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Spatio-temporal analysis of the vulnerability of typhoid fever in the municipality of Belém, Pará, Brazil

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***Abstract*— The study sought to analyze the sociodemographic, epidemiological profile, and spatial-temporal distribution of typhoid fever in the municipality of Belém, Pará. For that, we used the confirmed cases of the disease obtained from SINAN by SESPA from 2007 to 2016. The data was categorized based on the sociodemographic, epidemiological profile, incidence rates, and monthly variation. For spatial distribution, we used the Kernel Density Estimator and the Buffer technique. Thus, we obtained 152 confirmed cases, with a higher proportion in males (67.76%), in the age group between 30 and 59 years (48.03%), and with high school education (19.08%). The transmission was mainly related to the ingestion of contaminated water and food (11.18%), with resolution at an outpatient level (69.08%), confirmed at a laboratory level (93.42%), without death records. The annual incidence rate varied from 0.07% in 2011 to 3.28% in 2014. It was also observed that the spatial distribution of the disease was concentrated in the districts of Guamá, Entroncamento, and near the Tucunduba watershed demonstrating that the greatest risk of transmission is in areas that present socioeconomic fragility and are precarious in basic sanitation. Thus there is a need for investments in sanitary infrastructure and health surveillance actions, aiming at reducing the disease in the municipality.*

I. INTRODUCTION

Typhoid fever is a systemic infectious disease, exclusively human, which is caused by the gram-negative bacterium Salmonella typhi, with a clinical picture characterized by high fever, headache, abdominal pain, diarrhea, splenomegaly, and dry cough [1]. It is among the most significant waterborne diseases, acquired by the consumption of water or food contaminated with feces or urine of carriers, and its transmission (fecal-oral) is associated with poor hygiene and basic sanitation conditions [2].

Its distribution occurs worldwide, representing an important public health problem, mainly in developing countries, where high mortality rates for this disease are recorded, while in developed countries its occurrence is restricted to travelers who came into contact with endemic areas [3]. According to Crump and Mintz [4], the greatest endemicity occurs in countries in Asia and South Africa, as a result of the low socioeconomic levels of the population and precarious sanitary conditions. According to Keddy [5], measures such as antibiotic management, drinking water treatment, investments in sanitation and health education play a significant role in reducing infection, morbidity, and mortality.

It is estimated that the year 2000 recorded approximately 21.7 million cases causing 217,000 deaths worldwide [4]. Studies showed a decline to 9 million cases in 2010 with 129,000 deaths [6].

According to the Ministry of Health [7], in Brazil, this infection is endemic with epidemic periods in the North and Northeast regions, corresponding to respectively 71.4% and 18.6% of confirmed cases in the temporal analysis from 2010 to 2017.

In the state of Pará, the seasonality of typhoid fever is concentrated in periods with low rainfall, coinciding with the harvest and consumption of açaí juice (Euterpe oleracea Mart.) which takes place in the latter half of the year [8]. As the infective load is 106 to 109 bacteria, it is inferred that very rainy periods dilute the concentration of the infecting agent in the environment, making the transmission of the disease difficult [9]. However, the municipality of Belém is composed of fourteen hydrographic basins that, associated with the topo-hydrographic characteristics of the city, with quotas of less than four meters, contribute to the formation of areas subject to flooding, exposing the resident population to Salmonella typhi [10,11].

The identification of endemic areas is essential for the establishment of surveillance strategies enabling the control and prevention of the disease [12]. Till now, many studies in the field of health have highlighted in their methodologies, the contribution of geoprocessing in the perspective of analysis, monitoring, and planning of public health actions [13,14].

According to Silva [15], geoprocessing is a “set of computational techniques that operate on a georeferenced database to generate information”. Thus, the epidemiological analysis using this tool to gather socioeconomic, environmental, and geographic elements, makes it possible to investigate the influence of several variables on the dynamics of disease transmission [13,16,17].

Given the above, the objective of this research was to carry out a space-time analysis and characterize the sociodemographic and epidemiological profile of typhoid fever in Belém - Pará.

II. METHOD

This research was carried out in accordance with the provisions of the Law on Access to Information (LAI) No. 12,527/2011, guaranteeing the confidentiality of patients' personal data.

This is an ecological, cross-sectional, and retrospective study based on reported and confirmed cases of typhoid fever in Belém-Pará, Brazil, in the period from 2007 to 2016.

The research was carried out in the city of Belém, the capital of the state of Pará, located in the North region of Brazil. Belém has an area of 1,059,458 km², an estimated population of 1,485,732 inhabitants in 2018, with an estimated population density of 1,315.26 inhab./km² and a Municipal Human Development Index (IDHM), in 2010, of 0,746 [18]. The city consists of eight administrative districts, which are: Administrative Districts of: Belém (DABEL), Benguí (DABEN), Entroncamento (DAENT), Guamá (DAGUA), Icoaraci (DAICO), Mosqueiro (DAMOS), Outeiro (DAOUT) and Sacramenta (DASAC) [19].

Data on typhoid fever cases were obtained from the Information System on Notifiable Diseases (SINAN) of the Pará State Health Department (SESPA) and population data obtained from the Brazilian Institute of Geography and Statistics (IBGE) from the last census of 2010. The information extracted from the typhoid fever notification form (http://portalsinan.saude.gov.br/febre-tifoide) [20] included sociodemographic (age, sex, and education), epidemiological (risk situation, hospitalization, confirmation or discard criteria, the final classification of the case, the evolution of the case, and location (street and neighborhood).

The limits of neighborhoods, districts, municipalities, and the state were obtained from the IBGE and drainage from the Housing Company of the State of Pará (COHAB).

Initially, the data was organized in spreadsheets in Microsoft Office Excel and represented in tables and graphs according to the means, absolute frequency, and relative frequency.

Statistical analysis of sociodemographic and epidemiological variables was performed using the BioEstat version 5.3 program, applying the G test, with an accepted significance level of 95% and $p < 0.05$.

The incidence rate was calculated annually for each administrative district, based on the population estimated by IBGE for each year, using the following formula: [(number of cases/resident population) * 100,000]. For the analysis of the monthly variation, the absolute number of cases was used.

The SINAN database was converted into a geographic database (BDG) by geocoding the addresses where the reported cases occurred. To obtain the geographic coordinates of latitude and longitude, the website http://www.freegeocoding.com/batch.php and the cartographic database of the Companhia de Desenvolvimento e Administração da Área Metropolitana de Belém (Codem) were used. The BDG was imported into a Geographic Information System (GIS), which enabled the construction of epidemiological maps with the spatial distribution of typhoid fever cases.

The spatial analyzes performed were distance map and Kernel density estimator (EDK). The software used was TerraView 4.2.2 (http://www.dpi.inpe.br/terralib5/wiki/doku.php) and ArcGIS 10.3 (https://www.arcgis.com/).

The distance map, obtained by applying the Buffer technique, was applied to the drainage of watersheds, with a radius of 300 meters [21]. This form of analysis allows the measurement of the proximity between the number of cases of disease and the zone of influence around the drainages according to a two-dimensional Cartesian plane.

The EDK was applied according to the number of cases using adaptive radius. This geostatistical technique is adjusted by a two-dimensional function that calculates the concentration of an event or phenomenon spatially distributed on a continuous surface, enabling the identification of hot areas (clusters) and the geographic delimitation of endemic diseases [17,21].

III. RESULTS

In the period from 2007 to 2016, 152 cases of typhoid fever were confirmed in Belém - Pará. The distribution of the relative frequencies of cases by the administrative district was in the order of DAGUA (37.50%), DAENT (21.71%), DABEN (15.79%), DASAC (9.21%), DABEL (8.55%), DAICO (5.26%), DAMOS (1.32%) and DAOUT (0.66).

The predominant sociodemographic profile was male (67.76%), aged between 30-59 years (48.03%), and those who attended high school (19.08%) (Table 1). Among these variables, “education” presented a large number of records filled in as ignored (34.87%). The difference between samples was highly significant ($p<0.001$).

In the epidemiological profile, the variables “risk situation” and “evolution of the case” indicated low completeness of information, with respectively 86.84% and 23.03% of fields filled in as ignored, which hampered the qualitative characterization of the data. Even so, it was possible to observe that: in 9.21% of the cases the source of risk of transmission comprised contaminated food, 69.08% of the patients received outpatient care, with 25.66% hospitalizations; 93.42% of the cases were diagnosed by clinical laboratory criteria, 57.89% of the cases progressed to cure and there was no record of death from typhoid fever in the analyzed period (Table 2). There was a highly significant difference between the epidemiological variables ($p<0.001$).

Table.1: Sociodemographic profile of typhoid fever cases in the city of Belém-Pará, Brazil, between 2007-2016.

Variable	Category	Absolute Frequency (n)	Relative Frequency (%)
Gender			
	Male	103	67,76%
	Female	49	32,24%
	Total	152	100,00%
Age Group			
	(< 12)	16	10,53%
	(12-18)	19	12,50%
	(19-29)	36	23,68%
	(30-59)	73	48,03%
	(+60)	8	5,26%
	Total	152	100,00%
Education			
	Illiterate	0	0,00%
	EFI (1ª - 4ª Series)	14	9,21%
	EFII (5ª - 8ª Series)	23	15,13%
	High school (1º - 3º Years)	29	19,08%
	University Education	20	13,16%
	Ignored	53	34,87%
	Not applicable	10	6,58%
	(Empty)	3	1,97%
	Total	152	100,00%

According to the temporal analysis of the cases, it can be seen in Figure 1 (A), that the incidence rate ranged from 0.07 in 2011 to 3.28 in 2014, with a decline of 0.97 in 2015, and an increase to 1.73 in 2016. In the monthly distribution, Figure 1 (B), the highest peaks occurred in the months of September and November, respectively, and the lowest in June. Regarding the incidence rates by administrative district, Figure 1 (C), the following results were obtained: DAENT (2.56), DAGUA (1.62), DABEL (0.88), DABEN (0.82), DAMOS (0.58), DASAC (0.53), DAICO (0.47) and DAOUT (0.25).

Table 2 - Epidemiological profile of typhoid fever cases in the city of Belém-Pará, Brazil, between 2007-2016.

Category	Absolute Frequency (n)	Relative Frequency (%)
Risk Situation		
Untreated water consumption	3	1.97%
Exposure to sewage	1	0.66%
Unhygienic food	14	9.21%
Displacement	2	1.32%
Ignored	132	86.84%
Total	152	100.00%
Evolution of the case		
Cured	88	57.89%
Death from disease	0	0.00%
Death from other causes	0	0.00%
Ignored	35	23.03%
Empty	29	19.08%
Total	152	100.00%
Type of service		
Hospital	39	25.66%
Outpatient	105	69.08%
Ignored	8	5.26%
Total	152	100.00%
Diagnostic criteria		
Laboratory clinic	142	93.42%
Epidemilogical clinic	8	5.26%
(Empty)	2	1.32%
Total	152	100.00%

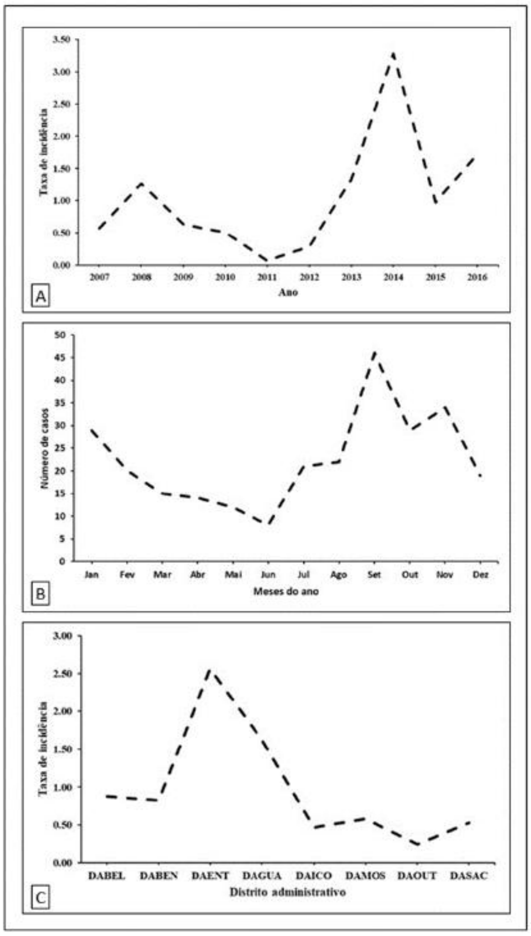

Fig. 1: Distribution of typhoid fever in the city of Belém-Pará, Brazil, between 2007-2016. (A) Annual incidence rate of typhoid fever; (B) Monthly variation in the absolute number of typhoid cases; (C) Variation of incidence rate by administrative district.

In the spatial analysis, the application of the EDK highlights in red the areas with the highest risk of cases of typhoid fever (Figure 2). During the ten years of the study, the largest cluster was concentrated in DAGUA, however, the technique also revealed a hotspot in DAENT in an outbreak that occurred in 2014.

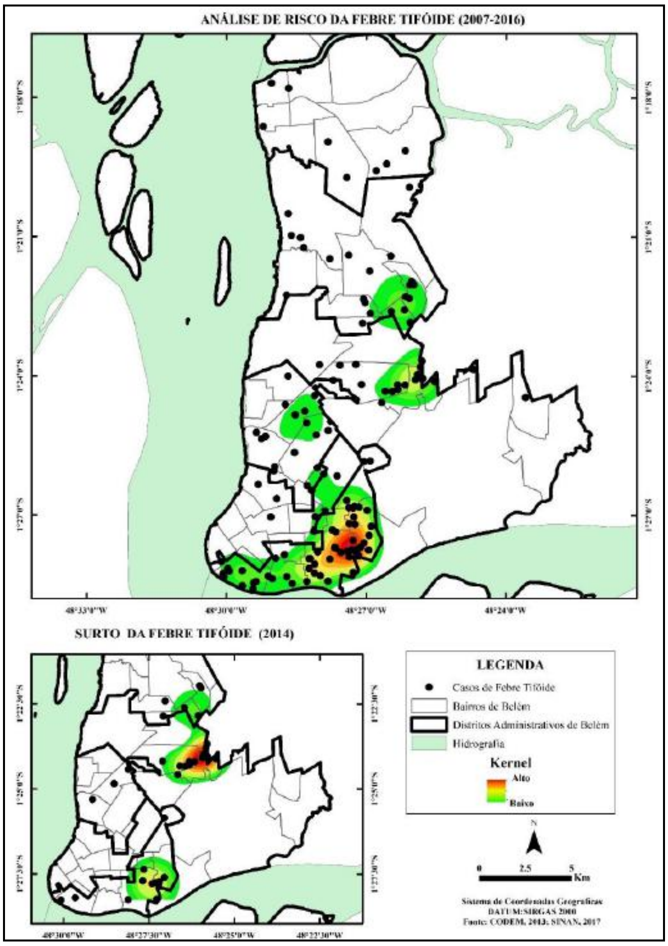

Fig. 2: Spatial distribution of typhoid fever cases and the application of EDK in the city of Belém-Pará, Brazil, between 2007-2016 and, in particular, the year 2014.

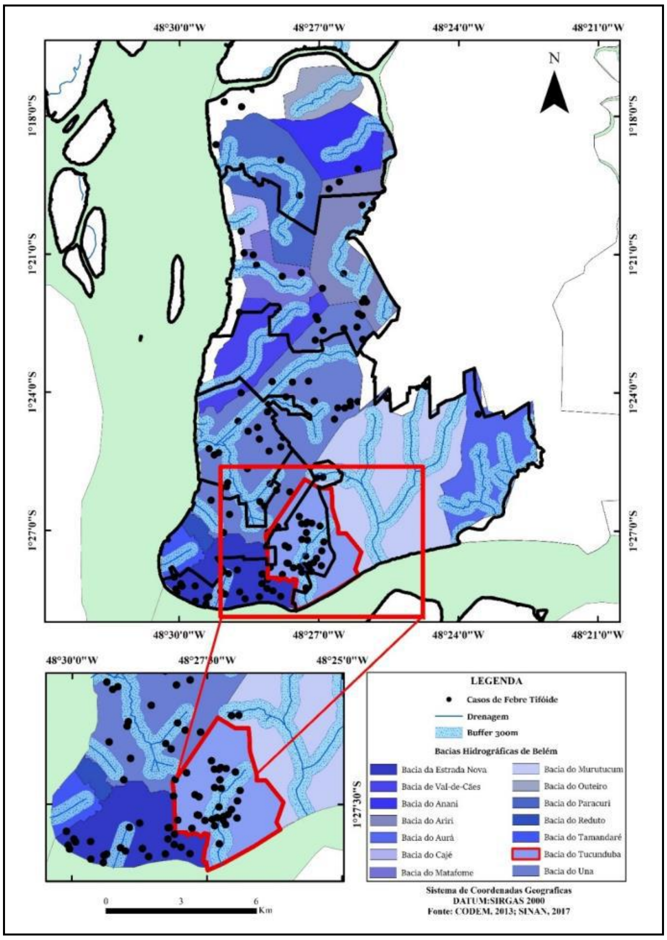

Fig. 3: Spatial distribution of typhoid fever cases and the application of EDK in the city of Belém-Pará, Brazil, between 2007-2016 and, in particular, the year 2014.

The map made using the Buffer technique represents the distance between the number of infections and the drainage areas with the risk of flooding (Figure 3).

IV. DISCUSSION

The study shows that the most affected population is composed of males aged between 30 and 59 years, which is in accordance with the results of the research carried out in Belém by Rocha et al. [8], in which men in this age group are believed to be more predisposed to this infection due to the level of exposure to risk situations, as described in Table 2. Regarding education, most of the records, which contained information, were composed of individuals who attended high school. According to Keddy [5], better education levels can act as a factor in reducing the incidence of typhoid fever, however, possible deficiencies in basic sanitation and in the drinking water supply system are identified as the most relevant factors for transmission. Infection in the areas analyzed in this study, with more impact than schooling itself.

The epidemiological profile showed low completeness in filling out the SINAN notification forms since 86.84% of the information regarding the risk situation and case evolution were filled in as ignored, resulting in significant damage to the planning and implementation of strategic measures. However, even so, it was possible to observe that the highest frequency regarding the risk of transmission was in the consumption of unhygienic foods (9.21%) and water contaminated by the bacteria (1.97%). Dhadwal and Shetty [22], studying an outbreak of typhoid fever recorded in school children in India, also found that the main source of infection was the consumption of contaminated water.

It was observed that the most used criterion for confirmation of the diagnosis was the laboratory (93.42%), in contrast to the epidemiological clinic (5.26%), which gives greater veracity to the notifications. For Thieu et al. [23], the most reliable method for identifying individuals with typhoid fever is performed in the laboratory by means of the culture and isolation of the causative bacteria. Nsutebu et al. [24] noted that many professionals have difficulty diagnosing typhoid fever, which may overestimate or underestimate the diagnosis.

In the present study, 69.08% of the cases were treated on an outpatient basis and only 25.66% needed hospital care, with no death records, demonstrating that there was a good resolution of the clinical condition. The epidemiological profile presented by Dhadwal and Shetty [22] corroborated this study, by indicating the laboratory diagnosis as the most effective, where most of those affected received outpatient care without serious complications or deaths. Possibly early intervention and the application of a rapid and effective treatment protocol contributed to the outcome.

The temporal analysis, Figure 1 (A), showed that the years 2011 and 2014 had the lowest and highest incidence rates, respectively. According to Moraes and Francisco Filho [25], the lowest incidence rate, observed in 2011, coincides with the significant increase in precipitation levels in the city of Belém. In 2014, according to Matos et al. [26], there was an outbreak of the disease in the municipality of Breves (PA), located on Ilha do Marajó, and in this same work, an outbreak of typhoid fever was also identified in the metropolitan region of Belém, as seen in Figure 2. According to Santos and Alcântara [3], most outbreaks of typhoid fever in Brazil occur in the North and Northeast regions. The study by Dhadwal and Shetty [22] identified the occurrence of an outbreak of typhoid fever in India due to fecal contamination of drinking water. According to Rocha et al. [8], as the virulence factor of typhoid fever is high, outbreaks are uncommon in the wettest months due to the dilution of the pathogen in the environment.

According to Figure 1 (B), it can be inferred from the results that the highest number of infections occurred in the period of low rainfall, between July and November, disagreeing with the study by Thanh et al. [12] in which the rainiest periods act as an environmental factor that predisposes to the endemicity of the disease. These results corroborate the study by Bastos et al. [27] who also observed the existence of a peculiarity in the seasonal distribution of typhoid fever in the state of Pará, where the highest occurrence of infection occurred in the months of intense heat, between July and December. As described by Moraes and Francisco Filho [25], the least rainy season in the municipality of Belém occurs between September and November during the Amazonian summer. Matos et al. [26] showed that between September and November 2015 an outbreak of typhoid fever occurred on Marajó Island. According to Leão et al. [10], the main cause of the spread of typhoid fever in Belém is linked to the consumption of açaí juice, whose harvest takes place in the second half of the year. Therefore, two factors together may be related to the greater number of cases, one of a climatic nature and the other of a food nature.

During the analyzed period, approximately 60% of the absolute number of cases are concentrated in two administrative districts: DAGUA with 37.50% and DAENT with 21.71%.

The study showed heterogeneous incidence rates among administrative districts, with higher rates being observed in DAENT (Figure 1 (C)). In addition, the use of EDK analysis (Figure 2) made it possible to identify an outbreak that occurred in 2014 in DAENT.

However, in the spatial analysis from 2007 to 2016 using the EDK (Figure 2) it was found that the largest cluster of cases was concentrated in DAGUA (especially in the neighborhoods of Guamá and Terra Firme), which represents the greatest risk of transmission. This fact may be associated with the large number of people exposed due to the high population density found in DAGUA. Bastos et al. [27] also observed the occurrence of typhoid fever outbreaks in the Guamá neighborhood between 2005 and 2006. According to Rocha et al. [8], the occurrence of typhoid fever in DAGUA may be linked to the ingestion of açaí juice contaminated with the bacteria, since in this district there is the highest consumption and commercialization of this typical fruit. The studies by Campos et al. [28] found that most neighborhoods belonging to DAGUA are reported daily as they are among the most affected by flooding resulting from the lack of adequate drainage and sewage networks, which, according to Santos and Alcântara [3], investments in sanitation have repercussions. In the prevention and reduction of cases of typhoid fever.

The distance map generated by the Buffer technique, shown in Figure 3, showed that there is a relationship between the concentration of cases and the Tucunduba watershed, which is located in DAGUA. According to Gonçalves et al. [29], the problem found in DAGUA is due to the socio-economic fragility of this area, which concentrates a high number of people living on the banks of water bodies with risk of flooding and insufficient sanitary infrastructure. The study by Alwis et al. [9], showed that the number of typhoid fever cases in Fuji increased after flooding caused by cyclones, noting that environmental factors (annual rainfall and proximity to water bodies with potential for flooding) were the main predictors for the incidence of infection in the region. A study by Liu et al. [30] concluded that areas subject to flooding represent an important risk factor for the transmission of gastrointestinal diseases.

V. CONCLUSION

The main finding of this study is the hypothesis that the factors that condition the transmission of typhoid fever in Belém are related to the drinking water supply system, where spatial analyzes showed that the most affected population is concentrated in urban periphery areas with precarious conditions, sanitary conditions, whose typical eating habits are strongly related to the consumption and handling of açaí juice.

The use of geoprocessing enabled the geographical delimitation of important areas for the Spatio-temporal understanding of typhoid fever. Mapping the infection foci facilitated the visualization of outbreaks and the analysis of the results.

The main resolute measure to reduce the incidence rates of typhoid fever consists of investing in basic sanitation, drinking water treatment, and increasing family health strategy teams with home visits for guidance and identification of the disease.

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