Dynamics of exposure to mercury in a population of the upper Madeira River, Rondônia – Brazil

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SUMMARY

This work evaluates the influence of cognitive and sociodemographic functions on the dynamics of human exposure to mercury in communities on the upper Madeira River in the state of Rondônia, Brazil. In this longitudinal epidemiological study of convenience sampling (2009 to 2019), semi-structured questionnaires on cognitive and sociodemographic aspects were applied to 1,089 participants (646 men and 443 women) divided into 6 groups with distinct geographic characteristics and lifestyles. Total mercury concentrations in hair samples were determined by direct analysis using atomic spectroscopy. In this population, cognitive (memory, attention span, concentration and difficulties in reading, writing and mathematical calculations) and sociodemographic (location, gender, age, education, alcohol consumption, smoking habits, time of residence in the region, occupation) grouping showed the differentiation between the groups with lifestyle directly related and dependent on extractivism/gold mining dispersed along the Madeira River (G1 and G2), and the groups that have urban dynamics on the margins of the federal highway BR-364 (G3, G4, G5 and G6). Sex, age and lifestyle (groups) were significant indicators of total mercury concentrations in hair. The organization of participants according to cognitive and sociodemographic profiles, regardless of geographic location, highlights the contribution of individualized social dynamics to mercury exposure in the Madeira River basin region. Despite socio-historical and socio-economic similarities, cognitive and sociodemographic functions show individualized social behaviors within communities, which may influence the process of exposure to THg.

Keywords: Sociodemographic profile; Cognitive functions; Amazon communities.

1 INTRODUCTION

Mercury (Hg) contamination has been a matter of deep concern in the Amazon region due to the potential health effects associated with its exposure in artisanal gold mining areas (CASTILHOS et al., 2015). In Amazonia, the elevated levels of Hg found in soils, sediments, fish and humans were initially attributed to gold mining activity, however, subsequent studies have shown that elevated concentrations of Hg in abiotic and biotic compartments are also found in non-anthropogenic source regions (FARRINA et al., 2011, ARRIFANO et al., 2018).

Mercury from natural and/or anthropogenic sources that enters aquatic ecosystems participates in biogeochemical cycles mediated by microorganisms, passing through biomagnification and bioaccumulation in the food chain (AZEVEDO-SILVA et al., 2016, BASTOS et al., 2015, SAMPAIO DA SILVA et al., 2009). The biotransformation process of inorganic Hg into methylmercury (MeHg) in aquatic environments favors human exposure through fish consumption (ARRIFANO et al., 2018).

Amazonian populations that use local fish as their main source of protein are more susceptible to Hg exposure through different trophic levels of food chains (LINO et al., 2018). Several variables interfere in the exposure of these individuals, relating to both the Hg distribution along the food chain and the pattern of fish consumption (GUIDA et al., 2018).

The lifestyle of the population living in the upper Madeira River was initially impacted by gold mining during the 1980s and 1990s, then followed by the creation of roads and deforestation for agricultural projects, and, over the last decade, by the expansion of the hydroelectric sector in the Amazon basin (FEARNSIDE, 2016). The Madeira River hydroelectric complex was implemented between 2009 and 2013, with the construction of Jirau Power Plant (120 km from Porto Velho, the capital city of the state of Rondônia) and of Santo Antônio Power Plant (in Porto Velho surroundings), with the aim of increasing the energy supply to meet Brazil's industrial growth (FEARNSIDE, 2014). Both were built using run-of-river (ROR) technology, which uses the flow of the river channel to optimize energy generation (BASTOS et al., 2020).

Economic development affects the dynamics of exposure as populations change their lifestyles and food consumption (OBRIST et al., 2018). Several studies have shown fish consumption and artisanal gold mining activities among the main contamination routes (ARRIFANO et al., 2018, BASTOS et al., 2015). As Hg exposure mainly affects the Central Nervous System (CNS) (MASLEY et al., 2012), in cognitive functions there may be loss of memory, decreased concentration and attention span (CORDEIRO et al., 2003). Professionals directly exposed to Hg may have cognitive deficits and losses in sympathetic autonomic activity (MILIONI et al., 2017). At different levels of Hg exposure, there may be a decline in psychomotor functions, and verbal comprehension is significantly different (ROHLING & DEMAKIS, 2006).

Among demographic aspects, gender is variable consistently associated with Hg exposure, with a higher prevalence in the female subpopulation (SHIM et al., 2017). Additionally, it appears that the occupation of the participants may significantly contribute to the variation of Hg concentrations (BARBIERI et al., 2009). It has been suggested that having up to 3 years of education, being female and a smoker may represent a greater probability of symptoms for Hg intoxication (DA SILVA-JUNIOR et al., 2018).

In this current study, the contribution of cognitive (memory, attention span, concentration and difficulties in reading, writing and mathematical calculations) and sociodemographic (location, sex, age, education, alcohol consumption and smoking, time of residence in the region, occupation) features were evaluated in heterogeneous population groups influenced by the expansion of the hydroelectric sector in the upper Madeira River, all in relation to the dynamics of Hg human exposure.

2 METHODS

2.1 ETHICAL CONSIDERATIONS

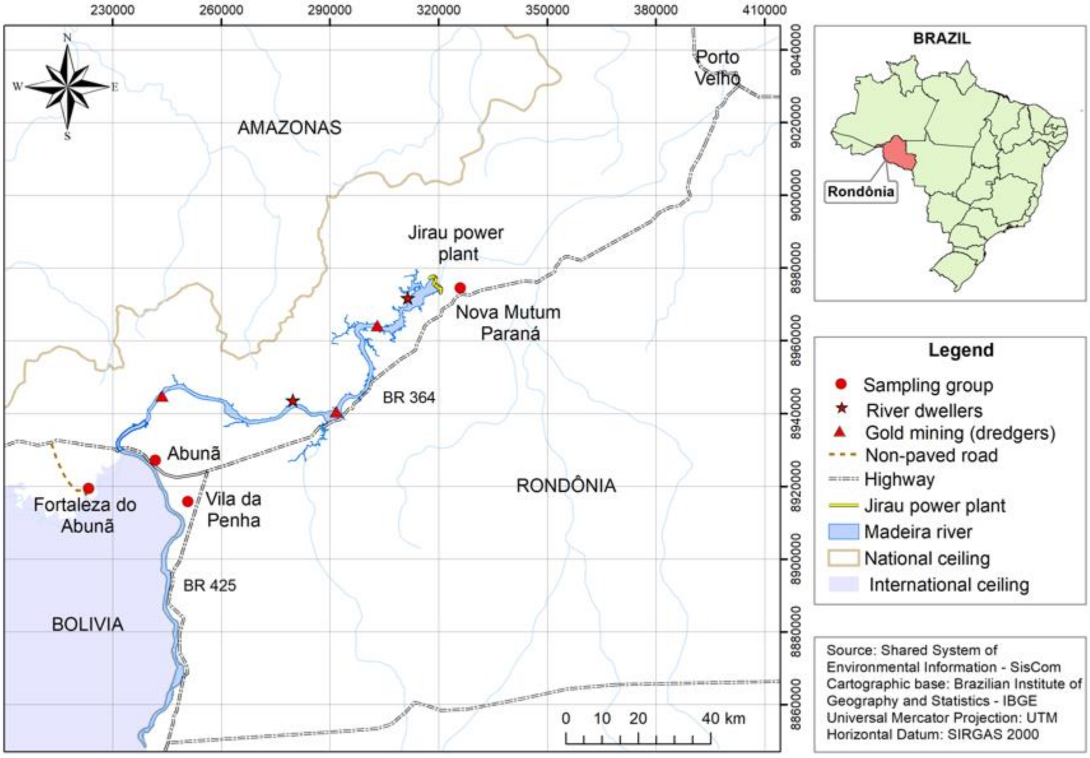
The semi-structured questionnaires and the research protocol were approved by the Ethics Committee of Medical School of the University of Brasília - UnB under opinion CEP-FM 038/2010, on August 2, 2010.

2.2 STUDY AREA AND POPULATION

This epidemiological study is part of the hydro-biogeochemical monitoring program for Hg in the area of influence of the Jirau Hydroelectric Power Plant –Jirau HPP, which integrates social, environmental and health monitoring of the population living in that area. This hydroelectric plant was built on the Madeira River from 2009 through 2013, on the axis of the Padre Island, at a distance of 120 km from the state of Rondônia capital - Porto Velho. The flooded area varies between 21 km^2 and 207.7 km^2 throughout the year, depending on the hydrological cycles in the region, , and the reservoir area is about 361.6 km^2

The study consisted of combining a series of cross-sectional samplings (biannual) from 2010 through 2019, without repetition of participants and in the upper Madeira River region. **Figure 1** shows the area of this study, upstream of the axis of Jirau power plant and illustrates the 6 groups of the study population. These groups live in different geographic locations, and when individually analyzed, their heterogeneity is evident due to the influence of Hg exposure. The G1 group (goldminers) comprises artisanal gold mining workers in small and large river dredgers dispersed along the Madeira River, all of which use metallic Hg in the gold amalgamation process, and they are housed in the dredgers for 6 days/week with a work schedule of 4:4 hours. The G2 group (riparian) refers to traditional residents on the banks of the Madeira River between Jirau power plant and the district of Abunã, with greater isolation from urban centers, with extractivism and fishing as the main food source. Only G2 had a sampling period from 2010 to 2014, due to the flood axis caused by the plant. The G3 group is constituted by residents of the Fortaleza do Abunã district (9º46’25.1"S; 65º31’01.7"W), on the banks of the Abunã river on the border with Bolivia. The region is difficult to access, and the fishing activity is the main economic source for the community. In this region, artisanal gold mining is incipient. The G4 group is comprised of participants from the district of Abunã (9º41’38.1"S; 65º21’23.9"W), located on the banks of the Madeira River and by federal highway BR-364, the only overland route to the state of Acre in the extreme northwest of Brazil. Participants from the village of Penha (9º44’06.5"S; 65º13’31.8"W), along BR-425 federal highway towards Bolivia, were included in the G4. The communities are characterized as urban, with the following main economic activities: cattle raising, subsistence extraction and trade of products and services for the artisanal gold mining dredgers on the Madeira River. The G5 group represents the participants of the district of Nova Mutum Paraná (9º15'55.7"S; 64º33'03.4"W), a planned city along the federal road BR-364, at 115 km from Porto Velho, with all urban equipment, having been built for the resettlement of the population directly affected by the construction of the power plant and its workers. The G6 group is composed of workers from Jirau power plant (9º16’16.0"S; 64º38’22.7"W), living in the district of Nova Mutum Paraná, and coming from different regions of the country with habits and customs characteristic of each region.

Figure 1- Illustration of the study area showing the sampling design groups. Note: G3 – Fortaleza do Abunã district (9º46’25.1"S; 65º31’01.7"W); G4 – Abunã district (9º44’06.5"S; 65º13’31.8"W); G5 – Nova Mutum Paraná district (9º15’55.7"S; 64º33’03.4"W) and G6 – Jirau Power Plant (9º16’16.0"S; 64º38’22.7"W).



2.3 COGNITIVE AND SOCIODEMOGRAPHIC QUESTIONNAIRES

Before the application of the questionnaires, the Informed Consent Form was presented in detail for signature by those who agreed to voluntarily participate. The semi-structured questionnaires and the research protocol as a whole were all approved by the Institutional Review Board of the University of Brasília. The population was invited to participate, from which 1,089 people agreed. The inclusion criterion was to have been living in the region for over a year. Exclusion criteria were having neurological diseases (self-reported or diagnosed by our physician during fieldwork), being part of special groups (indigenous population and people with disabilities) and minors. The semi-structured cognitive questionnaire included reference to memory, attention span, concentration and difficulties in reading, writing and performing mathematical calculations. The semi-structured sociodemographic questionnaire covered location, gender, age, education, alcohol consumption, smoking habits, time of residence in the region, occupation; the food survey investigated the consumption of animal protein (beef, chicken, fish and other). In this work, convenience sampling was applied, which has been shown to be appropriate to represent base populations in other studies and contexts in the Amazon region (PASSOS et al., 2007, PASSOS et al., 2008).

2.4 DETERMINATION OF TOTAL Hg IN HAIR

The hair samples were cut in small locks in the occipital region close to the scalp of the participants after finishing the application of the semi-structured questionnaires, and then stored in small, sealed polyethylene bags. The samples were previously washed (ultrapure water and acetone), and the total Hg (THg) was determined by using an automatic analyzer for its direct determination by thermal decomposition and amalgamation in a gold column, SMS 100 Solid Mercury Analysis Systems, Perkin Elmer, Waltham, Massachusetts, USA (DOS SANTOS et al., 2015, CERBINO, et al. 2018). Analyses of IAEA-85 certified material (Human Hair – IAEA Reference Products for Environment and Trace) showed recovery rates above 87%. The detection limit was of 0.01 ng Hg.

2.5 DATA ANALYSIS

The cognitive functions, sociodemographic features, eating habits and total hair Hg concentrations of the participants were initially analyzed using descriptive statistics. The results of THg levels were broken down by gender and the 6 groups in the study area, being expressed by the median. The questionnaire responses were transformed into a binary file (0 – No; 1 – Yes). The analysis of cognitive and sociodemographic variables showed a non-normal distribution, and non-parametric statistical tests were applied in these cases. The Bonferroni multiple comparison test was applied to the variable of THg concentrations and the cognitive and sociodemographic aspects for a paired comparison of the groups. Hierarchical cluster analysis using a fully linked Euclidean distance algorithm was applied to examine the clustering of cognitive aspects and sociodemographic profiles of the population in relation to Hair Total Hg (THHg) concentration. Graphs and statistics were generated with XLSTAT 2020 and STATISTICA 17 (trial) softwares, being considered significant when $p<0.05$.

3 RESULTS

The final sample comprises 1,089 participants sorted into 6 groups, 646 males (59%) and 443 females (41%), with an average age of 33.6 ± 12.5 years (**Table 1**). The stratification of the sample according to the level of education shows the low level of education in the communities of the upper Madeira River (G1 and G2 < < G3 < G4 < G5 << G6). The inferences of the participants regarding the deficit of memory, attention and concentration make it possible to establish the descending order in the groups of G4 > G3 and G5 > G2, G1 >> G6. As for the difficulties in reading, writing and simple mathematical calculation, it is possible to infer the descending order of G2 > G1, G3 and G4 > G5 >> G6. The regions with greater difficulty in geographical access (G1 and G2) have proportionally lower levels of education and cognitive indices directly associated. However, a greater degree of attention and memory is observed, probably due to the stimuli of socio-environmental factors (e.g., housing, infrastructure, income, education, living conditions and others).

The concentration of THHg of the study population has a median of 2.73 $\mu g\ g^{-1}$. The stratification by gender and groups (**Table 1**) shows the highest medians of THHg are in G1 (4.04 and 4.25 $\mu g\ g^{-1}$) and G2 (3.11 and 4.83 $\mu g\ g^{-1}$). The G3 group (2.76 and 3.87 $\mu g\ g^{-1}$), referring to the most isolated region with the greatest difficulty in accessing, showed a small trend towards higher medians of THHg when compared to the groups G4 (2.71 and 2.94 $\mu g\ g^{-1}$), G5 (2.10 and 2.37 µg g-1) and G6 (2.50 and 2.85 $\mu g\ g^{-1}$) along highway BR-101 (**Figure 2**).

In the female sample, the highest medians of THHg (4.15 $\mu g\ g^{-1}$) were characterized by women who work in goldmining in the region, followed by riverine women with a traditional lifestyle (3.11 μg g^{-1}). Inverse behavior was observed in the male sample, with the highest medians of THHg in the riparian group (4.83 μg g^{-1}), followed by the group referring to goldminers (4.04 μg g^{-1}). Groups G1 and G2 had higher medians of THHg and are composed of participants with lower memory, attention and concentration deficits. Therefore, in this work, cognitive aspects were analyzed with a bias associated with the influence on the population's behavioral dynamics.

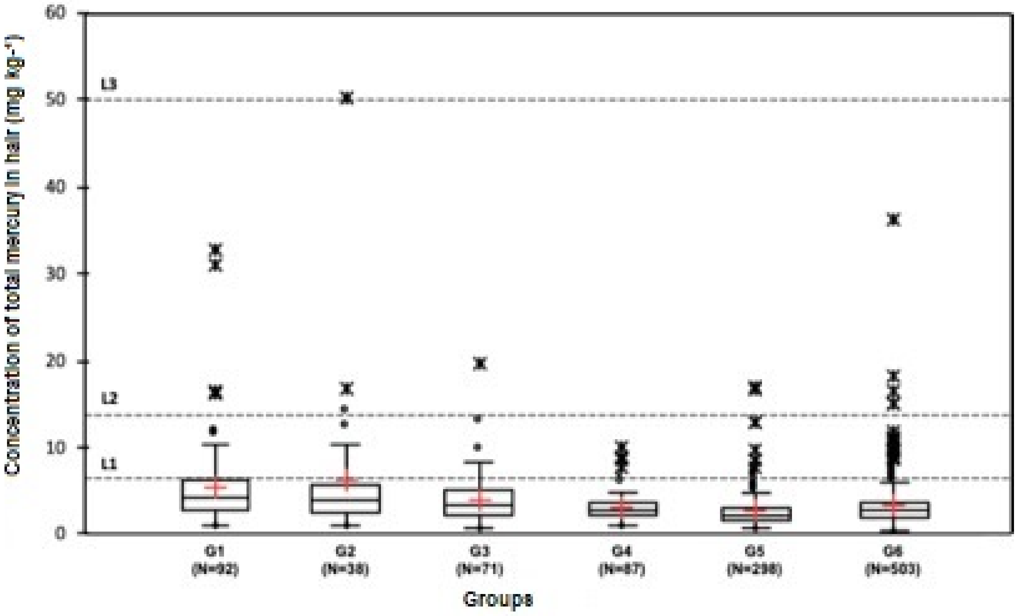
The stratification by time of residence indicates that 62.7% have been living in the region for between 1 and 5 years, 9.8% between 5 and 10 years, and 27.5% for more than 10 years in the upper Madeira River region. In the study population, 15 participants (1.4%) had THHg concentrations > 14 μg g^{-1}, 78 participants (7.2%) 14 < THHg > 6 μg g^{-1}, and 996 participants (91.4%) concentration of THHg < 6 μg g^{-1}. In terms of eating habits, the consumption of animal protein in this heterogeneous group is primarily bovine (70.4%), followed by chicken (13.6%), fish (10.0%), pork (3.2%), and other (2.8%).

Table 1 – Mean and median concentrations of THHg (μg g^{-1}) in hair samples from volunteers participating in this study, distributed by gender and location.

Group	Gender	Age (years)		THHg (μg g-1)		
		Range Age	M ± SD	Range THHg	M ± SD	Med.
Goldminers (G1)	Female (N 17)	27 a 62	43,8 ± 9,6	1,76 a 10,28	4,84 ± 2,49	4,15
	Male (N 75)	16 a 87	41,5 ± 12,4	1,06 a 32,74	5,62 ± 5,37	4,04
River dwellers (G2)	Female (N 20)	19 a 70	44,0 ± 13,4	1,21 a 12,40	4,11 ± 2,91	3,11
	Male (N 18)	18 a 75	39,5 ± 16,5	1,00 a 50,16	8,42 ± 11,31	4,83
Fortaleza do Abunã (G3)	Female (N 30)	17 a 59	37,4 ± 12,1	0,56 a 6,23	2,79 ± 1,45	2,76
	Male (N 41)	16 a 73	41,6 ± 15,5	1,15 a 19,46	4,87 ± 3,39	3,87
Abunã (G4)	Female (N 60)	17 a 60	35,9 ± 11,0	1,11 a 10,13	2,90 ± 1,30	2,71
	Male (N 27)	21 a 72	43,4 ± 13,2	1,03 a 8,97	3,69 ± 2,34	2,94
Nova Mutum Paraná (G5)	Female (N 156)	16 a 65	28,6 ± 12,1	0,59 a 12,84	2,43 ± 1,51	2,10
	Male (N 142)	16 a 75	28,5 ± 14,4	0,68 a 17,01	2,82 ± 2,33	2,37
Power plant (G6)	Female (N 160)	16 a 74	31,6 ± 9,2	0,52 a 15,05	2,81 ± 1,76	2,58
	Male (N 343)	18 a 68	33,1 ± 10,2	0,45 a 36,97	3,42 ± 2,93	2,85

Notes: N – Number of participants; M ± SD – Mean ± standard deviation; Med – Median.

Figure 2 – Box plots representing THHg concentrations in the study population. Notes: G1 – goldmining; G2 – Riparian; G3 – Fortaleza do Abunã; G4 - Abunã; G5 – Nova Mutum and G6 – Power Plant; Empirical limits: L1 - 6 mg kg-1 (associated with a 3 point decrease in IQ (KJELLSTROM et al., 1986, KJELLSTROM et al., 1989); L2 - 14 mg kg-1 (recommended by WHO/FAO, 2002); L3 - 50 mg kg-1 (associated with a 5% risk of neurological damage in adults (WHO, 1990).



The Bonferroni multiple comparison test for the variable THHg indicates that the G1 group does not only differ from G2, which is heterogeneous to groups G3, G4, G5 and G6. Group G2 is different from groups G4, G5 and G6. The G3 group diverges from G1, G5 and G6 groups, and the G4 group distances itself from G1, G2 and G5 groups. The G5 group is different from all other groups and the G6 group is different from all but G4. It is noteworthy that the G5 group is different from all other groups (**Table 2**).

Table 2 – Bonferroni test with p values of paired comparisons between groups in relation to THHg concentrations in hair samples (corrected significance level of 0.0033).

	G1	G2	G3	G4	G5	G6
G1	1	0.311	0.014	**<0,0001**	**<0,0001**	**<0,0001**
G2	0.311	1	0.342	0.021	**<0,0001**	**0.001**
G3	0.014	0.342	1	0.105	**<0,0001**	0.005
G4	**<0,0001**	0.021	0.105	1	**0.000**	0.423
G5	**<0,0001**	**<0,0001**	**<0,0001**	**0.000**	1	**<0,0001**
G6	**<0,0001**	**0.001**	0.005	0.423	**<0,0001**	1

Notes: G1 Goldminers; G2 River dwellers ; G3 Fortaleza do Abunã; G4 Abunã; G5 Nova Mutum e G6 Power plant

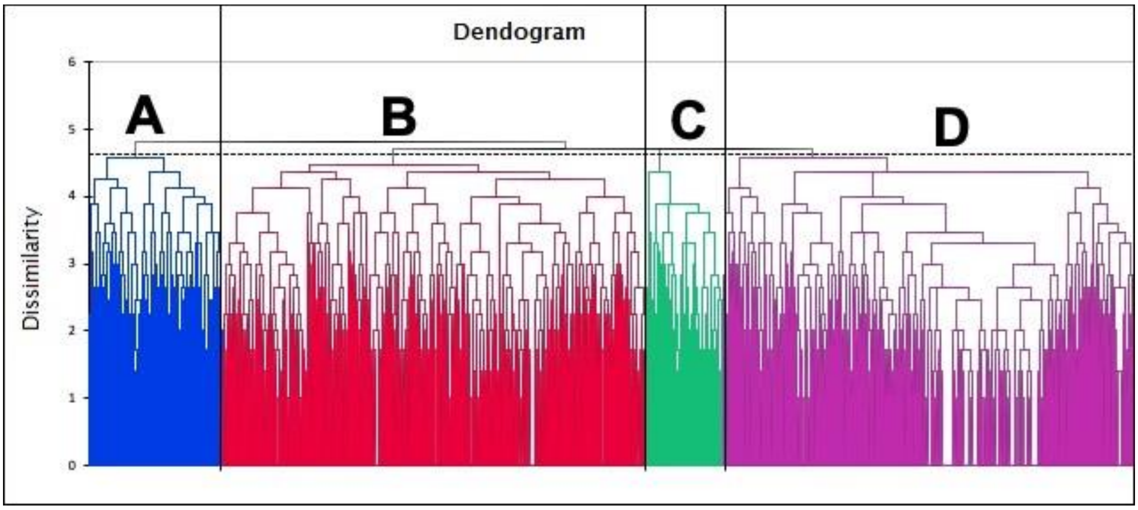
The analysis shows the complexity of the groupings of cognitive and sociodemographic features in the social dynamics of exposure, and it is possible to organize the groups into G1 > G2 >> G3 and G4 > G5 and G6. Groups G1 and G2 have, to a greater degree, a lifestyle directly related to and dependent on extractivism/goldmining on the banks of the Madeira River. G3 and G4 groups have an intermittent lifestyle between extractivism/goldmining on the banks of the Abuña and Madeira rivers and the urban dynamics of the Abunã district (360 km from Porto

Velho), while G5 and G6 groups have significant dependence on urban dynamics of the district of Nova Mutum Paraná (130 km from Porto Velho).

The grouping of the participants' Euclidean distances (n=1,089) by class of cognitive and sociodemographic features in relation to the concentration of THHg (**Figure 3**) shows the ordering in 4 groups instead of the previous 6 groups, with a cophenetic correlation of 0.491, and group A aggregates 139 participants (12.78%) with percentiles of 43.88% G5 (N=61), 28.06% G4 (N=39), 10.79% G3 (N=15) , 8.63% G2 (N=12), 5.04% G6 (N=7) and 3.6% G1 (N=5). Group B is represented by 442 participants (40.62%) with percentiles of 47.06% G5 (N=208), 31.9% G6 (N=141), 8.6% G4 (N=38),6.11% G3 (N=27), 4.53% G2 (N=20), and 1.8% G1 (N=8). Group C had 79 participants (7.27%), being 93.67% G1 (N=74) and 6.33% G2 N=5). Group D correlates 429 participants (39.33%) being 82.98% G6 (N=356), 6.76% G3 (N=29), 6.53% G5 (N=28), 2.33% G4 (N=10), 1.17% G1 (N=5) and 0.23% G2 (N=1).

The organization of participants according to cognitive and sociodemographic features shows the relevant contribution of individualized social dynamics in Hg exposure in the Madeira River region. However, there was no significant correlation with THHg, possibly due to the low Hg concentration in the population (median 2.73 µg g^{-1}). It was possible to infer that G1 participants primarily have profile C, G2 / G4 / G5 profiles A and B, G3 profiles A, B and D, and G6 profiles B and D. Because the socioeconomic dynamics of G1 are directly associated with goldmining on the Madeira River, it shows a selective social profile of Hg exposure.

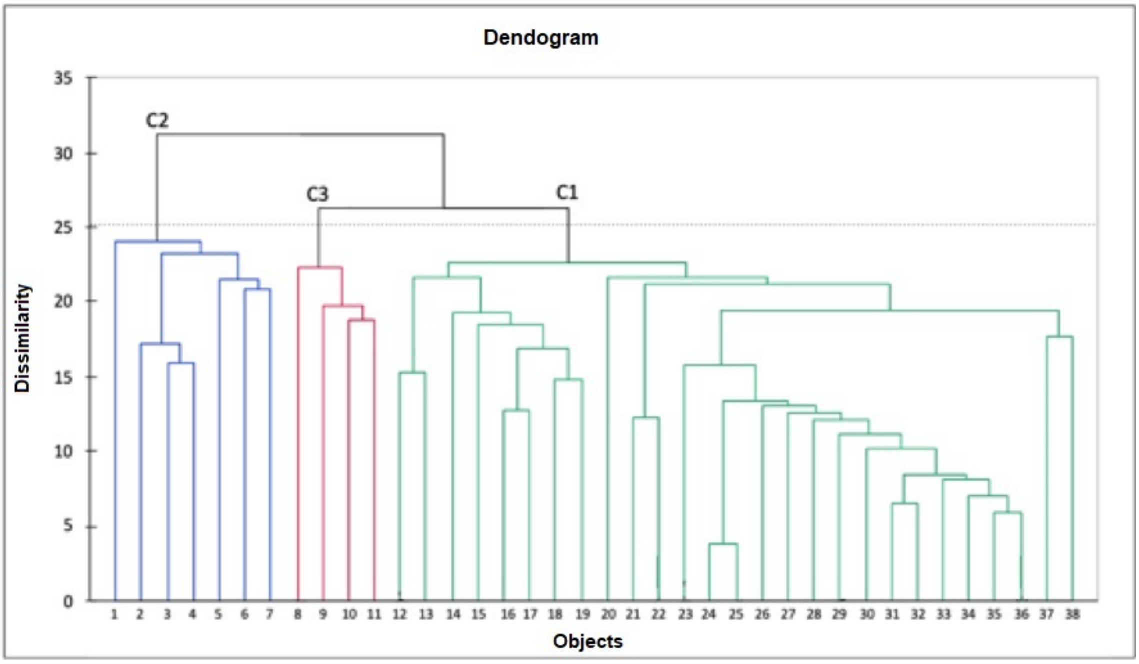
Figure 3 – Hierarchization of the cognitive and sociodemographic features of the study population in relation to the concentration of THHg.



The hierarchical cluster analysis of sociodemographic and cognitive variables that indicate greater influence on THHg concentrations in hair samples (**Figure 4**) showed3 classes with a dissimilarity measure and a cophenetic ratio of 0.907. In class C2 (7 objects) the central object is to be currently working, in class C3 (4 objects) the central object is residence over 10 years in the study region, and in class C1 (27 objects) the central object is the degree of schooling classified as illiterate, showing the effects of cognitive and sociodemographic features on the dynamics of exposure in this region of the upper Madeira River.

Figure 4 - Hierarchical cluster analysis of measured sociodemographic and cognitive variables from binary data. Note: 1 - Resident for up to 1 year in the study region; 2 - Works in goldmining; 3 - Sleeps well; 4 - Currently working;

5 – Gender; 6 - Plant; 7 - Alcohol consumption; 8 - Median THHg; 9 –malaria; 10 - Incomplete basic education; 11 - Resident for more than 10 years in the study region; 12 - Nova Mutum Paraná; 13 - Incomplete high school education; 14 - Memory deficit; 15 - Difficulties in simple mathematical calculations; 16 - Attention deficit; 17 – Loss of concentration; 18 – Reading; 19 - Writing; 20 - Completed high school education; 21 - Smoker; 22 - Non-smoker; 23 - Not currently work in goldmining; 24 - Worked in goldmining; 25 – Goldminer; 26 - Resident from 1 to 5 years old; 27 - Abunã; 28 - Incomplete higher education; 29 - Fortaleza do Abunã; 30 - Complete basic education; 31 - Riparian; 32 - Rural worker; 33 - Health professional; 34 - Not working; 35 - Illiteracy; 36 - Fisherman; 37 - Completed higher education and 39 - Resident under 1 year.



4 DISCUSSION

Sociodemographic aspects are important to identify individuals at potentially higher risk of exposure to environmental pollutants (LIU & LEWIS, 2014). Cognitive functions and sociodemographic features influence social dynamics and, consequently, Hg exposure, inferring the differentiation of groups G1 and G2 >> G3 and G4 > G5 and G6. Groups G1 (goldminers) and G2 (riparian) have, to a greater degree, a lifestyle directly related to and dependent on extractivism/goldmining on the banks of the Madeira River. Occupational exposure during the rudimentary goldmining process is associated with high exposure and high concentrations of Hg (ARRIAFNO et al., 2018, DA SILVA-JUNIOR et al., 2018, LANGELAND et al., 2017, LIMA et al. , 2009, SOARES et al., 2002). Occupational Hg exposure during the process of small-scale artisanal goldmining contributes to the increase in the median of THHg observed in group G1. The variables of whether the participant works in goldmining and or is a goldminer refer to the highest level of Hg exposure.

Stratification by gender shows the highest medians of THHg in the male sample in G2 > G1; however, for females in G1 > G2. Males generally present higher concentrations of Hg in relation to females due to the type of professional activity (MALM et al., 1995), other studies have observed high concentrations in women who live under the influence of the goldmining activity (HACON et al., 2014, PINHEIRO et al., 2008). In the G1 group, the female sample has working shifts with more days worked at the exposure site, often performing similar services to men, in addition to being responsible for feeding the working team.

In this context, sociodemographic aspects directly influence exposure, and usually men have a higher food intake when compared to women and, consequently, greater exposure through food (CASTILHOS et al., 2015). On the other hand, females that present lower education and income, smoking habits and have lived for more than 10 years in the Amazon region are more likely to present symptoms resulting from Hg exposure (DA SILVA-JUNIOR et al., 2018).

The complexity of multiple interrelationships of cognitive functions and sociodemographic features in the social dynamics of exposure puts into evidence the differentiation of groups with a lifestyle directly related to and dependent on extractivism/goldmining on the banks of the Madeira River (G1 and G2), when compared to the other groups that have a lifestyle with greater dependence on urban dynamics along the highway (G3, G4, G5 and G6), ultimately contributing to discussions on the differentiation between the Amazon of rivers and the Amazon of roads.

Populations that have access to the road have lower Hg concentrations as compared to those that only have access to canoes (CASTOLDI & COCCINI, 2003). Fish consumption habits are directly related to THHg concentrations in the population (MONRROY et al., 2008), which are influenced by sociodemographic and socioeconomic aspects (EAGLES-SMITH et al., 2018). The low fish consumption noticed in the groups contributes to the low Hg concentration values observed in this population when compared to other regions of the Amazon (LOUREIRO et al., 2002) and to the limits recommended by the World Health Organization (WHO/FAO, 2002). Indeed, based on large longitudinal and international studies, the WHO/FAO in 2003 estimated the value of 14 µg of Hg per gram of hair as a reference concentration, from which neurotoxic effects might be expected in the exposed population (GRANDJEAN et al., 2005). The United States Environmental Protection Agency (US EPA) indicates the reference dose (RfD) for methylmercury as 0.1 µg/kg/day (MARQUES et al., 2016).

Fish consumption, gender and place of residence are significant indicators of Hg concentration in the population (ASHE, 2012). In the analysis of community networks, residence time is relevant as it encompasses an extension to the social environment in which people are inserted (CHO & KANG, 2016).

Human Hg exposure can cause sensory deficits, motor dysfunction, delay in psychomotor development, genotoxicity and several other health problems that are related to the magnitude of the dose and the duration of exposure (PINHEIRO et al., 2008, OLIVERO-VERBEL et al. ., 2016). Among the neuropsychiatric symptoms associated with exposure, there is an increase in anxiety, depression, irritability and impulsivity (FIEDLER et al., 2015, HAN et al., 2011, RANER et al., 2002). Cognitive functions are generally used as indicators of effect resulting from chronic Hg exposure (WYATT et al., 2019, KHOURY et al., 2013). Memory deficit, difficulty concentrating, fatigue, weakness and mood changes are symptoms most likely related to Hg intoxication in communities on the Xingu River in the Amazon (DA SILVA-JUNIOR et al., 2018). In this study, the organization of participants regarding Hg exposure in relation to cognitive functions and sociodemographic aspects show the relevant contribution of individualized social dynamics in environmental and occupational Hg exposure in the Amazon region.

In the hierarchical cluster analysis, the variables 'currently working, 'resident over 10 years in the study region' and 'illiteracy' are the central objects related to Hg concentration (**Figure 4**). The increase in Hg in the Amazon is also related to soil covering and change in soil use (MISERENDINO et al., 2018). In this sense, the change in soil use can be indicative of the potential of the variable 'currently working', given that the participants have activities aimed at agro-extraction and farming. In the analysis of community networks, residence time encompasses an extension to the social environment in which people are inserted (CHO & KANG et al., 2016). The low levels of education and economic income make Amazonian communities more susceptible to diseases (DA SILVA-JUNIOR et al., 2018). The significant and positive relation between the number of symptoms and age, smoking and work are associated with high concentrations of Hg in the population (ELLINGSEN et al., 2001).

It is clear that studies on environmental Hg exposure tend to have a persistent cycle between Hg, fish and humans, however, there are limiting factors for understanding the effect of exposure to this global pollutant (OKPALA et al., 2018). The different exposure limits presented by national and international bodies highlight the imprecision of calculations and the uncertainties in the susceptible exposure level of the communities (GRANDJEAN et al., 2005). The population in this study lives in a region that has a low level of urbanization and infrastructure, and a considerable portion of this population presented deficits in memory, concentration and attention, and these cognitive functions might be symptoms of Hg exposure.

5 CONCLUDING REMARKS

Despite socio-historical and socioeconomic similarities, cognitive functions and sociodemographic features highlight individualized social behaviors within communities, which may influence the process of Hg exposure. Understanding the risk of environmental and occupational exposure in the Amazon region requires greater understanding of the interfaces with cognitive functions and sociodemographic features. The continuous human exposure, even in low concentration in these locations, must be evaluated in the context of community health.

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