REVIEW OF RESEARCH
ISSN: 2249-894X
IMPACT FACTOR : 5.2331(UIF)
VOLUME - 7 | ISSUE - 6 | MARCH - 2018

LEVELS OF MERCURY IN SOILS OF THE VEGETABLES PLANTATIONS COLLECTED IN ONE INDIGENOUS LAND OF THE STATE OF RONDÔNIA, WESTERN AMAZON

OLIVEIRA, D.F. de; CASTRO, B.S. de; RECKTENVALD, M.C.N do N; MENEZES, C.L.A. de; QUINTINO, S.M.;BASTOS, W.R.; OTT, A.M.T.

ABSTRACT:

Mercury has a cumulative effect on living organisms and can cause serious health problems in medium and long time to humans who ingest this toxic element through the consumption of food of animal and plant origin. This is because mercury when present in soils can reach plants through soil absorption and also fish when leached from soil to rivers. The situation is aggravated when it comes to the indigenous population that has in fish the main protein source, as well as consuming in considerable quantities several vegetables that produce in their villages. This study aimed to quantify total mercury (THg) in 216 soil samples collected during the seasons of the rainy and dry in areas of planting of three villages in the Rio Branco indigenous Land, in the western region of the state of Rondônia, in the Brazilian Amazon. The analyzes were carried in cold vapor atomic absorption spectrophotometer. All the samples presented THg concentrations below the value of prevention suggested by Brazilian legislation, although for the village Serrinha the values were approximated of the maximum value regulated as safe. Occurred dispersion greated of THg levels in the soils during the rainy season. It was verified positive influence of the rainfall contents on the THg in the soils of the plantations of Serrinha village, with the hight average value during the rainy season. The soils collected in the plantations of the village Serrinha had average levels of THg higher than those found in the soils of the villages Nazaré and Trindade, suggesting a possibility of greater exposure of the Serrinha plantactions through the consumption of the plants produced in the areas where the soils analyzed in this study were collected. The continuity of the research is suggested in the sense of dosing mercury in the vegetal foods produced in these villages, because they are foods very present in the diet of these indigenous and may have their concentrations increased in function of the content of this element in the soils of these villages.

KEYWORDS: *Indigenous; Contamination, Soil, Agricultural crops, Toxic metal.*

1.INTRODUTION

The process of development of the Brazilian Amazon brought to this region of the country socio-spatial and economic growth. Among the activities that promoted the development of the Amazon, we highlight the production of beef cattle, mining, hydroelectric complexes and recently the production of large-scale soybean (DOMINGUES; BERMANN, 2012). These activities have a significant contribution to the process economic of Amazonian development, however, according to the literature with perceptible environmental, mainly for the contamination of the soils, rivers and fish of that region of the country by mercury (MCKEYA et al., 2010; KIM et al., 2012; BASTOS et al., 2016).

The literature show several studies that have prove the presence of mercury in the Amazon region at levels above those recommended by the pertinent legislation, mainly in areas under the influence of gold mining (MIRANDA, 2010; BASTOS et al., 2015). In Rondônia, particularly, there are few studies that have the objective of evaluating mercury in areas with history of gold mining.

According to Kehrig et al. (2009) besides the anthropogenic origins, the heavy metals also have lithogenic origin, related to geological sources, such as rock residues and the process of weathering and soil erosion, indicating that this natural content may be related to the source material. Of the heavy metals, mercury is reported to be the most representative of the toxicity presented. It is commonly found in several natural compartments, such as: in the earth's crust, in water, in biota aquatic and terrestrial, in the atmosphere (LACERDA et al., 2007). This metal is capable of forming stable chemical species in water and may reach relatively high and toxic concentrations (MAGARELLI; FOSTIER, 2005a).

Rodella e Alcarde (2001) added that contamination of soil, atmosphere, water groundwate and surface, as well as food by mercury, has negative effects on the health of terrestrial organisms and aquáticos in addition to human intoxication from the consumption of water and contaminated food. Because it is a neurotoxic element, mercury acts in the central nervous system causing intoxication by direct contact or by eating contaminated food can trigger in the medium and long time several diseases among which cancer (IARC, 2002, SILVA, 2009).

The health problems caused by the contact or ingestion of high levels of mercury are greater for the indigenous population living in villages near the Rivers, therefore are more exposed to methylmercury and mercury through diet. Because these indigenous have the fish as the main of protein source (SANTOS et al., 2003; BASTOS et al., 2007), besides consuming water directly from the river, in some situations. The contamination of the fish by mercury has been reported because this element is drained to the rivers through the leaching caused by the rains and bioaccumulating in the aquatic biota.

The indigenous peoples still have the habit of feeding on vegetables they produce in their villages, among which cassava (*M. esculenta*), cará (*D. trifida*), yam (*D. cayennensis*), corn (*Z. mays*) e banana (*M. paradisiaca*). The problem is that if the soils of these plantations they are contaminated with mercury, this element can be absorbed by plants and concentrated in vegetables, especially those classified as roots, as is the case of cassava and yam, considerably present in the daily diet of this population group.

In this sense, it is extremely important to know the content of mercury in soils used for the production of vegetable foods produced and consumed, often in large quantities by indigenous.

For these reasons, the objective of this study was to evaluate the levels of total mercury (THg) in samples of soils of different plantings collected during periods of dry and rainy in different indigenous Tupari villages in the Rio Branco Indigenous Territory, located in the western region of the state of Rondônia, Brazil, Amazon.

2 .MATERIALS AND METHODS

2.1.Licenses for Study

Due this study involves indigenous population and collets in Federal Conservation Unit, the execution of the research was conditioned the permission of the Chico Mendes Institute for Biodiversity Conservation (ICMBio), of the National Indian Foundation (FUNAI), and also from the Ethics Research Committee (REC) of the Federal University of Rondônia Foundation (UNIR).

The authorization by ICMBio is registered under the final number 47500-3. The research was deferred by Funai under number 58/AAEP/PRES/2016. The project was registered in the REC of the Federal University of Rondônia Foundation with the CAAE number 42357615.7.0000.5300 and approved under the number 1.294.398.

2.2.Study Area

The study villages are located in the Rio Branco Indigenous Land, which involves the municipalities of Alta Floresta d'Oeste and São Miguel do Guaporé, near Nova Brasilândia d'Oeste, Alto Alegre do Parecis, São Francisco do Guaporé and Costa Marques, in the western region of the state of Rondônia. The villages of Serrinha, Trindade and Nazaré were chosen because they have the largest number of Tupari individuals (116 indigenous) and also a larger geographical area in relation to the other villages of the Rio Branco Indigenous Land.

2.3.Sample Collections

Two collect were carried out in the Trindade and Nazaré Serrinha villages, considering the periods of dry and rain in the year 2017. For each collec period (dry and rainy season) soil samples were collected from rows of six vegetales foods. Three soil samples were collected in each village (one in each crop area), totaling 108 samples per collec period, therefore in all 216 samples of the soils. For the choice of the 3 areas of cultivation in each village from which the soils would be collected was taken into account their locations in the village, deciding for two crop areas l located at the extremities of the villages (beginning and end of the village) and another in the central. Approximately 1000 grams of soils were collected from the central region for each planting at an average depth of 30 cm from the surface. The samples were packed in plastics and transported in iceboxes to the Wolfgang C. Pfeiffer Environmental Biogeochemistry Laboratory, at the Federal University of Rondônia, in Porto Velho, where they were refrigerated without access to light and then analyzed.

2.4.Analysis of THg

2.4.1 Preparation and chemical digestion of samples

The soil samples were homogenized with ultrapure water (Milli-Q, Millipore), and then sieved in stainless steel and Pronustet mesh sizes of <200 mesh (<74 µm). In the sequence the fine fraction of the soil was dried in an oven at 40 ºC for 72 hours. For the chemical extraction of the samples weighed approximately 0.5 grams of dry weight of soil in glass test tubes, in duplicate. In the sequence 1.0 mL of ultrapure water and 5.0 mL ofregal water (HCl and HNO_3 - 3:1) were added. Na sequência the samples were agitated, which proceeded to the digester block at 70 ° C for 30 minutes. After cooling the samples to room temperature 6.0 mL of 5% (w/v) $KMnO_4$ was added, e and the samples were returned to the digester block for another 30 minutes at 70 ° C. The samples were removed from the digester block and after cooling covered with PVC film to avoid contamination, where they remained in 12 hours at rest (BASTOS et al., 1998). On the other day 5 drops of hydroxylamine hydrochloride 12% (m / v) were added by filtration of the samples by gravity in cellulose paper filters (3.0 µm e 9.0 cm de diâmetro - Whatman). From the filtered material was packed 12.0 mL in falcon type tubes.

2.4.2.Determination of THg in soils

For the analytical quality control, all the materials used in the quantification of THg have previously undergone a process of cleaning and decontamination. The materials were: (i) rinsed in running water and neutral detergent, (ii) rinsed with distilled water, (iii) sterilized in 5% nitric acid solution (HNO_3) for 24 hours, (iv) rinsed again with distilled water and stove at 40 ° C for 24 hours. The solutions used in the analysis procedures were all prepared with Ultra Pure water produced in Milli-Q Plus Ultra-pure Water System and Direct-Q V (Millipore) with conductivity of 18 m Ω / cm^2. Samples for the quantification of THg were carried out in duplicates in the Atomic Absorption Spectrophotometer by Cold Steam Generation (FIMS-400, Perkin Elmer). To obtain reliability in the analytical technique two white controls were used for each reading, following all steps of the analytical procedures without the analyte. Reference values of SCP SCIENCE EnviroMAT SS-2 Soil Standard certified sample. Samples were quantified in duplicate (BONOTTO; SILVEIRA, 2003).

2.5.Statistical analyzes

The statistical tests were carried out by the software R (R CORE TEAM, 2013), of the European Environment Agency*,* licensed by the *General Public License* (GNU) and downloaded from site www.r-project.org, as well as the packages used for the tests: readxl, ggplot2, Rmisc, tidyr, FSA, PMCMR, Hmisc, boot, gridExtra e RColorBrewer. A percentage of 5% probability of error was considered for the tests. For the comparisons between the soils of the vegetables plantations collected in the three villages, the confidence intervals of the means (CI) were calculated by the non-parametric Bootstrap method via CBa (Correction of Accelerated Addiction), guaranteeing more reliable results, for not requiring any assumption and also due to the low N sample. The Wilcoxon-Mann-Whithey U test was used for the comparison between two groups (dry and rainy seasons), mainly because in this case the samples are more than 10. Both tests used are applied when there is no distribution normal in the data, therefore, are nonparametric tests.

3. RESULTS AND DISCUSSION

3.1. Analytical validation

The Limit of detection of the analytical technique (LDT) was calculated by means of the average of the standard deviation of the control whites, multiplied by three. The limit of detection of the calculated technique was 0.0146 mg.THg.Kg^{-1}. The experimental results for the certified reference samples are shown in Table 1.

Table 1 - Reference value and value found for certified sample, and percentages of THg recovery

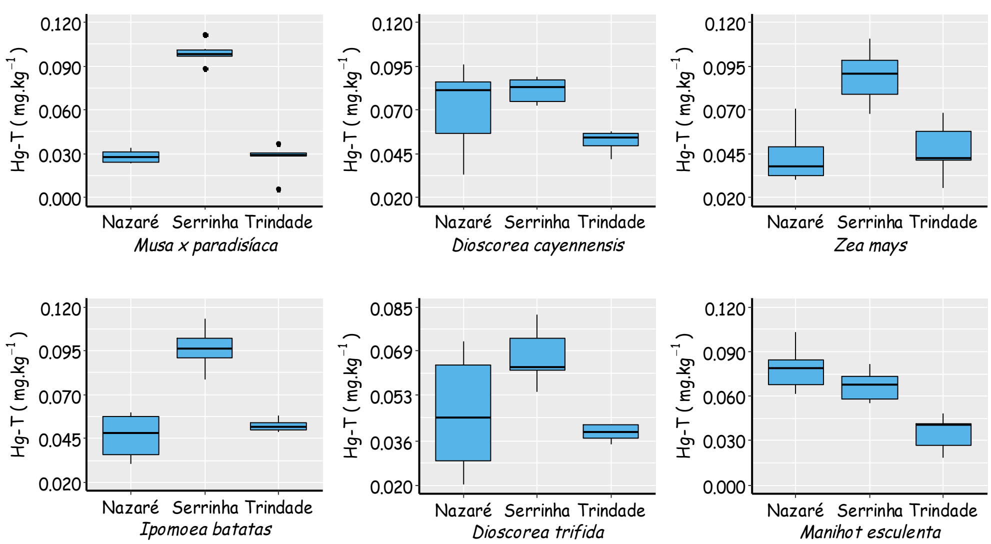
Sample	Certified sample	Heavy metal	Reference value	Value found (mg.kg^{-1})	Recovery
Soils	SS2	THg	0.28	0.27	97 %

As shown in Table 1, the experimental results for the certified reference samples used for the THg determinations showed good agreement with the certified values, as well as satisfactory recovery percentages, indicating the high reproducibility of the analytical method.

3.2 THg levels in solos

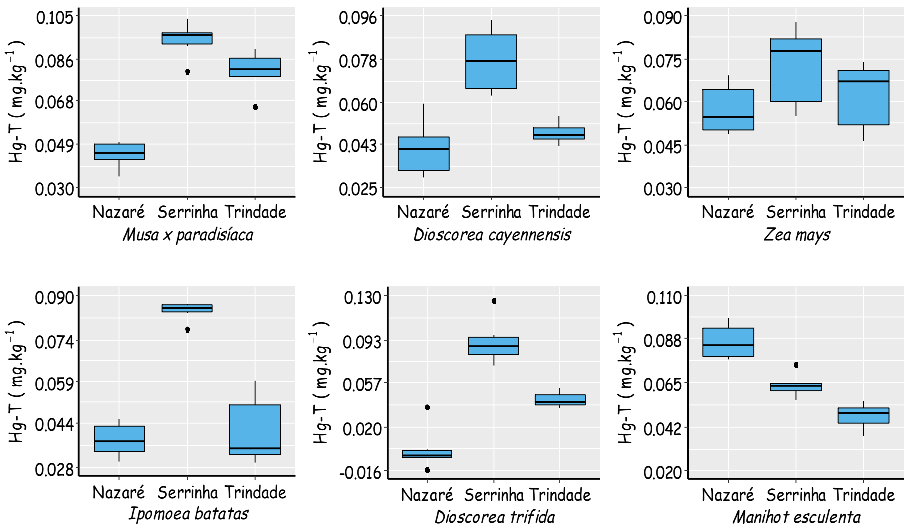
Figures 1 and 2 show the distribution of THg contents in soils, by planting type collected in the villages of Nazaré, Serrinha and Trindade during the dry season and rainy season, respectively.

Figure 1 - Distribution of THg levels in the soils of the plantings collected in the villages of Nazaré, Serrinha and Trindade in the dry



During the dry period there was a greater variability of THg contents for the soil of Nazaré village, demonstrated mainly by the dispersion of the values found for the plantations of *D. trifida* and *D. cayennensis*, while the lower variability was verified for the soils of Trindade village.

Figure 2- Distribution of THg concentrations in the soils of the plant crops collected in the Nazaré, Serrinha and Trindade during the rainy season



Differently from the dry season, during the rainy season, a lower variability of the THg contents for the village of Nazaré was observed, while a similar dispersion was observed between the values obtained for Trindade and Serrinha.

In general, there was greater variability of THg concentrations in the soils of the different plantings collected in the rainy season. This may have to do with the leaching of mercury present in soils and/or with small erosions in the plantation areas provoked by the great volume of rains in the state of Rondônia in the summer.

Table 2 present the statistical treatment of the mean THg levels in the soils of the different plantings collected in the Nazaré, Serrinha and Trindade villages in the dry and rainy seasons, respectively.

Table 2 - Descriptive and discriminative statistics for the concentrations of THg ($mg.kg^{-1}$) in the soils collected in the villages of Nazaré, Serrinha and Trindade during the dry season, by type of plantation

DRY SEASON						
Soil plantaction	Village	N	*Medium± SD	CI		Tests of averages
				Bottom	Higher	
M. paradisíaca (Banana terra)	Nazaré	3	0.028±0.004	0.025	0.031	B
	Serrinha	3	0.100±0.007	0.094	0.105	A
	Trindade	3	0.027±0.010	0.014	0.032	B
D. cayennensis (Inhame)	Nazaré	3	0.071±0.024	0.049	0.086	AB
	Serrinha	3	0.081±0.007	0.075	0.086	A
	Trindade	3	0.052±0.006	0.046	0.056	B
Z. mays (Milho)	Nazaré	3	0.043±0.016	0.034	0.058	B
	Serrinha	3	0.089±0.016	0.078	0.100	A
	Trindade	3	0.047±0.016	0.036	0.059	B
I. batatas (Batata doce)	Nazaré	3	0.046±0.013	0.036	0.055	B
	Serrinha	3	0.096±0.012	0.087	0.105	A
	Trindade	3	0.052±0.004	0.050	0.055	B
D. trifida (Cará roxo)	Nazaré	3	0.046±0.022	0.030	0.061	AB
	Serrinha	3	0.067±0.010	0.060	0.075	A

	Trindade	3	0.039±0.003	0.037	0.041	B
M. esculenta (Mandioca)	Nazaré	3	0.079±0.015	0.069	0.091	A
	Serrinha	3	0.067±0.010	0.060	0.075	A
	Trindade	3	0.035±0.012	0.025	0.043	B

* Average concentration of THg expressed in $mg.Kg^{-1}$. N: Sample number. SD: Standard deviation of the sample. CI: Confidence interval of the mean. Equal letters in the same column for soils of the same plant crop do not differ from each other ($p > 0.05$) in relation to the villages in the dry season.

In the dry season the village Serrinha presented in isolation the highest concentrations of THg for the soils of three of the six plantations studied, while the soils of the Trindade and Nazaré villages were statistically the same as the second largest concentration for the soils of five plant crops, differing only in the case of *M. esculenta* when Nazaré was responsible for the highest average percentage of THg between the two, not differing from Serrinha.

Table 3 present the statistical treatment of the mean THg levels in the soils of the different plantings collected in the Nazaré, Serrinha and Trindade villages in the dry and rainy seasons, respectively.

Table 3 - Descriptive and discriminative statistics for the concentrations of THg ($mg.kg^{-1}$) in the soils collected in the Nazaré, Serrinha and Trindade villages during the rainy season, by type of plantation

RAINY SEASON						
Soil plantaction	Village	N	*Medium±SD	IC		Tests of averages
				Inferior	Superior	
M. paradisíaca (Banana terra)	Nazaré	3	0.044±0.006	0.040	0.048	C
	Serrinha	3	0.094±0.007	0.087	0.099	A
	Trindade	3	0.081±0.009	0.072	0.086	B
D. cayennensis (Inhame)	Nazaré	3	0.041±0.011	0.034	0.051	B
	Serrinha	3	0.078±0.013	0.068	0.087	A
	Trindade	3	0.048±0.004	0.045	0.051	B
Z. mays (Milho)	Nazaré	3	0.057±0.009	0.051	0.064	A
	Serrinha	3	0.073±0.014	0.061	0.082	A
	Trindade	3	0.062±0.012	0.051	0.070	A
I. batatas (Batata doce)	Nazaré	3	0.038±0.006	0.033	0.042	B
	Serrinha	3	0.084±0.003	0.080	0.086	A
	Trindade	3	0.041±0.013	0.033	0.052	B
D. trifida (Cará roxo)	Nazaré	3	**0.002**±0.018	-0.007	0.022	**---**
	Serrinha	3	0.091±0.019	0.081	0.109	A
	Trindade	3	0.043±0.006	0.039	0.048	B
M. esculenta (Mandioca)	Nazaré	3	0.086±0.009	0.080	0.093	A
	Serrinha	3	0.063±0.006	0.060	0.069	B
	Trindade	3	0.048±0.006	0.042	0.052	C

* Average concentration of THg expressed in mg.Kg-1. N: Sample number. SD: Standard deviation of the sample. CI: Mean confidence interval. Bold number: Single mean <LDT. --- Sample discarded for the test of averages due to present average content of THg below the detection limit of the technique (<LDT). Equal letters in the same column for soils of the same plant crop do not differ from each other ($p > 0.05$) in relation to villages in the rainy season.

The comparison considering the rainy season highlights again the village Serrinha for having presented the highest levels of THg observed for soils of four plantations (*M. paradisiaca, D. cayennensis, I. batatas and D. trifida*), without having deferred of the other villages with respect to the soil of the plantation of *Z. mays*. Of the six values (replicates) of THg found for the *D. trifida* soil of Nazaré village in the rainy season, only one was above (0.037 mg.Kg^{-1}) of the LDT, visualized as outlier in Figure 2, implying concentration (0.002 mg.Kg^{-1}) lower than the LDT (0.0025 mg.Kg-^{1}), which is why this sample was discarded for the means test.

The lower and higher confidence intervals (CI) for THg contents in soils collected during dry and rainy periods in the village of Trindade were not found, thus suggesting a difference between the two rainy seasons. The opposite was visualized for the other villages, insinuating equality between them during the two collection periods, which could only be proved by the means test, which is presented in Table 4.

Table 4 - Descriptive and discriminative statistics for THg concentrations (mg.kg^{-1}) in soils collected in Nazaré, Serrinha and Trindade villages during periods of dry and rainy

Village	Season	N	*Medium±sd	Test of Averages
Trindade	Rainy	18	0,053±0,027	Ab
	Dry	18	0,042±0,024	Bb
Serrinha	Rainy	18	0,081±0,015	Aa
	Dry	18	0,083±0,016	Aa
Nazaré	Rainy	15	0,045±0,027	Ac
	Dry	18	0,052±0,023	Ab

*Average concentration of THg expressed mg.Kg-1. SD: Standard deviation of the sample. Equal capital letters in the same column for the soils of the same village do not differ from each other (p> 0.05) in relation to rainy and dry periods. Equal lowercase letters for the same rainfall period do not differ from each other (p> 0.05) in relation to the villages.

The average THg content obtained for Nazaré village soils in the rainy season was calculated from a sample N of 15, since the soils of *D. trifida* (N = 3) had a mean content <LDT in this period and therefore were disregarded. Only the soils collected in the Trindade village showed different mean concentrations between the seasons and dry and rainy, with the highest value for the samples collected in the rainy season, and the results of the U-Wilcoxon test (paired comparison) confirmed the assumptions raised through the CI calculated by Bootstrap.

The fact that soil samples collected in the plantations of Trindade village presented higher average value of THg in the rainy season compared to the dry season may have to do with the leaching caused in the soil by the rains in this collect period, washing the chemical components of surrounding soils, including mercury to the collection area. The statistical comparison between the villages for each rainy period showed that the soils of Serrinha presented the highest average concentrations of THg in comparison to the other villages, both in the rainy season and in the dry season.

The soils of each type of vegetable show more expressive THg results for *D. caynnensis* and *I. potatoes* in the dry season while in the rainy season for *M. esculenta* and *M. paradisiaca*. A particular analysis of the soils of the different plantations and collected in the three villages revealed Serrinha>Trindade>Nazaré regarding the concentrations of THg in the soils of their fields at both collection stations.

Wong et al. (2003) verified a higher atmospheric deposition of heavy metals (Hg, Cu, Cr and Zn) in summer than in winter. The authors justified this result because of the soil washing effect during the summer, a season characterized by high rainfall in that subtropical region of China, as in the Brazilian Amazon, where the collection area for this research is located, no influence of the level of rainfall precipitation on the soils of the plantations collected in two of the three studied villages was observed.

The Resolution of the National Environmental Council n. 420 (CONAMA, 2009) establishes as value of prevention in soils 0.5 mg Hg.kg^{-1}. All the soil samples analyzed in this study presented values considerably lower than the maximum limit considered reliable by CONAMA. Among the villages, the soils collected in Serrinha presented the average values (rainy and dry periods) closer to the maximum limit recommended by the mentioned legislation.

Magarelli and Fostier (2005b) found values of Hg fluxes at the soil / atmosphere interface of deforested areas of the Rio Negro Basin well above that of forest areas (mean of 12.3 ± 9.9 $pmol.m^{-2}.h^{-1}$).The authors conclude that the absence of vegetation increases Hg emission fluxes, both in land areas and in flood areas. Therefore, the assumption of mercury leaching from the nearby soils to the collecting areas in the Trindade village during the rains was raised, since of the three plantations from which the soil samples were collected, two are upstream with other areas already deforested by and will be used for new plantations.

The average THg results obtained in this research for the soils collected in the village Serrinha during rainy and dry seasons are much lower than those found by Qiu et al. (2005) in soils as well as in this non-mining study in Wanshan District, China (0.10 to 1.2 $mg.kg^{-1}$ of THg), while behaving near the average value found (0.081 $mg.kg^{-1}$) by Soares et al. (2015) when they measured THg in soil samples collected in areas of natural forest not impacted by agricultural and industrial activities in the states of Minas Gerais and Rio de Janeiro.

On the other hand, the soils of the villages Trindade and Nazaré presented lower values than those verified by the mentioned authors, and in some cases near the intermediate values identified by Carvalho (2016), that found a concentration between 0.003 and 0,355 $mg.THg.kg^{-1}$ in soils near the Santo Antônio hydroelectric reservoir, located in the Madeira River basin, Rondônia, Brazil. Although the low levels of THg in the soils of the plantations collected in the different villages, it is known that the Amazon soils are an important reservoir of this heavy metal due to its long history of bioaccumulation (MAINVILLE et al. 2006; ROULET; LUCOTTE, 1995).

When studying the emission of mercury gaseous after deforestation followed by fires in different areas of New York (USA) and Acre (Brazil), Carpi et al. (2014) observed that deforested soil released 0.41 g / ha-1 / year-1 in the American experiment and 2.3 g / ha-1 / year -1 of gaseous mercury to the atmosphere in the brazilian experiment. The authors suggested that deforestation in the Brazilian Amazon has induced changes in soil mineral composition and led to the contamination of biotic and non-biotic compartments by mercury.

Comte et al. (2013) added that such changes induced by deforestation lead to a drastic loss of soil fertility and soil compaction triggering soil erosion. This situation, according to Berzas et al. (2010) is aggravated by the large volumes of rainfall in this region of the country in a short period of time, This situation, according to Berzas et al. (2010) is aggravated by the large amounts of rainfall in this region of the country in a short period of time, causing the leaching of natural mercury in Amazonian soils or due to anthropogenic activities for the region rivers (ROULET et al., 1998).

With the objective of evaluating the impacts of deforestation on fertility and Hg levels in soils from deforested areas (pastures) and with primary vegetation from the Ecuadorian Amazon to the surroundings of the Napo River, Mainville et al. (2006) observed a significant decrease in organic matter (15 to 70%) and a reduction of up to 60% in Hg concentrations in the surface soils (0-5cm) covered with pastures compared to forest soils (primary vegetation).

Mainville et al. (2006) also identified that the longer the area was deforested, the lower the organic matter and Hg concentrations in the pasture soils. With these findings the researchers concluded that soil erosion, increased by deforestation and associated with leaching over time, acts as a source of Hg for aquatic ecosystems, and may lead to the contamination of the fish of the Napo River basin by methylmercury, which has a neurotoxic activity in humans.

Valle et al. (2006) corroborated with Mainville et al. (2006) when they proposed that organic matter is an important factor for transporting elemental mercury from mountain and wetland soils to river water and also for its retention in soils. The findings of Mainville et al. (2006) are related to those found in this study since the areas of plantations of the village Serrinha are younger (between 8 months and 3 years) in relation to Trindade (between 1.2 months and 4 years) and Nazaré (2 to 5 years). This is because, it is inferred that due to the latest deforestation for the preparation of the areas of plantations of the village Serrinha, the soils of the plantations suffered less erosion and leaching in relation to the soils of the other villages and for that reason may have presented higher average concentrations of THg for the soils of some vegetal crops in comparison with the soils of Trindade and Nazaré.

In addition to the previous explanation, it is assumed that because the areas of planting of the village Serrinha are more new, more THg has in the soil, therefore, they suffered less amount of fires between one harvest and other, which according to the indigenous informed is a necessary procedure for the preparation of the area before re-planting, which eliminates weeds, since they do not make use of agrochemicals in their plantations.

This assumption was raised by what was reported by Mailman and Bodaly (2005) when they found a 79 % reduction in THg of soils after successive burnings. Other researchers (RAISON et al., 1985; PACYNA; MUNCH, 1991) have already shown that elemental Hg (Hg^0) is highly volatile at temperatures between 100 and 200 ^oC and therefore also defended the potential of fires to reduce levels of THg in soils.

On the other hand, it is worth mentioning that metallic or elemental mercury when subjected to high temperatures can remain in the atmosphere for months or even years and return to the soil thus revealing itself very important in the mercury's geochemical cycle, since it can suffer oxidation and form the other states: mercury and mercury, which, combined with elements such as chlorine, sulfur or oxygen, form mercury salts (mercurous and mercuric salts), which, when covalently bonding to at least one carbon atom, give rise to to organic mercury compounds (methylmercury, ethylmercury, phenylmercury), the most toxic forms of this element (VEIGA et al., 1994).

In order to elucidate the importance of the pulse of flooding in the deposition, remobilization and distribution of mercury and organic matter in soils and sediments in the Madeira River basin (Brazilian Amazon), this region is influenced by gold mining, Almeida et al. (2014) found values of THg in the order of 0.053 and 0.067 $mg.kg^{-1}$ in the region of Puruzinho Lake, Humaitá, Amazonas. These results are therefore close to those observed for the soils of the Nazaré and Trindade villages in both seasonal periods, but lower than those found in the soils of Serrinha, which was unexpected since the areas of this study have no previous history of use for mineral extraction.

The Hg in the soils of these villages may be of natural soil origin or due to a region with marked agricultural exploration in recent years, and therefore, that comes from residues of agrochemicals and / or pesticides carried to that region by means of leaching or precipitation gas and rainy.The hypothesis on gas transfer is also raised based on what Yang et al. (2016) and Cooke et al. (2009), when they reported that this global pollutant can be transported for a long time and for long distances in its gaseous elemental form (Hg^0), which in turn may have been carried, oxidized and deposited in the study region. It should be noted that the study area is located at a distance of approximately 415 kilometers in a straight line from the region of the Madeira River, in Porto Velho, known for high gold mining activity and with several records of high levels of mercury (ALMEIDA et al., 2014; MIRANDA, 2010).

According to Kirk et al. (2012) and Rydberg et al. (2010), a large portion of soil THg is associated with the mineral constitution and organic matter due to its high binding affinity, implying that this factor may be responsible for the Hg levels found in the soils of the studied villages, mainly from Serrinha, which suffered less leaching in its soils since they were prepared more recently for the vegetables plantations.

4.CONCLUSIONS

There was no influence of rainfall seasonality on average levels of total mercury in the soils of the Nazaré and Serrinha villages, while the soils collected in the Trindade village during the rainy season had a mean concentration of this heavy metal significantly higher than the average values found for soils of the same village collected during the dry season.

All the soil samples analyzed in this study showed concentrations of THg consistent with that determined by Brazilian legislation, although the Serrinha village presented average levels close to what is considered a value of prevention by Conama. This result contributed to the fact that the soils collected in the plantations of the village Serrinha presented a higher average level of THg in both the dry and rainy seasons compared to the other villages, which can be explained because the plantations of this village are younger compared to the roças of the other villages, and for that reason they did not undergo sufficient leaching for the mercury flow present in the soil to other areas downstream or to the river.

Although the soils collected in the plantations of the three villages showed average concentrations of THg lower than the limit of prevention established by Brazilian regulations, this element can be absorbed by the roots of the plants and contaminate the plant foods, as well as by leaching process can be drained to the rivers and bioaccumulate in the fish, which as well as for some vegetables are present in the diet of the Tupari

Indians routinely and in considerable amounts and can therefore affect the health of this population in the medium and long time.

REFERENCES

ALMEIDA, R. de; BERNARDI, J.V.E.; OLIVEIRA, R.C.; CARVALHO, D. P. de; MANZATTO, A.G.; LACERDA, L.D. de.; BASTOS, W.R. Flood pulse and spatial dynamics of mercury in sediments in Puruzinho lake, Brazilian Amazon.**Acta Amazonica**, v.44, n.1, p.99-106, 2014.

BASTOS, W.R.; ALMEIDA, R.; DÓREA, J.G.; BARBOSA, A.C. Annual flooding and fish-mercury bioaccumulation in the environmentally impacted rio Madeira (Amazon). **Ecotoxicology**, v. 16, n. 3, p. 341-346, 2007.

BASTOS, W.R.; DÓREA, J.G.; BERNARDI, J.V.E.; LAUTHARTTE, L.C.; MUSSY, M.H.; LACERDA, L.D.; MALM, O. Mercúrio em peixes do rio Madeira (avaliação temporal e espacial), Amazônia brasileira. **Pesquisa Ambiental**, v. 140, p.191-197, 2015.

BASTOS, W.R.; DÓREA,J.G.; BERNARDI, J.V.E.; MANZATTO,A.G.; MUSSY, M.H.; LAUTHARTTE, L.C.; LACERDA, L.D.;MALM, O. Sex-related Mercury bioaccumulation in fish from the Madeira River, Amazon. **Environmental Research**, v.144, (Pt A), p.73-80, 2016.

BASTOS, W.R.; MALM, O.; PFEIFFER, W.C.; CLEARY, D. Establishment and analytical quality control of laboratories for Hg determination in biological and geological samples in the Amazon, Brazil. **Journal of the Brazilian Association for the Advancement of Science**, v.50, n.4, 255-260. 1998.

BERZAS NEVADO, J.J.; RODRÍGUES MARTÍN-DOIMEDIOS, R.C.; GÚZMAN BERNARDO, F.; JIMÉNEZ MORENO, M.; HERCULANO, A.M.; NASCIMENTO, J.L. do; CRESPO-LÓPEZ, M.E. Mercury in the Tapajós River basin, Brazilian Amazon: a review. **Environment International**, v.36, n.6, p.593-608, 2010.

BONOTTO, M.D.; SILVEIRA, E.G. Preference rations for mercury and other chemical elements in the Madeira River, Brazil. **Journal of South American Earth Sciences**, v.15, n.8, p.911-923, 2003.

CARPI, A.; FOSTIER, A.H.; ORTA, O.R.;SANTOS, J.C. dos; GITTINGS, M. Gaseous mercury emissions from soil following forest loss and land use changes: Field experiments in the United States and Brazil. **Atmospheric Environment**, v.96, p.423–429, 2014.

CARVALHO, D.P. de. **Dinâmica e especiação de mercúrio em compartimentos abióticos na formação do reservatório da hidrelétrica Santo Antônio do rio Madeira, RO**. 2016. 100 f. Tese (Doutorado em Ciências), Universidade Federal do Rio de Janeiro, Rio de Janeiro/RJ, 2016.

COMTE, I.; LUCOTTE, M.; DAVIDSON, R.; CARVALHO, C.J.R. de;., OLIVEIRA, F. de A.; ROUSSEAU, G.X. Impacts of land uses on mercury retention in long-time cultivated soils, Brazilian Amazon. **Water, Air, and Soil Pollution**, v.224, n.4, p.1–14, 2013.

CONAMA. Conselho Nacional do Meio Ambiente. **Resolução nº 420/2009**. Disponível em: <http://www.mma.gov.br/port/conama/legiabre.cfm.htm>. Acesso em: 20 de set. 2017.

COOKE, C.A.; BALCOM, P.H.; BIESTER, H.; WOLFE, A.P. Over three millennia of mercury pollution in the Peruvian Andes. **Proceedings of the National Scinces of the United States of America**, v.106, n.22, p.8830-8834, 2009.

DOMINGUES, M.S.; BERMANN, C. O arco de desflorestamento na Amazônia: da pecuária à soja. **Ambiente & Sociedade**, v.XV, n.2, p.1-22, 2012.

IARC. International Agency for Research on Cancer. 2002. **Overall evaluations of carcinogenicity to humans**. 2002. Disponível em: http://monographs.iarc.fr/ENG/Monographs/suppl7/. Acesso em: 23 de agosto de 2017.

KEHRIG, H.A.; HOWARD, B.M.; MALM, O. Methylmercury in a predatory fish (*Cichla* spp.) inhabiting the Brazilian Amazon. **Environmental Pollution**, v.154, n.1, p.68-76, 2008.

KIM, J.H.; ZELL, C.; MOREIRATURCQ, P.; PÉREZ, M.A.P.; ABRIL, G.; MORTILLARO, J.M.; WEIJERS, J.W.H.; MEZIANE, T.; SINNINGHE DAMSTÉ, J.S. Tracing soil organic carbon in the lower Amazon River and its tributaries using GDGT distributions and bulk organic matter properties. **Geochimica et Cosmochimica Acta**, v.90, p.163-180, 2012.

KIRK, J.L.; LEHNHERR, I.; ANDERSSON, M.; BRAUNE, B.M.; CHAN, L.; DASTOOR, A.P.; DURNFORD, D.; GLEASON, A.L.; LOSETO, L.L.; STEFFEN, A.;LOUIS, V.L. St. Mercury in Arctic Marine Ecosystems: Sources, Pathways, and Exposure. **Environmental Research**, v.119, p.64-87, 2012.

LACERDA, L. D.; DOS SANTOS, A. F.; MARINS, R. V. Emissão de Mercúrio para a Atmosfera pela Queima de Gás Natural no Brasil. **Química Nova**, v.30, n.2, p.366-369, 2007.

MAGARELLI, G., FOSTIER A.H. Influence of deforestation on the mercury air/soil exchange in the Negro River Basin, Amazon**. Atmospheric Environmental**, v.39, n.39, p.7518-7528, 2005.

MAGARELLI, G.; FOSTIER, A.H. Quantification of atmosphere - soil mercury fluxes by using a dynamic flux chamber: application at the Negro River basin, Amazon. **Química Nova**, v.28, n.6, p.968-974, 2005.

MAILMAN, M.; BODALY, R.A. Total mercury, methyl mercury, and carbon in fresh and burned plants and soil in Northwestern Ontario. **Environmental Pollution**, v.138, n.1, p.161-166, 2005.

MCKEYA, D.; ROSTAINB, S.; IRIARTEC, J.; GLASERD, B.; BIRKD, J. J.; HOLSTE, I.; RENARDA, D. Pre-Columbian agricultural landscapes, ecosystem engineers, and self-organized patchiness in Amazonia. **Proceedings of the National Academy of Sciences of the United States of America**, v.107, n.17, p.7823-7828, 2010.

MIRANDA, M.R. **Formação de metilmercúrio na bacia do rio Madeira, Rondônia**. 2010. 138 f. Tese (Doutorado em Biofísica), Universidade Federal do Rio de Janeiro, Rio de Janeiro/RJ, 2010.

PACYNA, J.M.; MUNCH, J. Anthropogenic mercury emission in Europe. **Water, Air, and Soil Pollution**, v.56, n.1, p.51-61, 1991.

QIU, G.; FENG, X.; WANG, S.; SHANG, L. Mercury and methylmercury in riparian soil, sediments, mine-waste calcines, and moss from abandoned Hg mines in east Guizhou province, southwestern China Guangle. **Applied Geochemistry**, v.20, n.3, p.627-638, 2005.

RAISON, R.J.; KHANNA, P.K.; WOODS, P.V. Mechanisms of element transfer to the atmosphere during vegetation fires. **Canadian Journal of Forest Research**, v.15, n.1, p.132-140, 1985.

R CORE TEAM. 2013. **R: A language and environmental for statistical comuting**. R Foundation for Statistical Computing: Viena, Austria. Disponível em: www.r-project.org>. Acesso em: 16 set. 2017.

RODELLA, A.A.; ALCARDE, J.C.; Legislação sobre micronutrientes e metais pesados. In: FEREIRA, M. E. (Ed.). **Micronutrientes e elementos tóxicos na agricultura**. Jaboticabal: CNPq: Fapesp, Potafos, 2001. 599 p

ROULET, M.; LUCOTTE, M. Geochemistry of mercury in pristine and flooded ferralitic soil of a tropical rain forest in French Guiana, South America. **Water, Air, and Soil Pollution**, v.80, n.1-4, p.1079-1088, 1995.

ROULET, M.; LUCOTTE, M.; SAINT-AUBIN, A.; TRAN, S.; AMORIN, M. The geochemistry of Hg in Central Amazonian soils developed on the Alter-do-chão formation of the lower Tapajós River Valley, Pará State, Brasil. **Science Total Environment**, v.223, n.1, p.1-24, 1998.

RYDBERG, J.; KARLSSON, J.; NYMAN, R.; WANHATALO, I.; NÄTHE, K.; BINDLER, R.Importance of vegetation type for mercury sequestration in the northern Swedish mire, Rödmossamyran. **Geochimica et Cosmochimica Acta**, v.74, n.24, p.7116-7126, 2010.

SANTOS, E.C.O. CÂMARA, V. de M.; BRABO, E. da S.; LOUREIRO, E.C.B.; JESUS, I. M. de; FAYAL, K.; SAGICA, F. Avaliação dos níveis de exposição ao mercúrio entre índios Pakaanóva, Amazônia, Brasil. **Cadernos de Saúde Pública**, v.19, n.2, p.199-206, 2003.

SILVA, H.D. da. **Metais e agrotóxicos no fruto de melancia (*Citrullus lanatus*) oriundos dos estados do Tocantins e Goiás**. 2009. 129 f. Dissertação (Mestrado em Produção Vegetal), Universidade Federal do Tocantins, Gurupi/TO, 2009.

SOARES, L.C.; LINHARES, L.A.; FILHO, F.B.E.; WINDMOLLER, C.C.; YOSHIDA, M.I. Mercúrio em Solos da Região Sudeste do Brasil sem Influência Antropogênica e sua Correlação com as Características Químicas e Físicas. **Revista Brasileira de Ciência do Solo**, v.39, n.3, p.903-914, 2015.

VALLE, C.M. do; SANTANA, G.P.; WINDMÖLLER, C.C. Mercury conversion processes in Amazon soils evaluated by thermodesorption analysis. **Chemosphere**, v.65, n.11, p.1966-1975, 2006.

VEIGA, M.M.; MEECH, J.A.; ONANTE, N. Mercury pollution from deforestation. **Nature**, v.368, p.816-817, 1994.

YANG,Z.; FANG, W.; LU, X.; SHENG, G-P.; GRAHAM , D.E.; LIANG, L.; WULLSCHLEGER, S.D.; GU, B. Warming increases methylmercury production in an Arctic soil. **Environmental Pollution**, v.214, n. p.504-509, 2016.

WONG, C.S.C., LI, X.D., ZHANG, G., QI, S.H., PENG, X.Z. Atmospheric depositions of heavy metals in the Pearl River Delta, China. **Atmospheric Environment**, v.37, n.6, p.767-776, 2003.

NÍVEIS DE MERCÚRIO EM SOLOS DE PLANTAÇÕES VEGETAIS COLETADOS EM UMA TERRA INDÍGENA DO ESTADO DE RONDÔNIA, AMAZÔNIA OCIDENTAL

RESUMO:

O mercúrio apresenta efeito cumulativo nos organismos vivos, podendo acarretar a médio e longo prazo graves problemas de saúde aos seres humanos que ingerem esse elemento tóxico através do consumo de alimentos de origem vegetal e animal. Isso porque o mercúrio quando presente nos solos pode atingir as plantas por meio de absorção do solo e também os peixes quando é lixiviado do solo para os rios. A situação é agravada quando se trata da população indígena que tem no peixe sua principal fonte de proteínas, assim como por consumirem em quantidades consideráveis vários vegetais que produzem em suas aldeias. Esse estudo objetivou quantificar mercúrio Total (Hg-T) em 216 amostras de solos coletadas durante os períodos de seca e chuvas em áreas de plantação vegetal de três aldeias da Terra Indígena Rio Branco, na região oeste do estado de Rondônia, na Amazônia brasileira. As análises foram realizadas em Espectrofotômetro de absorção atômica por geração de vapor frio. Todas as amostras analisadas apresentaram concentrações de Hg-T abaixo do valor de prevenção sugerido pela legislação brasileira, embora, para a aldeia Serrinha os valores terem sido muito próximos do valor máximo regulamentado como seguro. Houve uma maior dispersão dos níveis de Hg-T nos solos durante a estação chuvosa. Foi verificada influência positiva do nível de precipitação pluvial nos teores de Hg-T nos solos das plantações da aldeia Serrinha, com maior valor médio encontrado durante a estação chuvosa. Os solos coletados nas lavouras da aldeia Serrinha apresentaram níveis médios de Hg-T superiores aos encontrados nos solos das aldeias Trindade e Nazaré, sugerindo uma possibilidade de maior exposição dos indígenas da Serrinha através do consumo dos vegetais produzidos nas áreas onde foram coletados os solos analisados nesse estudo. A continuidade da pesquisa é sugerida no sentido de dosar mercúrio nos alimentos vegetais produzidos nessas aldeias, assim como nos peixes, os quais são alimentos consideravelmente presentes na dieta desses indígenas e podem ter suas concentrações aumentadas em função do conteúdo desse elemento nos solos das aldeias.

Palavras-chave: *Indígenas; Contaminação; Solo; Lavouras agrícolas; Metal tóxico.*