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FOOD SAFETY IN AMAZON: POTENTIAL MERCURY CONTAMINATION OF PREFERRED FISH IN THE TAPAJÓS RIVER

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FOOD SAFETY IN AMAZON: POTENTIAL MERCURY CONTAMINATION OF PREFERRED FISH IN THE TAPAJÓS RIVER

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ABSTRACT

Methylmercury (MeHg) is a persistent bioaccumulative toxic metal, verified in tropical river-floodplain systems and it is recognized as a major environmental pollution issue and health hazard for humans. Tapajós River (Brazil), one of the major tributaries of the Amazon has been impacted by traditional gold mining from the mid-1980s and largely deforested, which causes its water to be highly contaminated with mercury. The riverine populations consume native fish from Tapajós river, which sets a potential health risk due to mercury toxicity to the nervous, digestive and immune systems, lungs and kidneys. This paper presents an association between the most captured fish in Tapajós downstream regions, mercury contamination and consumption safety. We used mercury contamination data from literature, in addition to interviews with fishermen conducted on sixteen riverine communities along Tapajós. Fifty-four and eight percent of the evaluated fish demonstrated low Hg levels, 40.76% demonstrated high levels of Hg and 4.88% had no data available.

KEYWORDS: food safety; mercury; fish; Amazon; Tapajós; environmental contamination; human health.

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SUMMARY

1. INTRODUCTION

Mercury is a toxic heavy metal which is widely dispersed in nature. Mercury occurs in several chemical forms, with complex pharmacokinetics (Bernhoft 2012). Although all forms of mercury are poisonous, alkylmercury compounds are of special concern because of their easy penetration through biological membranes, efficient bio-accumulation, high volatility and long-term elimination from tissues (Moore and Ramamoorthy, 1984; Baird and Cann, 2004; Crespo-López et al., 2005; Clarkson and Magos, 2006).

Metal exposure and excess can lead to a variety of pathologies including mental retardation, cognitive impairment, and developmental delay (Aelion and Davis, 2007; Liu et al., 2010; Hsueh et al., 2017). The development of Parkinson's and Alzheimer's diseases (Hegde et al., 2009; Chin-Chan et al., 2015; Chakraborty, 2017), and multiple sclerosis (Siblerud and Kienholz, 1994; Anglen et al., 2015; Kahrizi et al., 2016) appear also to be expedited by toxic metal exposure. The toxic effects involve structural and functional impairment of various organs, including the nervous system (Milioni et al., 2016; Bakar et al., 2017), the lungs (Lilis et al., 1985; Hirano, 1996), the cardiovascular (Bottino et al., 2016; Takahashi et al., 2017) and the renal systems (Lin et al., 2014; Li et al., 2015).

Methylmercury is the most toxic and frequently encountered compound of the organic forms found in the environment and is formed as a result of the methylation of inorganic forms of mercury by microorganisms found in soil and water (Dopp, 2004). Humans and wildlife are exposed to MeHg primarily through the consumption of contaminated fish, particularly large predatory fish (National Research Council, 2000). Methylmercury (MeHg) formation and bioaccumulation have been verified in tropical river-floodplain systems (Guimarães et al., 2000a, 2000b; Roulet et al., 2001), and it is recognized as a major environmental pollution issue and health hazard for humans (Baird and Cann, 2004; Crespo-López et al., 2005; Clarkson and Magos, 2006). The Amazon basin presents a wide diversity of freshwater ecosystems, with different geomorphological, physicochemical and biological features, including river-floodplain systems (Furch & Junk, 1997; Junk et al., 1989). A floodplain constitutes a mosaic of open waters (lakes and rivers), flooded forests and floating meadows that have their areas and proportions modified according to the water level seasonal variation (Junk et al., 1989, Junk, 1997).

The Amazon region has been the main gold producer in Brazil since the 1970–1980s (Porto et al., 2002), where artisanal gold mining activity *(garimpo)* makes use of mercury to extract gold from secondary or primary ore bodies. Usually, secondary deposits or very fine gold particles need mercury for good gold recovery. Final recovery of fine gold particles extracted is always done through heating or burning of the amalgam with high mercury emissions to the atmosphere. This amalgamation process is used in many countries of South America, including Brazil, Venezuela, Colombia, Bolivia, French Guyana, Guyana, Ecuador, and Peru since the 1980s (Malm, 1998). Investigations performed in the region during the 1980s and 1990s attributed the high environmental levels of Hg to these activities (e.g. Martinelli et al., 1988; Lacerda et al., 1989; Pfeiffer et al., 1991).

Large pastures, logging activities, family agriculture and the introduction of large-scale soya plantations are a threat to the forest cover in this Brazilian region (Parayil and Tong, 1998; Weinhold, 1999; Margulis, 2004; Fearnside, 2001; Scouvart and Lambin, 2006). Later investigations carried out in the Amazon region demonstrated the high soil Hg concentrations to be of natural origin (Roulet et al., 1998; Lechler et al., 2000; Fadini and Jardim, 2001). It has been suggested that the erosion of cultivated soil contributed to the leaching of natural soil Hg to aquatic environments (Roulet et al., 1998; Farella et al., 2001). The largest *garimpo* is found in the central area of the Tapajós River basin, a major tributary of the Amazon River. Since 1980, approximately 500 tons of gold has been produced in this area (Veiga, 1997). The peak production, in 1989, reached 4 tons of gold per month and, during the 1990s, *garimpo* activity was responsible for the emission of up to 120 tons of mercury per year (Veiga, 1997). Despite a steady decline over the last few years, the Tapajós area is nowadays one of the largest gold production areas in Brazil, which makes it chronically exposed to environmental contamination, including human exposure to mercury compounds (Akagi, 1995; Malm, 1998).

Newman and Unger (2002) define biomagnification as an increase in the concentration of a contaminant from a trophic level to the superior one through feeding, i.e., between prey and predator. Methylmercury is biomagnified through the aquatic trophic chain and, as a result, the highest concentrations are found in the species occupying the highest trophic positions, including human beings (Beek et al., 2000). Piscivorous or carnivorous fish from several gold mining areas show higher mercury concentrations followed by fish from lower trophic levels such as omnivorous, detritivorous, and herbivorous species. Amazonian riverine populations constitute a group at risk, as they depend on fish as their main source of protein (Malm, 1998; Isaac et al 2015). and the average proportion of methylmercury over total mercury in fish tissues can be up to 95% (Malm et al., 1995).

Previous studies in the Amazon have suggested that the pattern of fish consumption must be understood in order to reduce Hg exposure in the Amazonian ecosystems (Akagi et al., 1994; Boischio et al., 1995; Harada, 1997;

Lebel et al., 1997). In this work, my purpose is to evaluate the potential levels of mercury contamination in preferred fish sold and consumed by local fishers in Tapajós River, Brazilian Amazon.

2. METHODS

The Tapajos Basin drains an area of 493.000 km² between the latitudes of 2º and 15° south and 53° and 61° west in the Brazilian states of Pará, Mato Grosso and Amazonas. The Tapajos River expands over 851km and represents the most important tributary of the Amazon’s right margin (Figueiredo & Blanco, 2014).

This study was conducted along a ~275km stretch of the river, downstream from the proposed São Luiz de Tapajos (SLT) hydroelectricity dam (4° 33' 7,51" S, 56° 16' 42,76" W) in the state of Pará, Brazil (CNEC Worley Parson Engenharia, 2014). The study area was divided into two regions based on geomorphologic heterogeneity as suggested by Runde 2018 and on the previous research within the literature (Hallwass, 2015; Silvano et al., 2017).

The approximate distance from São Luiz de Tapajos to the city of Aveiro is 125km, it has a maximum river width of around 5km and is referred to as the Middle Tapajos (MT). The approximate distance from Aveiro to Santarem is 150km, it has a river width of around 10km to 15km and is referred to as the Lower Tapajos (LT) (Runde 2018 - Fig. 1).

The communities were selected on the basis that there was a minimum distance of around ten kilometres between each one, that they had approximately ten or more fishers and that the fishers from the community consented to participate in the study. A few exceptions regarding the distance between the communities were made; and also a few communities were combined into individual study sites (Runde 2018).

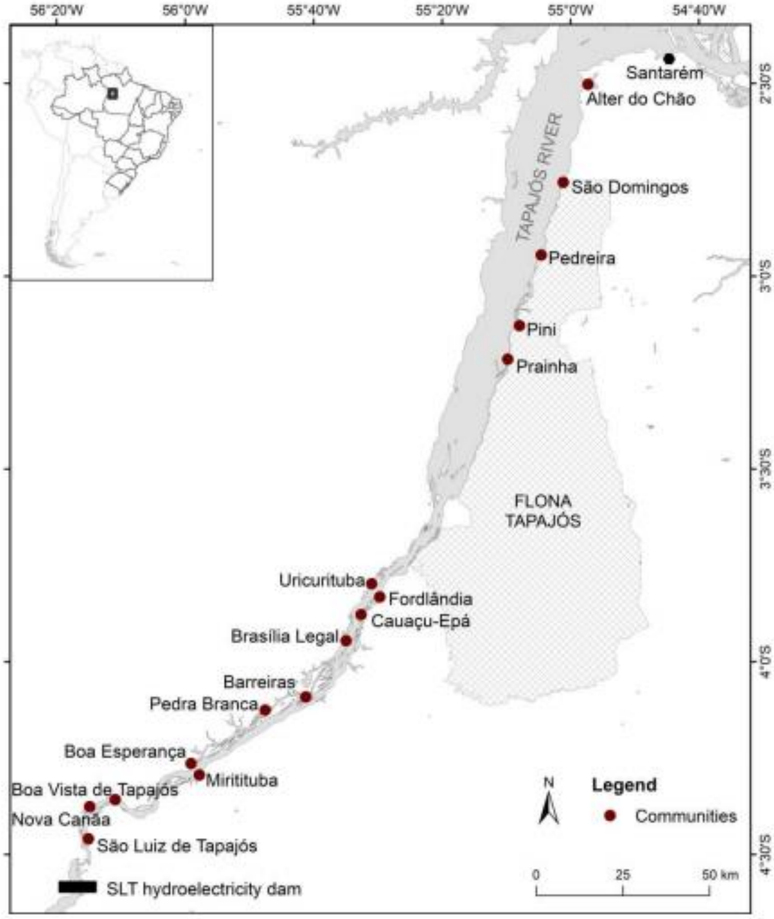

Figure 1. (Runde 2018) The Lower and Middle downstream regions of the planned São Luiz de Tapajos (SLT) hydroelectricity dam. Red dots indicate communities where interviews were conducted. The black rectangle indicates the planned site for the SLT dam. The inset shows the location of the studied region in Brazil (Google Earth, 2018).

One hundred and seventy-one fishermen were interviewed between March and May 2018, in 16 communities along the Lower and Middle downstream regions of Tapajos. Since the interview is part of a larger project not all questions were used for the purpose of this study. One aspect of these interviews was the commercialization of fish, where we asked *What fish do you capture the most?*, in which answers were limited by 5 species. Since Acaratinga (*Geophagus proximus*) was considered separate from the remaining species of its genera by the majority of fishers, it was considered separate from the Acarás in this analysis (Runde 2018). Fish species were identified by their local common names, some of which encompass groups of species. Average Hg (ng.g^{-1}) informations for each species from scientific literature consulted at Google Scholar both from Lower Tapajos (de

Souza Lima, A.P. et al. 2000; da Silva, D.S et al. 2006) and Middle Tapajos studies (dos Santos, L.S.N. et al. 2000; Castilhos, Z. et al. 2015; Uryu, Y. et al. 2001) were used to assess consumption safety according to the World Health Organization, which imposes a limit of 500 $ng.g^{-1}$ of Hg for human consumption of fish (WHO, 1972).

3. RESULTS AND DISCUSSION

A total of 815 citations were gathered. Species were united into 28 different groups, called by their common names (Table 1). Sixteen of all the evaluated groups (54.08% out of total citations, n = 815) demonstrated low Hg levels, therefore they may be safe for consumption. Six groups (40.76%) demonstrated a high level of Hg, thus making them unsafe for consumption. Out of these six groups, Peixe-cachorro, Piranha and Apapa/Sarda, fortunately, were seldom cited as most caught fish by fishermen. On the other hand, Tucunaré, Dourada and Surubim were highly cited, making up 19.19% of total citations (Table 1). Thus, the population's and fisher's health may be at risk when buying these fish for consumption. A special case should be made relating to Pescada/Corvina and Filhote. Both fish were highly cited by fishermen, making up 19.99% of the total citations. Although Hg levels below 500 $ng.g^{-1}$ were found, these values are very close to 500 $ng.g^{-1}$, thus making their consumption potentially risky. Pescada/Corvina and Filhote should be consumed with caution, according with our results. Six fishes out of total (4.88%) made it not possible to assess safety consumption due to a lack of data (Table 1).

Methylmercury is a neurotoxic agent that affects the developing nervous system at lower doses than it affects the mature nervous system (Choi, 1989). Several studies indicate that maternal Hg exposures may adversely affect the motor and cognitive development of children exposed during prenatal life (Kjellstrom et al., 1989; Grandjean et al., 1995, 1997; Julvez et al., 2016). This is a special concern for this study, because a large part of the evaluated fish demonstrated low levels of Hg, being considered as safe for consumption; however, it is a concern for pregnant women as their child may be affected. Therefore, those fishes considered as safe should also be consumed with caution by pregnant women.

There is a growing discussion on the safety limits of mercury exposure generated during the last years, especially since long-term intake of relatively low levels of mercury was proven to induce sub-clinical neurobehavioral abnormalities, especially on psychomotor coordination (Dourson et al., 2001; Carta et al., 2003; Auger et al., 2005; Pinheiro et al., 2007). This is also a special concern for this study, which could make most of the evaluated fish unsafe for consumption depending on the safety limit futurely adopted.

Deterioration of motor performance is one of the most commonly reported alterations in riverside populations of the Tapajós River basin exposed to mercury through diet (Lebel et al., 1998; Grandjean et al., 1999; Dolbec et al., 2000; Harada et al., 2001). These studies point out to the metal as one of the factors responsible for the deleterious effects on motor performance. In addition to alterations of motor performance, deleterious effects on the visual function were already highlighted as one of the most common symptoms described in exposed populations in Amazon (Lebel et al., 1998; Grandjean et al., 1999; Rodrigues et al., 2007; da Costa et al., 2008).

Table 1. Preferred fish from the Tapajos River cited in interviews. Total citations: 815

Common name	Scientific name	Family	Citations total	% of citations	Average Hg (ng.g-1) LT	Average Hg (ng.g-1) MT	Consumption Safety	Reference
Aracu/ Piau	*Anostomoides spp.,* *Leporinus spp.,* *Rhytiodus spp.,* *Schizodon spp.*	Anostomidae	132	16.19%	447 (*A. laticeps*) 131±14 (*L. friderici*) 148±88.4 (*L. fasciatus*) 117±39 (*L. affinis*) 131±46 (*R. argenteofuscus*) 163±7 (*S. fasciatus*) 236±20 (*S. vit*tatum)	0.14±0.07 (*A. laticeps*) 65.4±26.7 (*Leporinus sp.*)	Safe	da Silva, D.S. et al. 2006; de Souza Lima, A.P. 2000; Castilhos, Z. 2015
Branquinha	*Curimata spp.,* *Curimatella spp.,* *Cyphocharax spp.,* *Potamorhina spp.,* *Psectrogaster amazonica*	Curimatidae	14	1.71%	66±12 (*Curimata inorata*) 31±8 (*Potamorhina altamazonica*)	0.23±0.08 (*Cyphocharax sp.*)	Safe	da Silva, D.S. et al. 2006; Castilhos, Z. et al. 2015
Charuto	*Hemiodus spp.,* *Anodus elongatus*	Hemiodontidae	15	1.84%	85±21.8 (*H. unimaculatus*)	Unknown	Safe	da Silva, D.S. et al. 2006;
Curimatã	*Prochilodus nigricans*	Prochilodontidae	3	0.36%	Unknown	120.8±76.8	Safe	dos Santos, L.S.N. 2000
Jaraqui	*Semaprochilodus spp*	Prochilodontidae	104	12.76%	50±6 (*S. insignis*)	Unknown	Safe	da Silva, D.S. et al. 2006;
Matrinxã	*Brycon spp.*	Characidae	5	0.61%	Unknown	Unknown		
Pacu	*Metynnis spp.,* *Myleus spp.,* *Myloplus spp.,* *Tometes spp.*	Serrasalmidae	58	7.11%	67±2.1 (*Metynnis argenteus*)	0.09 (*Myleus sp.*)	Safe	da Silva, D.S. et al. 2006; Castilhos, Z. et al. 2015
Peixe-cachorro	*Hydrolycus spp.,* *Rhaphiodon vulpinus,* *Cynodon gibbus*	Cynodontidae	1	0.12%	124.6±68.1 (*Hydrolycus sp.*)	763.0 (*H. scomberoides*, *R. vulpinus*)	Unsafe	de Souza Lima, A.P. 2000; Uryu, Y. 2001
Piranha	*Pygocentrus natereri,* *Pristobrycon spp.,* *Serrasalmus spp*	Serrasalmidae	6	0.73%	881±54 (*S. rhombeus*) 471±21 (*S. eigenmanni*)	848.0 (Serrasalmus sp.)	Unsafe	da Silva, D.S. et al. 2006; Uryu, Y. 2001
Pirapitinga	*Piraractus brachypomus*	Serrasalmidae	3	0.36%	Unknown	Unknown		
Tambaqui	*Colossoma macropomum*	Serrasalmidae	29	3.55%	57.2±37.0	84.3±32.1	Safe	de Souza Lima, A.P. 2000; dos Santos, L.S.N. 2000
Apapa/ Sarda	*Ilisha amazonica,* *Pellona spp.*	Pristigasteridae	6	0.73%	633±84.5 (*P. castelnaeana*)	Unknown	Unsafe	da Silva, D.S. et al. 2006; dos Santos, L.S.N. 2000
Pirarucu	*Arapaima spp.*	Arapaimidae	15	1.84%	Unknown	Unknown		
Acará	*Aequidens spp.,* *Astronotus spp.,* *Caquetaia spectabilis,* *Chaetobranchus spp.,* *Cichlasoma spp.,* *Geophagus spp.,* *Heros spp.,* *Satanoperca spp.,* *Symphysodon spp.,* *Uaru amphiacanthoides*	Cichlidae	6	0.73%	90 (*Astronotus crassipinnis*) 15 (*Cichlasoma amazonarum*) 150±15 (*Satanoperca acuticeps*) 177±84 (*Symphysodon aequifasciatus*)	2.21±0.35 (*Cichlasoma sp.*)	Safe	da Silva, D.S. et al. 2006; Castilhos, Z. 2015
Acaratinga	*Geophagus proximus*	Cichlidae	44	5.3%	70±19	Unknown	Safe	da Silva, D.S. et al. 2006;
Jacundá	*Crenicichla spp.*	Cichlidae	1	0.12%	225±79.1	Unknown	Safe	da Silva, D.S. et al. 2006;

Pescada/ Corvina	*Plagioscion spp.*, *Pachypops spp.*, *Pachyurus spp*	Sciaenidae	112	13.74%	463±152 (*Plagioscion squamosissimus*)	Unknown	Unsafe	da Silva, D.S. et al. 2006;
Tucunaré	*Cichla spp.*	Cichilidae	83	10.18%	490±101 (C. *temensis*) 631±46 (*C. monoculus*) 409±11.3 (*Cichla sp.*)	375.9±155.3	Unsafe	de Souza Lima, A.P. 2000; dos Santos, L.S.N. 2000
Raia	*Potamotrygon spp.*, *Paratrygon aiereba*	Potamotrygonidae	1	0.12%	Unknown	0.63±0.27	Safe	Castilhos, Z. et al. 2015
Barbado	*Brachyplatystoma platynemum*, *Pinirampus pirinampu*	Pimelodidae	9	1.10%	Unknown	Unknown		
Dourada	*Brachyplatystoma rousseauxii* *(B. flavicans)*	Pimelodidae	38	4.6%	252.0±79.9	815.0±372.0	Unsafe	de Souza Lima, A.P. 2000; dos Santos, L.S.N. 2000
Filhote	*Brachyplatystoma filamentosum*	Pimelodidae	51	6.25%	Unknown	422.2±218.2	Unsafe	dos Santos, L.S.N. 2000
Jandiá	*Leiarius marmoratus*	Pimelodidae	5	0.61%	Unknown	Unknown		
Mapará	*Hypophthalmus spp.*	Pimelodidae	31	3.80%	171.0±122.0 (*H. marginatus*)	Unknown	Safe	da Silva, D.S. et al. 2006
Piramutaba	*Brachyplatystoma vaillantii*	Pimelodidae	2	0.24%	Unknown	Unknown		
Piranambu	*Pinirampus pirinampu*	Pimelodidae	1	0.12%	Unknown	Unknown		
Pirarara	*Phractocephalus hemioliopterus*	Pimelodidae	4	0.49%	Unknown	0.28	Safe	Castilhos, Z. et al. 2015
Surubim	*Pseudoplatystoma spp.*	Pimelodidae	36	4.41%	560±166 (*P. tigrinus*)	839.0±511.0	Unsafe	da Silva, D.S. 2006; dos Santos, L.S.N. 2000

4. CONCLUSION

There is a need of studying mercury contamination especially on these communities and on those fishes where data is missing and have more knowledge on consumption estimates. Initiatives aiming to give information on the diet habits of the Amazon riverine population are highly needed, in order to understand the potential risks they are exposed to. This work sheds light on this topic, by contributing to a direct association between highly consumed fishes from Tapajós river, the mercury contamination level on them and the risk of consuming them. We believe it is difficult to establish which fish species should be consumed or not by the population of these regions due to the unreliable safety limit set by the World Health Organization; and also, considering that fish is the main protein source for riverine populations, there are implications on removing fishes from their diets. Finally, we believe there is an urgent need to redefine the safety limit of mercury exposure.

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