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**Original Article**

# Is it possible to consider the control of human Visceral Leishmaniasis from the perspective of Biomimetics?

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**Summary**
As an insidious disease, Visceral Leishmaniasis (VL), is considered a serious public health issue that affects Brazil in almost its totality. This study evaluated the endemicity of VL in municipalities in the State of Minas Gerais in a historical series from the perspective of Biomimetics Science. A retrospective analysis was carried out between 2010 and 2019 of VL cases registered in the National System of Reported Diseases (Sistema de Informação de Agravos de Notificação - SINAN). In the studied period, 4.834 cases of the disease were reported in Minas Gerais. The cities of Belo Horizonte and Montes Claros were identified as the locations with the most expressive numbers of cases. The absence or reduced endemicity of the disease in the west and extreme south of the state of Minas Gerais was detected in the period analyzed. It is suggested that, over the time, there are areas that control the transmission of the disease by itself. Considering the principle of biomimetics, it would be important to identify that in these areas without the disease, which elements can be learned from nature to direct LV control actions.
***Keywords:*** Visceral Leishmaniasis, Biomimetics, Endemicity, Minas Gerais, Brazil.

## Introduction

Visceral Leishmaniasis (VL) is a relevant public health issue in Brazil due to the recent expansion of endemic areas affected by the disease, rare studies in the literature, and the increased lethality, which was 7,7% in 2019 (OPAS, 2020; Donato et al., 2020). The fatal outcome is associated with late diagnosis and, therefore, delayed treatment at an advanced stage of the disease. There are several factors contributing to the delay in the diagnosis of VL, including the population's lack of knowledge about the possibility of the transmission in their municipalities, also the lack of information from health teams about the clinical characteristics of the disease and methods available for confirmation.

It is an anthropozoonosis that is transmitted by insects of the Phlebotominae family, known as sandflies, and is caused by protozoa of the genus *Leishmania*. The predominant species that causes VL in Brazil is *L. (L.) infantum* (OPAS, 2019). The vector responsible for transmission is well adapted to the urban environment and widespread throughout Brazil (Marconde and Rossi, 2013; Maroli et al., 2013). The increase in the diffusion and density of the sandflies is a result of the expansion of breeding sites, blood sources, human migrations, the effects of deforestation, and climate changes (Marcondes and Rossi, 2013). These factors can lead to outbreaks, and it could also be related to the risks of emergency and re-emergence of the disease (Costa et al., 1990; Rosas Filho and Silveira, 2007; Oryan and Akbari, 2016; Reis et al., 2017). In Latin America, the main transmitting species is *Lutzomyia longipalpis* that in addition to having a wide geographic distribution, is well adapted to the peridomestic environment (Lainson and Rangel, 2005). Among the reservoir hosts, the dog stands out in the domestic cycle. When asymptomatic, they are sources of infection for the vectors (Carvalho et al., 2018; Marcondes and Day, 2019).

Humans, once infected with *Leishmania*, may not present any clinical manifestations, and it is estimated that this condition is related to most asymptomatic cases (Ferreira-Silva et al., 2018). When the manifestation occurs, the individual classically presents with persistent fever, visceromegaly (especially splenomegaly), and skin-mucosal pallor. Severe cases can evolve with hemorrhagic phenomena, associated bacterial infection, edema, and jaundice among others (Maia-Elkhoury et al., 2021). According to the literature, children with compromised nutritional status can be a source of infection, increasing the complexity of the transmission cycle and extension of the VL problem (Silva and Prata, 2018; Da Silva et al., 2020).

According to the epidemiological report of the Americas (OPAS, 2020), Brazil is among the countries that registered the highest case numbers, with an incidence of 4.84 (Triennium VL composite indicator 2017-2019). In 2019, there were 2,529 records with 304 cases registered in the State of Minas Gerais.

The VL is included among the Neglected Tropical Diseases (NTD), especially because it affects marginalized populations in places with scarce resources, requiring intersectoral and collaborative efforts from all human health systems with a multidisciplinary approach.

In most distribution maps of human VL cases in Brazil, there are areas in which the disease does not establish in a permanent way. Expanding the level of spatiotemporal detail of these observations can provide subsidies for understanding the role of environmental conditions in the dynamics (e.g., non-permanent installation) of human VL.

Therefore, Biomimetics (science that finds inspiration and optimized solutions for projects from different areas of knowledge in nature's content) is able to relate directly to the Leishmaniasis complex, as natural factors such as climatic conditions, habitat levels, social, and temporal conditions are linked to how the disease does not spread into silent areas. These parameters lead us to reflect, for instance, how the fitness (or reproductive success) of sandflies is associated with the maintenance of VL in Brazil (Meira, 2008; Detanico et al., 2010).

In this context, this study aimed to evaluate the endemicity of human VL in the municipalities of Minas Gerais in a recent historical series, with the perspective of contributing to the reflection on surveillance, prevention, and control measures of the perspective of Biomimetics.

**Methods**

A retrospective analysis of confirmed VL cases in the State of Minas Gerais was fulfilled. As the disease demands compulsory notification in Brazil, the data has been extracted from the National System of Reported Diseases (Sistema de Informação de Agravos de Notificação - SINAN), and the period surveyed was between 2010 and 2019 (last year with data available in a consultation fulfilled out in March 2021) (SINAN, 2021). This database search was based on the checklist RECORD (*Reporting of studies Conducted using Observational Routinely-collected Data*), defined as a guideline for studies using health database (http://www.record-statement.org/checklist.php).

Among the registration fields of the SINAN VL investigation form, the following data were collected: date and place of notification, age, gender, race, HIV coinfection, diagnostic method, confirmation criteria, autochthonous cases, and evolution.

The study data were tabulated in Microsoft Excel® 2010 program. The results were analyzed descriptively and expressed in maps. To illustrate the spatial and temporal distribution of the disease, graduated symbol maps were created in ArcGIS© 10.6 software. This cartographic representation was based on the indication of the numerical attribute of the disease (number of confirmed autochthonous cases) by the municipality in the state of Minas Gerais throughout the 2010-2019 historical series. The municipal mesh of Minas Gerais was extracted from the digital vector database (https://www.ibge.gov.br/geociencias/organizacao-do-territorio/) of the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística - IBGE) (IBGE, 2021).

**Results**

In the period 2010-2019, 4,834 VL cases were registered in Minas Gerais. The years 2017 and 2010 presented, respectively, the highest numbers of confirmed cases, comprising 861 and 578 notifications. The municipality of Belo Horizonte occupied the 1st position throughout the series, with 1,625 cases. The 2nd position was occupied by Montes Claros, with 715 cases. These municipalities are followed by the total cases reported in the cities of Governador Valadares (227), Ipatinga (221), Araçuaí (120), and Paracatu (103). In addition to these high numbers in the period, there is a large amount of municipalities with up to 5 confirmed autochthonous cases.

The analysis of the maps (Figure 1) reveals two consistent templates of distribution of confirmed cases in Minas Gerais: (i) high concentration in the central and northern areas of the state and, (ii) the absence or reduced endemicity for VL in the west and extreme south of the state.

When considering the profile of the affected individuals, the autochthonous cases, and the existence of coinfection with HIV, it was observed that men were the most affected by the disease, with 3,117 (64.48%) cases. The age group between 40 and 59 years old was the most affected, representing 1,176 (24.32%) cases, followed by the age between 20 and 39 years old with 1,148 (23.74%) cases and children between 1 and 4 years old with 879 (18.18%) confirmations. The brown (refers to "pardo") race/color corresponded to 2,635 (54.50%) cases. The HIV coinfection cases represented 518 (10.71%) cases during the study period. Table 1 (supplementary file) shows the variables analyzed between 2010- 2019.

One thousand six hundred eighty-one (1,681) individuals were submitted to parasitological examination, of which 1,276 (75.09%) were positive. Two thousand five hundred forty-one (2,541) patients were diagnosed by serological method, obtaining 2,151 (84.65%) positive results. The clinical-epidemiological criterion was used for the institution of specific therapy in 314 cases, while the laboratory criterion (by complementary exams) was adopted in 4,519; one case had this field filled out.

From the total number of cases in the period, 3,896 evolved to cure, and 483 died from VL, resulting in a lethality rate of 12.4% in the period studied.

**Discussion**

According to Meira (2008), Biomimetics Science (from *bios*, meaning life, and *mimesis*, meaning imitation) is constituted by an innovative method that seeks sustainable solutions following the example of nature, in which it uses templates and survival strategies of biological systems. The aim of this method is to create sustainable development products, processes, and policies inspired by ways of life that are well adapted to life on Earth during a long period of evolution of living beings (Guild, 2007).

Therefore, thinking about the process of urbanization of VL in Brazil from this premise is fundamental in the development of strategies to reconsider the control measures for this disease.

In Minas Gerais, the first human cases of the VL were reported in large and medium-sized cities, such as Belo Horizonte and Montes Claros (Silva et al., 2001; Sousa et al., 2008). In the present study, it was observed that the number of VL cases suffered few changes over the years evaluated (exceptions for 2017 and 2010). However, there was a significant expansion of the disease to other medium-sized urban centers, and especially in small cities. Despite the emergence of new areas with the sustained transmission of human VL, it is possible to observe that, in some sectors of the state, the disease has not established itself significantly over the ten years, especially in the west and extreme south of Minas Gerais.

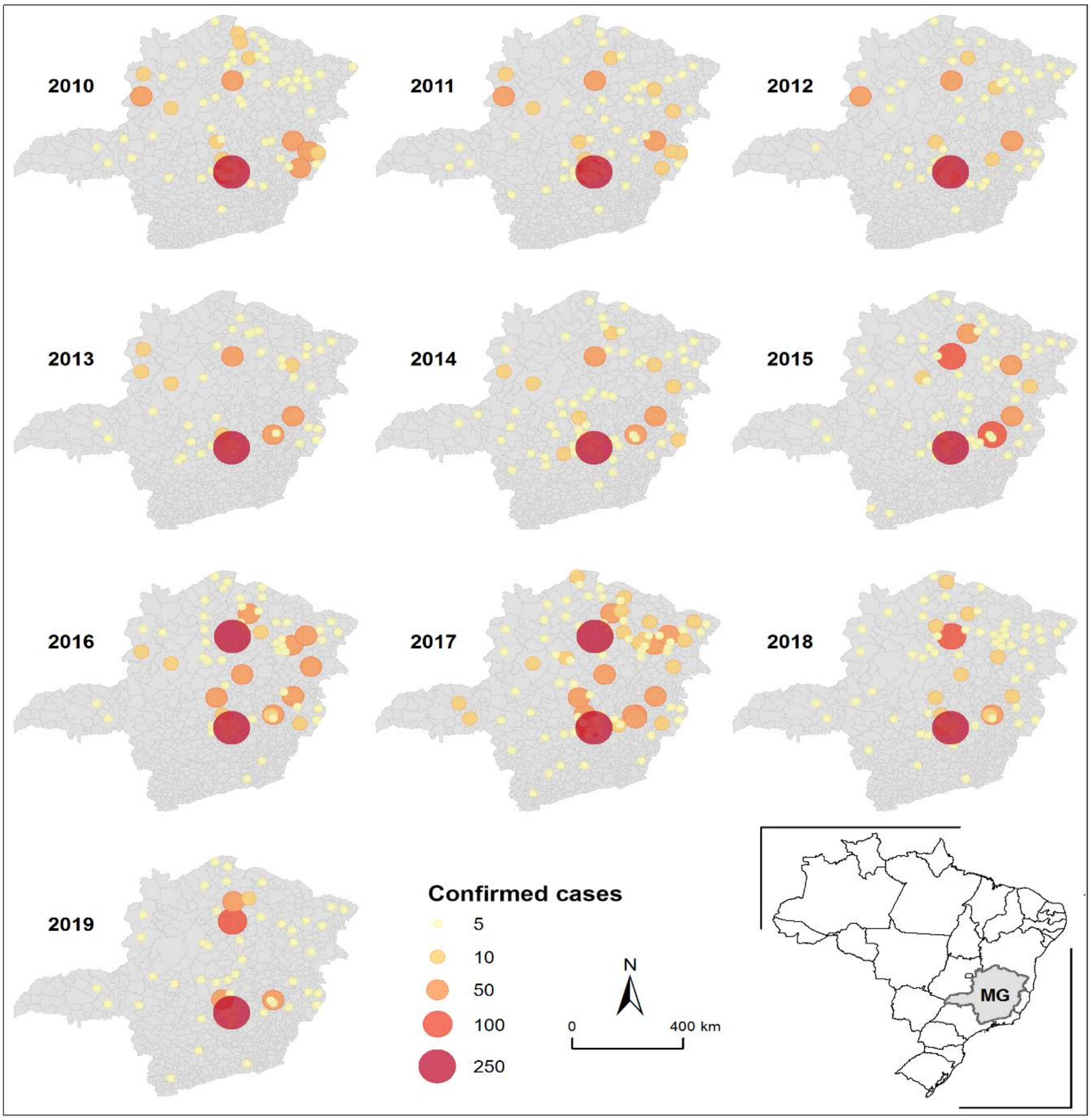


**Fig. 1.** Spatial and temporal distribution of VL in the state of Minas Gerais, 2010-2019 (Source: Elaborated by the authors).

Such areas have distinct physiographic and climatic characteristics. The west of the state has moderate altitudes (range ~ from 350 to 750 m), while the extreme south involves more rugged ground (elevations from 750 to ~2,900 m). According to the climate classification by Köppen and Geiger (1954), the Aw type (hot climate with summer rain) is predominant in the west of the state, and the Cwa type (temperate climate with hot and humid summer) in the extreme south (Dubreuil et al., 2017). The physical-natural differences found between the areas denote the nonexistence of a direct association between the effects of these aspects in the dynamics of VL endemicity. However, this first qualitative approach does not allow the exclusion of the influence of these aspects or other abiotic factors in VL transmission. The pronounced and persistent concentration of the cases in the north of the Minas Gerais is converging with the public health issue that is the spread of the disease in the whole country, thereby especially affecting the most socioeconomically vulnerable populations (Brasil, 2006; Maia-Elkhoury et al., 2008; Morais, 2020).

In the last ten years, the most expressive rates of prevalence were observed in municipalities (e.g., Belo Horizonte, Montes Claros, and Paracatu) that are known due to the presence of studies on the vector responsible for transmission cohabiting with domestic animals, a situation that favors its adaptation (Michalsky et al., 2009; Dias et al., 2011). However, when the Human Development Index (HDI) of these municipalities is analyzed, differences between them are revealed. The HDI is related to how each region endures demands related to the education, income, and health indicators. Thus, Belo Horizonte has an HDI of 0.810, Montes Claros 0.770, and Paracatu 0.744. All of them are above the state index, currently at 0.731 (IBGE, 2019). Therefore, in this small analysis of the social condition, a specific pattern of vulnerability was not identified, as there is practically no difference between the social conditions of the endemic and non-endemic municipalities of VL.

Bruhn et al. (2018) reinforced in their study the need to understand the ecoepidemiology of VL and its social determinants, considering the specific characteristics of the affected region. Morais et al. (2020) emphasized that in the last 30 years, VL has become a challenge to surveillance and control programs implemented in Brazil, once the country is responsible for more than 95% of notifications in the Americas, reflecting the failure in the effectiveness of these actions (Ribeiro et al., 2013; Morais et al., 2020).

The data on the spatiotemporal distribution of human VL cases reported in Minas Gerais along with a recent historical series (2010-2019) demonstrates that the disease is still a serious public health issue in the state. At the same time, the qualitative approximation of physical-natural aspects of areas in Minas Gerais does not show a direct causal relationship with the absence (or reduced) sustained transmission of human VL, but it reinforces the need for investigations into the particular patterns of influence of these aspects and other aspects at a local scale. It is believed that the combination of several factors determines the installation-dissemination of VL or the limitation of transmission of this infection in one location. The control measures currently recommended in Brazil are based on interventions directed at areas with high transmission and considered endemic for the disease. Thus, actions are directed towards early diagnosis and treatment of human cases, vector control through environmental management and the use of insecticides in endemic areas, and the canine investigation followed by euthanasia or treatment with a close follow-up of the animal conditions.

## Conclusion

The reflection on the ineffectiveness of these measures from the perspective of biomimetics is to turn the design of control measures to areas without transmission, which remain stable over the years, as it was possible to verify in this study. A more in-depth look is necessary to find out what are the potential solutions of nature so that the disease does not install itself in certain regions. It should bring elements for innovation in control measures. In this sense, a greater knowledge with more detailed information about these natural aspects and their forms of interaction can help define the best ways to contain the progression of the infection, with the proposal of sustainable control measures applicable in each situation.

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**Ethics approval**

Not applicable.

**Conflict of interest statement**

The authors declare no conflicts of interest.

**References**

Brazil. Ministry of Health. Secretary of Vigilância em Saúde. Epidemiological Surveillance Department. Manual of surveillance and control of visceral leishmaniose. Brasília: Ministry of Health; 2006.

Bruhn F., Morais M., Bruhn N., Cardoso D., Ferreira F., Rocha C. Human visceral leishmaniasis: Factors associated with deaths in Belo Horizonte, Minas Gerais state, Brazil from 2006 to 2013. *Epidemiology and Infection*. 2018, 146(5), 565-70.

Carvalho A. G., Luz J. G. G., Rodrigues L. D., Dias J. V. L., Fontes C. J. F. High seroprevalence and peripheral spatial distribution of visceral leishmaniasis among domestic dogs in an emerging urban focus in Central Brazil: a cross-sectional study. *Pathogens and Global Health*. 2018, 112(1), 29-36.

Costa C. H. N., Pereira H. F., Araújo M. V. Epidemia de Leishmaniose Visceral no estado do Piauí, Brasil 1980-1986. *Revista de Saúde pública / Universidade de São Paulo*, 1990, 24(5), 361-72.

Da Silva T. A. M., Morais M. H. F., Lopes H. M. de O. R., Gonçalves S. A., Magalhães F. do C., Amâncio F. F., Carneiro M. Prognostic factors associated with death from visceral leishmaniasis: a case-control study in Brazil. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. 2020, 114(5), 346-54.

Detanico F. G., Teixeira T. K., Silva A. Biomimética como Método Criativo para o Projeto de Produto. *Design & Tecnologia*. 2010, 1(02), 101-13.

Dias E. S., Regina-Silva S., França-Silva J. C., Paz G. F., Michalsky E. M., Araújo S. C., Valadão J. L. O., Lara-Silva F., de O. F. S., Pacheco R. S., Fortes-Dias C. L. Eco-epidemiology of visceral leishmaniasis in the urban area of Paracatu, state of Minas Gerais, Brazil. *Veterinary Parasitology*. 2011, 176(2-3), 101-11.

Donato L. E., Freitas L. R. S., Duarte E. C., Romero G. A. S. Visceral leishmaniasis lethality in Brazil: an exploratory analysis of associated demographic and socioeconomic factors. *Revista da Sociedade Brasileira de Medicina Tropical*. 2020, (53), 1-8.

Dubreuil V., Pechutti Fante K., Planchon O. & Neto J. L. S. a. Les types de climats annuels au Brésil : une application de la classification de Köppen de 1961 à 2015. *EchoGéo,* 2017, (41), 1-27.

Ferreira-Silva M. M., Teixeira L. A. S., Tibúrcio M. S., Pereira G. A., Rodrigues V., Palis M., Moraes-Souza H. Socio-epidemiological characterization of blood donors with asymptomatic *Leishmania infantum* infection from three Brazilian endemic regions and analysis of the transfusional transmission risk of visceral leishmaniasis. *Transfusion Medicine*. 2018, 28(6), 433-39.

Guild, B. *Innovation Inspired by Nature Work Book*, Biomimicry Guild, April 2007. https://biomimicry.org/

Instituto Brasileiro de Geografia e Estatística – (IBGE). Censo demográfico 2019. Índice de Desenvolvimento Humano Brasil. https://www.ibge.gov.br/busca.html?searchword=IDH&searchphrase=all.

Instituto Brasileiro de Geografia e Estatística – (IBGE). Censo demográfico 2019. Panorama da população. https://biblioteca.ibge.gov.br/visualizacao/livros/liv101707_informativo.pdf.

Köppen W., Geiger R. Klima der Erde (*climate of the earth*). Wall map 1:16 mill, Klett-Perthes, Gotha. 1654. http://koeppen-geiger.vu-wien.ac.at/pics/Geiger_1954_Map.jpg

Lainson R., Rangel E. F. Lutzomyia longipalpis and the eco-epidemiology of American visceral leishmaniasis, with particular reference to Brazil: a review. *Memórias do Instituto Oswaldo Cruz*, 2005, 100(8), 811-27.

Maia-Elkhoury A. N. S., Alves W. A., Sousa-Gomes M. L., Sena J. M., Luna E. A. Visceral leishmaniasis in Brazil: trends and challenges. *Cadernos de Saúde Pública*. 2008, 24(12), 2941-7.

Atlas interativo de leishmaniose nas Américas: aspectos clínicos e diagnósticos diferenciais. Washington, D.C.: Organização Pan-Americana da Saúde, 2021. https://doi.org/10.37774/9789275721902.

Marcondes M., Day M. J. Current status and management of canine leishmaniasis in Latin America. *Research in Veterinary Science*. 2019, 123(2019), 261-72.

Marcondes M., Rossi C. N. Visceral leishmaniasis in Brazil. *Brazilian Journal of Veterinary Research and Animal Science*. 2013, 50(5), 341-52.

Maroli M., Feliciangeli M. D., Bichaud L., Charrel R. N., Gradoni L. Phlebotomine sandflies and the spreadin of leishmaniases and other diseases of public health concern. *Medical and Veterinary Entomology*, 2013, 27(2), 123-47.

Meira G. L. A Biomimética utilizada como ferramenta alternativa na criação de novos produtos. *II Encontro de Sustentabilidade em Projeto do Vale do Itajaí*, 2008.

Michalsky E. M., Fortes-Dias C. L., França-Silva J. C., Rocha M. F., Barata R. A., Dias E. S. Association of Lutzomyia longipalpis (Diptera: Psychodidae) population density with climate variables in Montes Claros, an area of American visceral leishmaniasis transmission in the state of Minas Gerais, Brazil. *Memórias do Instituto Oswaldo Cruz.* 2009, 104(8), 1191-3.

Morais M. H. F., Sabroza P. C., Pessanha J. E., Sobral A. Visceral leishmaniasis control actions: epidemiological indicators for its effectiveness evaluation in a Brazilian urban area. *Cadernos de Saúde Pública*. 2020, 36(6), 1-10.

Organização Pan-Americana da Saúde – (OPAS). *Leishmanioses*: Informe Epidemiológico nas Américas: Washington: Organização Pan-Americana da Saúde; 2019, https://iris.paho.org/handle/10665.2/51738.

Organização Pan-Americana da Saúde - (OPAS). *Leishmanioses*: Informe epidemiológico nas Américas. Washington, D.C.; 2020. https://iris.paho.org/handle/10665.2/51742.

Oryan A., Akbari M. Worldwide risk factors in Leishmaniasis. *Asian Pacific Journal of Tropical Medicine*, 2016, 9(10), 925-32.

Reis L. L., Balieiro A. A. S., Fonseca F. R., Gonçalves M. J. F. Changes in the epidemiology of visceral leishmaniasis in Brazil from 2001 to 2014. *Revista da Sociedade Brasileira de Medicina Tropical*, 2017, 50(5), 638-45.

Ribeiro V. M., da Silva S. M., Menz I., Tabanez P., Nogueira F. dos S., Werkhaüser M., Dantas-Torres F. Control of visceral leishmaniasis in Brazil: recommendations from Brasileish. *Parasites & Vectors*. 2013, 6(1), 8.

Rosas Filho M. S., Silveira F. T. Epidemiologia, clínica e imunologia da infecção humana por Leishmania (Leishmania) infantum chagasi em área endêmica de Leishmaniose Visceral no Pará. *Revista Paraense de Medicina*, 2007, 21(3), 7-18.

Silva E. S., Gontijo C. M. F., Pacheco R. S., Fiuza V. O. P., Brazil R. P. Visceral Leishmaniasis in the Metropolitan Region of Belo Horizonte, State of Minas Gerais, Brazil. *Memórias do Instituto Oswaldo Cruz*. 2001, 96(3), 285-91.

Silva L. A., Prata A. Calazar. In: Coura J. R. *Dinâmica das doenças infecciosas e parasitárias*. 2. ed. – [Reimpr.]. – Rio de Janeiro: Guanabara Koogan 2018, 761-79.

Sistema de Informação de Agravos de Notificação - (SINAN). Sinan Net – Ministério da Saúde/SVS - Dados coletados em março de 2021. http://tabnet.datasus.gov.br/cgi/deftohtm.exe?sinannet/cnv/leishvmg.def

Sousa R. G., Santos J. F., Rodrigues H. G., Aversi-Ferreira T. A. Casos de leishmaniose visceral registrados no município de Montes Claros, Estado de Minas Gerais. *Acta Scientiarum. Health Sciences*. 2008, 30(2), 155-59.