Epidemiological and toxicological profile of a community exposed environmentally to mercury in the amazon

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Abstract— Objective: to know the epidemiology and the toxicological profile in relation to the total Hg in the sample of the population of Sena Madureira, in the State of Acre, northern region of Brazil. Method: Cross-sectional, population-based, descriptive study with a quantitative approach. Result: The sample consisted of 302 484 people from a community in the municipality of Sena Madureira, state of Acre, Brazil, located southwest of the northern region of Pan-Amazon. This study found that total blood and hair Hg levels were above the limits considered safe by the World Health Organization. The presence of total Hg in the blood and in the capillary matrix shows that the population of the municipality of Sena Madureira is environmentally exposed to metal. This exposure occurs through the existence of the biogeochemical cycle with the participation of fish consumption and the anthropic activity of artisanal gold mining in the bordering region of the state of Acre. Conclusion: The high content of total Hg in the biological matrices of the studied population indicates the physiological dynamics of the metal in the organism. The distribution of mercury in both sexes and in different age groups, suggests that there is a significant risk to the health of individuals, especially women and children.

Keywords— Metals Heavy, Mercury, epidemiology, Toxicological Phenomena.

I. INTRODUCTION

The Amazon Basin is the most extensive hydrographic network on the planet, with 25,000 kilometers of navigable rivers. Its area corresponds to 6.1 million square kilometers distributed in five countries (Brazil, Bolivia, Peru, Colombia and Venezuela) that form the Pan-Amazon region[1].

In the Triple Border (Brazil, Bolivia and Peru), since the 1970s there has been an intensification of gold mining, mainly in the Department of Madre de Dios, in Peru[2]. The use of a large amount of mercury (Hg) for its extraction, contaminated the aquatic environment, contributing to the exposure of riverside communities, through the consumption of fish with high levels of methylmercury (MeHg) in the region[3].

In continuity, in the Amazon context, it is estimated that there are about 300 thousand gold miners and about 3 thousand tons of Hg were dumped in the rivers of the region[4]. In Madre de Dios, Peru, illegal gold activity produces about 18,000 kg per year of Hg, with an average of 2.8 kg for each kilogram of gold produced[5].

The Hg is a natural element that can be distributed in the environment by natural processes and human activities, whose high persistence in different environmental compartments produces toxicity for several biological species, including humans[6]. Therefore, it is highlighted that human activities are related to the burning of fossil

fuels, industrial waste, mineral activity, erosion process and leaching of particles that promote soil exposure[7].

In addition, artisanal gold mining uses amalgam of mercury to extract this ore, which represents a significant source of exposure for workers and nearby populations[8]. This artisanal activity is responsible for 37% of anthropogenic mercury, whose persistence of metallic vapor in the atmosphere and its precipitation in different aquatic compartments is part of the biogeochemical cycle of the place[9], and this process may explain the presence of the metal in places without industry and mining activities.

Os efeitos tóxicos do mercúrio dependem da espécie química do metal e do tempo de exposição, cujos efeitos adversos variam em diferentes grupos populacionais[10]. Destaque para o MeHg, que, ao entrar no corpo, produz graves alterações nos órgãos e tecidos humanos. Além disso, esse metal pode cruzar a barreira hematoencefálica e atingir gravemente o sistema nervoso central. Em mulheres grávidas, pode cruzar a barreira placentária e prejudicar gravemente o desenvolvimento fetal[11].

Hg concentrations in blood and hair have been used as biomarkers to assess human exposure[12]. Total Hg in human hair is an efficient indicator of long-term exposure to MeHg, while blood establishes an early relationship with metal[13].

In this study, epidemiological and toxicological indicators were used to assess environmental exposure to total Hg in the population sample of the municipality of a region of the Pan Amazon, free from this economic activity. From this, the objective was to know the epidemiology and the toxicological profile in relation to the total Hg in the sample of the population of Sena Madureira, in the State of Acre, northern region of Brazil.

II. METHOD

Cross-sectional, population-based, descriptive study with a quantitative approach conducted with 484 people from a community in the municipality of Sena Madureira, state of Acre, Brazil, located southwest of the northern region of Pan-Amazon.

This survey included people who lived in the city in question for at least 12 months. For the selection of individuals, a spatial distribution of the conglomerate type was performed, that is, a street was drawn in the neighborhood, totaling 21 neighborhoods. In each street 5 families were visited until reaching 24 individuals, regardless of age.

From then on, the Informed Consent Term was made available and questionnaires with socioeconomic and epidemiological information and eating habits of the interviewees were applied. Blood and hair samples were collected from the participants during the home visit, through biosafety procedures with biological material. In addition, this research was approved by the Human Research Ethics Committee of the Evandro Chagas Institute (Reference nº 141.519, CAAE: 10114212.1.0000.0019/2012).

Venous blood samples were collected in 10 mL of 10% EDTA tubes and stored and transported at 40°C to the IEC toxicology laboratory. Hair samples were collected from the occipital region and stored in white paper envelopes and kept at room temperature until analysis. The determinations of total Hg were made from the opening with nitric/perchloric acid 1:1 and sulfuric acid, whose calibration curve for blood and hair showed excellent linearity (0 -100 µg/L) with detection limit 0.1 µg/L and 1.0 µg/kg, respectively.

The certified reference for Seronorm™ Trace Elements L-1 whole blood, certified concentration of 1.97 μg/L Hg and standard deviation of 0.15 μg/L, while for hair the IAEA 085 certified reference which has a certified concentration of 23 , 2 µg/g Hg, reproducibility was 90.35% with a standard deviation of 0.25 µg/g. Analyzed by Atomic Absorption Spectrometry with the Cold Steam Generation System (CV-AAS) (Mercury Analyzer, Hg-201, Sanso Inc), according to the method proposed by Akagi[14].

Descriptive statistical analyzes and correlation studies were performed with Microsoft Excel 10 and MINITAB 17. The distribution of data by matrices considered the 95% confidence interval. For univariate and bivariate continuous analysis for two or more groups, parametric and nonparametric tests were used, when indicated. The Mann-Whitney test was used to analyze categorical variables. In Spearman's correlation analysis, generalized linear models were used when considering quantitative variables[15].

III. RESULTS

The sample consisted of 484 people of both sexes, 61.2% women and 38.8% men. Most patients were between 18 and 39 years old, most of these individuals (52.69%) reported residing at the study site between 10 and 29 years old. In addition, it was observed that the consumption of fish represented a frequent eating habit that occurred twice a month for 69.63% of the interviewees, as shown in Table 1.

Table 1 – Description of the researched population in relation to sex, age in years, residence time and fish consumption, Sena Madureira, AC. 2018.

All participants	n=484	%	Man (n=188)		Woman (n=296)	
			n	%	n	%
Age (years)						
0-09	33	6.82	16	8.51	17	5.74
10-17	95	19.63	45	23.94	50	16.89
18-39	193	39.88	67	35.64	126	42.57
40-59	92	19.01	27	14.36	65	21.96
≥ 60	71	14.67	33	17.55	38	12.84
Residence time						
0-9	91	18.80	38	20.21	53	17.91
10-29	255	52.69	100	53.19	155	52.36
30-59	122	25.21	44	23.40	78	26.35
≥ 60	16	3.31	6	3.19	10	3.38
Fish consumption						
0-2 times/week	337	69.63	122	64.89	215	72.64
3-5 times/week	132	27.27	60	31.91	72	24.32
> 5 times/week	15	3.10	6	3.19	9	3.04

As for sex, age group, residence time and fish consumption with their average levels of total Hg in the blood and hair, it is observed that the average metal in the blood was 11.92 (0.00-176, 95) μg.L-1 and hair 3.65 (0.00-55.40) μg.g-1. It is noteworthy that the Spearman Correlation (r = 0.8256; t = 32.1215; p <0.0001) was positive among the biological matrices investigated. In addition, the mean total Hg, in both sexes and in biological matrices, was above normal limits for the unexposed population. Another important finding highlights that an age group above 60 years has greater exposure to metal in the blood and hair.

The residence time above 30 years and the significant consumption of fish seem to influence the increase in the average of total Hg among the individuals surveyed. These averages practically double with the increase in the values of the studied variables. In addition, in this study, the shorter residence time in the region showed levels considered high for the dynamics of exposure to mercury in the region, that is, the longer the residence time, the greater the exposure. This fact can be justified by the marked migration in the Amazon region, as shown in Table 2.

Table 2 – Association of mean total Hg in blood and without hair and its relationship with sex, age group, residence time and fish consumption, Sena Madureira, AC, 2018.

All Participants	Hg in Blood Mean (μg.L^{-1})	Hg in Hair Mean (μg.g^{-1})
Total	11.92 (0.001-176,95)	3.65(0.001-55.40)
Sex		
Woman	10.85(0.00-142.62)	3.47(0.04 - 45.08)
Man	13.62(0.00 -176.95)	3.94(0.00 - 55.40)

Age (years)		
0-11	9.2(0.00 -52.74)	2.8(0.06-17.51)
12-19	9.35(0.00-176.90)	2.75(0.05-55.40)
20-59	13.4(0.00-130.27)	4.0(0.07-42.43)
≥60	13.75 (0.00-132.57)	4.2(0.00-22.44)
Residence time		
0-9	8.75(0.00-176.96)	2.79(0.06-55.40)
10-29	4.69(0.00-145.18)	1.65(0.00-36.21)
30-59	9.20(0.72-103.34)	3.02(0.10-26.76)
≥60	7.39(0.66-44.11)	1.89(0.18-13.15)
Fish Consumption		
0-2 times/week	7.43(0.00-142.62)	2.69(0.00-45.08)
3-5 times/week	14.68(0.00-176.96)	4.77(0.00-55.40)
> 5 times/week	14.01(1.21-35.80)	4.4(0.48-9.14)

Regarding the distribution of total Hg according to sex and age group, it was observed that 296 women had an average total Hg of 10,851 (0.001-142,622) µg.L-1 in the blood. Among men (n = 188), the total mean Hg in the blood was 13.62 (0.001-176.956) µg.L-1 in the blood and 3,938 (0.001-55,400) µg.g-1 in the hair. The Mann-Whitney test, for the means in the biological matrices of both sexes, did not reveal a statistically significant difference for the results found in blood (Z = 0.36, p = 0.36) and in hair (Z = 1, 03, p = 0.15).

In addition, the highest mean of total Hg coincided in the age group of 20 to 59 years in both sexes. In particular, the level of metal in women indicates long-term exposure in the municipality of Sena Madureira, in the state of Acre, as shown in Table 3.

Table 3 – Average total Hg according to sex and age group. Sena Madureira, AC. 2016.

Age (Years)	N	Woman			Man		
		N	$\bar{X}$ Blood	$\bar{X}$ Hair	N	$\bar{X}$ Blood	$\bar{X}$ Hair
0 a 11	52	30	6.40	2.00	22	12.00	3.60
12 a 19	88	45	9.70	2.60	43	9.00	2.90
20 a 59	273	183	12.41	4.10	90	14.40	3.90
≥ 60	71	38	8.54	2.70	33	19.00	5.70
Total	484	296	10.85	3.47	188	13.62	3.94

In relation to the average levels of total Hg by gender and age groups, it is observed that the majority of participants were in the age group of 20 to 59 years, as well as the highest levels of metal in the blood and hair.

The average total Hg by age group is compared with the normal limit values in both blood and hair. Spearman's correlation for age and total mean Hg concentration: blood (r = 0.2337; t = 5.2766) and hair (r = 0.2969; t = 6.1340)

does not show a significant correlation between these variables In both biological matrices, as shown in the figures below.
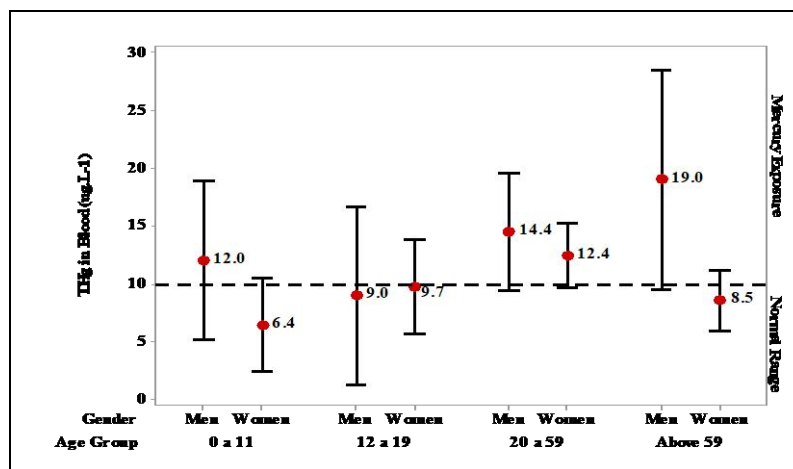

Fig.1: Average total Hg in the blood by gender and age group in years. Sena Madureira, AC. 2018.
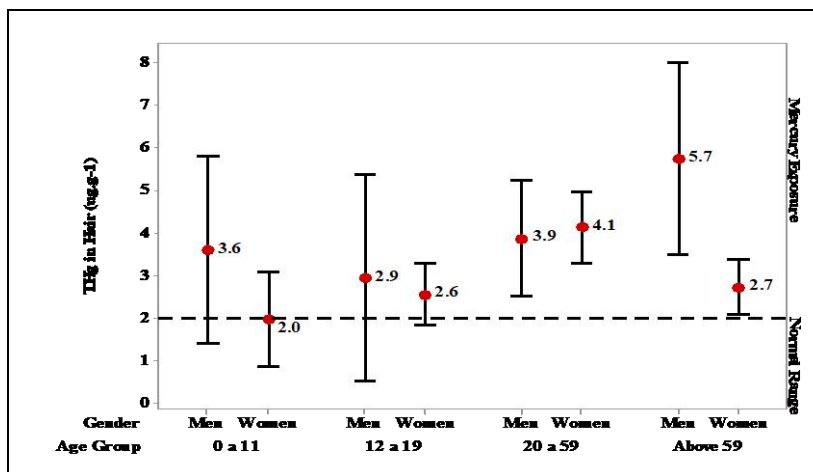

Fig.2: Average total Hg in hair by gender and age group in years. Sena Madureira, AC. 2018.

The average residence time was 22 years and 77% were informal workers. The eating habits of 84.9% of the population indicated eating up to 4 meals a day, of that total, 94% said they consume fish in their diet. Therefore, the fish-based diet represented approximately 17.5 meals / month in the region of the municipality surveyed.

Regarding the community's perception of mercury in the Amazon environment, only 24.9% of participants recognized the metal as a risk to human health in the region. The source of information most used by the population is radio and television with reports on gold mining, thus, the participants associate only gold mining with human contamination by Hg.

IV. DISCUSSION

The World Health Organization (WHO) considers the range of 5 to 10 $\mu g.L-1$ as a normal reference for total Hg in the blood, while the Biological Tolerance Limit (BTL) is 30 $\mu g.L-1$. In hair, this range is between 1 and 2 $\mu g.g-1$ and the BTL is 6 $\mu g.g-1$. Hair has been shown to be an excellent bioindicator of prolonged exposure to metal, while in the blood it indicates a recent presence[16].

From this, this research showed that the average levels of total Hg in the blood and hair of the researched population are higher than the safety limits established by the WHO, that is, this evidence indicates that the researched population is exposed to Hg environmentally in the long term. These results corroborate other studies that indicate a significant circulation of Hg in the environment and in the populations that live in the Amazon region[17].

The total blood and hair Hg levels in the study population indicate a positive correlation between these biological matrices. Hair is widely used to assess exposure to metals and bioaccumulation in the population[13]. The excellent correlation of total Hg in blood and hair is indicative of the flow and accumulation in the body of the individuals in this study. The concentrations of metals in these matrices are used as biomarkers to assess human exposure, whose origin is environmental[3].

The level of total Hg in the hair is associated with the presence of MeHg in the fish-based diet in individuals[18]. The averages of total Hg in blood and hair were increasing in relation to age group, residence time and fish consumption in the individuals investigated. Except among children with shorter residence times, probably due to the intense migration of individuals from places heavily impacted by metal in the region.

The presence of natural and anthropic factors, related to the Hg cycle in the Amazon, promotes different levels of exposure of needs to metal. The illegal activity of gold mining on an artisanal scale, contributes to the production of metallic residues in the atmosphere and in the complex hydrography of the region, conditions that raise MeHg levels in aquatic biota[19].

In this study, the total concentration of Hg in blood and hair indicates a risk of vulnerability to the child's health, due to the possibility of negative metallic interference in the child's neuropsychomotor development. Studies with children of different ages found a directly proportional relationship between the frequency of fish consumption and the Hg concentrations in the hair[20]. In the Amazon, several studies indicate health risks for children with high fish consumption and exposure to total Hg in the region[21-22].

The Hg rates in the blood and hair of the population in this study suggest an increase in the presence of the metal in both sexes, although some age groups indicate a greater accumulation among women. The metal content in the hair of women in the reproductive phase above normal limits, allows vertical transmission during pregnancy[23].

Women in the reproductive phase are concerned with the evolution of pregnancy and the possibility of having children with high levels of total Hg at birth, characterizing congenital mercurialism. In the studies by Santos et al., (2007) a highly significant correlation ($r = 0.8019$; $p = 0.000$) was found between blood levels of total Hg (11.5 μg.L-1; 0.4 to 117 , 6 μg. L-1) and blood levels of the umbilical cord (16.7 mg.L-1 0.3 - 135.0 μg.L-1) in 1,510 women and their newborns in the Tapajós River basin, in the state of Pará, a situation that suggests the passage of metal from the mother to the fetus.

In this study, the residence time at the study site and the consumption of fish seem to be decisive for the bioaccumulation and biomagnification of Hg in the region, factors that cause the accumulation of the metal, progressively over time, in the human organism. The high presence of total Hg in the blood and hair reveals the presence of a strong correlation between the biological matrices of the population and anthropic activities in the Pan-Amazon region.

In continuity, it is worth noting that the significant increase in artisanal gold mining activity in Madre de Dios, Peru, which makes up Pan Amazonia, coincides with the high presence of Hg in the fish and hair of local populations[24]. Therefore, populations living on the banks of rivers and tributaries that pass-through mining are at high risk for Hg in the region.

Although there is no mining in the state of Acre, the levels of total Hg in the individuals selected in this study are high. This contamination, therefore, is justified by the fact that the biogeochemical cycle of the metal in the region allows Hg to be transported to individuals by atmospheric air and by fish, widely found in rivers in the region[25].

In addition, a review study on Hg in populations from various states in the Amazon region indicates high levels of metal in the hair in both sexes and in various age groups, including among indigenous people[17]. Some results go beyond the limits considered safe for the health of the population, whose deficiency in the health surveillance system makes it difficult to diagnose and quantify the risk.

The impact of Hg on the health of the Amazonian population depends on the coexistence of the human organism with different exposures to metal, associated with infectious and non-infectious comorbidities, in addition to the genetic characteristics of individuals. It is necessary to structure the environmental health surveillance system for the early detection of physiological changes and the development of biochemical indicators, related to the action of metal in the body.

In the Amazon region, it is appropriate to suggest that the population groups that live in the riverside communities have similarities in relation to geographic isolation, low education, low income, precariousness of the home infrastructure and fish feeding, conditions that contribute to the persistence of Hg in the body of the individuals. This scenario contributes to the decrease in the population's quality of life, due to the involvement of

organs with silent clinical symptoms in widely impacted individuals[26].

In view of the reality observed in this research, the need for adequate studies to understand the reality of risk groups, such as pregnant women and children, to identify vertical transmission and the relationship between metal and its complications in the studied populations is highlighted.

V. CONCLUSION

The presence of total Hg in the blood and in the capillary matrix shows that the population of the municipality of Sena Madureira is environmentally exposed to metal. This exposure occurs through the existence of the biogeochemical cycle with the participation of fish consumption and the anthropic activity of artisanal gold mining in the bordering region of the state of Acre.

The high content of total Hg in the biological matrices of the studied population indicates the physiological dynamics of the metal in the organism. The distribution of mercury in both sexes and in different age groups, suggests that there is a significant risk to the health of individuals, especially women and children.

It is essential to develop a network for monitoring the environmental health of mercury among the countries that make up the Pan-Amazon. Therefore, studies aimed at recognizing the health-disease process in relation to Hg should be part of the routine of assessing the health of individuals in the region.

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