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ORIGINAL PAPER

Vulnerability associated with "symptoms similar to those of mercury poisoning" in communities from Xingu River, Amazon basin

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Abstract The Brazilian Amazon is known to be a region with high levels of mercury (Hg) in the environment and studies point to an association between high levels of natural mercury in the mother rock and the vast number of clandestine gold mines. Other studies already report the contamination of fish in this region, as well as high levels of Hg in biological material from environmentally exposed populations. On the other hand, this is one of the least developed regions of the planet and it is necessary to understand the vulnerability factors in these populations that may be intoxicated by this element. The purpose of the present study was to investigate the vulnerability factors in communities from Xingu River—Amazon basin probably exposed to Hg. A cross-selection study in two cities localized in Xingu River was conducted, and the sample contained was 268 individuals. sociodemographic questions, lifestyle, diet habits and health conditions were collated. The majority of the sample was female, between 30 and 59 years old, had less than 3 years of educational level and lived in the local of study more than 240 months. There was regular fish consumption (95.9%), principally carnivorous species (80.5%). The visual problem has a highest prevalence (43.3%) between the health problems and about the symptoms of Hg intoxication, memory loss (42.9%), weakness (35.1%), fatigue (34.3%), mood changes (28.7%) and difficulties in concentration (27.2%) was most reported. The female sex, age over 60, educational level below 3 years of study, did not had flush toilet, smoke and least one chronic non-communicable disease represent higher probability to had symptoms of Hg intoxication. Lack of access to health services, low education level and income evidence the susceptibility of this community to diseases and injuries. The vulnerable groups identified in this study should be a priority in public health and environmental health policies.

Keywords Amazon · Mercury · Intoxication · Vulnerability

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Introduction

The mercury (Hg) is a naturally occurring element that is present throughout the environment. This metal is recognized as a global contaminant because it is persistent in the environment, can be accumulated in the food web and cause severe adverse effects on humans and ecosystem health (Driscoll et al. 2013). Environmental contamination with Hg is extensive in all environmental compartments, including land, air, water and wildlife (Olivero-Verbel et al. 2016).

The human exposure to Hg can produce permanent damage to the nervous system, resulting in a variety of symptoms such as paresthesia, sensory disturbances, tremors, impairment of hearing, difficulty in walking (Harada 1995), blurred vision, slurred speech, hearing difficulties, blindness, deafness and death (Marsh et al. 1987). In addition, there are several chronic symptoms of Hg exposure, affecting other systems, and sequentially cause adverse effects including renal toxicity (Mottet et al. 1985; Miller et al. 2013), myocardial infarction (Guallar et al. 2002), immune malfunction (Moszczyński 1996) and irregular blood pressure (Rossoni et al. 1999). Furthermore, the major toxic effects of Hg reported in humans are related to the central nervous system damage (Olivero-Verbel et al. 2016; Carvalho et al. 2009; Castilhos et al. 2015).

The health problems related to Hg exposure depend on the magnitude of the dose as well as on time and duration of exposure (Olivero-Verbel et al. 2016). There are two main forms of human exposure to mercury, through occupational exposure or diet. In the Brazilian Amazon, the Hg exposure of communities was attributed to intense gold mining activity in the region, making use of large quantities of Hg to extract the gold from the gold ore (Khoury et al. 2015). Moreover, the Hg content in fish consumed in Amazon region represents potential harm to human health (Zillioux 2015) since fish consumption is an important source of animal foods for riverside communities (Benefice et al. 2006) and provides high quality protein (Carvalho et al. 2009).

Xingu River is the largest tributaries of the Amazon basin, localized at the state of Pará (Alho et al. 2015). This area has a great diversity of natural resources, including fauna, flora and an immense mineralogical potential (Mesquita and Isaac-Nahum 2015). This region has been under gold mining activities a long time ago, using Hg in extraction processes (Carvalho et al. 2009), as well as under threat of deforestation (Alho et al. 2015). This situation may contribute to increase in human Hg exposure. Furthermore, a previous study shows that living conditions in the Amazon are often considered to be precarious, with a negative impact upon health (Benefice et al. 2008), demonstrating the fragility of this population. In Amazon region, the high blood levels of mercury do not extend only to gold mining workers, but the general population (Pinheiro et al. 2006; Castilhos et al. 2015).

Concerning the Amazon populations, which make daily fish intake, some studies have been conducted to identify the presence of Hg in biological fluid (Santos et al. 2003a, b; Carvalho et al. 2009), being the exposure through the diet an important exposure factor. This is a critical condition, especially in populations whose diet is restricted and mainly consists of fish.

It is observed that the problem related to contamination by mercury in the Amazon region is already well reported in the literature. In their review of human exposure to Hg, Passos and Megler (2008) reported mean values of capillary mercury above 15 μg/g of hair and daily intake rate of 1–2 μg/kg/day, considerably above international recommendations. Authors also report neurobehavioral deficits and clinical signs of intoxication in adults and children.

The purpose of the present study was to investigate the vulnerability factors of communities potentially exposed to Hg contamination from Xingu River—Brazilian Amazon.

Methodology

Study design, site and sampling

This was a cross-sectional study conducted in 2015 at two cities in the Pará state: Altamira and Senador José Porfírio (Fig. 1). These two cities are situated within the Xingu River, Amazon basin, and are subject to environmental impacts such as the construction of hydroelectric power, changing the landscape and environmental contamination resulting from activities of gold mining. The choice of these municipalities was based on the presence of illegal mining in its surroundings and by the majority of the population does not have access to treated water.

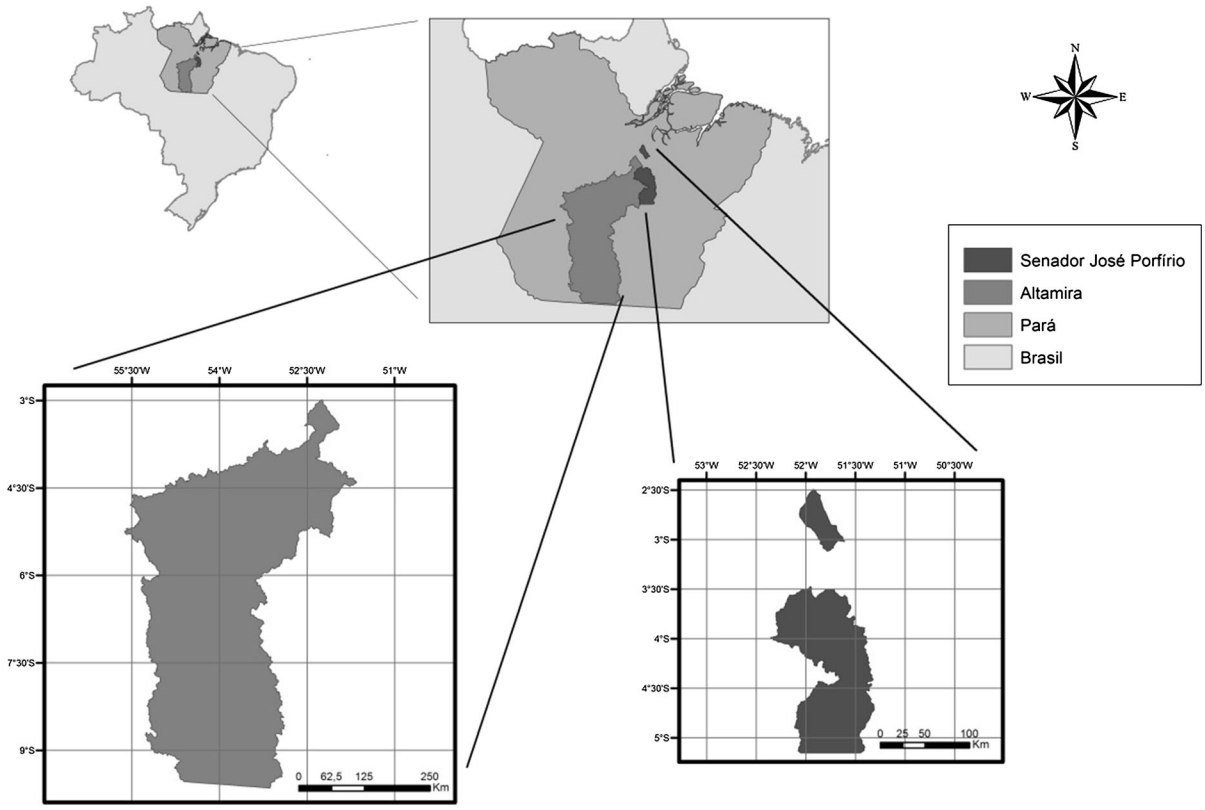

Fig. 1 Geographical location of the municipalities of Altamira and Senador Jose Porfirio, Pará state—Brazil

According to data from IBGE (2015), the city of Altamira has 108,382 inhabitants and the city of Senador José Porfirio 11,837 inhabitants. This was a convenience sample, composed of men and women adults (above 18 years) living in the cities and who agreed to participate in the study. The collections respected the distribution of the population among the different regions of the cities, but the choice of residence in each region was random. Only one resident from each visited residence was interviewed. The exclusion criteria were: those under 18 years of age, people who were unable to answer the questionnaire or those who refused to participate in the research. The total sample contained 268 participants ($N = 155$ from Altamira and $N = 113$ from Senador José Porfírio).

Data collection

The data collection was performed from the application of a structured questionnaire. The interviews were conducted at the residence of each individual by academics from the Federal University of Pará, Altamira campus. The instrument contained sociodemographic questions, lifestyle, diet habits and health conditions. The health conditions include some diseases, such as hypertension, diabetes, renal dysfunction and liver failure, problems in the blood, lungs or visual impairment, depression and cardiac problems. Furthermore, we study the prevalence of symptoms of Hg intoxication (neurobehavioral symptoms and/or neurological signs) reported to interviewed in populations, and these symptoms are as follows: weakness, tremors, excessive salivation, difficulty in motor coordination, speaking alteration, walking alteration, shifting the balance, irritability, frequent changes of mood, memory loss, hopelessness, insomnia, inattention and difficulty in concentration (De Carvalho et al. 2011). Additionally, the participants were questioned about cases of abortion in the home, cases of cancer in the family and malformations.

Data analysis

The main outcomes of the study were the vulnerability factors and the symptoms similar to those of mercury poisoning in communities from Xingu River—Amazon basin. Vulnerability factors were considered as the sociodemographic and the diet habits variables while the health effects were considered as the health problems and the symptoms of Hg poisoning were reported by participants.

The independent variables were family income *per capita*, sex, age (18–29, 30–59 years and older than 60 years), educational level (0–3 years of study, 4–8 years of study and over 9 years of study), housing conditions (house of masonry or other and type of sanitation with or without discharge), municipality (Altamira or Senador José Porpfírio), time of housing (0–59, 60–240 or more than 240 months), exposure to work (yes or no), consumption of water (water from public supply or other sources), consumption of alcohol, tobacco, physical activities, number of daily meals, fish consumption, type of fish consumed (carnivorous and piscivorous or others), fish consumption and chronic non-communicable diseases (hepatic or renal dysfunction or diabetes).

The data obtained were entered twice on a scheduled basis and then corrected possible errors in Epi Info 6.0 prior to statistical analysis. The data were checked for consistency, and results were expressed as frequency of response. All analyzes were performed in STATA 10.0. Descriptive analysis (bivariate) and Poisson regression analysis (multivariate) were performed. The theoretical hierarchical model in the multivariate analysis was used, the four-level compounds are as follows: first level—sociodemographic characteristics (family income *per capita*, sex, age and educational level); second level—housing conditions, municipality, time of housing, exposure to work, consumption of water; third level—consumption of alcohol, tobacco, activities Physical, eating habits (number of daily meals, fish consumption, type of fish consumed (carnivorous or others) and what is the frequency of consumption); and fourth level—metabolic disorders. The dependent variable was "mercury intoxication symptoms," where the individual was framed when he/she reported having three or more symptoms. In all analyzes, we considered a critical level of $p < 0.05$.

Ethical aspects

Those who agreed to participate in the study signed beforehand the informed consent form. This project was approved by the Ethics Committee from the Federal University of Pará under the Legal opinion number 811.807. During the study, the ethical principles advocated by Resolution 466/12 of the National Health Council of the Ministry of Health regulate research involving human beings.

Results

Interviews were held with 268 individuals, of whom 74.6% subjects were female. About the sociodemographic variables, a half of the sample has between 30

Table 1 Descriptive analysis of sociodemographic variables and lifestyle of communities from Xingu River—Amazon basin, 2015 ($N = 268$)

	N	%
Sex		
Male	68	25.4
Female	200	74.6
Age (years)		
18–29	83	31.0
30–59	134	50.0
≥60	51	19.0
Educational level (years)		
>9	84	31.3
4–8	88	32.8
≤3	95	35.4
Residence time in the house (months)		
0–59	27	11.3
60–240	104	43.7
>240	107	45.0
In relation to smoking[a]		
Non-smoking	236	88.1
Smoker	31	11.6
Ingesting alcohol[a]		
No	72	26.9
Yes	195	72.8
Physical activity[a]		
No	204	76.1
Yes	63	23.5

[a] One missing information

and 59 years old (50.0%) (Table 1), while the most of the individuals have less than 3 years of educational level (35.4%) and lived in the local of study more than 240 months (45.0%). Among the lifestyle of those interviewed, 11.6% responded to be smokers and over half consume alcohol (72.8%). A smaller portion has informed the practice of some activity (23.5%); among the activities mentioned are walking, fitness, soccer and dance.

The diet habits of communities from Xingu River are shown in Table 2. The majority of individuals have at least three meals a day (86.0%), and the consumption of fish was a regular habit in these communities. Almost 96% of individuals interviewed reported that consuming fish was a regular basis (weekly or daily consumption). The most of the fish consumed by the population comes from local fishmongers (86.2%), while 7.1% reported consuming fish caught straight from the river. Table 3 describes the frequency of the types of fish consumed. The consumption of carnivorous fish between the two cities studied is high, being Tucunaré (*Cichla* spp.) (44.8%) and Pescada (*Plagioscion* spp.) (29.0%) the most consumed. Even so, the omnivore fish comprise an important source of food, such as Pacu (*Myloplus* spp.) (15.4%), Tambaqui (*Colossoma macropomum*) (11.9%) and Piau (Anostomidae) (10.9%).

In relation to health problems in these two communities, the highest prevalence was found of visual problems (43.3%), followed by blood (25.4%) and renal problems (25.0%) (Table 4). Still in a health context, another relevant factor in this study is the prevalence of symptoms related to Hg intoxication recorded to participants (Table 5). The symptoms most often reported were memory loss (42.9%), weakness (35.1%) and fatigue (34.3%). We researched some pregnancy outcomes like at least one abortion and having a child with malformation, which obtained prevalence of 18.3 and 7.8%, respectively. Another important found was the prevalence of 18.3% of some type of cancer in the family.

Table 2 Diet habits of communities from Xingu River—Amazon basin, 2015 ($N = 268$)

	N	%
Number of daily meals		
1	12	4.6
2	25	9.4
3	121	45.3
4	81	30.2
5	28	10.5
Fish consumption (weekly or daily consumption)		
No	11	4.1
Yes	257	95.9
Origin of the fish consumed		
Fishmonger	231	86.2
River fish	19	7.1
No answer	15	5.6
Others locations	3	1.1

Table 3 Descriptive analysis of fish species consumed by communities from Xingu River—Amazon basin, 2015 ($N = 268$)

	N	%
Carnivorous		
Tucunaré (*Cichla* spp.)	120	44.8
Pescada (*Plagioscion* spp.)	78	29.0
Surubim (*Pseudoplatystoma punctifer*)	13	4.8
Fidalgo (*Ageneiosus inermis*)	8	3.0
Filhote (*Brachyplatystoma filamentosum*)	7	2.6
Traíra (*Hoplias* spp.)	6	2.3
Piranha (*Serrasalmus* spp.)	4	1.5
Dourado (*Brachyplatystoma rousseauxii*)	3	1.2
Other catfishes	3	1.2
Pirarucu (*Arapaima gigas*)	2	0.8
Pintado (*Pseudoplatystoma punctifer*)	1	0.4
Omnivorous		
Pacu (*Myloplus* spp.)	41	15.4
Tambaqui (*Colossoma macropomum*)	32	11.9
Piau (Anostomidae)	29	10.9
Mampara (*Hypophthalmus* spp.)	2	0.8
Salmon	1	0.4
Small Characins	1	0.4
Detritivore		
Curimatá (*Prochilodus nigricans*)	29	10.9
Cará (*Geophagus* spp.)	25	9.3
Caratinga (*Geophagus* spp.)	10	3.7
"Mocinha"	3	1.1
Flecheirinha (*Hemiodus* spp.)	3	1.1
Branquinha (Curimatidae)	1	0.4
Jaraqui (*Semaprochilodus insignis*)	1	0.4
Acari (Loricariidae)	1	0.4
Aridina (*Semaprochilodus brama*)	1	0.4
"Amarelinha"	1	0.4

Table 4 Prevalence of health problems reported by communities from Xingu River—Amazon basin, 2015 ($N = 268$)

	N	%
Visual problems	116	43.3
Blood problems	68	25.4
Hypertension	67	25.0
Renal problems	51	19.0
Liver problems	30	11.2
Depression	24	9.0
Diabetes	20	7.5
Heart problems	14	5.2
Breathing problems	12	4.5

Table 5 Prevalence of symptoms of mercury intoxication in communities from Xingu River—Amazon basin, 2015 ($N = 268$)

	N	%
Memory loss	115	42.9
Weakness	94	35.1
Fatigue	92	34.3
Mood changes	77	28.7
Difficulties in concentration	73	27.2
Despondency	72	26.9
Irritability	71	26.5
Listlessness	66	24.6
Insomnia	24.6	24.6
Tremors	64	23.9
Cases of cancer in the family	49	18.3
Abortion	49	18.3
Excessive salivation	39	14.6
Shifting the balance	31	11.6
Abnormal gait	30	11.2
Difficulties in motor coordination	26	9.7
Malformations	21	7.8
Change in speech	9	3.4

Table 6 describes the association between sociodemographic variables, lifestyle, metabolic alteration and "symptoms possibly related to mercury poisoning" in communities from Xingu River. The female sex (RP: 1.82; IC 95%: 1.06–3.15), age over 60 (RP: 1.97; IC 95%: 1.03–3.77), educational level below 3 years of study (RP: 2.28; IC 95%: 1.24–4.20), did not had flush toilet (RP: 1.63; IC 95%: 1.08–2.47), smoke (RP: 1.81; IC 95%: 1.18–2.79) and least one metabolic problem (RP: 1.61; IC 95%: 1.11–2.35) represent higher probability to had symptoms of Hg intoxication (Table 6).

Discussion

This study reports some sociodemographic characteristics and life habits of Amazonian populations possibly exposed to Hg contamination. It also reports the main health problems, highlighting the prevalence of symptoms that are similar to those listed as related to Hg poisoning. A limitation of the study is the absence of Hg analysis in biological material of the participants. On the other hand, there are already numerous studies that show that the Amazonian populations have high levels of mercury and a strong association with the consumption of contaminated fish (Santos et al. 2003a, b; Carvalho et al. 2009; Castilhos et al. 2015). The novelty of the current study is the association between these symptoms and vulnerability factors within these populations.

In this sense, few studies have been performed. We highlight the study by Kim et al. (2013) (Korea) that evaluated the association between lifestyle and blood levels of Hg and pointed out that factors such as sex, age, residence place, occupation and habit of smoking or drinking are associated with higher levels of Hg blood.

The communities from Xingu River had a regular fish consumption, the principal species of fish consumed was carnivorous fish, and this diet habits increase the Hg exposure in these population (Oliveira et al. 2010), since the carnivorous species have a mean Hg concentration almost four times higher than that of the non-carnivorous species (Castilhos et al. 2015). Several studies have demonstrated its risk to human health through the consumption of contaminated fish (Mason et al. 2000; Oliveira et al. 2010; Olivero-Verbel et al. 2016). Amazonians have traditionally relied on food habits with a diet based on manioc and fish (Dórea 2004). The fish is their most important source of animal protein and fat (Murrieta and Dufour 2004). Olivero-Verbal et al. (2016) related to a fish intake higher than ten meals/week in several municipalities of Colombian Amazon.

Table 6 Association between sociodemographic variables, lifestyle, chronic non-communicable diseases and symptoms of Hg intoxication of communities from Xingu River—Amazon basin, 2015 ($N = 268$)

Level	Variable	Crude analysis		Value p	Adjusted analysis		Value p
		RP	IC 95%		RP	IC 95%	
1	Gender			0.0106			0.029
	Male	1.00			1.00		
	Female	1.59	0.90–2.78		1.82	1.06–3.15	
	Age (years)			<0.001			0.035
	18–29	1.00			1.00		
	30–59	1.81	0.99–3.28		1.49	0.82–2.72	
	≥60	2.84	1.53–5.29		1.97	1.03–3.77	
	Educational level (years)			<0.001			0.006
	≥ 9	1.00					
	4–8	1.82	0.98–3.41		1.58	0.84–2.98	
	≤3	2.87	1.62–5.08		2.28	1.24–4.20	
2	Residence time in the house (months)			0.004			0.366
	≤59	1.00			1.00		
	60–240	1.40	0.87–2.27		1.04	0.63–1.71	
	>240	2.34	1.36–4.02		1.38	0.76–2.53	
	Flush toilet			0.009			0.02
	No	1.78	1.16–2.72		1.63	1.08–2.47	
	Yes	1.00			1.00		
3	Smoking			0.013			0.007
	No	1.00			1.00		
	Yes	1.83	1.14–2.95		1.81	1.18–2.79	
	Physical activity			0.033			0.235
	No	1.00			1.00		
	Yes	0.50	0.26–0.94		0.67	0.35–1.29	
4	Chronic non-communicable diseases			0.001			0.013
	No	1.00			1.00		
	Yes	2.03	1.36–3.03		1.61	1.11–2.35	

The literature reports several health effects of the Hg exposure in Amazon population, since the twentieth century. The principal effect of Hg exposure was neurotoxic (Khoury et al. 2013). Neurobehavioural manifestations of subtle neurotoxic effects on motor functions, associated with low-level methylmercury exposure, were observed (Dolbec et al. 2000). Moreover, studies are related Hg to central vision dysfunction (Fillion et al. 2011), to loss of color discrimination capacity and sensitivity (Silveira et al. 2004), to increased autoimmune dysfunction and to systemic inflammation (Gardner et al. 2009). These are consistent with the results of the present study. Between the health problems reported by the communities the visual problems was the highest prevalence, including myopia, hyperopia, astigmatism, cataract, and glaucoma. Memory loss, weakness, fatigue, mood changes and difficulties in concentration were the most symptoms possibly related to Hg intoxication reported by communities from Xingu River.

The gold mining activities are predominantly done by men who are willing always hard work. However, even though gold mining activities are not suitable for women and children (Dórea and Marques 2016), some "garimpos" still report the frequent presence of them in activities related to processing, washing, amalgam

and refining, which are activities done manually (Bartrem et al. 2014). In this study, the women are more vulnerable to had symptoms of Hg intoxication, probably because they were suffering more Hg exposure. This exposure to Hg may be neglected in some Amazonian studies. Other point that increases the vulnerability of individuals was suffered metabolic changes, and this is intimately related to aging. It was possible to verify that advanced age (>60 years) has a significant associated with poisoning symptoms. On other hand, Hoshino et al. (2015) observed no significant correlation between age and the level of Hg in the hair. Besides that, the results of this study show association between low educational level (≤3 years) with symptoms of Hg intoxication. According to this finding, two previous studies, (Castilhos et al. 2015; Olivero-Verbel et al. 2016), also reported low educational level in a different region of Amazonian. The living conditions in the Amazon communities are considered to be precarious (Benefice et al. 2008); moreover, the low educational level and, consequently, low income can make this population even more compromised.

According to WHO (2008), smoking has a significant interference on the life of smoker. These are consistent with the findings of the present study; those individuals who reported tobacco smoke had a higher probability to had symptoms of Hg intoxication, showing more vulnerable to Hg exposure. Furthermore, the results of this study show association between metabolic alteration and symptoms of Hg intoxication. This becomes more worrying, since there is a significant increase in the prevalence of noncommunicable chronic diseases in the Amazon region of Brazil (Penna et al. 2009). In accordance with WHO, these diseases are related to poverty, negatively impacting the macroeconomic development of countries, especially those of medium and low income (Abegunde et al. 2007).

The risk assessment of poisoning through chemicals, such as the Hg, should take into account in addition to the daily doses of exposure, factors that can contribute to increased vulnerability, as, for example, environmental stress and history of diseases (Fechine and Trompieri 2015). The stress or environmental pressure can be explained by a number of factors related to demographic, social, lifestyle habits and food products.

In general, the two populations studied are characterized as low educational level and low income. Also, the current study showed that the populations studied reported low consumption of tobacco but not of alcohol, and the practice of physical activity is not very prevalent. Due to residing in riverside areas, fish consumption ends up being an important food resource, standing out fish from the region (Vergotti et al. 2012).

The most consumed fish between the populations are fish considered as top of food chain and with the greatest potential for biomagnification. It has been reported that some of these fish have high concentrations of Hg, even in areas that are not influenced by mining (Rodrigues et al. 2010). In the study area, Souza-Araújo et al. (2016) reported that predatory fishes had high Hg concentration and the most prevalent form was methylmercury.

A limiting factor is the lack of reports about the origin of the fish consumed by these populations. Furthermore, the robustness of the analysis was compromised because the majority of the population reports the fish consumption (>95%) and preferably of top of chain fish. On the other hand, this high consumption is a relevant factor to investigate the prevalence of health problems and the vulnerability factors of the communities from Xingu River to symptoms of Hg intoxication. We also point out that this study did not aim to diagnose cases of intoxication in individuals of these communities, but rather to carry out a population-based scientific study. On the other hand, since this population has little access to health services, it is possible that the health problems reported by the interviewees are underestimated.

Studies on potential exposure to mercury cannot be overlooked, because studies show that preterit exposures or in low doses are sufficient for the ongoing maintenance of the symptoms of poisoning (Kishi et al. 1993, 1994). Special attention should be given to populations in less developed areas, such as the current study, as they are more susceptible to the effects of environmental contamination (Sheehan et al. 2014).

Conclusion

The risk assessment of Hg intoxication should take into account in addition to the daily doses of exposure,

factors that can contribute to increase vulnerability, as factors sociodemographic, lifestyle and diet habits.

In this study, it was possible to outline a profile of communities from Xingu River, who were living in areas with Hg exposure. These communities who had a regular fish consumption, principally carnivorous fish species, are more susceptible to Hg exposure. Furthermore, the individuals most vulnerable to symptoms related to Hg intoxication were the female sex, age over 60 years, low educational level, not possessing flush toilets, residing for more than 20 years in the same place, smoking and metabolic changes. Lack of access to health services, basic sanitation, low education level and income evidences the susceptibility of this community to diseases and injuries.

We suggest the continuity of studies in the Amazon region, for in the future to exist orientation programs for riverside populations exposed to these pollutant risks, besides subsidies for the elaboration of public policies to promote health and environmental health.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

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