TECNOLOGIA AMBIENTAL

MERCURY EXPOSURE AND HEALTH EFFECTS AMONG URBAN RESIDENTS DUE TO GOLD COMMERCIALIZATION IN POCONÉ, MT, BRAZIL

19

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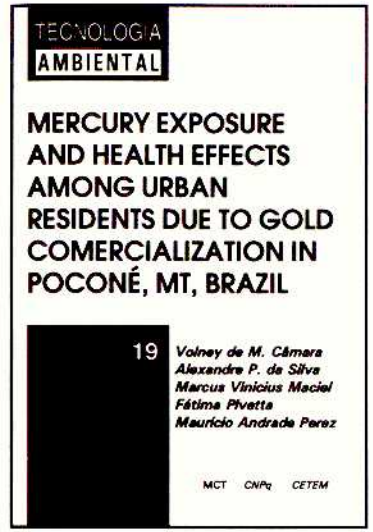

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PRESENTATION

Continuing our series of articles and monographies on mercury in the environment, this study conducted by these higly qualified professionals, headed by Prof. Volney M. Câmara and Alexandre Pessôa da Silva, shows the mercury exposure to urban residents due to gold shops that are active in Poconé, the gateway of the "Pantanal" area. This study was sponsored by the Pan-American Health Organization (PAHO) and Geselllshaft für Technische Zusammenarbeit (GTZ)

Quite recently CETEM held a workshop on mercury in the atmosphere of Alta Floresta and discussions were presented regarding the exposure limits for occupational workers and those accepted for the environment. This monography is quite an allert for those in charge of setting these limits.

Rio de Janeiro, August, 1997.

Roberto C. Villas Bôas
Director

CONTENTS

RESUMO

Foi realizado um estudo epidemiológico comparativo do tipo seccional, com o objetivo de avaliar níveis de exposição e efeitos causados por emissões de mercúrio metálico na atmosfera provenientes de casas compradoras de ouro na população residente do Município de Poconé, Estado de Mato Grosso. Os dados coletados incluíram um questionário, exames clínicos e determinações dos níveis de mercúrio no ar, poeira e solo das residências. Os resultados demonstraram que a exposição ao mercúrio no centro da cidade tinha sua origem nas emissões das casas compradoras de ouro, enquanto que na área periférica ocorria devido à queima de amálgamas ouro-mercúrio dentro das residências. Como conclusão foram sugeridas propostas de intervenção para controle das emissões de mercúrio das lojas e programas de educação para a saúde para serem desenvolvidos nas áreas periféricas da cidade.

Palavras-chave: mercúrio, áreas urbanas, medidas

ABSTRACT

The main objective of this study was to evaluate levels of exposure and health effects of residents from the city of Poconé, State of Mato Grosso, Brazil, caused by metallic mercury emissions to the atmosphere from gold-buying establishments. The data collected includes a questionnaire, clinical exams and the measure of total mercury in urine and also in air, dust and soil inside the houses.The results demonstrated that the exposure in the city center had its origin in the gold-buying establishments and in the peripheral group it came from amalgam-burning inside the houses. As a conclusion it was suggested intervention proposals to control metallic mercury emissions from the gold-buying establishments and a educational program for the peripheral area residents.

Key words: mercury, urban areas, measurements

1. INTRODUCTION

This study is part of the "Project Strengthening of ECO Pan-American Network of Sanitary Waste Management" created by the Pan American Health Organization (Environmental Health Program, EUA; Regional Office in Brazil and Pan-American Center for Human Ecology and Health, Mexico) and financed by the German Society of Technical Cooperation (GTZ-*Gesellschaft für Technische Zusammenarbeit*) whose main objective was the evaluation of human exposure and health effects caused by mercury vapor emissions to the atmosphere released from gold-selling stores in an urban area of the city of Poconé.

The number of studies concerning how the general populations is affected by occupational risks is still very small, and for this reason, research of the impact of mercury emissions caused by gold production should be considered as a priority in Brazil.

Gold production in Brazil increased in recent decades and employed a large number of people in its process, resulting in high mercury exposure among those occupationally involved, to the environment and also to general population in the surrounding areas.

The emphasis to study urban populations exposed to elemental mercury is due to the lack of publications regarding health effects to non-occupationally exposed personnel except for one study being made in the city of Alta Floresta/MT (Hacon,1996). The existing publications are aimed on occupational exposure in Gold mining sites and inside the gold-selling stores. Non-occupationally exposed populations were studied only through the view of methyl-mercury potential exposure or by measurements of mercury in the air near gold-selling stores.

Mercury is a highly toxic metal and has a number of important industrial, health, agriculture and mining uses. Poisoning

from occupational exposure and environmental pollution continues to be an area of concern. With regard to its toxicity, three major chemical forms of the metal must be distinguished: mercury vapor (elemental mercury), salts of mercury, and organic mercurials. This study is based on the environmental elemental mercury poisoning and its health effects on general population.

Elemental Mercury is the most volatile of the inorganic forms of the metal. Human exposure to mercury vapor is mainly occupational and has been known since antiquity. Chronic exposure to mercury in ambient air after mercury spills in poorly ventilated rooms, often scientific laboratories or in gold mining facilities, can produce toxic effects. Mercury vapor also can be released from silver amalgam dental restorations, but the amount of mercury released does not seem to be of significance for human health (Eley and Cox, 1993).

The metallic mercury is not particularly toxic when ingested because of very low absorption from the gastrointestinal tract. However, inhaled mercury vapor is completely absorbed by the lung and then is oxidized to divalent mercury cation by catalase in the erythrocytes (Magos *et al*, 1978). Mercury vapor crosses membranes much more readily than does divalent mercury and a significant amount of the vapor enters the brain before it is oxidized. Central Nervous System toxicity is thus more prominent after exposure to mercury vapor than to divalent forms of the metal. It is then partially deposited in tissues combined with sulfhydryl groups. Excretion is via the urine and feces. The half-life of elemental mercury is approximately 60 days (Friberg and Vostal, 1972).

Short-term exposure to the vapor of elemental mercury may produce symptoms within a few hours; these include weakness, chills, metallic taste, nausea, vomiting, dyspnea and coughing. Chronic exposure to mercury vapor produces a more insidious form of toxicity that is dominated by neurological effects (Friberg and Vostal, 1972). Initial symptoms include lassitude, anorexia, weight loss and gastrointestinal disturbances. Increasing exposure produces the characteristic intention tremor of mercury poisoning and is accompanied by mercurial *erethism*

(timidity, memory loss, insomnia, excitability, and, in severe cases, delirium) and can also affect the kidneys and skin (ATSDR, 1989; WHO, 1976, 1991; Clarkson *et al.*,1988).

The fraction that is not absorbed is eliminated in urine and feces. Urinary concentration is a good measure of elemental mercury but not to methylmercury poisoning (Bakir *et al.*,1980).

Mercury transformation in the environment can occur as biomagnification and bio-accumulation. When in aquatic environment microorganisms can convert mercury into methylmercury, which is more toxic than the inorganic forms; the compound is then taken up by plankton algae and is concentrated in fish via the food chain reaching much higher concentrations than the originally found in the environment.

As pointed before, the use of mercury in gold mining activities in Brazil causes metallic emissions to the atmosphere when the gold mercury amalgam is fired. Because gold is found in a powdered form, the use of mercury is necessary in the mining area to form a mercury/gold amalgam to make the extraction easier. For each kilogram of gold, an average of one kilogram of mercury is used (Pfeiffer, 1993). The three major types of *garimpos* (gold mining sites) are barges (gold is in the sediments of rivers), vein (gold in the rocks) and alluvial (gold on the banks of small rivers).

A description of the working processes at a gold mining placer of the alluvial type is shown on Figure 1. At the end of the mining procedure, gold-amalgam (*bullion*) still needs to be purified as it holds 3 to 5 % of mercury in its composition (Farid *et al*, 1991). Most commonly, the *bullion* is taken to gold-selling stores located in urban centers, where it will be reburned to end-stage purification and its gaseous residues emitted to the atmosphere without treatment (Câmara & Corey, 1992). The risk to human health, affects not only occupationally exposed personnel but also the general population in the surrounding areas.

The number of non-occupationally exposed population to emissions of elemental mercury is practically impossible to be measured. The National Department of Mineral Production estimated 300 thousand gold-miners as the occupationally exposed population in Brazil, mainly in the Pará State (DNPM, 1993). The number of miners is directly proportional to the level of gold production, which depends on gold prices in national and international markets.

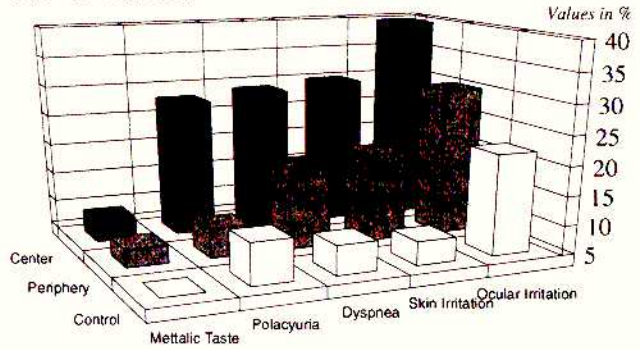

Figure 1 - General symptoms

The city of Poconé was chosen as a study area because it is situated in an environmental preservation area, the Pantanal Matogrossense, and represents a stable or even ascending gold-producing area. Official data released from the Brazilian Central Bank states that Poconé gold production increased between 1990 to 1994 from 1.855,1 to 2.539,6 kg while its state's (Mato Grosso) production fell from 25.230,4 to 17.304,1 kilograms and total gold production from Brazil fell from 98.2 to 75 tons.

In the gold mining regions, the city center concentrates the gold-selling establishments where the gold-mercury amalgam is fired and commercialized. They are settled in houses among residential and other commercial buildings and its air outflow is released without treatment containing high concentrations of elemental mercury.

World Health Organization (WHO, 1976) states mercury concentration limits for public settings as 1,0 $\mu g/m^3$. Limits for industrial environment should not exceed 25 $\mu g/m^3$, but in Poconé's gold-selling establishments it was found to be up to 100 $\mu g/m^3$ (Marins *et al*, 1991).

2. METHODS

This pilot study was designed as a sectional, randomic, comparative, epidemiological survey and it was aimed to evaluate exposure levels and health effects to residents in the urban area of Poconé, who are exposed to elemental mercury vapor emitted from the specialized stores where the metal-amalgam is burned for purification purposes.

The population of Poconé is 29,705 inhabitants, 21,185 of whom live in the urban area (IBGE, 1993). In the region, cattle-breeding is one of the main economical activities along with gold-mining. Gold mining activities in the region started in 1716 when a gold mine was found in the *Caxipó-Mirim* river (Silva, 1991).

As mercury vapors constantly released in the city are result of multiple punctual emissions restricted to a small area in the city center, it was defined as the main target area of our project. The extension of this area is known to be affected by wind orientation and the distribution of mercury vapor sources throughout the city area. In Poconé, wind blows predominately in a northerly direction. Based on this, a 400 meters distance limit north from the gold selling stores was set as the exposed area.

The calculated sample size of exposed population was 196, rounded to 200. This could be able to detect differences between groups with an 80% power and primary error of 5%. Residents were randomly selected from houses listed in the census maps of the Brazilian Institute of Geography and Statistics (IBGE) within the 400 meters limits from any gold-selling store.

The control group was defined as residents of an agricultural area outside the city limits, a place known as free of gold mining and commercialization activities. Other urban areas of the city

were excluded as controls because it was found that the practice of gold mining and amalgam burning inside their houses were common. This practice did not happen in the city center since it holds administration and commerce facilities in town.

There were no problems in collecting data in the city center and 200 people were included in the study. However, in the agricultural area only 41 persons could be enrolled albeit it accounted for nearly the census of that population, and for this reason a third group was included for comparison with the exposed group. Their population was located in a periphery area more than 500 meters away from the last gold selling store and their houses were all comparable with each other, sharing good sanitary conditions, although presenting a lower economical status than the city center group.

In order to be included in the study, each person should not met any of the exclusion criteria (Table 1). The data collected included a questionaire, clinical exams, the measurement of total mercury in urine applied to all individuals of the three groups and also measures of air, dust and soil inside some of the houses of each group.

Table 1 - Exclusion criteria

Age below 5 and over 60 years-old
Any previous mercury related activities (mining, burning, Commerce)
Known neurological or psichiatric disease
Use of drugs affecting the Nervous System

The questionnaire required the following information:

- Identification and address
- Occupational history
- General morbidity
- Mercury specific morbidity
- Alcohol abuse

- Fish related dietary habits

Physical examination was aimed to elemental mercury health effects focusing mainly central nervous system and kidneys disorders. Alcohol abuse was assessed by four questions extracted from **Cage** questionnaire which is widely accepted internationally (Masur & Monteiro, 1983).

Urine samples were obtained from each person enrolled in the study and 50 ml of morning first urine was conditioned in a polipropyl flask later cooled below 20ºC and it was analyzed by the toxicology laboratory of the Human Ecology and Worker's Health Study Center (CESTEH) of the Oswaldo Cruz Foundation through atomic absorption spectrofotometry method.

The samples of air, dust and soil were analyzed both for the CESTEH/FIOCRUZ and the Chemical Institute of the Mato Grosso Federal University, also by atomic absorption spectrofotometry method. These institutions employed their own quality control procedures aimed to met international standards of quality. Some of the dust and soil samples were analyzed simultaneously by both laboratories and the results were quite similar.

Collected data was stored and analyzed in a PC running the EPI-INFO program (Dean *et al.*, 1992). Statistical analysis of the differences between the three groups used Qui-square testing (Fleiss, 1979 and Armitage, 1971). Interpretation of this test used the most strict probability value (Yates corrected). When appropriate, the Fisher Test and the Kruskal-Wallis Test were used.

3. RESULTS

Data collected from 200 people from the city center (group A or Center), 124 from an intermediate area (group B or Periphery) and 41 from the agricultural area (group C or Control) was divided in two main parts: Mercury Exposure and Health Effects.

3.1 Mercury Exposure

In order to evaluate exposure to elemental mercury vapors, samples from air, dust and soil from some houses of the area of the three studied groups and urine samples from all enrolled people were collected and analyzed. In order to match the health results with the environmental pollution data, we analyzed only the measurements that were taken inside the houses of the interviewed personnel. For this reason, the air measures, which had been collected on a different day, did not match any of the houses of the enrolled people leading to exclusion of those samples from the analysis.

Urinary and environmental mercury (dust and soil) concentrations are shown in Table 2. Mercury levels measured in urinary samples of the three groups showed a highly significant difference between the mean values in the center (4,35 µg/l) and periphery (4,89 µg/l) as compared to the control group (1,25 µg/l). That also happened with dust and soil, when the mean values were respectively 1.91 and 0.09 ppm in the center, 63.3 and 3.2 ppm in the periphery, highly significant as compared to the control group where the mean value for dust was 0.25 ppm and soil was 0.27 ppm.

The control group included all residents of the agricultural area, the only place in the city limits where it was certain that there was no mercury exposure either occupational or environmental. Althoug there were only 41 people, the size of the control group did not represented a limitation when

assessing mercury concentrations obtained from urine samples or environmental measurements because there was a very small variance of the data.

It is also observed that mercury concentrations in urine are related to the environmental exposure. In people where urinary mercury were high (above 10 µg/L), environmental levels of mercury in dust and soil was found to be elevated in as well (Table 3).

Table 2 - Urinary and Environmental Mercury Concentration Poconé, MT, 1995*

	Center			Periphery			Control		
	Urine	Dust	Soil	Urine	Dust	Soil	Urine	Dust	Soil
Number of Samples	**158**	**49**	**47**	**117**	**18**	**18**	**41**	**21**	**21**
Means	4.35	1.908	0.089	4.89	63.303	3.186	1.25	0.253	0.272
Variance	121.70	17.888	0.010	129.38	2742.946	13.012	0.09	0.015	0.052
Standart Deviat.	11.03	4.229	0.099	11.37	52.373	3.607	0.31	0.123	0.229
Minimum	1.2	0.040	0.020	1.2	0.300	0.040	1.2	0.070	0.010
25%	1.2	0.430	0.050	1.2	0.030	0.070	1.2	0.120	0.060
Median	1.2	0.770	0.070	1.2	80.660	2.410	1.2	0.310	0.400
75%	3.3	1.240	0.080	2.9	100.860	4.260	1.2	0.350	0.400
Maximum	102.40	21.290	0.460	86.0	151.540	9.800	3.2	0.520	0.590

*Values in µg/L (urine) and ppm (dust and soil)

Urine - Kruskal-Wallis Probability = 23.0 - $p < 0.000$
Dust - Kruskal-Wallis Probability = 45.623 - $p < 0.000$
Soil - Kruskal-Wallis Probability = 16.447 - $p < 0.000$

Table 3 - Environmental Mercury Means (ppm) related to Urinary Mercury Concentration (µg/l) by location in Poconé, MT, Brazil,1995

Local	Urinary Mercury	
	<10 µg/l	≥ 10 µg/l
City Center		
Dust	0.70	8.02
Soil	0.07	0.22
Total		
Dust	7.07	53.97
Soil	0.31	3.01

Both the city center and the periphery groups were found to be exposed to mercury concentrations in their environment that was higher than the maximum value recommended by WHO and 14 persons (city center) and 13 persons (periphery) presented mercury levels higher than 10 µg/L. Further investigations showed that in the city center the only reasonable explanation was the mercury emissions to the atmosphere in the neighboring areas of the gold stores.

In contrast, this could not explain the even higher mercury concentrations in urine, dust and soil of periphery group members which were more than 500 meters from the gold stores. In this group, all the 13 people, with high values of mercury in urine, resided in 4 houses. The environment measures of mercury in this houses were also elevated (Table 4).

Table 4 - Mercury in Urine, Soil and Dust by houses and Persons in the Periphery of the City of Poconé - MT, Brazil, 1995

House person	Urinary Mercury (µg/l)		Mercury in Soil	Mercury in Dust
	First	Second	(ppm)	
House A			9.8	80.66
	29.7	30.3		
	18.4	28.3		
	86.0	-		
House B			0.56	151.54
	7.2	-		
	75.8	54.3		
House C			0.04	24.13
	18.4	12.2		
	46.6	29.7		
	28.6	13.2		
House D			4.26	100.86
	9.8	-		
	10.6	-		
	11.4	-		
	16.5	-		
	22.9	12.2		

Reference Values: Urine = 9.9 µg/l ; Soil = 0.027 ppm and Dust= 0.3 ppm

After these results were released, a new research party returned to the study place and confronted the periphery group members with their mercury measurements results, and only then the residents with very high values admitted to having burned mercury-gold amalgam inside their own houses.

A second measurement of urinary mercury concentration was performed at least 60 days after the first measure on those who agreed and also had urinary mercury values higher than 10 µg/l (Table 5). The mercury concentration in urine fell for almost every one in the second measure, except for those who lived in house A, where apparently bullion continued to be burned inside walls. There is also the possibility that in the time the second measurement was collected, there was a fall in the region's gold production leading to a lesser extent of exposure.

Table 5 - Sequential Measures of Mercury in Urine Values in µg/l

Person	First measure	Second Measure
14	13.0	< 2.5
21	13.4	12.2
22	102.4	36.3
69	12.6	8.2
96	16.4	4.2
166	20.2	14.2
185	88.2	41.3
524	29.7	30.3
525	18.4	28.3
536	75.8	54.3
585	18.4	12.2
586	46.6	29.7
587	28.6	13.2
594	12.4	10.2
605	22.9	12.2

3.2 Health Effects

Health effects were assessed by analysis of data collected in the questionnaire and physical examination. Despite the city center which had the highest proportions of general complaints (Figure 1), showed significant differences only to metallic taste, eye irritation, skin irritation and dyspnea when compared to the control group. In general, the periphery group showed intermediate proportions of complaints when compared to the remaining groups.

Regarding specifically neurological complaints (Figure 2) the exposed group also showed a higher proportion when compared to the control group. Significant differences were found on anxiety, excitability, memory loss, insomnia, lack of will, asthenia and fine tremor in the hands. These specific complaints configure the mercurial *erethism* often found on chronic mercury exposure.

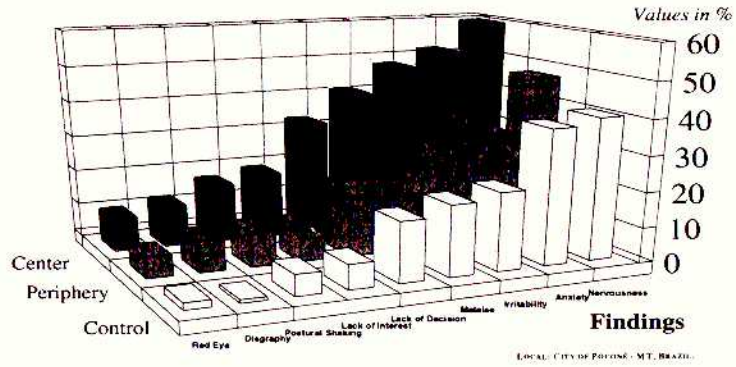

Figure 2 - Alterations in physical examination and neurological symptoms

Unfortunately, economical and educational level was different between the groups and the highest educational level was found in the city center. This could have contributed negatively to the controls capacity to understand and answer the questions in the questionnaire. On the other hand, the lower economical status of the control group can lead to a higher spontaneous proportion of health problems, which in the final analysis enhances the health effects found in higher proportion in the wealthy exposed group.

The neurologic-aimed physical examination showed significant differences in the exposed group only in Postural shivering, Red-eye and a positive Romberg sign. Kidney related complaints showed no difference between the three studied groups.

The referred morbidity and findings in physical examination that although showing a higher proportion in the exposed group revealed no significant differences are listed in Table 6. Probability tests comparing these variables showed *p* values higher than 0,05 maybe because of the small number of samples and high variance of collected data.

Table 6 - List of findings and complaints with higher proportion and no statistically significant differences between the mercury exposed and non-exposed groups. Poconé - MT, Brazil, 1995.

Oral bleeding	Anger	lower limbs Tremor
Oral inflamation	Hiporexia	lower limbs edema
Oral ulcers	intention tremor	Periorbital edema
excessive Sudoresis	eye-lid tremor	Sadness
sensibility reduction	lip tremor	slowing of deep reflex

4. CONCLUSIONS

It is clear that a mercury pollution process is taking place in center of Poconé and it cannot be explained for any other reason than mercury emissions to the atmosphere from the stores. Concerning the periphery, the practice of bullion burning inside the houses of some people contributes to mercury shedding in the environment in a lesser extent.

In the study of environment pollution, measures of dust concentration are the main source of investigation and its correlation with urinary mercury concentrations appears to be a great tool to exposure awareness.

Health effects analysis shows that the population is not alarmingly affected, with increasing levels of exposure leading to a higher proportion of mercury induced signs and symptoms, but true intoxication is not a fact.

At this time, intervention is a priority, because mercury contamination, although present, does not seem to be severe and can be controlled. Controlling methods include direct treatment of mercury emissions from the gold selling stores through forced air exhaust systems and gas cleaning.

Another important action is a health education program aimed at mercury handling and poisoning, together with providing adequate places for individuals to purify their own *bullion* without dealing with gold-selling stores and without wild open air exposure.

The effectiveness of these activities after their implementation could be evaluated by a subsequent cohort study with the same population.

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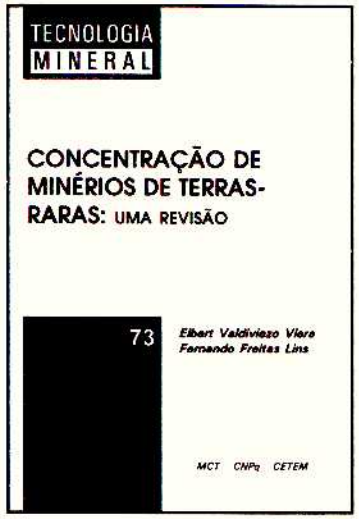

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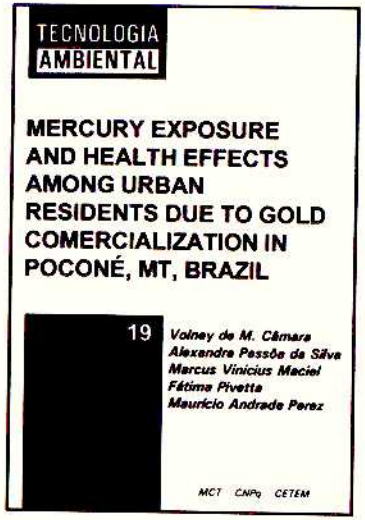

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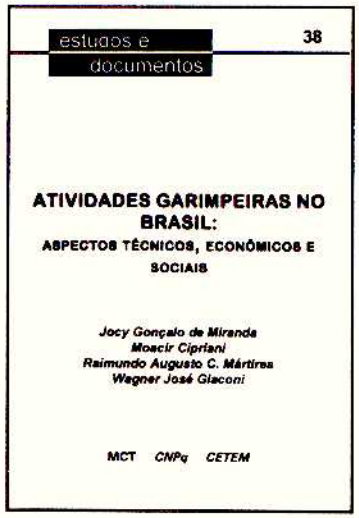

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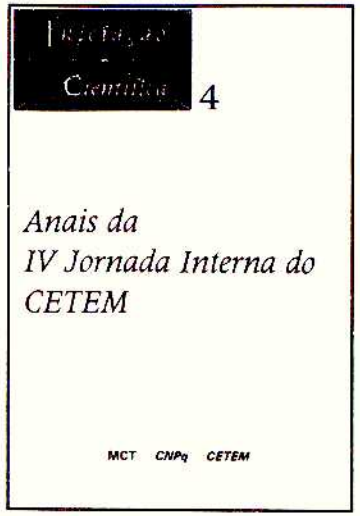

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