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Exposure to Elemental Mercury in Urban Workers and Gold Miners from the Tapajós Region, Pará, Brazil

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Environmental contamination in the Amazonian Region caused by mercury used in gold extraction in last four decades has become a serious health risk to exposed populations, in addition to being hazardous to the environment. Main anthropogenic sources of Hg in the environment include fossil fuel combustion, chloralkali plants, production of electrical equipment and measuring instruments, dyes and detonators for military use, the application of dental amalgam, and some catalysts in the plastic industry (Ferreira and Appel 1991). Mercury occurrence in Amazon has been associated with the release of wastes from gold extraction and amalgam burning in gold mining sites as well as with reburning in urban centers of gold commerce (Marins et al.1991; Silva 1993; Malm 1998; Hacon et al.1997).

Mercury exposure In the Brazilian Amazonian can affect human health by different routes, as it happens through the direct inhalation of mercury vapor by miners (*garimpeiros*) and gold shop workers during the process of amalgam burning for gold recovery. People living in and around those places can also be subjected to mercury exposure (Câmara et al. 1997). The consumption of contaminated fish represents another possible threat by this pollutant in Amazonian communities, for which is necessary that part of this Hg be released into aquatic ecosystems (Akagi et al. 1996; Lebel et al. 1997). Given the frequent concomitance of health problems such as infectious diseases and malnutrition in an area where life conditions are quite adverse, it is very important a careful diagnosis be made by sorting out signs and symptoms that can be related to mercury exposure or to regional diseases respectively (Santos et al. 2000).

In this study, mercury levels were assessed in urine samples, and local work conditions evaluated as reported by gold shop workers from the cities of Santarém and Itaituba, in the State of Pará. A group of workers from *Garimpo do Rato,* a gold mining site in the rural area of Itaituba, on the right margin of the Rato River, was also studied. Both groups were exposed to Hg vapor during the burning of gold-mercury amalgam.

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MATERIALS AND METHODS

A cross-sectional study protocol was developed by the Instituto Evandro Chagas in order to obtain a general diagnosis of health and life conditions of groups under occupational exposure to mercury (Santos et al. 1995). Epidemiological survey and clinical evaluation were done in all localities under study, in addition to laboratorial analysis. A total of 98 goldminers at *Garimpo do Rato* were interviewed. Fifty workers of 9 gold shops in Santarém and 81 workers of 22 gold shops in Itaituba were included in this study. All volunteering subjects were registered and signed forms assuring informed consent. A questionnaire was used to collect information on life conditions, occupation and morbidity. Some of the data obtained through the inquiry – such as individual identification, occupational history, facilities and equipment used in the work process – are focused in this paper. These variables were related to mercury levels so as to verify statistical relationship through STATA Version 5 software (Stata Corp. 1997).

For the total mercury analysis (Hg-T), a 5 ml urine sample from each participant was placed into a 50 ml flask, to which 2 ml of HNO_3 - $HClO_4$ (1:1), 5 ml of H_2SO_4 and 1 ml of Hg free H_2O were added. The flask was then heated on a hot plate to 230 to 250 ºC for 20 min; after cooling, the digested sample solution was made up to 50 ml with water (Akagi et al. 1995). An aliquote was collected and introduced into an Automatic Mercury Analyzer HG 3500, consisting of an Hg cold vapor generating system and an atomic absorption spectrophotometer. Recovery level of this method is up to 98% and the detection limit is around 1 ng of Hg.

RESULTS AND DISCUSSION

A total of 131 urban workers and 98 *garimpeiros* were interviewed in this study. The gold miners from *Garimpo do Rato* were 96 males and 2 females, with ages varying from 14 to 57 y.o. Urban workers included 86.3% of males and 13.7% of females, ages ranging from 14 to 64. Mean Hg level in urine samples from workers in Santarém was 57.5 μg/l (range, 2.7 - 663.0 μg/l). Highest values were found in managers averaging 81.1 μg/l, followed by burners and cashiers with mean Hg values of 74.7 μg/l and 39.6 μg/l respectively. In this city, 64.0% of the workers had mercury levels above 10 μg/l, and 22.0% above the Biological Tolerance Limit of 50 μg/l. Gold shop workers from Itaituba showed a mean Hg level of 27.8 μg/l (2.9 - 255.0 μg/l). Mean mercury levels in that city were as follows: 33.65 μg/l in burners, 24.7 μg/l in managers and 21.5 μg/l in cashiers. Among the workers in Itaituba, 76.54% had Hg values above 10 μg/L, and 10.0% above 50 μg/l. As for the *garimpeiros,* the mean Hg value found was 6.4 μg/l (0.0 – 74.3 μg/L), and 12.4% registered values above 10 μg/l. Only one individual presented an Hg level above 50 μg/l (Table 1 and Fig. 1).

Table 1. Mercury levels in urine samples of workers from gold shops and *Garimpo do Rato*, according to occupational categories. Santarém and Itaituba, Pará, Brazil.

Occupation	Santarém (n=50)		Itaituba (n= 81) (n=98) *	
	Mean Hg μg/l	Range	Mean Hg μg/l	Range
Manager	81.1	5.1 – 663.0	24.8	8.7 – 58.8
Burner	74.7	2.7 – 409.0	33.6	2.9 – 255.0
Cashier	39.6	9.1 – 88.2	21.6	6.1 – 42.1
Secretary	17.1	13.8 – 22.4	15.7	2.9 – 32.7
Others	9.5	2.9 – 18.9	17.1	2.9 – 31.3
Garimpeiro *	-	-	6.4	0.01 – 74.3

Official Hg levels established by Brazilian Legislation: Normal Value = under 10 μg/l; Biological Tolerance Limit = 50 μg/l.

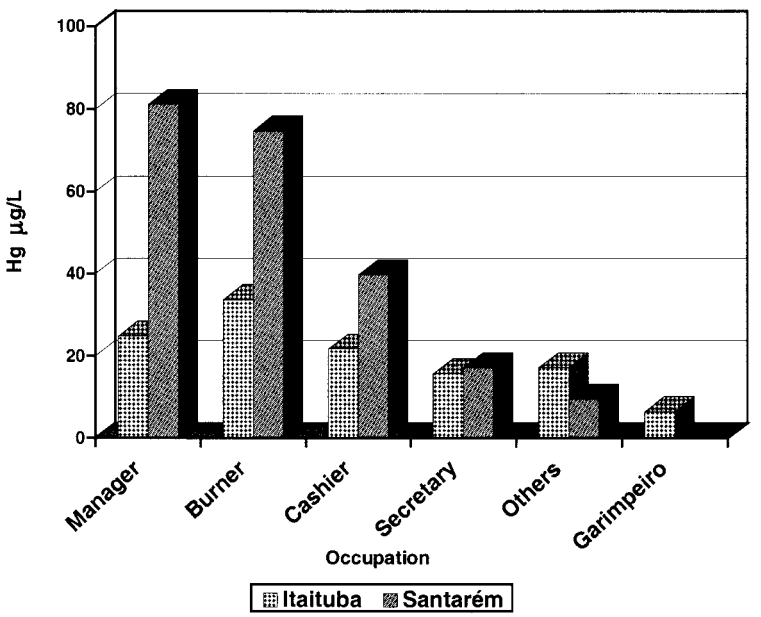

Figure 1. Mercury levels in urine of workers from gold shops and *Garimpo do Rato*, according to occupational categories. Santarém and Itaituba, Pará, Brazil.

The use of some protection equipment was reported by 36.4% of workers from Santarém and 46.0% from Itaituba. This practice was not observed among the *garimpeiros*. A rudimentary chapel (fume hood) to protect against Hg vapor was observed in 78.0% of gold shops in Santarém, while in Itaituba 73.0% of the establishments were equipped with a fume exhaust system with or without a filter, or also including a system for Hg recovery (Table 2).

Table 2. Equipments used on burning and weekly gold production (g)

Burning equipments	Santarém	Itaituba
No chapel	-	1
Rudimentary chapel	7	3
Chapel and exhaust	1	11
Chapel, exhaust and filter	1	4
Chapel, exhaust, filter and Hg recovery system	-	1
Total of gold shops	9	22
Amount of gold per week (mean)	1,111	3,089
Amount of gold in the week before the sampling	772	2,960

In order to verify a relationship between mercury levels and workplace situation among the study groups, a non-parametric statistical test was used (chi-square of independence), setting mercury levels in two classes, up to 10 μg/l and above 10 μg/l. Results showed a significant relationship between the exposure factor, i.e., the workplace, and mercury level (Pearson chi^2= 71.622, p=0.000). A case-control analysis revealed a significant odds ratio (OR=14.05766; CI=7.236366 to 27.27905 p=0.000), indicating gold shop workers had a fourteen times larger probability of exhibit urine mercury levels above 10 μg/l than gold miners had. Considering the use of chapels as protection equipment, the Kruskall-Wallis Test was used to verify uniformity of population among urban workers which results rejected the hypothesis of identical population medians (Chi^2=21.479 p=0.0003). A multivariate model adjusted by workplace, occupation, presence of chapel and years of work was established through ANOVA Test. Results indicated workplace situation (gold mining site or gold shops) and use of chapels were the best predictors of mercury levels (F=5.80 p=0.01 and F=3.10 p=0.01, respectively).

Among urban workers, the highest Hg values were observed in Santarém. At the time of this study, Itaituba was the busiest gold trading center in the region, its gold shops offering better protection equipment and facilities for workers. In both cities, however, mercury exposure of individuals who performed amalgam burning presented higher Hg levels than those found in *garimpeiros*. Overall, this study showed a significant difference in mercury levels between urban workers and gold miners ($p<0.01$), the latter presenting lower Hg exposure levels. Mercury values also varied according to the occupation in gold shops, where burners and managers (who usually spent more time inside the shop and also were involved in burning) presented higher mercury levels than others categories. In those shops, a significant relationship between mercury rates and use of chapels as protection equipment was found ($p<0.05$).

Work and life conditions in gold mining areas have long been considered as extremely hazardous to health due to several factors including chemical, physical, mechanical, biological, ergonomic and psychological agents. Those risks could be associated with the presence of adverse health effects, including mercury poisoning, as well as violence and infectious diseases (Câmara and Corey 1992; Santos et al. 1995). The fact that miners at *Garimpo do Rato* exhibit lower Hg levels than urban gold shop workers in spite of their insalubrious living conditions and the lack of protective equipment might suggest amalgam burning in open air could attenuate the intensity of exposure to mercury. However, this process of amalgam burning in open air as it happens inside the gold shops ends up dispersing mercury around the surrounding environment. In urban areas, people living nearby those sources of mercury vapor emission can be affected by this pollutant (Hacon et al. 1997).

The risk of mercury poisoning caused by gold burning is above all an occupational health problem that can be controlled or mitigated by using safety equipments. Some studies have already addressed the question of gold burning in urban gold shops as a public health risk, and called for the necessity of government intervention and a public health service program in controlling those activities (Câmara et al. 1997; Silva et al. 1997). Such a program would encompass aspects like individual protection, installation of efficient equipments for retention of mercury vapor generated during the amalgam burning, and safe mechanisms for residue recovery or deposition. The environmental pollution generated by burning represents indeed a public health concern for the potential health hazards that may affect exposed communities. Thus, the situation requires a more complex solution because it depends on integrated policies and control strategies by all sectors involved in health and environmental surveillance.

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