Abstract

**Background:** Incorporating spatial approaches into epidemiological research is a challenge in public health research. The goal in this study was to analyze the spatial distribution of cases of deaths by tuberculosis in Imperatriz – MA (Brazil) and to characterize these events according to sociodemographic and operational characteristics.

**Methods and Findings:** In this ecological study, all deaths from tuberculosis as the primary causeregistered in the Mortality Information System from 2005 to 2014 were considered. The research variables were subject to descriptive analysis, point density analysis (Kernel Intensity Estimation) and area analysis.

Fifty cases of deaths by TB were identified, particularly the pulmonary clinical form. Male patients were predominant, with a median age of 59 years, mulatto race/color, single, who had finished secondary education. Most deaths happened at the hospital, with medical care before death and without autopsy. Most events happened at the hospital, with medical care delivery by an assistant physician and without autopsy. The point density revealed heterogeneity in the spatial distribution of the deaths, with rates of up to 2.33 deaths/km². The
Introduction

Tuberculosis (TB) is considered one of the eldest infectious diseases in the history of mankind and, although effectively treatable, it remains an important global public health problem, due to its wide geographical dispersion, emergence of multiple drug resistant cases and HIV co-infection [1]. Internationally, the World Health Organization (WHO) appoints that 22 countries concentrate about 80.0% of TB cases and Brazil is part of this group, ranking 16th in absolute case numbers; India, China and South Africa, in turn, are the countries with the highest disease burden [2].

According to Ministry of Health [3], TB demonstrates a direct relation with poverty and is associated with social exclusion and the marginalization of part of the population submitted to bad living conditions, such as precarious housing, malnutrition and difficulties to access public services and goods. The noteworthy and continuing influence of the living conditions in the transmission process of TB has highlighted a profound picture of socioeconomic inequalities that result in social inequities in health [1].

Health surveillance is an important model for the territorial monitoring of the health situation; that is so because it is in the geographical space where people produce and reproduce socially that the needs and health problems should be captured and the intervention priorities should be defined [4]. The integration of health surveillance and care, information and action should be considered the target of best practices in health care, so that TB surveillance is truly capable of knowing and identifying the cases, hospitalizations and deaths and their locations, in order to guide the control actions with a view to interrupting the transmission chain and assessing the result of these actions [5].

In that perspective, geoprocessing, a set of collection, treatment and exhibition techniques of geographically referenced information, serves as a tool to visualize health events on maps [6], associated with statistical methods to analyze spatial data. This makes it an important field of epidemiological research on the role of space in the production and dissemination of diseases [7].

Studies inherent in TB mortality have been encouraged as they are considered an important tool for the detection of health system errors [8]. The investigation of this problem permits outlining the profile of TB, monitoring the individual in different disease situations besides permitting additional analyses on

area analysis by census sector presented age standardized mortality rates of 0.00 to 4.00 deaths/100,000 inhabitants-year. As limitations, we highlight the occurrence of underreporting of deaths due to the disease and gaps in filling out the records.

Conclusion: The results contributed to the knowledge on the spatial distribution of cases of deaths by Tuberculosis and their characteristics in the research scenario. The importance of space is highlighted as a methodological alternative to support the planning, monitoring and assessment of health actions, targeting interventions to the control of the disease in vulnerable territories.

Keywords
Tuberculosis; Health Information Systems; Mortality; Spatial Analysis.
In addition, it is important to emphasize that TB figures on the list of avoidable causes of death. If appropriate health promotion, protection and recovery actions were established for the individuals and families through local health systems, these events would not take place [10].

Through a literature review in indexed databases, such as the Medical Literature Analysis and Retrieval System on-line (MEDLINE), Latin-American Literature in Health Sciences (LILACS) and Scientific Electronic Library Online (SCIELO), few studies published in Brazil were found that specifically address the mortality by TB [1, 11, 12, 13, 14, 15]. None of these studies discussed the scenario of Imperatriz-MA, one of the 181 priority cities in Brazil for TB control and one of the eight priority cities in the state [3].

In that sense, it is important to use spatialization equipment, through the geoprocessing technique, in combination with a comprehensive view of the health-disease process, to identify contexts of vulnerabilities to TB in the city under investigation, and act not only in the clinical and biological spheres, but also on the social determinants of health-disease [7].

In view of the relevance of equipping managers and workers in the areas most affected by TB, evidencing the regions with inequitable access, the goal was the analyze the spatial distribution of deaths by the disease in the city of Imperatriz – MA between 2005 and 2014, as well as to characterize these events according to sociodemographic and operational characteristics.

Methods

Study design and scenario
An ecological, descriptive and exploratory study was undertaken in Imperatriz-Ma, in the Brazilian Northeast (Figure 1), with an estimated population of 252,320 inhabitants, a territory of 1,368.98 km² and 102 health establishments registered in the Unified Health System (SUS). The city is located at 626 km from the state capital São Luís and is the second largest population, economic, political and cultural hub in Maranhão, with only 23% of sewage network and 86% of tap water and 9.7% of illiteracy [16].

Population, data collection and selection criteria
The study population consisted of all deaths from tuberculosis as primary cause registered in the Mortality Information System (SIM) from 2005 to 2014. The International Disease Classification (ICD) covered all clinical forms of TB in codes A15.0 to A19.9. The SIM is the Brazilian national information system, which provides epidemiological and clinical
information on the cases of deaths [17]. The data were collected in July 2015 through the SIM of the Health Surveillance System of the Municipal Health Department (SEMUS) in Imperatriz.

Data analysis

The research variables for this study were obtained from the death certificate (DC) used in Brazil and included sociodemographic characteristics like age, sex, race/color, marital status, education and occupation, besides operational variables like the place of death, medical care, autopsy, basic cause and physician responsible for the death certificate. To analyze these data, the quantitative parameters were subject to descriptive analysis, calculating the average, median and standard deviation for the age variable and absolute and relative frequencies for the categorical variables.

After the consistency analysis of the collected data, these were converted for use in IBM SPSS, where the variables and analyses were recategorized. What the age variable is concerned, the individuals who evolved to death were categorized based on the median age, and were therefore classified as superior or inferior to the obtained median.

To analyze the spatial distribution of the deaths by TB, the cartographic base for the city of Imperatriz was used, purchased from the company Imagem/Esri. Initially, for the geocoding, the individual addresses where deaths by TB happened in the urban and rural regions of the city were standardized and matched with the cartographic base in projection UTM/WGS84, available with the extension.shp (Shapefile).

Next, using the software TerraView version 4.2.2, the actual geocoding took place, which corresponds to the linear interpolation of the full address to one point in the corresponding address segment, permitting the elaboration of event points. Thus, the geocoding of the data involved a process of associating the tabular data that did not present an explicit spatial reference in the case of TB deaths, transporting them to a map (cartographic base of the city) previously incorporated in a Geographic Information System (GIS) environment [18].

In view of the occurrence of non-geocoded cases, as a complement, the tool Batch Geocode (available in http://batchgeo.com/br/) was used to register deaths not located in the cartographic base, which looks for the address coordinates on Google Earth.

The research team visited the homes where the deaths took place to obtain the geographic coordinates of these events using the GPS, for the addresses that were not located in the address/street arrangement database and using the Batch Geocode tool. These geocoding procedures were adopted in view of the possibility for spatial geo-referencing of the largest number of events (deaths), followed by the spatial analysis. Next, the geocoded cases were spatially distributed in the respective census sectors of the city that were considered as ecological analysis units in this study.

It should be mentioned that Kernel estimation is very useful to provide a general view on the distribution of the sampling points, as well as an indication of clusters, suggesting spatial dependence [18]. Therefore, the point density analysis technique was applied, defined as Kernel estimation, which consists in exploratory interpolation, producing a density surface for the identification and visualization of hot spots [19], in this case areas with higher densities of deaths by TB, that is, areas that are potentially more vulnerable to the presence of this event.

In addition, the spatial analysis per area was performed [19], using the census sectors of the city as the spatial analysis units with a view to obtaining the age standardized mortality rates by TB (TMTBi) for each census sector in the analysis period. The direct standardization of rates is important to compare health indicators on a more realistic base. It is indicated in case of the unwanted unequal distribution of a given characteristic in two or more populations [20]. After the standardization, the compari-
sons were made under equal conditions, respecting the controlled variable.

Thus, the age standardized mortality rates by TB were calculated per census sector and for the research period, dividing, respectively, the sum of the standardized deaths by the standard population in the middle of the period (urban population of Imperatriz) for each census sector multiplied by 100,000 and finally divided by 10, related to the years of study, as evidenced below:

$$TMTBi = \left( \frac{\sum \text{age standardized deaths}}{\text{standard population}} \times 100,000 \right) / 10$$

This procedure was processed in the software ArcGis version 10.1, which consists of a software package by ESRI® (Environmental Systems Research-Institute) that permits the elaboration and manipulation of vector and matrix information for the use and management of thematic bases [21]. Finally, the thematic map of the distribution of mortality rates by TB was obtained, grouped in quintiles.

All information was managed and the thematic maps were elaborated in ArcGis version 10.1.

### Ethical aspects

In compliance with the premises of Resolution 466/2012, the research project was submitted to the Ethics Committee for Research Involving Human Beings at Universidade Federal do Maranhão. Approval was obtained under opinion 1.140.668, issued on 06/29/2015.

### Results

Between 2005 and 2014, 50 deaths by TB were registered in Imperatriz – MA, 37 (74.0%) of which refer to Pulmonary Tuberculosis (PTB) and 13 (26.0%) to Extrapulmonary Tuberculosis (ETB). Among the basic causes registered under PTB, 30 (60.0%) were registered as PTB without bacteriological or histological confirmation (ICD A16.2); 3 (6.0%) PTB without bacteriological or histological examination (ICD A16.1); one (2.0%) PTB with confirmation by unspecified means (ICD A15.3); and, finally, three (6.0%) PTB with confirmation by sputum microscopy with or without culture (ICD A15.0) (Table 1).

The mean age of the individuals who died of TB in the research period was 54.6 years, standard deviation (SD) 19.97, while the median was 59 years. The youngest patient was 22 and the eldest 93 years. Table 2 presents the sociodemographic and operational characteristics of the people who evolved to death by TB in Imperatriz-MA. The results were ranked in decreasing order according to the response category. For the research period, most deaths referred to men (n= 31; 62.0%), mulatto (n=33; 66.0%), single (n= 26; 52.0%). The predominant education level was finished secondary education (n=18; 36.0%) and retired individuals or pensioners

### Table 1. Basic causes of deaths due to tuberculosis. Imperatriz - MA (2005-2014).

<table>
<thead>
<tr>
<th>ICD 10 Code</th>
<th>Definition</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A15.0</td>
<td>Tuberculosis of lung, confirmed by sputum microscopy with or without culture</td>
<td>03</td>
<td>6.0</td>
</tr>
<tr>
<td>A15.3</td>
<td>Tuberculosis of lung, confirmed by unspecified means</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>A16.1</td>
<td>Tuberculosis of lung, bacteriological and histological examination not done</td>
<td>03</td>
<td>6.0</td>
</tr>
<tr>
<td>A16.2</td>
<td>Tuberculosis of lung, without mention of bacteriological or histological confirmation</td>
<td>30</td>
<td>60.0</td>
</tr>
<tr>
<td>A16.5</td>
<td>Tuberculous pleurisy, without mention of bacteriological or histological confirmation</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>A16.9</td>
<td>Respiratory tuberculosis unspecified, without mention of bacteriological or histological confirmation</td>
<td>10</td>
<td>20.0</td>
</tr>
<tr>
<td>A18.3</td>
<td>Tuberculosis of intestines, peritoneum and mesenteric glands</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>A19.9</td>
<td>Miliary tuberculosis, unspecified</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>50</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Obs: ICD: International Classification of Diseases
Table 2. Sociodemographic and operational characteristics of deaths by tuberculosis. Imperatriz - MA (2005 till 2014)

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 59 years</td>
<td>25</td>
<td>50.0</td>
</tr>
<tr>
<td>&gt; 59 years</td>
<td>25</td>
<td>50.0</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>31</td>
<td>62.0</td>
</tr>
<tr>
<td>Female</td>
<td>19</td>
<td>38.0</td>
</tr>
<tr>
<td>Race/color</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mulatto</td>
<td>33</td>
<td>66.0</td>
</tr>
<tr>
<td>White</td>
<td>11</td>
<td>22.0</td>
</tr>
<tr>
<td>Black</td>
<td>05</td>
<td>10.0</td>
</tr>
<tr>
<td>Yellow</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>Marital Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>26</td>
<td>52.0</td>
</tr>
<tr>
<td>Married</td>
<td>12</td>
<td>24.0</td>
</tr>
<tr>
<td>Widowed</td>
<td>10</td>
<td>20.0</td>
</tr>
<tr>
<td>Fixed Partner</td>
<td>02</td>
<td>4.0</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary education</td>
<td>18</td>
<td>36.0</td>
</tr>
<tr>
<td>5th to 8th grade</td>
<td>13</td>
<td>26.0</td>
</tr>
<tr>
<td>1st to 4th grade</td>
<td>10</td>
<td>20.0</td>
</tr>
<tr>
<td>Unfinished higher</td>
<td>05</td>
<td>10.0</td>
</tr>
<tr>
<td>No education</td>
<td>02</td>
<td>4.0</td>
</tr>
<tr>
<td>Finished higher</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>Unknown</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>Occupation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retired/Pensioner</td>
<td>15</td>
<td>30.0</td>
</tr>
<tr>
<td>Maintenance</td>
<td>09</td>
<td>20.0</td>
</tr>
<tr>
<td>Agricultural worker</td>
<td>09</td>
<td>20.0</td>
</tr>
<tr>
<td>Housewife</td>
<td>05</td>
<td>10.0</td>
</tr>
<tr>
<td>Trader</td>
<td>03</td>
<td>6.0</td>
</tr>
<tr>
<td>Driver</td>
<td>02</td>
<td>4.0</td>
</tr>
<tr>
<td>Unknown</td>
<td>02</td>
<td>4.0</td>
</tr>
<tr>
<td>Teacher</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>Craftsman</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>Fisherman</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>Prospector</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>Student</td>
<td>01</td>
<td>2.0</td>
</tr>
<tr>
<td>Place of Death</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital</td>
<td>40</td>
<td>80.0</td>
</tr>
<tr>
<td>Home</td>
<td>10</td>
<td>20.0</td>
</tr>
</tbody>
</table>

As for the operational indicators, most deaths happened at the hospital, (n=40; 80.0%) and received medical care before they died (n=40; 80.0%). In most cases, the assistant physician was responsible for the registers (n=21; 42.0%). In addition, the absolute majority of the deaths (n= 48; 96.0%) were not submitted to autopsy, one (2.0%) was submitted to autopsy and this information was unknown in the death certificate for one (2.0%) individual.

The standardization procedure to geocode the cases of TB deaths led to the successful georeferencing of 47 cases (94.00%). Three cases (6.00%) were excluded due to address inconsistencies, as they were impossible to identify even with the help of tools, such as Batchgeo Find Latitude and Longitude (Batch Geocode) and in loco visits to collect the coordinates.

Considering the distribution of deaths per census sectors in the city under analysis, the absolute majority happened in the urban area (about 98%), while only one case was geocoded in the rural area.

Figure 2 reveals the application result of the Kernel technique to identify the point density. For this purpose, the map of all census sectors in the city
was used, published by the IBGE, in accordance with data from the 2010 Census. The places with the highest density of deaths per square kilometer (km²), also known as “hot spots”, are highlighted in black. In addition, a heterogeneous distribution with possible clusters can be evidenced, mainly concentrated in the central region towards the south of the city, where the neighborhoods with the largest number of TB deaths were recorded.

The spatial analysis by area (Figure 3) demonstrates the distribution of the $TMTBi$ according to census sectors, with rates ranging between 0.00 and 4.00 deaths/100,000 inhabitants-year, confirming the heterogeneous distribution evidenced in the analysis of hot spots (Kernel).

**Discussion**

The analysis of the main sociodemographic characteristics described for the study population revealed the predominance of mulatto, adult men with low education level. These results are in line with the Brazilian standard of TB in distinct scenarios and with studies developed in other regions of the country [11, 12, 14].

TB more frequently affects men than women in all age ranges. This fact can be explained by the different exposure to risk factors among men, such as alcoholism, alcohol abuse, illegal drugs abuse and greater prevalence of HIV infection [22], although
these variables were not explored in this research. Without a biological explanation to justify this difference, it is reasonable to admit that this fact can be due to cultural differences in role performance among the sexes, which includes, among others, men’s limited visit of health services [1,5].

In terms of race/color, the results are equivalent to the study undertaken in Campo Grande [23], São Luís [11] and other priority cities in Mato Grosso do Sul [24] for TB control, indicating that most deaths involved mulatto individuals, in line with the morbidity problem in the country [25,26] and different from studies developed in the state of São Paulo [12,13] where the white race/color prevailed.

What the age is concerned, the same proportion of deaths by TB was evidenced in individuals over and under 59 years of age, therefore emphasizing results found in studies developed in Brazil, in cities like in the state of São Paulo and Salvador [13, 14, 27].

In this research, it was also observed that the marital status that stood out among the cases of death was single, in line with studies developed in the city of São Luís, in the states of Minas Gerais and Rio de Janeiro [8, 11, 12, 23].

The education and occupation data found in this research differed from some studies [11, 13, 23, 24, 28] that report the inexistence or low level of education and lack of income among the patients who died.

Specifically for occupation, financially lessprivileged people face a greater probability of developing the disease [11,13,23,24] but, in Imperatriz, death mainly affected people who had finished secondary education and were mainly retired or pensioners, evidencing the vulnerability of elderly people to this problematic illness [26].

It should also be highlighted that, according to Silva et al [29], education significantly influenced the individuals’ access to knowledge and ability to understand. Therefore, it is emphasized that the predominantly low education level in the TB patients reflects a set of unfavorable socioeconomic conditions that increase the vulnerability and are responsible for the higher incidence of this disease, besides contributing to lack of treatment compliance and the increase of treatment abandonment and, consequently, of avoidable hospitalizations and unacceptable deaths from the perspective of social justice [11, 30].

What the operational characteristics are concerned, about 80.0% of the deaths analyzed happened inside hospitals. This situation is similar to Brazilian studies undertaken in the states of Rio de Janeiro [8], São Paulo-SP [13], Mato Grosso do Sul [24], Ribeirão Preto - SP [12] and in the city of São Luís-MA [11] with records of 80.0% or higher. A population-based cohort in Brazil and in Latin America, China and India [31] also revealed that most deaths happened in hospitals.

Perrechi and Ribeiro [32] appoint that, although diagnosing TB is relatively simple, most cases are still diagnosed in hospitals, representing high costs for the health system and sequelae for the patients [33].

It should be highlighted that the evolution to death of patients hospitalized by TB suggests difficulties of Primary Health Care (PHC) in management, in the supply of diagnostic resources or in case management and in the referral system to other health services [34]. Another factor that helps to explain this result is treatment abandonment, which predicts the development of multiple drug resistance (MDR) and, thus, hospitalizations [35].

In that sense, it is relevant to restructure and strengthen the TB control actions, prioritizing the sputum microscopy and rapid molecular test for the diagnosis, control and monitoring of the disease, as well as the improvement of the records and the Health Information Systems (HIS) [26].

As for the operational variable medical care, 80.0% of the deaths received that care, in line with other studies [11, 12] in which most deaths also received medical care before death.
With regard to the confirmation of TB by means of an autopsy, it was observed that this examination was not performed in 96.0%, acknowledging that the lack of confirmation of the death by TB through an autopsy expresses exactly the weakness and insufficiency of the health service systems to reduce the social inequities in health, as evidenced Curtis [36], who emphasized the TB Geography dimension “use and access to health services”. In that sense, the need for restructuring is fundamental, as well as the strengthening of TB control actions in Primary Health Care.

What the geocoding of the cases is concerned, the percentage (94%) is considered excellent when working with addressing in a database, in accordance with Davis Jr and Alencar [37]. Those authors affirm that the use of addresses in the location of points of interest is routinely used and widely known, especially in cities. Therefore, addresses are usually included as attributes in conventional information systems.

In that sense, it is relevant to emphasize that one limitation in the geocoding was the incompleteness of the data informed in the SIM, mainly in the address registers. The quality of health information is fundamental to apprehend the reality, monitor diseases and problems distributed across the territory. Therefore, it is a necessary instrument to encourage strategies and the elaboration of public policies in the three governmental spheres [38].

In addition, the behavior of TB, like other endemic conditions, is strongly influenced by the midst. It can be evidenced that the association between TB and precarious socioeconomic conditions dates back to the origins of this disease’s epidemiology, therefore underlining the need for research and intervention, taking into account its spatial distribution [11].

In that line of reasoning, the spatial distribution of deaths by TB, particularly the heterogeneous distribution observed in the city of Imperatriz, should be considered the starting point for a research and surveillance process, which can trigger a focus on problem areas and the identification of weak links in the health care system for the target population.

The point density map visually appoints the locations most vulnerable to the occurrence of deaths by TB per km², spatially indicating the so-called “hot spots”, which permits evidencing inequalities among events, in this case deaths, in geographical areas of the city.

The areas with the highest density of deaths per km² were found in census sectors located in the neighborhoods of Bacuri, Santa Rita, Parque Alvorada, Centro, Parque Anhanguera, Vila Caféteira, Vila Lobão, Jardim São Luís, Nova Imperatriz and Parque Santa Lúcia, which are also areas classified as precarious in terms of housing conditions and residence quality, mainly concerning the urban agglomeratio [39]. The urban growth of Imperatriz without preliminary planning resulted in areas that are considered subnormal, lacking public and mostly essential services [40].

The occurrence of deaths by TB in the city under analysis also experiences the social scenario cited in Curtis [36] concerning these areas of greater social inequity. The spatial analysis per area revealed the $TMTBi$ distribution according to census sectors, ranging from 0.00 to 4.00 deaths/100,000 inhabitants-year, confirming the heterogeneous distribution evidenced in the analysis of the hot spots (Kernel).

Census sectors in the urban region of the city that obtained $TMTBi$ superior to three deaths/100,000 inhabitants are considered areas that demand special attention from health services, with a view to the intensification of disease control actions, considering that these rates exceed the Brazilian and state rates, which corresponded to 2.4 and 2.9 deaths/100,000 inhabitants, respectively, in 2014 [41].

In that sense, it should be mentioned that the largest number of deaths by TB among the poorest regions from the social perspective implies and
This article is available at: www.intarchmed.com and www.medbrary.com

justifies the intensification of activities linked to the search for patients with respiratory symptoms with a view to early case detection, treatment and the achievement of cure. In addition, the enhanced social inequality in Brazil, observed in the access to health resources, in education, income distribution, basic sanitation and other elements of the populations’ standard of life favor divergences in the risk of illness and, consequently, of death in the different social groups [22].

Concerning health problems requiring reporting, like in the case of TB, using data available in the HIS permits monitoring the problem, contributes to the identification of relevant aspects and encourages the search for new interventions to control the disease [11, 34]. Thus, the data collected from the SIM revealed the dynamics and behavior of TB in the city of Imperatriz – MA.

It should be mentioned that the SIM, as an information source to study deaths in a certain region, comes with some weaknesses. One of them is the underreporting in the country [24, 26]. The gaps in the completion of the registers are also highlighted, which provides relevant information for management and planning in health. In that perspective, improving the quality of the records in terms of completing the gaps and updating the data from the HIS are fundamental for the sake of reliable epidemiological analysis [11].

Despite the limitations, this research offers potential, highlighting its originality, as no other studies were found in which the spatial distribution of deaths by TB was assessed in the research scenario. In addition, the study can support managers and health workers in the planning of health actions, surveillance and control of TB cases in the affected territories.

Finally, these research results undoubtedly contributed to the knowledge on the spatial distribution of TB in the city, underlining the importance of the space category as a methodological alternative to support the planning, monitoring and assessment of health actions, guiding interventions to control the disease in vulnerable territories.

**Acknowledgments**

We are grateful to the Health Surveillance Service of the Municipal Health Department (SEMUS) of Imperatriz for the authorization to develop the research and for providing the data.

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**Competing and Conflicting interest**

The authors declare that they have no competing interest.

**Abbreviations**

TB: Tuberculosis; WHO - World Health Organization SIM: Mortality Information System; ICD-10: International Disease Classification version 10; TMTBi: Deaths Rate from Tuberculosis standardized by age; IBGE: Brazilian Institute of Geography and Statistics; SVO: Death Surveillance Service; IML: Institute of Forensic Medicine

**References**


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