Malaria: The Silent Crisis in Alto Alegre, Roraima and the Specter of Mining in the Yanomami Indigenous Land

Malária: A crise silenciosa em Alto Alegre, Roraima e o fantasma do garimpo na Terra Indígena Yanomami

Malaria: La crisis silenciosa en Alto Alegre, Roraima y el fantasma de la minería en la Tierra Indígena Yanomami

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RESUMO

Objetivo: analisar a evolução dos casos de malária em Roraima, principalmente no município de Alto Alegre, estratificado por aglomerações por área geográfica habitada - rural, urbana e área indígena no período de 2013 a 2022. **Método:** Estudo ecológico do tipo série temporal baseado em dados secundários dos casos confirmados de malária em Roraima, no período de 2013 a 2022. **Resultados:** nesse período foram confirmados 72.828 casos de malária em Roraima, dos quais 78,0% foram por Plasmodium vivax. Além disso, a maior parte dos casos se concentrou no município de Alto Alegre, correspondendo a 41,1%. Portanto, este foi o município que mais produziu malária procedente de garimpo, apesar de existirem outros que registraram aumento da doença nesse período. **Conclusão:** assim, os municípios de Alto Alegre, Amajari, Caracaraí, Iracema e Mucajaí, juntos respondem por 77.8% de toda malária produzida em Roraima. Estes municípios fazem parte da rota do garimpo ilegal na terra indígena Yanomami.
Descritores: Malária; Mineração; Povo Yanomami.

ABSTRACT

Objective: analyze the evolution of malaria cases in Roraima, especially in the municipality of Alto Alegre, stratified by geographical areas of habitation - rural, urban, and indigenous areas, from 2013 to 2022. Method: A time series ecological study based on secondary data of confirmed malaria cases in Roraima from 2013 to 2022. Results:During this period, 72,828 cases of malaria were confirmed in Roraima, of which 78.0% were due to Plasmodium vivax. Furthermore, the majority of cases were concentrated in the municipality of Alto Alegre, accounting for 41.1%. Therefore, this was the municipality that produced the most malaria from mining activities, despite others experiencing an increase in the disease during this period. Conclusion: Thus, the municipalities of Alto Alegre, Amajari, Caracaraí, Iracema, and Mucajaí together accounted for 77.8% of all malaria cases produced in Roraima. These municipalities are part of the illegal mining route within the Yanomami indigenous land.
Descriptores: Malaria; Mining; Yanomami People.

RESUMEN

Objetivo: analizar la evolución de los casos de malaria en Roraima, principalmente en el municipio de Alto Alegre, marcado por aglomeraciones por área geográfica habitada - rural, urbana, en el área indígena en el período comprendido desde 2013 hasta 2022. Método: Estudio ecológico de tipo serie temporal basado en datos secundarios de los casos confirmados de malaria en Roraima, en el periodo de 2013 hasta 2022. Resultados: Durante este periodo fueron confirmados 72.828 casos de malaria en Roraima, de los cuales 78,0% correspondieron a Plasmodium Vivax. Además, la mayor parte de los casos estaban concentrados en el municipio de Alto Alegre, correspondiendo a 41,1%. Por lo tanto, este fue el condado que más produjo malaria proveniente de la minería, a pesar de existir otros que registraron aumentos de la enfermedad durante este periodo. Conclusión: Siendo así, los condados de Alto Alegre, Amajari, Caracaraí, Iracema y Mucajaí, juntos representan el 77.8% de toda la malaria existente en Roraima. Estos condados hacen parte de la ruta de minería ilegal en tierras indígenas Yanomami.
Descriptores: Malária; Minería; Pueblo Yanomami

ORIGINAL

Introduction

Malaria is a parasitic infectious disease of vectorial transmission of worldwide distribution, especially between countries located in the tropical and subtropical belt of the planet. It is an endemic disease typical of regions with a low human development index and with potential for transmission due to multiple factors: environmental, climatic, presence of water collection, habitat of various vectors, in addition to social aspects, determinants for the process of transmission and illness of the individual. For this reason, it is considered a disease of multifactorial cause – of a social and occupational nature – given that man's exposure to unhealthy activities is associated with his survival.[1]

Mining is a good example of an unhealthy place to the extent that it reveals several facets of the social and occupational aspect of work, a place that is difficult to access, often represented by violence, the endemicity of the disease and the precariousness of work typified by occupational diseases. Generally, mining is associated with several vector-borne diseases, including malaria, which is considered an occupational disease according to Ordinance No. 1,339 of 1999 of the Ministry of Health.[2,3]

Historically, mining activities have been responsible for the large flow of people in the state of Roraima, since since the 1980s there has been an increase (N= 13,590) of malaria in the region.[4] Thus, the form of occupation by the state, especially in the capital, has produced a spatial dynamic around mining. This dynamic established in this space reveals, among other determinants, the health (malaria, mercury), the social with the social and environmental ills (pollution of the rivers, deforestation) and illness of the native peoples, especially the Yanomami.

Until the mid-1960s, the Yanomami lived in virtual isolation, with their first cases of the disease reported due to initial contact with non-indigenous peoples. Until the year 1980, malaria was still limited only to the peripheral areas of the Yanomami reserve, which were where some contacts with the rural area of the state occurred, resulting in imported cases that were soon introduced among the indigenous people.5 Specifically in 1987, there was a large invasion of more than 40,000 miners in the region, mainly in Yanomami land. part of its territorial extension is located in the state of Roraima, thus resulting in the establishment of autochthonous transmission of malaria among this people. With these events, the disease eventually spread to the most isolated communities, causing serious outbreaks. Without effective care, this health condition resulted in a high rate of morbidity and mortality, generating a serious health problem for this population identified by the Special Indigenous Health District that cares for the Yanomami.[6]

In addition, in 2021, there was a significant increase of 46% in the extent of land affected by mining activity, resulting in the destruction of 1,038 hectares,[7] and in recent years 862 illegal mines have been cataloged in the state, most of which are located on Yanomami indigenous lands, a fact that has promoted an extraordinary increase in the flow of miners in this region.[8] In this way, the circulation of these individuals in a receptive environment where very close contact with the indigenous people is established can generate health problems that are difficult to solve, considering the logistical, geographical and cultural complexity of the Yanomami people.

The municipality of Alto Alegre, geographically, is an important center for the concentration, maintenance and flow of products extracted from the various illegal mining points located on Yanomami land, the region with the highest occurrence of malaria in Roraima, especially in recent years. Therefore, it is important to analyze the evolution of malaria cases in Roraima, especially in the municipality of Alto Alegre, from 2013 to 2022.

Method

This is an ecological time series study based on secondary data from confirmed cases of malaria in Roraima from 2013 to 2022. Roraima is the northernmost state in Brazil, with a territorial extension of 223,644.530 km² and an estimated population of 652,713 inhabitants in 2021, of which 55,922 declared themselves indigenous in the last national census. Alto Alegre, a municipality located in the northern region of Roraima, has the largest area of indigenous lands of the Yanomami peoples, covering more than 72% of the 25,454.297 km² of territorial extension of the municipality. The estimated population of Alto Alegre was 15,249 inhabitants in 2021.[9]

Figure 1- Municipalities of Roraima in the area of Yanomami indigenous lands. Roraima, 2023.
Source: Portal Roraima 1.

Data on confirmed cases of malaria that occurred in Roraima from 2013 to 2022 were extracted from the Epidemiological Surveillance Information System – Malaria (SIVEP-Malaria), of the Health and Environment Surveillance Secretariat of the Ministry of Health.[6] Regarding the population estimates for incidence calculations, census data obtained from the Brazilian Institute of Geography and Statistics were used.[9]

Initially, the absolute and relative frequencies of malaria cases were calculated according to the municipalities, dividing the number of cases in each municipality by the total number of cases in the state. The Annual Parasite

Incidence (IPA) was also calculated by dividing the total number of reported cases by the total population estimated by municipality and for the state, multiplied by one thousand in the year. In Brazil, in endemic areas located in the Amazon, according to the Ministry of Health, the IPA can be classified according to risk levels expressed as: low (<10.0/thousand inhabitants), medium (10.0-49.9/thousand inhabitants) and high (≥50.0/thousand inhabitants).[1,6,10]

Sequentially, the temporal trend of malaria incidence per 1000 inhabitants in the municipality of Alto Alegre and for the state of Roraima for each year of analysis was calculated, considering the absolute number of confirmed cases in the numerator and the population in the denominator. Incidence rates were logarithmized (log10) in order to stabilize variance over time.

Finally, the Prais-Winsten autoregression method was applied to classify the temporal trend of malaria incidence as increasing, decreasing or stationary for Roraima and the municipality of Alto Alegre. The percentage of annual variation with respective 95% confidence intervals (95%CI) was also calculated in cases of increasing or decreasing temporal trend. For Alto Alegre, the temporal trend of incidence was also analyzed according to the type of malaria confirmed (P. vivax and P. falciparum).

The calculations of absolute and relative frequencies and the IPA were made in Microsoft Office Excel spreadsheets. The graphs of the distribution of cases and the estimated rates over the time series were produced using the RStudio software.

The study was approved by the Research Ethics Committee of the Federal University of Roraima, with a Certificate of Presentation for Ethical Appraisal (CAAE), opinion No. 4,784,311

Results and Discussion

The data analysis followed the same division defined by SIVEP-Malaria stratified by rural, urban, indigenous and mining zones, in the municipality of Alto Alegre, which in turn houses in its geographic space native peoples distributed in four ethnic groups: Wapichana, Yanomami, Ye'kwana and Macuxi, which together add up to 13,916 indigenous people (90%) total population of the municipality against 1,464 (10%) non-indigenous people. Among the indigenous population, the Yanomami people constitute the largest ethnic group in this municipality. Regarding the demographic aspect, the majority of Alto Alegre is inhabited by native populations, especially the Yanomami. Geographically, they are the people who live farther away and have the greatest difficulty of access, a fact, however, that does not constitute an impediment to the increase in the circulation of individuals in search of illegal mining on their lands.[8]

This characteristic of Alto Alegre needs to be seen as a great challenge, considering that most malaria comes from indigenous areas. This condition has been enhancing local transmission, including urban transmission, given the mobility of non-indigenous people from mining regions, which can be a major public health problem for the municipality. In Yanomami land, diagnosis and treatment are directed only to indigenous people. The miners who return to the city are not treated in the area, so they are sources of infection. This early control becomes impaired as the miner leaves by multiple means of transport: by air (clandestine airstrip), by means of a vessel that travels from various ports

distributed along the Uraricoera River. These aspects hinder the active search for malaria, as well as sanitary control in this municipality and in the state of Roraima as a whole.

From 2013 to 2022, 72,828 cases of malaria were confirmed in Roraima, of which 78.0% were caused by Plasmodium vivax. In addition, most of the cases were concentrated in the municipality of Alto Alegre, corresponding to 41.1% (Table 1). Considering these data, this was the municipality that produced the most malaria from mining, although there were other municipalities that recorded an increase in the disease in this period. Table 1 shows that the municipalities of Alto Alegre, Amajari, Caracaraí, Iracema and Mucajaí together account for 77.8% of all malaria produced in Roraima. These municipalities are part of the route of illegal mining in the Yanomami indigenous land. In this sense, considering this route, Alto Alegre is considered a strategic point for the trade generated from this mining. Gold was the second most exported product in the state.[8] There are several mining points located along the Uraricoera River, promoting intense circulation of people and products produced illegally in several mines.

Table 1- Distribution of malaria cases by municipality. Roraima, Brazil, 2013-2022(N=72,828).

City	N	%	Malaria		
			Falciparum (%)	Vivax (%)	Mixed (%)
Alto Alegre	29.954	41,1	23,4	70,2	6,4
Amajari	12.962	17,8	19,5	76,3	4,2
Boa Vista	781	1,1	2,9	96,3	0,8
Bonfim	1.352	1,9	4,2	95,3	0,5
Cantá	1.664	2,3	1,0	98,8	0,2
Caracaraí	6.692	9,2	16,2	80,9	2,9
Caroebe	57	0,1	1,8	98,2	0,0
Iracema	4.786	6,6	27,6	64,8	7,6
Mucajaí	2.317	3,2	24,7	67,1	8,2
Normandia	778	1,1	0,6	99,1	0,3
Pacaraima	7.187	9,9	1,2	98,6	0,2
Rorainópolis	6	0,0	0,0	100,0	0,0
São João da Baliza	111	0,2	0,0	99,1	0,9
São Luiz	114	0,2	0,0	100,0	0,0
Uiramutã	4067	5,6	1,4	98,4	0,2
Total	72.828	100,0	17,5	78,0	4,5

Figure 2 and Table 2 portray malaria from the perspective of the Annual Parasite Index, where two distinct scenarios with behavioral determinations can be seen in the municipality of Alto Alegre. It notes that throughout the period (2013-2017 and 2018-2022) malaria from an indigenous area was decisive in maintaining this municipality in the status of high malaria transmission,

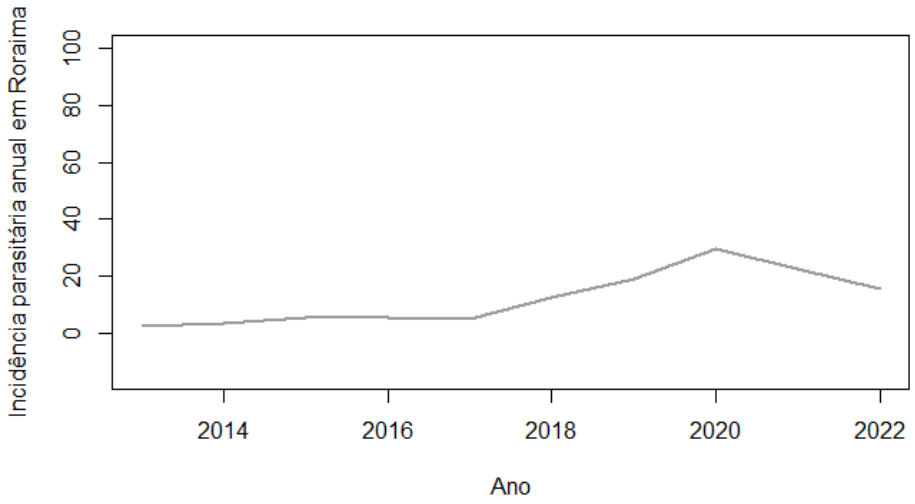
according to the Ministry of Health's classification: very low risk (< 1.0); low risk (1.0 to 9.9); medium risk (10.0 to 49.9); high risk (≥ 50.0).[6,10] The other scenario, in addition to perpetuating this classification of high transmission, also aggravates the situation from the second interval onwards, a period associated with the increase in mining. Therefore, this historical series reveals the impact of mining on the epidemiology of malaria in the indigenous area in the municipality of Alto Alegre and in other municipalities.

The municipality of Alto Alegre stood out with the highest rate throughout the period analyzed (figure 2). The IPA ranged from 4.1 to 332.9 cases per thousand inhabitants in Alto Alegre, which surpassed the IPA of the state of Roraima, which varied from 2.5 to 15.4 cases per thousand inhabitants in Roraima between 2013 and 2022. Thus, it was possible to verify that from 2015 onwards, Alto Alegre showed high risks (IPA ≥50.0/thousand inhabitants), overlapping the state of Roraima, which presented low to moderate risks (IPA 0.0 – 49.9/thousand inhabitants) in the period.

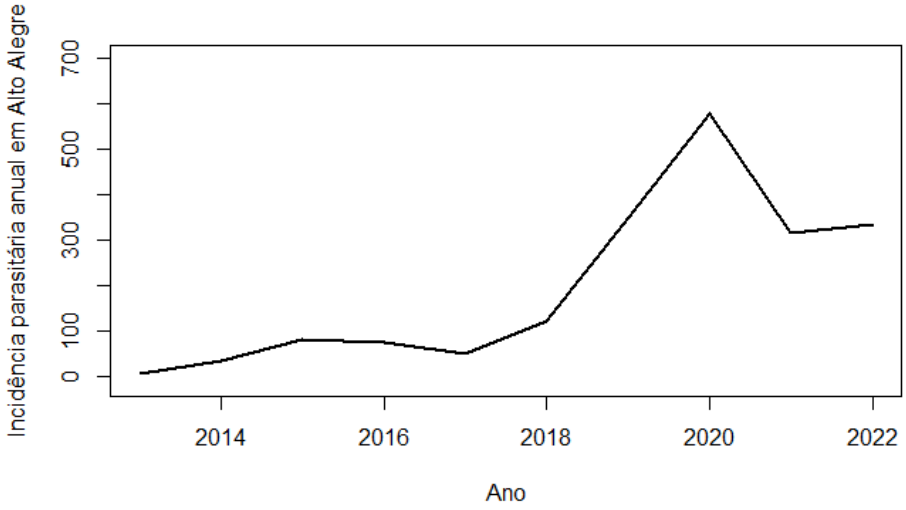
In Brazil, especially in the Amazon region, malaria has been showing a significant reduction, however, in border areas it is still highly vulnerable, constituting a challenge for its elimination.[11] Thus, this challenge involves several factors, including: lack of qualified health professionals, difficulty in accessing specialized health services, migratory movement, mobility of the indigenous population, presence of loggers around deforestation, movement of miners.[12-13] Corroborating the specificities of the typical dynamics of border zones, generally, the production and dissemination of communicable diseases generate crucial policies and actions in various health programs in several countries, especially those with border areas.[14] This may even trigger bilateral actions between countries for the control of malaria between nations.

Figure 2. Evolution of annual parasite incidence in Roraima (A) and in the municipality of Alto Alegre (B). 2013-2022.

A



B



Statistically significant increasing trends in the IPA for Roraima and Alto Alegre can also be observed, with annual growth rates of 28.0% and 54.4%, respectively (Table 2). When comparing the parasitic species for malaria occurrence in Alto Alegre, significant growth trends were evidenced for both, especially for P. falciparum, which presented an annual growth rate of 112.6% (Table 2 and Figure 2).

Table 2 - Temporal trend, variation of IPA and variation of IPA according to the type of species in Alto Alegre. Roraima, Brazil, 2013-2022.

Prais-Winsten			
	Coeficiente (IC95%)	Tendency	APC*
IPA			
Roraima	0,10731 (0,0622-0,1524)	Crescent	28,0
Alto Alegre	0,1888 (0,1139-0,2637)	Crescent	54,4
Prais-Winsten			
IPA Alto Alegre			
P. vivax	0,1449 (0,0530-0,2369)	Crescent	39,6
P. falciparum	0,3277 (0,1686-0,4868)	Crescent	112,6 (0,17-0,49)

*APC: Annual Percent Change

Regarding the distribution by species, it is observed that the greatest circulation of P. falciparum is mostly concentrated in the municipalities that make up the mining route. However, P. falciparum is also spread to other municipalities in Roraima (Graph 2). In fact, it is a major public health problem, given that this Plasmodium is commonly associated with severe manifestations of the disease more than P. vivax.[15-16] The increase and expansion of this species can be attributed to the expansion of the flow of miners, loggers and settlements. The increase in the incidence rates of P. falciparum has already been established in other studies carried out in regions with high human mobility.[12-13] However, the increase in the circulation of P. falciparum specifically has become a major

public health problem, which even goes beyond the borders of this municipality to other regions of the state.[15-16]

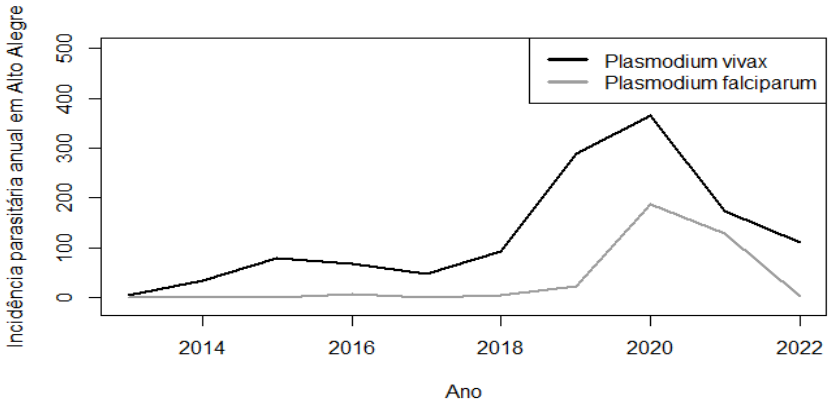


Figure 2. Evolution of annual parasite incidence in the municipality of Alto Alegre according to parasitic species of Plasmodium sp. 2013-2022.

Table 3 shows that the data were stratified by time interval divided into two periods. The first took place between 2013 and 2017, which preceded the process of illegal mining in Yanomami indigenous communities. The second moment, from 2018 to 2022, effectively marks the massive invasion of the communities by miners.

The epidemiological characterization of malaria in Alto Alegre is represented in several spaces of this municipality. In this sense, malaria from indigenous areas emerges as an important scenario for local epidemiology, given that during the period from 2013 to 2022 this region had the highest incidence, contributing with 24,120 cases of malaria against 131 occurrences in the urban area and 533 cases from the rural area. Of this total in the indigenous area, 6,384 (26.5%) cases come from mining in Yanomami indigenous land.[6]

However, the impact of mineral extraction goes beyond mining, as mercury contamination in the rivers of Roraima is a cause for concern.[17] In addition, malaria from the mining region is distributed in several municipalities, especially in Boa Vista, which in 2021 showed an increase in both the search for diagnosis (32,110 tests) and treatment for 7,711 individuals positive for malaria. This exacerbation in the number of cases is a cause for concern, as this increase has also been observed in malaria caused by Plasmodium falciparum, including in the municipality of Alto Alegre.[6]

Still on the impact of mining in Roraima, there are currently 1,097 illegal mining sites located in Venezuela, Guyana, and Brazil (Yanomami indigenous lands), producing high mobility of people in search of employment.[18] Although these mining regions are generally unhealthy and dangerous, they provide an economic incentive that motivates the return of these individuals in search of survival. even if they are still at risk of acquiring malaria. Considering this context, malaria emerges as an occupational disease. Overall, the situation observed in Roraima is consistent with reports emerging from other endemic areas in the Americas.[19-21] However, it is important to point out that both malaria data from indigenous areas and from mining regions are underreported.

Table 3 - Time interval by plasmodial species. 2023.

Inhabited geographical area	2012-2017			2018-2021		
	Pf	Pv	F+V	Pf	Pv	F+V
Urban area of Alto Alegre	5	42	0	11	70	3
Rural area of Alto Alegre	6	121	1	39	360	6
Indigenous area	122	3.846	13	5.229	14.149	762
Garimpo Area (Yanomami)	2	2	0	1.668	4.413	289

Source: DSEI/LESTE/Yanomami/IBGE

Final Consideration

The dynamics in the process of autochthonous transmission is capable of increasing and maintaining the circulation of the disease between municipalities, since the diagnosis and notification of malaria do not always occur in the same place or municipality of infection, showing that there is an intermunicipal movement of people in search of care.

This movement ends up hindering malaria control, because the bordering areas are extensive, multiple and difficult to access, generating demand beyond the operational capacity that the municipalities can offer. This mobility is an important aspect in the transmission chain, considering the potential for environmental receptivity of each municipality, including the presence of breeding sites in urban spaces.

Therefore, several aspects involving the operationalization of malaria control actions can determine its maintenance or elimination in a municipality. In this sense, it is essential to have adequate infrastructure, sufficient human resources and qualified management, which are sensitive to the importance of the activities of the endemic team for environmental management, respecting and particularizing such actions according to the reality of each municipality.

Thus, mining and the malaria that is produced in it are health problems that escape the control and management of the municipality of Alto Alegre, given that indigenous health is the direct responsibility of the Ministry of Health according to Law 8.080.

The increase in malaria, especially that caused by P. falciparum, has also increased in several municipalities since 2018, the year in which the flow of miners on Yanomami indigenous lands intensified. This is worrisome due to the reintroduction of this species in municipalities that had already controlled its transmission, in addition to being a species that causes a severe form of malaria, which is already a relevant reason for its combat.

In addition, this increase comes in the middle of the process of the National Plan for the Elimination of Malaria by P. falciparum, launched in 2015 and expected to eliminate it by 2035.

In addition to epidemiological issues, the indigenous inhabited area, whose belonging to the native peoples is guaranteed in the Brazilian Federal Constitution of 1988, now also inhabited by miners, is currently the scene of conflicts. Thus, the presence of miners on indigenous lands is perceived by the Yanomami as an invasion or generator of conflicts. Its presence, in addition to bringing diseases and increasing malaria, also brings destruction to the environment. However, this aspect of research where there are conflicts and

nature is not the object of our study, thus leaving an open door for future research.

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