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Review[1]

Meta-analysis of mercury pollution studies in the Beni River basin, Bolivia

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Keys: *Mercury, Beni River basin, Mercury in water, Mercury in sediments, Mercury in humans, Meta-analysis of mercury pollution;* **Claves:** *Mercurio, Río Beni, Cuenca, Mercurio en agua, Mercurio en sedimentos, Mercurio en personas, Metaanálisis de contaminación de mercurio.*

ABSTRACT

Bibliographic data on mercury contamination in water, sediments, and people in the Beni River basin, Bolivia (1995-2024) were collected. Zone A, from the Coroico River to Rurrenabaque, and Zone B, from Rurrenabaque to Riberalta. The most recent data (2022-2023) corresponds to the concentration of mercury in human hair (4 µg/g), a value that exceeds the reference limit for monitoring (2 µg/g). This value suggests contamination in water, sediments, and fish in recent years. In the case of mercury in water, the last recorded value was relative to mercury in particles in 2006 (880.07 ng/l), and in sediments it was from the period 2004-2005 (0.066 ng/g). The observed trends point to external and anthropogenic factors, such as mining and forest burning, which would be influencing the high concentrations of mercury in this basin, highlighting the wet season as the one with the highest concentrations.

RESUMEN

Metaanálisis de estudios de contaminación por mercurio en la cuenca del río Beni, Bolivia. Se recopiló datos bibliográficos sobre contaminación por mercurio en agua, sedimentos y personas en la cuenca del río Beni, Bolivia (1995 - 2024). Zona A, desde el río Coroico hasta Rurrenabaque, y Zona B, desde Rurrenabaque hasta Riberalta. El dato más reciente (2022-2023) corresponde a la concentración de mercurio en cabello humano (4 µg/g), valor que excede el límite de referencia para la vigilancia (2 µg/g). Este valor sugiere contaminación en agua, sedimentos y peces durante los últimos años. En el caso de mercurio en agua, el ultimo valor registrado fue relativo a mercurio en partículas en el año 2006 (880.07 ng/l) y en sedimentos fue del periodo 2004-2005 (0.066 ng/g). Las tendencias observadas apuntan a factores externos y antropogénicos, como la minería y la quema de bosque, que estarían influyendo en las elevadas concentraciones de mercurio en esta cuenca, destacando la temporada húmeda como la de mayores concentraciones.

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INTRODUCTION

Mercury is among the largest global pollutants, and much of the emissions in Latin America come from the Amazon.[1] The Beni River Basin, located in Bolivia and part of the upper Madera River Basin in the western Amazon, is one of the risk areas.

Artisanal and small-scale gold mining (ASM) is the anthropogenic activity that most contributes to atmospheric mercury emissions.[2] Gold mining, particularly in ASM, predominantly employs mercury amalgamation due to its cost-effectiveness and efficiency. The amalgamation method allows gold extraction with relatively high efficiency, recovering between 30% and 90% of the gold, depending on the ore type and processing conditions.[3] [4] However, mercury use is a major contributor to global mercury pollution, and estimates suggest that ASM activities release hundreds of tons of mercury into the environment annually.[5] [6] Thus, amalgamation poses significant environmental and health risks.[4] [6]

Mercury is emitted mainly in elemental form (Hg0), which can be oxidized and deposited in various ecosystems, including aquatic and terrestrial environments.[7] [8] Thus, mercury in the environment exists mainly in three forms: elemental mercury (Hg0), inorganic mercury (HgII) and organic mercury, predominantly methylmercury (MeHg).[9]

Studies on mercury contamination in the Beni River basin in Bolivia have been conducted at different periods. This review systematized and evaluated historical and spatial data from 1995 to June 2024 on mercury contamination in water, sediments, and people.

REVIEW

A bibliographic review of articles and documents from scientific journals was conducted, adapting established methodologies from similar studies conducted in other regions[10] [11]. Academic sources, gray literature, official information (government entities, international organizations), and specialized data sources were used, using the keywords "mercury in Bolivia," "mercury contamination in the Amazon," and "small-scale mining" in both English and Spanish. Search sources included Google Scholar, PubMed, Scielo, Research Gate, Scopus, Web Science, the repository of the Universidad Mayor de San Andrés (UMSA), and other sources such as the websites of the French Institute for Development Research (IRD) and the Central de Pueblos Indígenas de La Paz (CPILAB), among others. These documents totaled 200 copies.

From the articles/documents obtained in the search, an initial selection was made of those that included the upper Madera River basin in Bolivia. Thirty-two documents were obtained. The articles/documents were subsequently classified into: Beni River basin, Madre de Dios-Orthon River basin, and Iténez River basin.

Articles/documents from the Beni River basin were selected and formed into the bibliographic database. A database was then constructed with a selection of variables considered relevant to mercury contamination (Database I). Articles were excluded based on the following criteria: articles without information on the sampling year (two were eliminated), and articles quantifying mercury in plants, fish, or other animals.

The articles/documents in database I, which include information from references 42 to 59, were classified into three groups: water, sediments, and people. Some documents belong to more than one of these groups. In each case, information related to mercury quantification was obtained: mean, minimum, maximum, sample characteristics, location, date, month, and relevant variables according to the group.

Based on database I, a meta-analytic study was conducted, involving the selection of common variables, the classification of variables and data, and the selection of existing data to construct a database with specific variables to be used in the analysis (database II). In certain cases, the average value between the minimum and maximum was taken, with the high bias that this entails.

The following classification was made for each group:

• Seasonal variable: The months of April, May, June, July, August, September, and October were classified as the dry season, and the months of November, December, January, February, and March as the wet season. Documents lacking month information or including both periods were classified as indeterminate seasons.

• Zonal variable: Two zones were differentiated within the total area of the Beni River basin, as shown in Figure 1.

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Zone A - From the Coroico River to the city of Rurrenabaque.

Zone B - Downstream from the city of Rurrenabaque to the city of Riberalta.

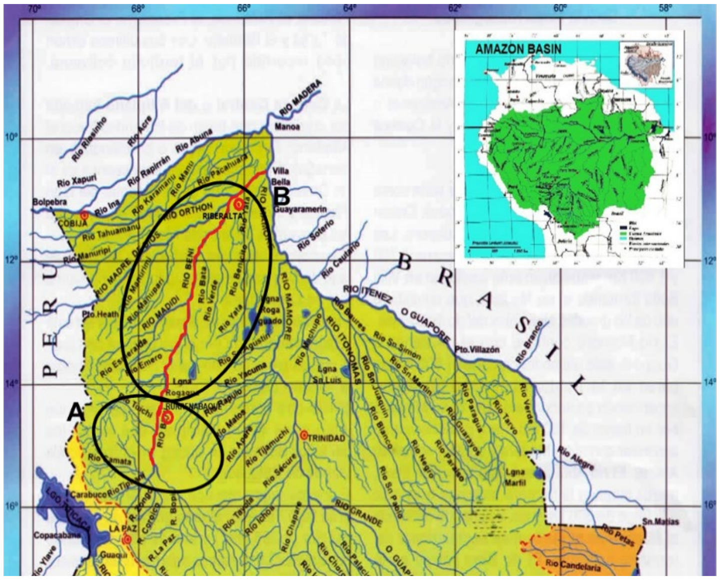


Figure 1: Definition of study areas (Map Modification[12])

In Article 13[13] mercury in water data were presented as mercury flux. The approximate value of total mercury was calculated using the area and discharge of the river to which the data pertain. Where discharge and area data were unavailable, the information was excluded.

For data analysis, R Studio was used as an integrated development environment for the R programming language.

RESULTS AND DISCUSSION

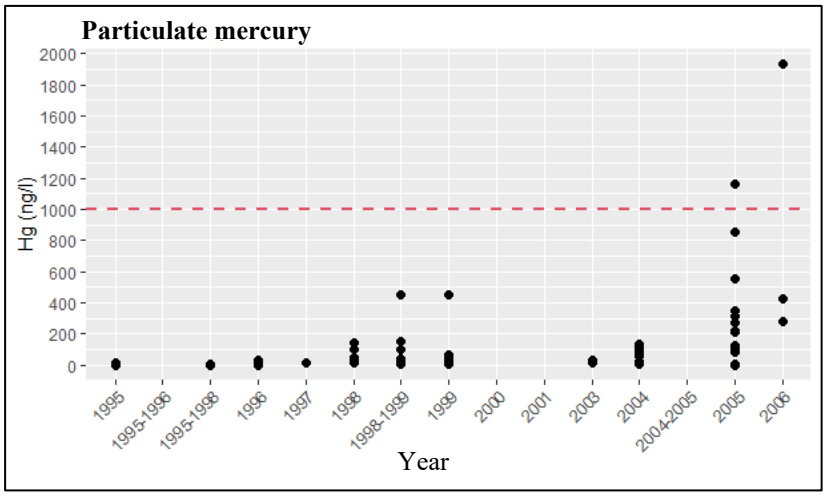
Mercury in water

Mercury in aquatic environments occurs in a variety of chemical forms, thus having a high potential for toxicity. The general oxidation of elemental mercury (Hg^0) to divalent mercury (Hg^{2+}), which is more soluble in water, can occur through photochemical reactions. Inorganic mercury (Hg^{2+}) can bind to sediments and form complexes with organic matter, impacting its mobility and bioavailability.[14 15]

Mercury can undergo methylation, a process that converts inorganic mercury to methylmercury (MeHg), the most toxic and bioaccumulative form.[16 17] Mercury speciation can vary spatially and temporally, influenced by local environmental conditions.[18] Recently deposited, transported, or mineralized Hg tends to be more reactive to methylation and bioaccumulation than long-standing "old" Hg in sediments and soil because it is a highly sorbed, crystalline, and microstructured species.[19]

According to the collected data, as seen in Figure 2, no studies on mercury in water were recorded prior to 1995. Additionally, existing analyses were not conducted consecutively, and in some cases, data were reported for ranges of years rather than a specific year. No data on particulate mercury were available after 2006, and no studies on total mercury were found after 2001. Regarding dissolved mercury, it was decided not to analyze the data in the present study because the information only goes back to 1999.

The Bolivian Regulation on Water Pollution under the Environmental Law, Supreme Decree No. 24176 of 1995,[20] establishes a maximum limit of 1000 ng/l for total mercury in water for all uses, including physical contact and food production. Figure 3 shows the maximum allowable limit for total mercury in red. This limit shows that, even without quantifying dissolved mercury in water, in 2005 and 2006, values exceeded the maximum allowable value based on particulate mercury data.



Unmarked years indicate inexistant report
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Figure 2. **Particulate mercury** in the Beni River basin.

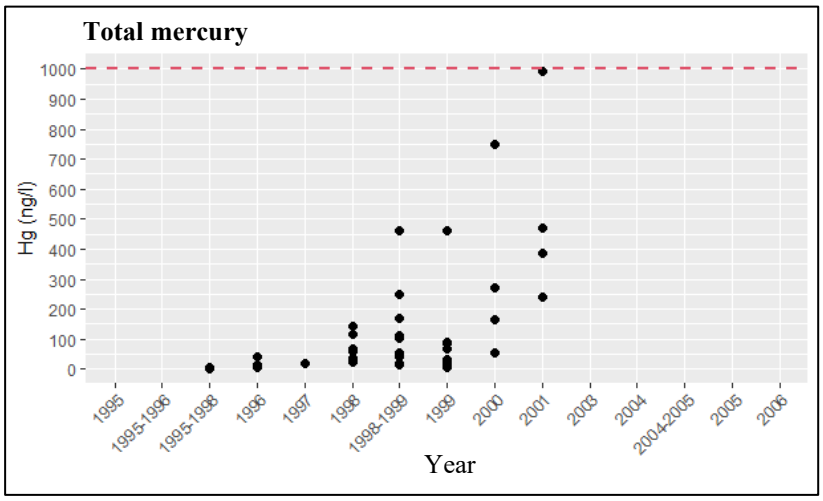

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Figure 3. **Total mercury** in the Beni River basin.

Table 1 shows the average particulate mercury and total mercury, per year.

Table 1. Average mercury in water per year

Year	Mercury in particles (ng/l)	Total Mercury (ng/l)
1995	10.17	NE
1995-1996	NE	NE
1995-1998	2.42	4.91
1996	9.65	12.31
1997	16.53	21.19
1998	59.40	72.66

(Table 1.)		
1998-1999	87.13	114.74
1999	68.14	80.20
2000	NE	310.20
2001	NE	522.53
2003	25.12	NE
2004	54.19	NE
2004-2005	NE	NE
2005	290.65	NE
2006	880.07	NE

NE: non-existent data
Source: Source: Author's preparation on bibliographic information indicated in References

Increases of over 100% in total mercury were observed between 1996 and 1997. Between 1997 and 1998, the increase reached 343% (from 21.19 ng/l to 72.66 ng/l). However, one data point was available in 1997, and seven in 1998. The amount of data quantified in 1997 makes it difficult to make a comparison that would lead to more accurate conclusions.

For particulate mercury, average values increased from 16.53 ng/l in 1997 to 59.4 ng/l in 1998, showing an increase of 359%.

The data show sustained growth over the years up to the period 1998-1999. In 1999, an apparent reduction in the concentration of mercury in water was observed. In subsequent years, the concentration increased again, reaching an average of 522.53 ng/l of total mercury in 2001 and 880.07 ng/l of particulate mercury in 2006. These data reflect a ratio of 1:106 for total mercury and 1:86 for particulate mercury when comparing the latest available data with the earliest available data for each of the two variables.

The variable "particulate mercury" is the one with the largest amount of data and the most recent records, and is therefore used as the evaluation variable in the following graphs and analyses.

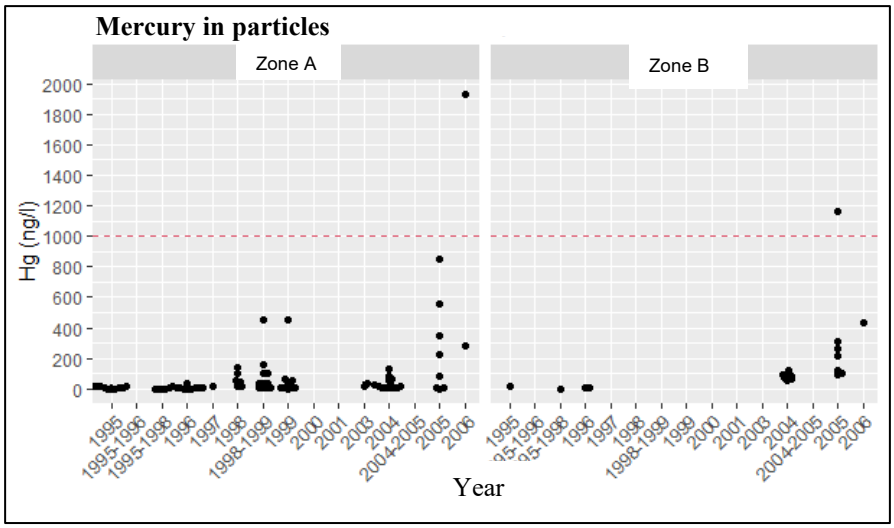

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Figure 4. Quantification of **mercury in particles**, by zone

Figure 4 shows the particulate mercury values distributed by zone. The average in Zone B is 171.12 ng/l, significantly higher than in Zone A (89.62 ng/l). Zone B has a smaller amount of data (19) compared to 80 in Zone A, which in

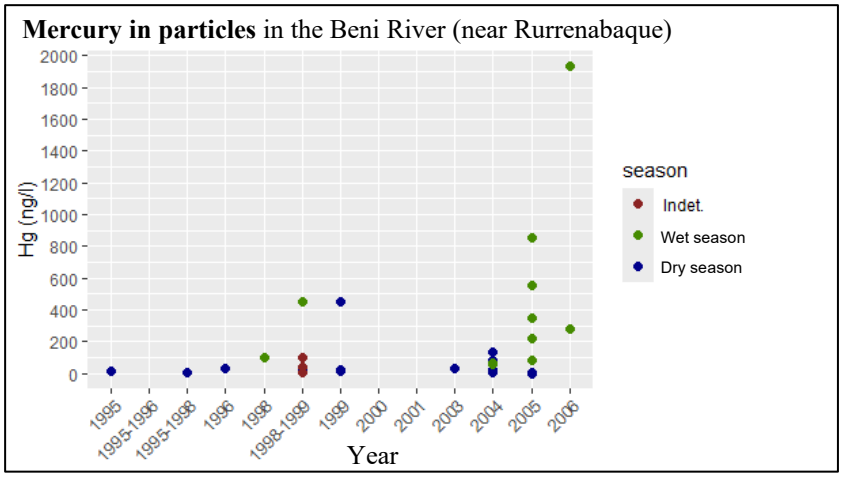
turn has a higher concentration of data in the last sampling years (2004 to 2006), which makes definitive conclusions difficult.

The highest mercury concentrations (greater than 1000 ng/l) are found near Rurrenabaque and Riberalta, both on the Beni River, considered key monitoring sites. With 31 and 19 data points, respectively, these locations present the largest amount of data. To better understand the trend and possible causes of the increase in mercury concentrations over the years in both areas, these two monitoring sites were analyzed in greater detail.

There are some locations with limited data over time, which limits our understanding of their situation. This is the case of the Beni River near Cachuela Esperanza, with one data point from 1996, and the Alto Beni, Coroico (Teoponte), Quiquibey, and Yata rivers, which have two data points over the years.

Beni River – Near Rurrenabaque

Figure 5 classifies the 31 particulate mercury data points in the Beni River near Rurrenabaque according to sampling season. Lower mercury concentrations would be expected during the wet season due to the river's higher flow (average annual flows range from 2,663 m3/s in the dry season to 898.8 m3/s in the wet season);[21] however, the data do not reflect the expected situation. In the few cases where data are available from both seasons (2004 and 2005), lower concentrations are not observed during the wet season, indicating the influence of external factors that could be linked to the flow of pollution from sub-basins with intense mining activity.



Source: Author's preparation on bibliographic information indicated in References

Figure 5. Quantification of **mercury in particles** in the Beni River (near Rurrenabaque)

The increase in the average concentration of mercury in particles has a ratio of 1:65 between 1995 and 2006 as shown in Table 2. The average value in 2006 exceeds the maximum permitted limit, reaching 1105.27 ng/l.

Table 2. Average mercury particulate matter in the Beni River (near Rurrenabaque)

Year	Mercury in particles (ng/l)
1995	16.90
1995-1998	2.53
1996	36.00
1998	101.09
1998-1999	118.01
1999	162.59
2003	32.74
2004	47.87

(Table 2.)	
2005	296.37
2006	1105.27

Source: Source: Author's preparation on bibliographic information indicated in References

Beni River – Near Riberalta

Figure 6 classifies 19 particulate mercury data points in the Beni River near Riberalta according to sampling season. Although there are insufficient data to establish a clear pattern, the trend based on the 2004, 2005, and 2006 data suggests that during the wet season, an external factor prevents the mercury concentration from decreasing with increasing flow. The average annual flow rate of the Beni River near Riberalta is 3,118 m3/s during the wet season and 1,581 m3/s during the dry season.[21]

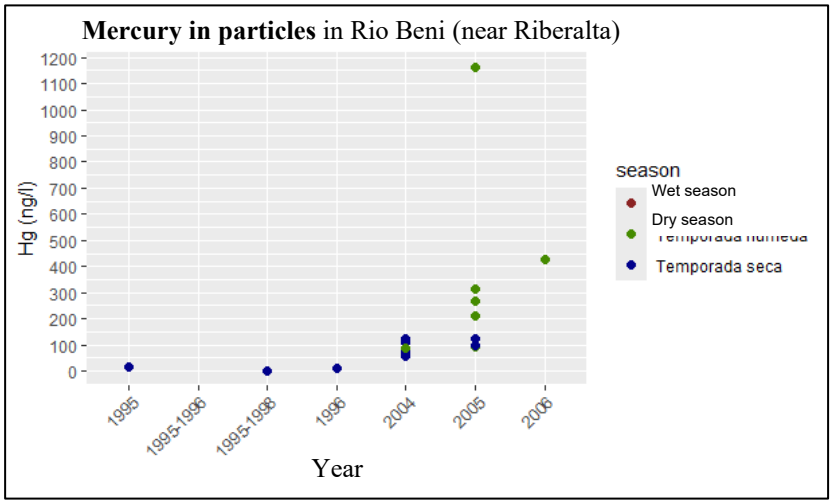


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Figure 6. Quantification of **mercury in particles** in Rio Beni (near Riberalta)

The ratio of mercury to particulate matter between 1995 and 2006, the first and last years with available data, is 1:32 as shown in Table 3. This significantly high difference suggests, as in the Beni River near Rurrenabaque, the influence of external factors.

Table 3. Average mercury particulate matter in Rio Beni (near Riberalta)

Year	Mercury in particles (ng/l)
1995	13.51
1995-1998	1.76
1996	12.25
2004	85.06
2005	324.92
2006	429.68

Source: Source: Author's preparation on bibliographic information indicated in References

Mercury in sediments

Sediments are sand and minerals washed from the soil into water. They accumulate in reservoirs, rivers, and harbors.[22] If mercury concentrations in the pore waters of sediments are significantly higher than in the overlying water column, this suggests that the sediment serves as a reservoir for mercury that can be released back into the water under certain environmental conditions.[23] [24] [25] This release can lead to increased levels of mercury in the water column, contributing to its bioaccumulation in aquatic organisms.[26]

Sediment characterization requires decisions about the sampling points and depths in the river. In the literature reviewed, many studies do not specify this variable, while others mention sampling at depths of 10 cm in the case of rivers and between 10 and 30 cm in the case of lakes. Due to the lack of this information in most studies or its variability, sampling depth will not be considered in the present analysis.

Regarding the maximum permissible limits for mercury in sediments, there is no established value in the Bolivian standard. At the international level, there is also no defined limit, and reference values and sediment quality criteria based on toxicity studies and risk levels are used. In this regard, the available criteria, although not adapted to the characteristics of the water bodies studied, are used as a reference.

The CCME (Canadian Council of Ministers of the Environment) has established threshold values for assessing ecological risks.[27] The methodological basis of these values is based on the work of Long et al., 1995.[28] The European Union and the EPA (United States Environmental Protection Agency) use reference values similar to those of Canada in different regulatory contexts.[29] The reference values used as guidelines for assessing ecological risks are:

o TEL (Threshold Effect Level): 0.17 µg/g

o PEL (Probable Effect Level): 0.486 µg/g

TEL is the level below which adverse effects are unlikely to occur, while PEL is the level above which adverse effects are more likely.

Figure 7 presents the mercury concentration in sediments over the years in the Beni River basin. The data set consists of 39 records from 1995 to 2004-2005. The year with the most data is 1998, with 14 records, and an extremely high value is observed in 1999. The last years with available data, 2003 and 2004-2005, have only four and three records, respectively, which influences the average.

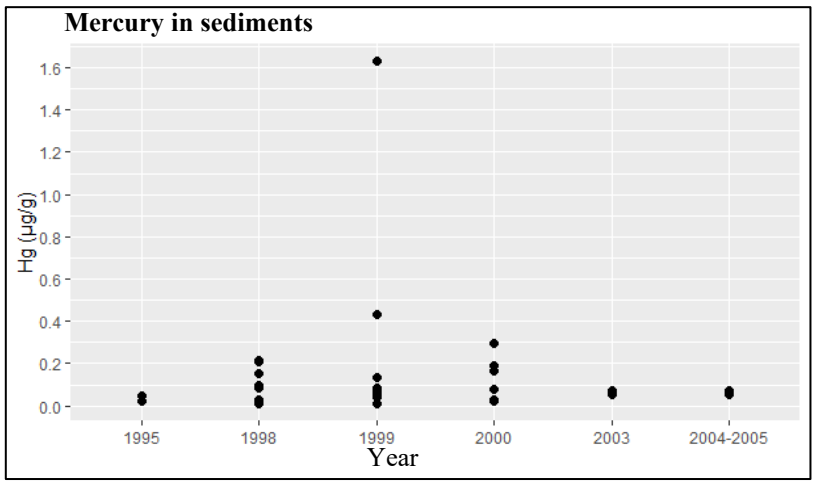

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Figure 7. Quantification of **mercury in sediments**.

Table 4. Average mercury quantification in sediments

Year	Hg (µg/g)
1995	0.033
1998	0.073
1999	0.306
2000	0.126
2003	0.064
2004-2005	0.066

Source: Author's preparation on bibliographic information indicated in References

A comparison of Figure 7 with the reference limits of 0.17 µg/g (TEL) and 0.486 µg/g (PEL) shows that five values exceed the TEL reference limit in 1998 (2 data), 1999 (2 data) and 2000 (1 data). In 1999, one value exceeded the PEL by 335%, which would indicate a significant ecological risk.

When comparing the annual averages (Table 4) with the reference limits, it is observed that in 1999 the concentration of mercury in sediments exceeded the TEL limit by 180%.

Figure 7 allows analysis by location and relates the concentration of mercury in sediments per year with the sampling location.

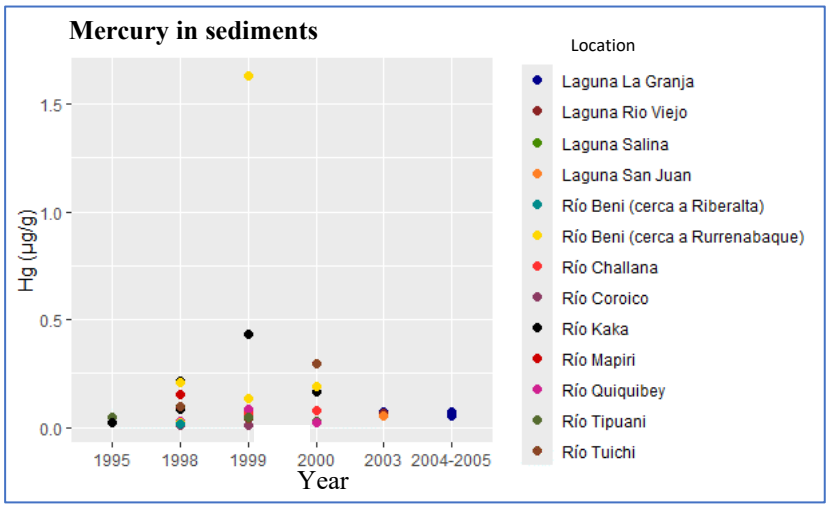

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Figure 7. Quantification of **mercury in sediments** by location

In the Beni River near Riberalta (Zone B), only one data point was available in 1998, with a concentration of 0.015 µg/g. Due to the scarcity of information in this area, the following analyses will focus on Zone A, where the annual averages are shown in Table 5.

Table 5. Average mercury quantification in sediments in zone A

Year	Hg (µg/g)
1995	0.033
1998	0.078
1999	0.306
2000	0.126
2003	0.064
2004-2005	0.066

Source: Author's preparation on bibliographic information indicated in References

The highest recorded value was found in the Beni River near Rurrenabaque, with 1.63 µg/g in 1999, which is 959% above the TEL reference limit. Other high values were found in the Kaka River in 1998 (0.214 µg/g) and 1999 (0.433 µg/g). The Beni River near Rurrenabaque was repeatedly exceeded in 1998 (0.21 µg/g) and 2000 (0.191 µg/g), indicating a risk of mercury in the sediments of these areas.

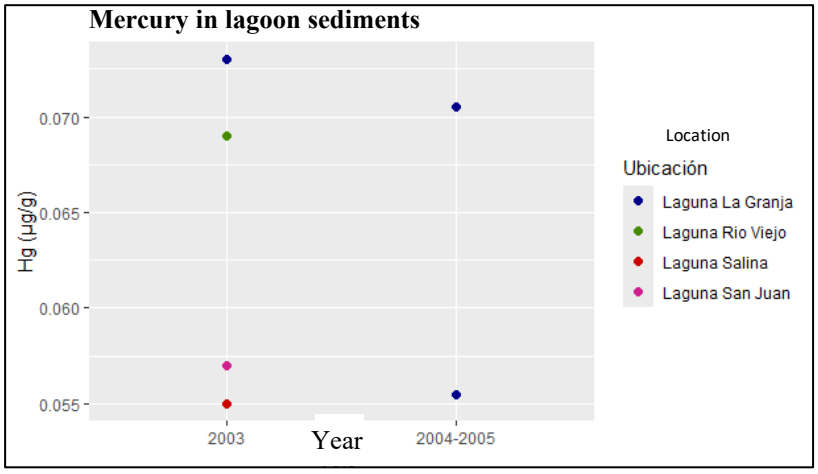
In the Kaka River, a value of 0.021 µg/g was recorded in 1995, and in 1998, two values, 0.088 µg/g and 0.214 µg/g (average of 0.151 µg/g), were obtained in the dry and wet seasons, respectively. This trend suggests that mercury

concentrations tend to be higher during the wet season, as is also the case with the mercury data in water. The latest data available for the Kaka River are from 2000, with a value of 0.168 µg/g, close to the TEL limit.

In the Beni River near Rurrenabaque, the first data are from 1998 (0.022 µg/g and 0.21 µg/g in the dry and wet seasons, respectively), with an average of 0.116 µg/g. In 1999, two values were recorded, 0.134 µg/g and 1.63 µg/g, both in the dry season, resulting in an annual average of 0.882 µg/g, exceeding the PEL limit by 519%. Finally, in 2000, a value of 0.19 µg/g was reported in the wet season, exceeding the TEL limit by 112%.

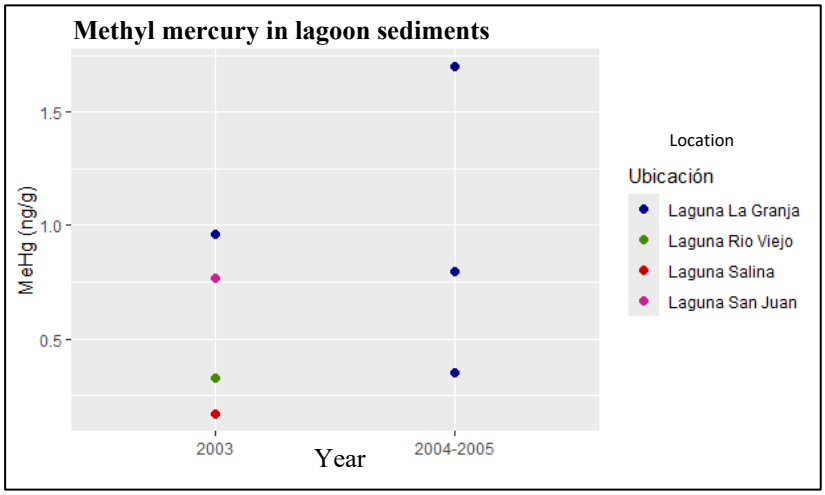
The latest data on the sites with the highest mercury concentrations in sediments were obtained in 2000. After this period, the available information was collected from gaps, which could explain the lower averages observed in 2003 and 2004-2005.The latest data on the sites with the highest mercury concentrations in sediments were obtained in 2000. After this period, the available information was collected from gaps, which could explain the lower averages observed in 2003 and 2004-2005.

Los valores de mercurio en lagunas en la Zona A del río Beni presentan un promedio de 0.064 µg/g en 2003 y 0.066 µg/g en el periodo 2004-2005. La laguna con mayor concentración es La Granja, con un valor de 0.073 µg/g en 2003 (Figura 8).



Source: Author's preparation on bibliographic information indicated in References

Figure 8. Quantification of **mercury in lagoon sediments**



Source: Author's preparation on bibliographic information indicated in References

Figure 9. Quantification of **methyl mercury in lagoon sediments**

Information on the concentration of methylmercury in the sediments of these lagoons is available, as shown in Figure 9. Although the quantification of total mercury in sediments includes methylmercury, it is essential to carry out specific quantification of the latter to identify differentiating characteristics of each site.

The average methylmercury level in the Zone A lagoons was 0.56 ng/g in 2003 and 0.95 ng/g during 2004-2005. Despite the proximity of the lagoons, each has different characteristics.

La Granja Lagoon had a methylmercury concentration of 0.96 ng/g in 2003 and an average of 0.95 ng/g in 2004-2005. The 2004-2005 value corresponds to the dry season, while the other two values were recorded during the wet season. La Granja Lagoon had the highest concentrations of methylmercury and total mercury (Figures 8 and 9), suggesting the following conditions:

• Increased microbial activity: In the anoxic sediments of lagoons, bacteria such as sulfate-reducing bacteria can transform inorganic mercury into methylmercury.[30] This methylation process is more efficient in environments with low oxygen concentrations, which could be the case in La Granja Lagoon.

• Inorganic mercury availability: A higher inorganic mercury load in the ecosystem can serve as a raw material for methylation. This is consistent with the fact that, while La Granja Lagoon has higher total mercury concentrations, the difference with other lagoons is less significant in methylmercury, suggesting that in other lagoons, much of the mercury remains as inorganic mercury because microbial activity may be lower.

• Water chemical conditions: A low pH could increase the availability of inorganic mercury for methylation.

Mercury in people

The environmental dynamics of mercury, particularly its transformation into methylmercury, play a crucial role in the human exposure pathway through fish consumption. [31] [32] The bioaccumulation process results in fish, especially those at higher levels of the food chain, containing significantly higher levels of mercury.[33] Evidence indicates that mercury concentrations in fish can remain elevated for years, even after reduced atmospheric deposition.[34] [35] This bioaccumulation is influenced by several factors such as fish type, size, and the level of pollution in their habitat.[36] [37]

Since the 1950s, mercury quantification in humans has been primarily performed through hair analysis, which is the most widely used method for assessing chronic and long-term exposure to methylmercury, the most common form of organic mercury to which humans are exposed. The ease of collection and hair's ability to accumulate mercury in a stable manner make it a valuable tool for population monitoring.[38]

Various public health agencies and toxicological studies have established reference limits for mercury exposure measured in hair:

• 1-2 µg/g (ppm): This is considered a normal level of mercury in hair for the general population.[39]

• 1 µg/g: The World Health Organization (WHO), through the Pan American Health Organization (PAHO), has established this value as a provisional reference level for pregnant women. Although other values have been used in practice, this serves as an important guideline for a sensitive group.[40]

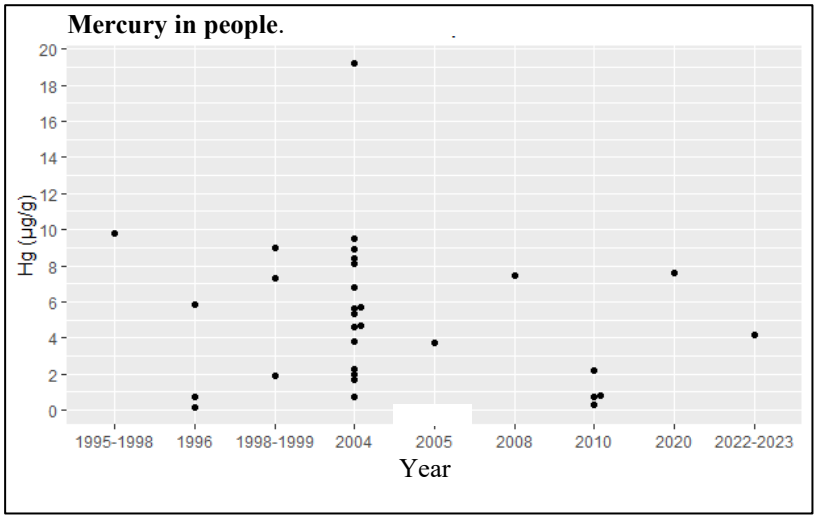
• 2 µg/g: This value is used as a reference level that warrants monitoring to prevent further increases. This is a range that expresses sensitivity. Health Canada refers to this concentration for sensitive groups or asymptomatic patients.[41] [39]

• 10 µg/g: This level indicates high exposure and requires immediate action. People who consume fish one or more times per day may have mercury levels in their hair above this level. Health Canada has used this value in research studies on Indigenous populations who consume large amounts of fish, but clarifies that it is a research reference value and not an official toxicity limit.

When mercury quantification is performed in urine for the occupationally exposed population, the limit is usually less than 5 µg/g creatinine.[40]

Of the reported data, one of the studies, corresponding to the year 1989, analyzes mercury in urine and reports three data from different locations in Zone A. The reported mean value of 0.64 µg/g of creatinine indicates that at the time of sampling the population of Zone A was within the range of less than 5 µg/g of creatinine.

Most of the data identified in the literature refer to mercury in hair, with records from 1995 to 2023, as shown in Figure 10.



Source: Author's preparation on bibliographic information indicated in References

Figure 10. Quantification of **mercury in people**.

In 2004, one mercury level in hair reached 19.2 µg/g, higher than 10 µg/g. Between 1995 and 1998, the level was close to the limit, reaching 9.8 µg/g.

In 23 of the 34 years for which non-consecutive data are available, hair mercury concentrations reached or exceeded 2 µg/g, a reference value for surveillance that indicates an alert and a need for caution.

Table 6. Average mercury quantification in people

Year	Hg (µg/g)
1995-1998	9.8
1996	
1998-1999	6.1
2004	6.1
2005	3.8
2008	7.5
2010	1.0
2020	7.6
2022-2023	4.1

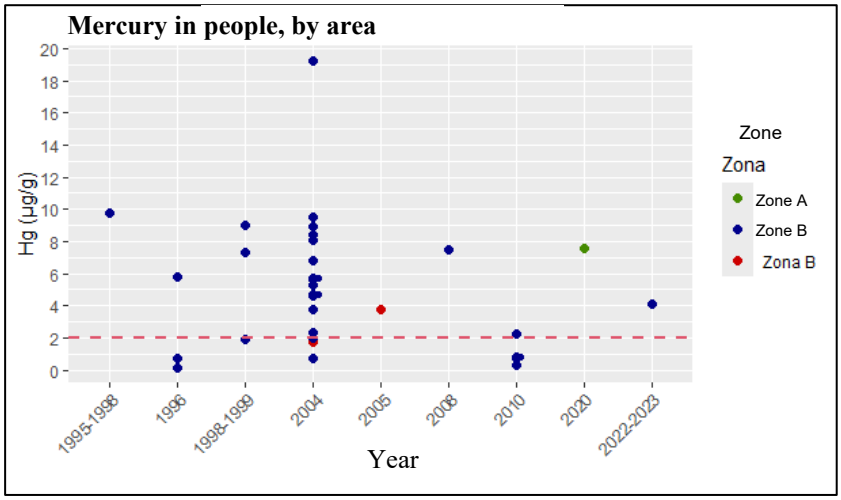
Source: Author's preparation on bibliographic information indicated in References

Of the annual averages for mercury in hair (Table 6), only one value, from 2010, falls below the 2 µg/g limit. Data variability may be due to factors such as the specific sampling location, the population group, dietary habits, and the population's main activity.

As shown in Figure 11, the data for Zone A, which has the most information, are temporally dispersed. Data are not available for periods such as 2000 to 2003, 2005 to 2007, and 2011 to 2019.

Of the 28 data points from Zone A, 15 were from 2004, with an average of 6.4 µg/g, more than three times the limit of 2 µg/g.

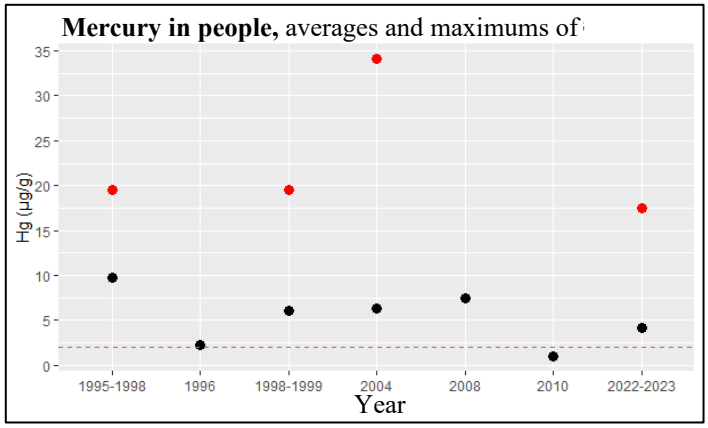
Some articles reviewed also report maximum values. This information would be crucial for taking specific measures. Figure 12 and Table 7 show the maximum annual values along with the annual average values.



Source: Author's preparation on bibliographic information indicated in References
"indet.": means that the data obtained is from a bibliographic source that reports the average within A and B. It prevents its assignment to a zone.

Figure 11. Quantification of **mercury in people**, by area

Of the 28 data points from Zone A, 15 were from 2004, with an average of 6.4 µg/g, more than three times the limit of 2 µg/g.



Source: Author's preparation on bibliographic information indicated in References
In black the average values, in red the maximum values

Figure 12. Averages and maximums of **mercury in people**

Table 7. Averages and maximums of mercury in people

Año	Valor Max (µg/g)
1995-1998	19.52
1998-1999	19.5
2004	34.1
2022-2023	17.5

Source: Author's preparation on bibliographic information indicated in References

The maximum values shown in Figure 12 and Table 7 indicate a high incidence in at least one of the samples. The ratios between the maximum values and the 2 µg/g limit range from 1:8.8 to 1:17. Compared with the 10 µg/g limit, the ratios range from 1:1.8 to 1:3.4.

CONCLUSIONS

According to the analysis of mercury concentrations in water, sediments, and people based on bibliographic information from 1995 to June 2024, it was determined that Zone A, from the Coroico River to the town of Rurrenabaque, has the largest amount of data. Zone B, from the town of Rurrenabaque (excluding it) to the town of Riberalta, has the smallest amount of data and fewer years of information. In neither case is there consecutive information over time.

The most recent data, corresponding to the concentration of mercury in human hair (2022-2023), is 4 µg/g, a value that exceeds the internationally accepted reference limit for monitoring (2 µg/g).[39] This value suggests contamination in water, sediments and fish in recent years, since the measurement of mercury in humans is the last link in the food chain and allows us to have an insight into the situation in water and fish mainly. In the case of mercury in water, the last recorded value was relative to mercury in particles in 2006 (880.07 ng/g) and in sediments it was from the period 2004-2005 (0.066 ng/g).

The observed trends in mercury concentrations in water particles, focused on key locations both in terms of geographic location and the availability of the largest amount of data, point to external and anthropogenic factors influencing the high mercury concentrations. The wet season stands out as the season with the highest concentrations, and the existence of incident factors such as mining and forest burning could be inferred as drivers of these concentrations.

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