In this work, a better correlation was obtained for two fish species. The correlations between total mercury concentration and fish weight presented in Figs. 2 and 3 for the predator species Sarda and Surubim are found to be r = 0.73 (P = 0.000) and r = 0.63 (P = 0.006), respectively.

Figure 4 shows that the largest contents of mercury were observed in the carnivorous species, and Tucunaré, in spite of being the predator species with a higher mercury level, is not a species presenting a larger average weight, while Surubim, among carnivorous species, presents the largest average weight and the smallest mercury level.

DISCUSSION

In the areas considered control (without direct effects of Hg contamination), the mercury contents in fish are smaller than 200 $ng.g^{-1}$ to freshwater fish

TABLE 1
Mercury Concentration in Fish Muscle Tissue from Santarém, Tapajós River Region

Species	Food habit (n)	Average ($ng.g^{-1}$)	Interval ($ng.g^{-1}$)
Brachyplatystoma flavicans (Dourada)	Carnivorous (10)	252.0 ± 79.9	129.2–429.6
Hydrolycus sp. (Peixe cachorro)	Carnivorous (10)	124.6 ± 68.1	75.2–302.8
Plagisocion squamosissimus (Pescada)	Carnivorous (10)	214.6 ± 60.6	113.5–317.8
Serrasalmus nattereri (Piranha)	Carnivorous (5)	280.4 ± 87.8	194.1–19.5
Pellona sp. (Sarda)	Carnivorous (14)	211.7 ± 105.6	91.0–400.7
Pseudoplatystoma sp. (Surubim)	Carnivorous (10)	198.9 ± 73.3	100.0–357.0
Cichla sp. (Tucunaré)	Carnivorous (10)	306.1 ± 261.2	112.7–878.4
Mylossoma sp. (Pacu)	Herbivorous (10)	29.7 ± 8.3	19.0–42.5
Piaractus brachypomus (Pirapitinga)	Herbivorous (10)	8.7 ± 4.7	1.3–17.0
Colossoma macropomum (Tambaqui)	Herbivorous (10)	57.2 ± 37.0	20.1–140.6
Leporinus sp. (Aracu)	Omnivorous (10)	68.7 ± 27.4	36.0–127.0

Note. n, number of fish analyzed.

TABLE 2
Relationship among Averages of the Concentrations of Total Mercury of the Samples of Fish with the Sampling Sites of Santarém

Sampling sites (*n*)	Distance[a] (km)	Interval (ng.g^{-1})
Enseada do Amorim (30)	377.5	19.0–878.4
Igarapé do Jari (43)	435.0	1.3–429.6
Ilha dos Patos (16)	445.0	36.0–247.0
Tapajós River[b] (20)	—	23.3–237.3

Note. n, number of fish analyzed.
[a] Distance between goldmining activities in the Itaituba Municipality (lat. 57° 8′ 20″ and long. 5° 7′ 46″) and sampling sites along the Tapajós River [Source: Seicom, Pará State].
[b] Localization not defined.

and 150 ng.g^{-1} to seawater fish (Malm *et al.,* 1995). In Santarém, to freshwater fish, 38 fish samples analyzed (around 35%) presented mercury concentrations higher than 200 ng.g^{-1}.

Tucunaré, the carnivorous species most consumed and exported in Santarém and at the top of the aquatic food chain, presented high levels of mercury (656.4 and 878.4 ng.g^{-1}) above 500 ng.g^{-1}. High Hg levels in this species were also found in the Balbina Reservoir ranging from 60 to 700 ng.g^{-1} methyl mercury (Kehrig *et al.,* 1998) and in the Tucuruí Reservoir at an average value of 1100 ng.g^{-1} (Lodernius, 1992).

These results deserve some concern, since the speciation of mercury in fish in the Amazon, Tapajós River, shows that methyl mercury corresponds to more than 90% of the total mercury concentration in fish (Lacerda *et al.,* 1992, 1994) and the principal accumulators of this organic form are the carnivorous species, which are situated in the upper extremity of the food chain (Fernandes *et al.,* 1990; Lacerda *et al.,* 1994). These results probably indicate mercury biomagnification in the local fauna.

The exact reason for this discrepancy in positive correlation between Hg concentration and body weight found for those two species is unknown (Figs. 2 and 3), but one can speculate some hypotheses based on the feeding behavior of those fish. Sarda (*Pellona* sp.) is a piscivore of the family Pristigasteridae and forms average size schools of individuals that occur in the middle to upper strata of the water column. It is possible that, as they grow, these individuals have access to prey with lower contents of mercury, probably coming from uncontaminated creeks and tributaries of the main river. On the other hand, Surubim (*Pseudoplatystoma* sp.) is a bottom-dwelling, primarily piscivorous species from the family Pimelodidae, known for migrating very long distances (Barthem *et al.,* 1997). It is conceivable that specimens of different sizes sampled in this survey are from different populations passing through the area and that the larger specimens had previously fed upon noncontaminated prey caught elsewhere.

In the Amazon, an area of tropical climate, the relationship between mercury concentration and fish weight (Fig. 4) for some fish species is always observed. This can be associated with the species biodiversity found in the region and also the alimentary dietary and capacity of species migration, as well as other parameters of the aquatic environment such as flow dynamic, Hg contents in sediments, and organic matter (Reuther, 1994).

In Santarém, several researchers have found low mercury levels in fish in relation to other areas in the Tapajós River Basin. It is about 800 km (Malm *et al.,* 1995) downstream of goldmining areas. Despite this, the area of Enseada do Amorim presents an average level of mercury (255.5 ng.g^{-1}); the people living along the Tapajós River and eating fish caught from the river will be exposed to the mercury and may develop a high toxicity through daily consumption of this metal in the fish.

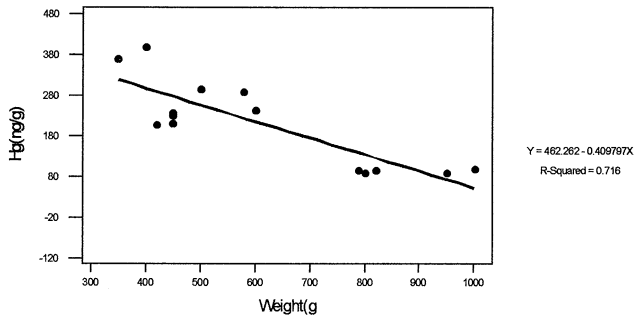

FIG. 2. Mercury concentration (ng.g^{-1}) versus fish weight of *Pellona* sp. (Sarda) from the Santarém Municipality.

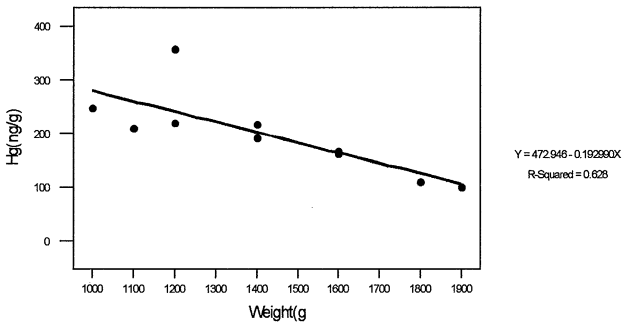

FIG. 3. Mercury concentration (ng.g^{-1}) versus fish weight of *Pseudoplatystoma* sp. (Surubim) from the Santarém Municipality.

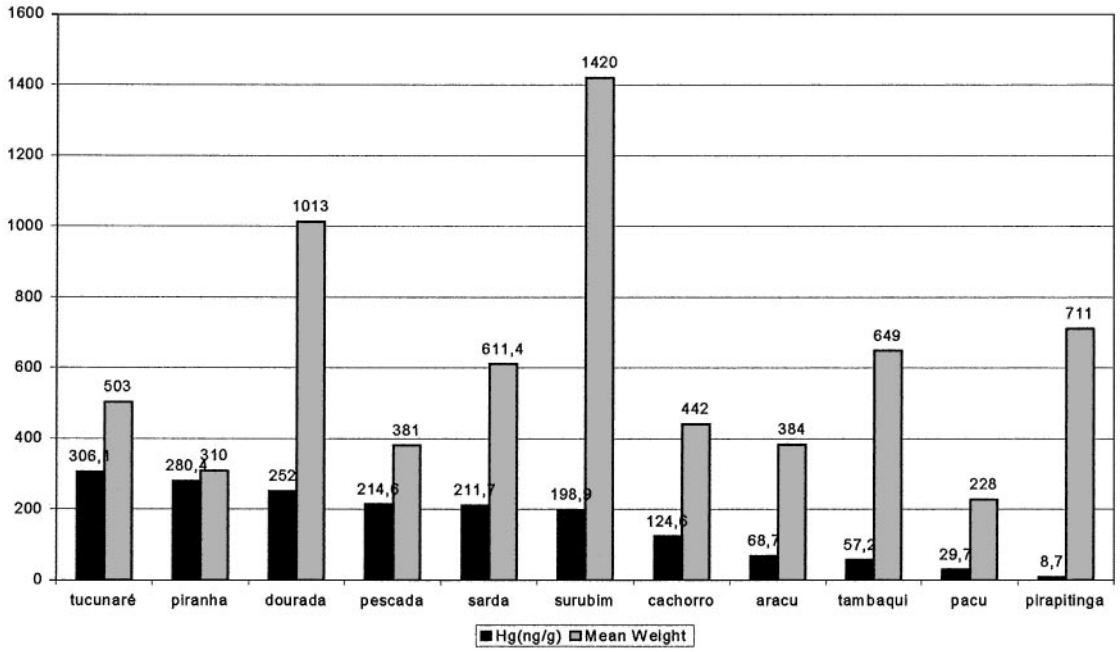

FIG. 4. Summary of the average distribution of total mercury concentration and average weight of the studied species.

CONCLUSION

In Santarém in 1991 (Rodrigues *et al.,* 1994), 1% of the fish samples presented mercury levels above 500 $ng.g^{-1}$ (control area). In 1998 (2%), in this study, Santarém can still be considered an area without direct influence of goldmining activities. However, a great deal of attention will need to be paid to the risks of mercury toxicity considering the bioaccumulation process of Hg in fish and the daily consumption of fish by people of this municipality.

It is difficult to establish which fish species should be consumed by the population of these regions due to the great diversity of fish species found in the Amazon region. Also, it is not appropriate to limit fish consumption by population because of health benefits. Fish contain proteins and antioxidants such as selenium and vitamin E, among others (Egeland *et al.,* 1997).

Therefore, any initiative of environmental politics and control alternatives is valid, aiming to decrease or even control the release of Hg in the Amazon environment, as well as informative on the alimentary diet of the population.

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