# Correlation between blood mercury levels in mothers and newborns in Itaituba, Pará State, Brazil

# Correlação de teores de mercúrio no sangue entre mulheres e recém-nascidos do Município de Itaituba, Pará, Brasil

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## Abstract

*This study evaluated transplacental mercury transfer by measuring Hg in blood samples of mothers and newborns (umbilical cord) in hospitals in the municipality (county) of Itaituba, Pará State, Brazil. Epidemiological and mercury exposure data were collected, besides clinical birth data. Mercury tests were performed by cold-vapor atomic absorption spectrophotometry. A total of 1,510 women and an equal number of their newborns participated in the study. Mean blood mercury was 11.53µg/L in mothers and 16.68µg/L in newborns (umbilical cord). The highest Hg levels were in the 31-40-year maternal age group and their newborns, with 14.37µg/L and 21.87µg/L, respectively. However, in all age groups the mean mercury level was higher in newborns than in mothers. There was a strong positive correlation between Hg levels in newborns and mothers (r = 0.8019; p = 0.000), with a significant linear regression model (r = 0.5283; p = 0.000). The results highlight the importance of monitoring pregnant women exposed to mercury as part of public health surveillance.*

*Mercury Poisoning; Mercury; Maternal Exposure*

## Introduction

Studies on mercury (Hg) in the Amazon region in the 1980s and 1990s emphasized the extent of mercury pollution in gold-mining areas, due mainly to source emission, dispersion mechanisms, and accumulation in geological materials (soils, sediments, and water) and in the aquatic biota, mainly fish. Several studies have also focused on identifying populations (especially riverside dwellers) potentially exposed to organic mercury compounds through consumption of foods containing high Hg levels [1,2,3,4,5,6]. These studies concentrated on mercury pollution in gold-mining areas, but without approaching clinical aspects of exposure to Hg compounds [5,7,8,9].

The first study on clinical signs and symptoms emphasized prospectors, gold shop workers, and riverside communities in the Tapajós Basin, with the first reports of suspected cases of mercury poisoning between 1986 and 1991 [10]. The study assessed Hg levels in blood and urine samples and included motor coordination tests. Despite high Hg levels in the samples, no clinically confirmed signs and symptoms of mercury poisoning were identified in these individuals. This apparent paradox has been attributed to the high prevalence of tropical diseases in the Amazon region that can mask the classical signs and symptoms of Hg poisoning. However, studies are needed that integrate information on the health conditions of these communities, including the prevalence of tropical diseases, in order to identify clinical symptoms associated with mercury exposure. A study in the Tapajós River Basin assessed the local population's health conditions [11]. The methodology included an epidemiological survey, clinical evaluation, and laboratory tests, besides assessment of metallic Hg exposure through urine and blood tests. A total of 225 individuals participated in the study. Urine Hg samples from 173 individuals showed 9.2% in the 10-19μg/L range and 5.2% above 20μg/L. The values were relatively low, suggesting low exposure. This situation was attributed to the fact that not all workers involved in gold-mining directly handle the burning of gold-mercury amalgam, and when they do, they prefer to work in open-air areas that minimize exposure to Hg vapor. The most worrisome situation observed in this area was the additional exposure to such diseases as malaria, hepatitis B, syphilis, and intestinal parasites and the precarious local living and working conditions and substandard sanitation [10,11].

To evaluate the exposure of riverside populations to methyl mercury (MeHg), fish and hair samples were collected in the Tapajós Basin [12]. The highest Hg levels were observed in carnivorous fish, with a mean value of 0.69μg/g. In human hair samples, the highest level was 151μg/g, with a mean of 25μg/g. This study identified the critical areas and fish species and the most heavily exposed population groups [12]. In the Tapajós Basin, a study in the Brasilia Legal community measured Hg levels in fish samples from 40 species and 96 human hair samples. Some 26% of the fish samples showed Hg values greater than 0.5μg/g (the maximum level recommended for consumption) among all the piscivorous and omnivorous species. The 96 individuals were divided into three groups, according to fish consumption. Mean hair Hg was 16.1μg/g in the group with high fish consumption, 14.8μg/g in the mixed- diet group, and 7.8μg/g in the group with low fish consumption. Fish-eating habits vary according to rainfall in the region, with piscivorous and omnivorous species prevailing during the rainy season and herbivorous species during the dry season [13].

Other recently identified sources of Hg emission in the Amazon, besides traditional gold-mining, like burning of forest biomass and soil leaching, have been indicated as an important factor in food chain biomagnification processes in the aquatic ecosystems. Immediate consequences include increased exposure of riverside communities to organic Hg compounds through fish consumption [13,14,15,16].

Various studies in the Amazon have focused on the possible neurological alterations related to Hg exposure. Some have used a quantitative behavioral neurophysiological test battery including near and far visual acuity testing, color discrimination capacity, near visual contrast sensitivity profiles, peripheral visual field profiles, and manual dexterity (Santa Ana, Helsinki version). The test results were associated with Hg levels and demonstrated that a sensitive test battery can detect alterations in nervous system functions at levels below the currently recognized threshold of 50μg/g total mercury (Hg-T) [17,18]. Another study in the Tapajós Basin applied the Santa Ana manual dexterity, grooved pegboard fine motor, and finger-tapping motor speed tests to evaluate psychomotor performance. A face-to-face questionnaire was used to obtain information on socio-demographics, health, smoking habits, alcohol consumption, dietary habits, and work history, besides Hg levels from blood and hair samples. The study showed neurobehavioral manifestations of subtle neurotoxic effects on motor functions associated with low-level MeHg exposure [19].

Another study in the Amazon applied neuropsychological tests of motor function, attention, and visuospatial performance in 351 children 7 to 12 years of age in four Amazonian communities and associated the results with Hg levels in hair samples. Especially on the Santa Ana form board and the Stanford-Binet copying tests, similar associations were apparent in the 105 children from the village with the lowest exposures. The results of this study indicated that average exposure levels had not changed in recent years, while noting that prenatal exposure levels are unknown [20].

However, elsewhere in the world, longitudinal studies on prenatal Hg exposure and childhood development are widely cited in the literature [21,22]. One such study (including a pilot and principal phase) was performed in the Seychelles Islands, where most residents consumed fish and it was possible to assess the data with a low level of confounding factors due to the high quality of health, socioeconomic, and educational indicators. The study began in the mid-1980s, testing hair mercury during pregnancy with subsequent stages applying neurological, psychological, and developmental test battery to the children. However, the results did not show an association with Hg exposure. In the studies, no adverse association was observed between fish consumption as a form of prenatal Hg exposure and the results of the clinical tests [22].

In the Faroe Islands, where fish and pilot whales are an important part of the diet, a longitudinal study assessed Hg levels in mothers and newborns through hair and cord blood samples.

The study found a significant association between prenatal Hg exposure and at least one type of assessment (neurological, neuropsychological, or neurophysiological). In addition to mercury, exposure to polychlorinated biphenyl (PCB) was reported in the population [21].

Although numerous studies have already been conducted in the Amazon region on population exposure to mercury compounds, few have focused on prenatal exposure. In studies on exposure to chemical substances, children (and especially newborns) represent a priority group due to the possible transfer of these substances across the placental barrier and later through breastfeeding. The current study was carried out in the municipality (county) of Itaituba in the southwest region of the State of Pará, Brazil (Figure 1).

## Materials and Methods

The study population included mothers and their newborn infants at three hospitals in Itaituba from November 2000 to March 2002. The study aimed to include a representative sample of births at the hospitals. The data refer to the first approach to the study population, of which a part (30%) has been researched in subsequent evaluations (data not available).

Maternal and cord blood was drawn with disposable syringes and stored in Vacutainer® tubes with 10% EDTA to preserve the samples. After separation of the plasma and erythrocytes, the samples were stored at -20ºC until laboratory analysis.

For Hg-T analysis, 0.5ml of erythrocytes were measured with an automatic pipette and placed in 50ml volumetric flasks, to which 2ml of $HNO_3$-$HClO_4$ (1:1), 5ml of $H_2SO_4$, and 1ml of Hg-free $H_2O$ were added, and the mixture was heated on a hot plate to 230-250ºC for 20 minutes. After cooling, the digested sample solution was completed to 50ml with $H_2O$, and an aliquot was placed in an Automatic Mercury Analyzer Hg 3500 (K.K. Sanso) consisting of an Hg cold-vapor generation system and atomic absorption spectrophotometer [23]. Quality control used reference materials for hair (IAEA-85 and GBW 07601) and blood (whole blood 1 and 3).

The epidemiological data included demographics, living and health conditions, schooling, history of Hg exposure, eating habits, and disease history. Descriptive statistics considered the maternal age groups with 5-year intervals to identify possible differences in Hg exposure and to separate pregnancy in adolescents and young women. Occupational and clinical variables were also described. Clinical variables included low birth weight and neonatal jaundice and cyanosis, since such clinical indicators could have important repercussions on post-neonatal health, depending on the etiology and care received by the child. Statistical analysis used the Stata software (Stata Corp., College Station, U.S.A.) to verify the association between maternal and cord blood Hg levels by the Pearson correlation and establish a linear regression model. A nonparametric correlation was used to compare the variables age and ordinal weekly fish ingestion per week with Hg concentration, using the Spearman coefficient [24].

This study complied with the ethical standards recommended by the Code of Research Ethics (196/96) of the Brazilian National Health Council (Ministry of Health). The pregnant women participated voluntarily, signing a free informed consent form. All the women received appropriate medical care at the participating hospitals.

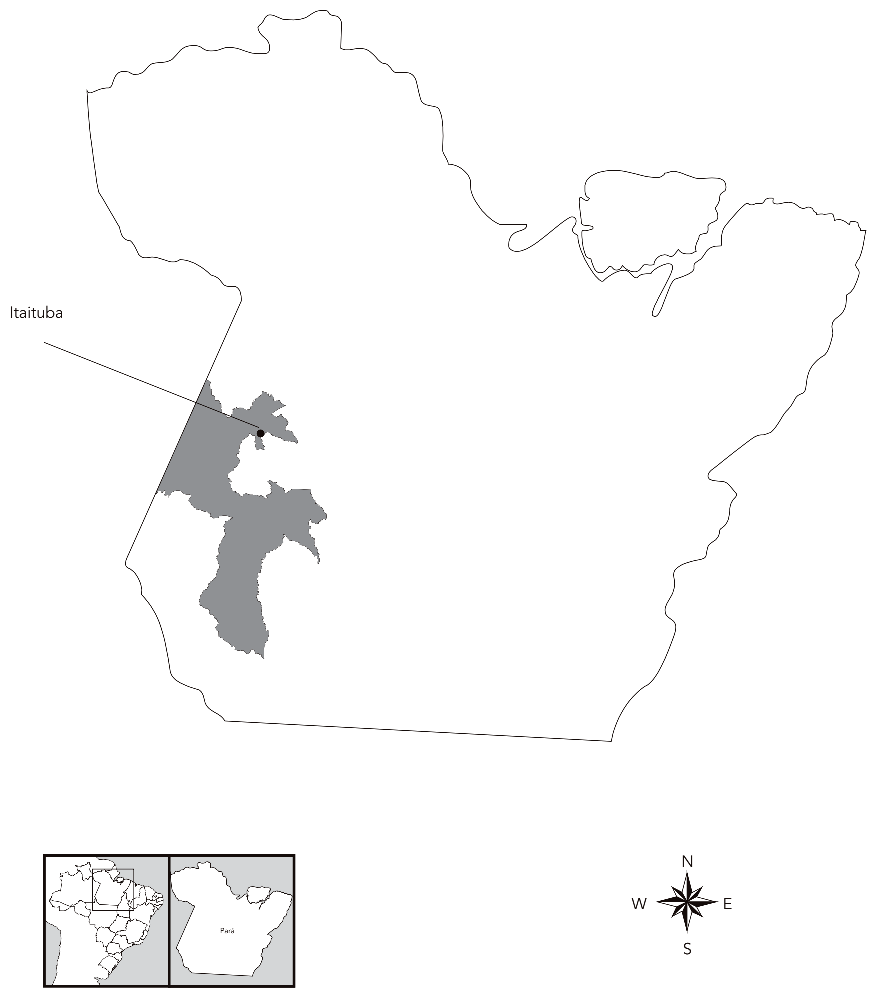
## Results and Discussion

A total of 1,510 women and an equal number of their newborns participated in this study, representing 44% of the births at the three hospitals in Itaituba during the study period. Mean maternal age was 22 years (range 12-46), and nearly all (94.2%) of the mothers resided in the municipality of Itaituba. Some 30% were riverside or rural residents, and only about 1% lived in gold-mining areas. Occupations included housewives (61.2%), rural workers (14.8%), and domestic workers (10.9%). Mean maternal and cord blood Hg levels were 11.53μg/L (0.38-117.62μg/L) and 16.68μg/L (0.35-135.04μg/L), respectively.

Table 1 shows the distribution of maternal and cord blood Hg levels by maternal age group, highlighting early pregnancy in adolescents, with the 16-to-20-year-old group representing 68.4% of all the mothers. The 31-40-year group (range 14.37-16.27μg/L) and their newborns (21.87-25.39μg/L) showed higher mean Hg than the other age groups. In all age groups, mean blood Hg was higher in the newborns than in their mothers (Figure 2), which is consistent with mercury crossing the placenta and accumulating in the fetus at the same (or higher levels) than in the mother. During pregnancy, an extensive transfer of organic and inorganic nutrients/substances to the fetus is known to occur, which could also explain the higher Hg concentration in newborns [25]. In 75% of the mothers, Hg levels were greater than or equal to 13.99μg/L (third quartile). In the newborns, the third quartile cutoff was 20.09μg/L.

Figure 1

Map of the Municipality of Itaituba, Pará State, Brazil.




Maternal blood Hg showed a strong positive correlation with age ($r = 0.812$; $p = 0.002$) and a positive (but weak) correlation with frequency of fish consumption ($r = 0.2518$; $p < 0.01$). Approximately 33% of the mothers and their children showed blood Hg levels above the mean for their respective groups.

Clinical birth data did not show any cases of congenital disorders, but 7.3% of the newborns presented low weight, 7% cyanosis, and 1% jaundice, and 12.3% required intensive care. These findings involve diverse etiologies (data not available) and constitute an exclusion criterion for subsequent developmental assessment. The correlation between maternal and cord blood Hg levels (Figures 2 and 3) was strongly positive ($r = 0.8019$; $p = 0.000$), with a significant linear regression model (regression coefficient = 0.5283; $p = 0.000$), whereby maternal Hg was predictive of neonatal Hg. Other studies in the Amazon have shown a significant correlation between Hg levels in mothers and children, where for example maternal hair and breast milk Hg were associated with hair Hg levels in the children [26].

The maternal and neonatal Hg levels characterize an exposure profile that has been observed along the Tapajós Basin, with mean Hg frequently above the normal limits (8μg/L in blood) and in some cases above the limits of biological tolerance (30μg/L) recommended by the International Pro-

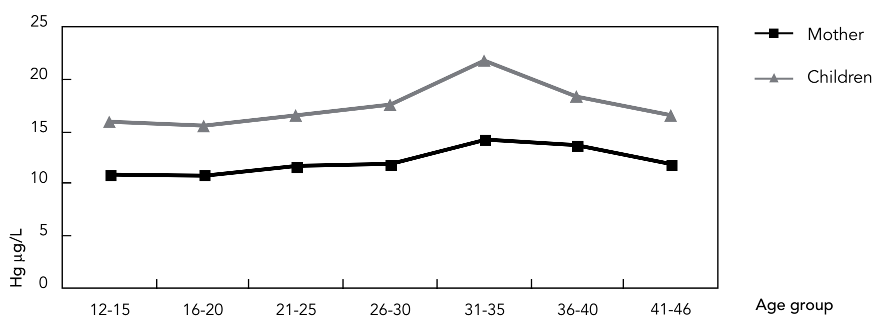
Table 1

Maternal and neonatal blood Hg levels in the Tapajós Basin, Itaituba, Pará State, Brazil.

| Maternal age group (years) | N | Mean maternal Hg and standard deviation (μg/L) | Range (μg/L) | Mean neonatal (cord blood) Hg and standard deviation (μg/L) | Range (μg/L) |
|---|---|---|---|---|---|
| 11-15 | 92 | 10.81± 6.92 | 0.96-42.60 | 15.87±11.51 | 0.73-68.48 |
| 16-20 | 575 | 10.84±9.87 | 0.38-117.62 | 15.59±15.16 | 0.35-135.04 |
| 21-25 | 459 | 11.74±11,56 | 0.65-90.95 | 16.46±17.02 | 0.70-131.65 |
| 26-30 | 212 | 11.88±11.41 | 0.65-76.26 | 17.50±19.43 | 0.76-111.62 |
| 31-35 | 103 | 14.37±16.27 | 0.62-93.91 | 21.87±25.39 | 1.22-126.87 |
| 36-40 | 59 | 13.71±15.88 | 0.70-101.31 | 18.37±17.34 | 0.76-90.50 |
| 41-46 | 10 | 11.96± 9.63 | 3.88-33.01 | 16.49±10.25 | 5.10-39.30 |
| **Total** | 1,510 | 11.53±11.30 | 0.38-117.62 | 16.68±17.16 | 0.35-135.04 |

Figure 2

Blood mercury levels in mothers and newborns according to maternal age group. Itaituba, Pará State, Brazil.



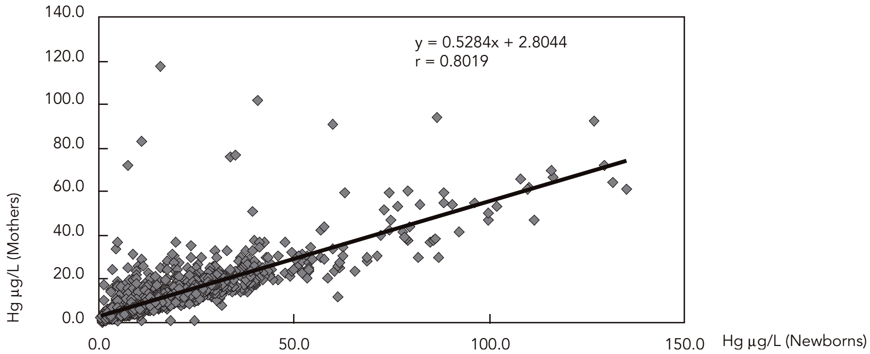

gram on Chemical Safety [27]. Unlike other studies that used maternal hair and cord blood to assess prenatal exposure, in this study the first assessment used maternal and newborn (umbilical cord) blood, the latter showing a mean Hg of 16.60μg/L, lower than in Faroese newborns, for example, in whom mean blood Hg was 22.0μg/L [28].

Although this study found no clinical signs that could be associated with neonatal Hg concentration, the cord blood Hg level deserves attention due to this metal's intrauterine accumulation and the potential developmental consequences for children living in areas with mercury pollution. In addition, postnatal mother-to-child Hg transfer continues through other mechanisms like breastfeeding, characterizing an additional potential risk of Hg exposure and its effects on infants [29,30].

One of this study's potential limitations was the analysis of blood Hg-T rather than MeHg. However, this population is basically exposed to MeHg, so we can assume that the total levels represent mostly MeHg exposure. The various forms of organic Hg are particularly neurotoxic. Both prenatal and postnatal exposure to MeHg can adversely affect the central nervous system, but the compound appears to be most neurotoxic during the prenatal period, when the brain is developing rapidly [31,32]. We should also assume that these blood levels only provide accurate information on recent exposure, and that cord blood cannot be expected to reflect exposure earlier in pregnancy. Although measuring Hg in maternal hair growing during pregnancy by segmental analysis could detect exposures throughout the entire gestation, it is not clear which of

Figure 3

Correlation between maternal and cord blood mercury levels in the Tapajós Basin, Itaituba, Pará State, Brazil.




the two methods provides a better measure of fetal exposure [26].

Associations between exposure to low doses of MeHg and adverse effects on children have not been consistent. Factors correlated with exposure or development, like nutritional factors (breast milk or MeHg exposure from consumption of fish, marine mammals, or both) and social and cultural factors (maternal intelligence and socioeconomic status) may modify the association between exposure to this neurotoxic substance and its effects on development. Adverse effects have been reported in relation to attention, learning, and memory in 7-year-old children with prenatal exposure to MeHg measured in cord blood and associated with maternal hair Hg (5.6µg/g) [28,33]. A different result was found in the Seychelles prospective study, analyzing maternal hair Hg (6.8µg/g in the main study) and applying a test battery in a child development study at birth, 19, 29, and 66 months, showing no adverse association between Hg levels and clinical outcomes [22,28].

The Hg levels in our study could lead to developmental toxicity resulting from exposure prior to birth (in either parent), during prenatal development, or in the postnatal period until sexual maturation. At higher levels, such developmental exposures could result in health effects observed during the prenatal period and at birth, including spontaneous abortion, stillbirth, low birth weight, infant mortality, and malformations, as well as in childhood, like asthma and neurological and behavioral disorders; and finally in adulthood and old age, such as degenerative neurological/behavioral disorders [31,34]. Although Hg exposure is considered low in the Amazon, some studies suggest that long-term exposure has neurotoxic effects in riverside communities, suggesting dose-dependent nervous system alterations at hair Hg levels below 50µg/g [17,18].

## Conclusions

This type of study involving mothers and newborns is the first by our research group in the Tapajós Basin. We plan to develop further research to identify mechanisms that could prevent severe mercury poisoning in these age groups with proven exposure.

The results highlight the importance of monitoring pregnant women exposed to Hg as part of public health surveillance and the pressing need to plan health care practices to monitor these children over time in order to detect possible developmental impairments that can be attributed to Hg exposure, or even clinical signs and symptoms of Hg poisoning.

Another important focus of this on-going research will be the mechanisms related to postnatal Hg toxicokinetics, more precisely how children eliminate Hg during their first years of life. Early childhood development presents specific biological processes that cannot be compared exactly to those occurring in adults. We thus view the current study as the first step in a cohort study, aimed at following and observing the adverse effects in these newborns during their first years of life. This entire process is being accompanied by preventive measures and recommendations to participants and their families to avoid exposure to mercury compounds.

## Resumo

*Este estudo avaliou a transferência transplacentária de mercúrio (Hg) utilizando amostras de sangue das mães e recém-nascidos (cordão umbilical) de hospitais do Município de Itaituba, Pará, Brazil. Foram coletados dados epidemiológicos e de exposição ao Hg, além de dados clínicos ao nascimento. As análises de mercúrio foram realizadas por espectrofotometria de absorção atômica com sistema de vapor frio. Um total de 1.510 mulheres e seus recém-nascidos participaram do estudo. A média de Hg em sangue das mães foi de 11,52µg/L e no cordão umbilical foi 16,68µg/L. Os níveis mais elevados de Hg foram verificados nas idades entre 31 a 40 anos, com médias de 14,37µg/L nas mães e 21,87µg/L nos recém-nascidos. Entretanto, em todas as faixas de idade materna as médias de Hg estavam mais elevadas nos recém-nascidos em relação às mães. Verificou-se correlação positiva e forte entre os níveis de Hg nas mães e recém-nascidos (r = 0,8019; p = 0,000) com modelo de regressão linear significante (r = 0,5283; p = 0,000). Estes resultados indicam a importância do monitoramento de mulheres grávidas expostas ao Hg como parte da vigilância em saúde.*

*Intoxicação por Mercúrio; Mercúrio; Exposição Materna*

## Contributors

E. O. Santos coordinated the project, fieldwork, data collection, and analysis and discussion of the results. I. M. Jesus participated in the planning, fieldwork, and analysis and discussion of the results. V. M. Câmara participated in the project and analysis and discussion of the results. E. S. Brabo conducted the mercury laboratory tests and participated in the analysis and discussion of the results. M. I. Jesus contributed to the supervision and implementation of the fieldwork and discussion of the results. K. F. Fayal participated in the mercury laboratory tests and discussion of the results. C. I. R. F. Asmus contributed to the analysis and discussion of the results.

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