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Short Communication

Spatial-temporal analysis of dengue deaths: identifying social vulnerabilities

***Maria do Socorro da Silva*[1], *Maria dos Remédios Freitas Carvalho Branco*[2],[3],[4], *José Aquino Junior*[3],[5], *Rejane Christine de Sousa Queiroz*[5],[6], *Emanuele Bani*[3], *Emnielle Pinto Borges Moreira*[3], *Maria Nilza Lima Medeiros*[7] and *Zulimar Márita Ribeiro Rodrigues*[3],[5]**

[1]. Programa Municipal de Controle da Dengue, São Luis, Maranhão, Brasil. [2]. Departamento de Patologia, Universidade Federal do Maranhão, São Luis, Maranhão, Brasil. [3]. Programa de Pós-Graduação em Saúde e Ambiente, Universidade Federal do Maranhão, São Luis, Maranhão, Brasil.
[4]. Programa de Pós-Graduação em Saúde Coletiva, Universidade Federal do Maranhão, São Luis, Maranhão, Brasil.
[5]. Departamento de Geociências, Universidade Federal do Maranhão, São Luis, Maranhão, Brasil.
[6]. Departamento de Saúde Pública, Universidade Federal do Maranhão, São Luis, Maranhão, Brasil.
[7]. Programa de Pós-Graduação em Gestão de Programas e Serviços de Saúde, Universidade Ceuma, São Luis, Maranhão, Brasil.

Abstract

Introduction: Currently, dengue fever, chikungunya fever, and zika virus represent serious public health issues in Brazil, despite efforts to control the vector, the *Aedes aegypti* mosquito. **Methods:** This was a descriptive and ecological study of dengue deaths occurring from 2002 to 2013 in São Luis, Maranhão, Brazil. Geoprocessing software was used to draw maps, linking the geo-referenced deaths with urban/social data at census tract level. **Results:** There were 74 deaths, concentrated in areas of social vulnerability. **Conclusions:** The use of geo-technology tools pointed to a concentration of dengue deaths in specific intra-urban areas.

Keywords: Dengue fever. Death. Spatial analysis.

Dengue fever is a disease of great public health importance in tropical and subtropical countries where the social and environmental conditions favor the development and proliferation of its main vector, the *Aedes aegypti* mosquito[1]. Dengue fever is the most important human arboviral disease globally[2]. The preparedness of health services to properly care for patients suspected to have dengue fever, thereby avoiding deaths, is as important as avoiding transmission of the virus itself[3]. Although climatic conditions affect the proliferation of *Aedes aegypti* mosquitoes, the conditions facilitating the permanence and circulation of the vector are strongly associated with how urban spaces are organized, the increase in non-organic waste generation, and the population's way of living[4]. Usually, research about disease epidemiology does not consider intra-urban inequalities. Public health surveillance systems, following the same pattern, either do not use or underuse spatial analysis to investigate the dynamics of unequal urban spaces. In order to assess the effect of intra-urban inequality on dengue deaths, it is necessary to consider the macro and micro determinants of the transmission of the dengue virus. Macro determinants are social and environmental factors such as latitude, altitude, climate, vegetation, population density, type of housing, and population flow. Micro determinants are those associated with the host, agent, and disease vector; they include factors such as host immunity, age, sex, and comorbidities[3]. Taking into account the social and environmental determinants of dengue fever, this study aimed to perform a spatial-temporal analysis of dengue deaths in São Luis. This research comprises a descriptive study on dengue deaths and an ecological study on the geographic distribution dengue deaths, whose unit of analysis was a census tract. A systemic and multi-causal approach was used.

Data on dengue deaths were obtained from the National Mandatory Reporting System **(**SINAN) and the Mortality Information System (SIM) at the Municipal Dengue Control Program of São Luis (PMCD). All confirmed dengue deaths from 2002 to 2013 occurring in persons whose place of residence was the municipality of São Luis, were included. An epidemiological surveillance team from the PMCD conducted an investigation in the households of all deaths in which dengue fever was suspected.

Several social and environmental variables were obtained from the *Instituto Brasileiro de Geografia e Estatística* (IBGE) database[5] according to census tract, including: population density, total nominal monthly income of the head of the household, open sewage at the permanent residence, lack of

Corresponding author: Maria do Socorro da Silva
e-mail: socorroepidemiologia@gmail.com
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public waste removal or surrounding waste collection, and subnormal agglomerations.

Fieldwork was conducted with the purpose of assessing the location of areas with a high concentration of deaths by means of on-site observation and obtaining photographic documentation to allow a qualitative analysis of the social and environmental data obtained from IBGE. Furthermore, using the global positioning system *GARMIN® eTrex 10* device (Garmin Ltd.), the geographic coordinates of the areas surrounding the households that reported deaths were obtained. The geographic information systems, *Google Earth Pro* and *ArcGis 10.2*, and *Microsoft Excel* were used for computation of the geographic data. We evaluated the overlap of georeferenced points of deaths with the social and environmental data from the census tracts, as well as with data from the seven sanitary districts administratively defined by the Municipal Health Authority of São Luis (SEMUS). For the spatial-temporal analysis, the census tract of the municipality of São Luis was used as a geographic division. According to the territorial division of IBGE[5], the municipality possessed 1,126 tracts.

In order to better understand the dynamics of the disease on the macro-spatial analysis scale, six areas within the urban perimeter of São Luis – those with the highest number of deaths – were chosen for on-site investigation The spatial representations were drawn on six maps, as shown in Figures 1A, 1B, 1C, 1D, 1F and 1F. Dengue deaths per sanitary district and photographic register of the surrounding areas. Red dots represent deaths and yellow dots represent the visited areas where photographic documentation was obtained (**Figure 1A).** Dengue deaths per subnormal agglomeration. A subnormal agglomeration was defined as a set of ≥ 51 habitational units characterized by the absence of a property title and at least one of the following: irregularity of roads, size, and shape of allotments, and/or lacking essential public services such as waste collection, a sewage system, a water network, electric power, and street lighting[5] (**Figure 1B)**. Dengue deaths by population density (**Figure 1C)**. Dengue deaths per total income of the household head (**Figure 1D)**. Dengue deaths per habitational units lacking waste collection (absolute number of households) (**Figure 1E)** and **d**engue deaths per habitational units lacking a sewage system (absolute number of households) (**Figure 1F).**

All 74 confirmed dengue deaths in São Luis in the period under consideration were included. The case-fatality rate of severe cases varied from zero to 35%. Most deaths occurred in women (58.1%) and persons of mixed ethnicity (85.1%). The sanitary district with the highest proportion of deaths (29.7%) was Tiririca**l (Table 1**).

The median duration of disease in those aged <15 years and ≥15 years was 4 and 5 days, respectively. Hemorrhagic manifestations were more common in those aged <15 years (86.5%), especially petechiae (51.4%); however, gastrointestinal bleeding was more frequent in patients aged ≥15 years (51.4%). Regarding plasma leak criteria, cavity effusion occurred frequently in both age groups (73.3%). In terms of the final classification, dengue fever with complications predominated (77%) (**Table 2**).

TABLE 1

Case-fatality rate of severe cases and sociodemographic characteristics of dengue deaths, stratified by age.

Year	Severe cases n	Deaths n	Case-fatality rate %	Deaths n (%)		
				<15 years old	≥15 years old	total
2002	15	1	6. 7	0 (0.0)	1 (2.7)	1 (1.4)
2003	34	1	2.9	0 (0.0)	1 (2.7)	1 (1.4)
2004	7	0	0.0	0 (0.0)	0 (0.0)	0 (0.0)
2005	66	5	7.6	2 (5.4)	3 (8.1)	5 (6.8)
2006	172	6	3.5	2 (5.4)	4 (10.8)	6 (8.1)
2007	424	24	5.7	22 (59.5)	2 (5.4)	24 (32.4)
2008	32	5	15.6	0 (0.0)	5 (13.5)	5 (6.8)
2009	11	1	9.1	0 (0.0)	1 (2.7)	1 (1.4)
2010	108	3	2.8	2 (5.4)	1 (2.7)	3 (4.1)
2011	108	14	13.0	5 (13.5)	9 (24.3)	14 (18.9)
2012	21	7	33.3	3 (8.1)	4 (10.8)	7 (9.5)
2013	20	7	35.0	1 (2.7)	6 (16.2)	7 (9.5)
Total	1,018	74	7.3	37	37	74
Female sex	–	–	–	22 (59.5)	21 (56.8)	43 (58.1)
Mixed race	–	–	–	30 (81.1)	33 (89.2)	63 (85.1)
Sanitary district	–	–	–			
Bequimão	–	–	–	2 (5.4)	5 (13.5)	7 (9.5)
Tiririca**l**	–	–	–	13 (35.1)	9 (24.3)	22 (29.7)
Centro	–	–	–	2 (5.4)	3 (8.1)	5 (6.8)
Cohab	–	–	–	6 (16.2)	7 (18.9)	13 (17.6)
Itaqui Bacanga	–	–	–	4 (10.8)	4 (10.8)	8 (10.8)
Coroadinho	–	–	–	8 (21.6)	7 (18.9)	15 (20.3)
Vila Esperança	–	–	–	2 (5.4)	2 (5.4)	4 (5.4)

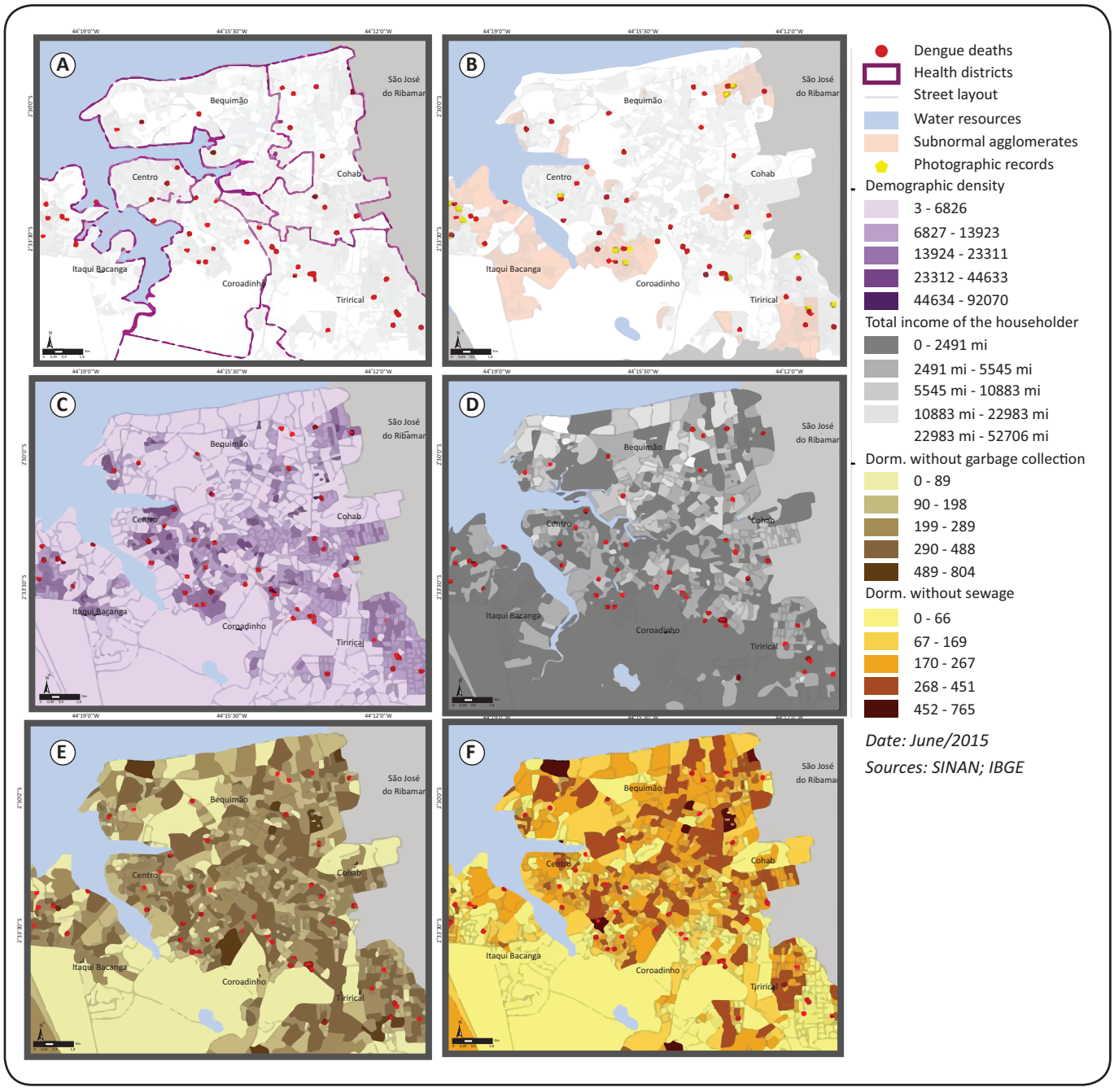

FIGURE 1: Spatialization of dengue deaths, 2002-2003, City of São Luis, Maranhão State, Brazil.

The serotype was identified in nine patients, distributed as follows according to year of occurrence: in 2006, one death from DENV-1; in 2007, four from DENV-2 and two from DENV-3; and in 2008, one from DENV-1 and one from DENV-2.

The results of the spatial-temporal representations, sanitary districts, and distribution of deaths during the study period are highlighted on **Figure 1A**. **Figure 1B** displays the superimposition of social vulnerability and concentration of dengue deaths. **Figure 1C** demonstrates the overlap between the concentration of deaths and the concentration of population data; however, there were areas with high and with low population density overlapping with the geo-referenced data, indicating that other variables (apart from the demographic values) affect mortality. **Figure 1D** shows the superimposition of geo-referenced data and low income of the head of the household. There were no dengue deaths in the northern areas of the municipality, which comprise the census tracts with the highest income levels. **Figure 1E** demonstrates overlap between areas with poor waste collection and dengue deaths. It also shows that all neighborhoods and/or census tracts present some degree of precariousness of the waste collection system, demonstrating that the entire municipality is subject to this vulnerability.

TABLE 2

Clinical and laboratory characteristics of dengue deaths, stratified by age.

Characteristic	< 15 years old	≥ 15 years old	Total
Duration of disease (days)			
number	37	37	74
median	4	5	5
mean ± sd	5.81 ± 5.53	5.70 ± 2.53	5.76 ± 4.27
minimum value	1	0	0
maximum value	30	12	30
Duration of hospitalization (days)			
number	31	28	59
median	1	2	1
mean ± sd	2.94 ± 4.63	2.57 ± 3.37	2.76 ± 4.05
minimum value	0	0	0
maximum value	23	18	23
Platelet count (per mm³)			
number	28	21	49
median	33,000	40,000	34,000
mean ± SD	50,035.9 ± 44,112.2	53,728.6 ± 41,908.4	51,618.5 ± 42,775.8
minimum value	12,000	11,000	11,000
maximum value	184,000	154,000	184,000
Bleeding, n (%)			
any bleeding	32 (86.5)	26 (70.3)	58 (78.4)
epistaxis	7 (18.9)	4 (10.8)	11 (14.9)
gingival bleeding	3 (8.1)	4 (10.8)	7 (9.5)
metrorrhagia	2 (9.1)	0 (0.0)	2 (4.7)
petechiae	19 (51.4)	12 (32.4)	31 (41.9)
hematuria	3 (8.1)	4 (10.8)	7 (9.5)
gastrointestinal bleeding	17 (46.0)	19 (51.4)	36 (48.7)
positive tourniquet test	4 (10.8)	2 (5.4)	6 (8.1)
Plasma leak criteria, n (%)			
hemoconcentration	6 (21.4)	3 (17.7)	9 (20.0)
cavity effusion	20 (71.4)	13 (76.5)	33 (73.3)
hypoproteinemia	2 (7.1)	1 (5.9)	3 (6.7)
Final classification, n (%)			
dengue fever with complications	28 (75.7)	29 (78.4)	57 (77.0)
dengue hemorrhagic fever	9 (24.3)	8 (21.6)	17 (23.0)
Confirmation criteria, n (%)			
laboratory	22 (59.5)	29 (78.4)	51 (68.9)
clinical-epidemiological	15 (40.5)	8 (21.6)	23 (31.1)

SD: standard deviation.

Figure 1F identifies that every neighborhood has some degree of shortcoming of the public sewage system, demonstrating that the municipality still lacks basic sanitary infrastructure.

The on-site investigation revealed housing units arranged along narrow streets, resulting in shaded areas that prevent evaporation and promote high humidity and milder temperatures favorable to the life cycle of *Aedes aegypti*; roofs that favor semi-permanent water accumulation; and the accumulation of waste both in the open and alongside and within streams that serve to drain rainwater and sewage.

Death is an avoidable outcome of dengue fever[6]. According to the World Health Organization[7], the acceptable dengue case-fatality rate is <1%. However, in this study, high case-fatality rates were found. This might be explained by the underreporting of severe cases. The case-fatality rate for patients with severe dengue points to the quality of attention to health in these cases and how health services organize themselves to provide care[8]. There were deaths among all age groups, including those in the extremes of age. We observed a higher proportion of deaths in those <15 years old in 2007, corresponding to the findings of Farias[9] in Rio de Janeiro during this same period. The disease duration was very short, matching the period of increased severity of dengue, from day 3 to 5 of the disease course, as widely reported[3]. These data reinforce the need for early clinical suspicion and resultant adequate and timely clinical management to avoid deaths. On the other hand, Farias[9]

determined that the survival rate was not related to early or late hospitalization, raising questions on the effect of disease severity at the moment of admission if no treatment is available or if the hospital medical service is inefficient. Regarding ethnicity, there was a preponderance of deaths among persons of mixed ethnicity, a demographic more predominant in the state's population[10].

Hemorrhagic manifestations, particularly petechiae, were more frequent in those aged <15 years. However, gastrointestinal bleeding was more prevalent in those aged ≥15 years. Bleeding indicates a worsening prognosis, especially from day 3 to 5 of the disease, during defervescence[3]. In terms of plasma leak criteria, there was a high prevalence of cavity effusion in both age groups. Escosteguy et al.[11] and Brito et al.[12] found cavity effusions in 62.2% of children and in 64% of adults with severe dengue fever.

Most deaths were classified as being due to dengue fever with complications. It should be noted deaths occurring in patients who did not meet the criteria for dengue hemorrhagic fever were classified as deaths due to dengue fever with complications, in accordance with the Health Ministry's recommendation[1]. Additionally, it is important to emphasize the difficulty in confirming cases of dengue hemorrhagic fever because complementary tests, such as hematocrit and platelet count, are required. Although a high proportion of patients in both age groups were diagnosed on laboratory criteria, this proportion was below that recommended by the Health Ministry, namely, laboratory confirmation in 100% of deaths. However, lack of confirmation of infection by dengue virus is not a deterrent for treatment.

Laboratory specimens, especially from critically patients, should be obtained by health units to confirm or exclude dengue[1]. Several hypotheses could be considered for the absence of laboratory confirmation, including health professionals not following the recommendation of collecting and storing serum from critically ill patients, despite national[1] and municipal[13] directives; difficulty collecting samples from patients in hypovolemic shock; and a lack of operational and logistic structures for storage and transportation of clinical specimens.

In our study, the most prevalent serotype was DENV-2, which is apparently associated with the most severe cases of dengue. The circulation of serotype DENV-2 in Rio de Janeiro in 2008 was also associated with an increased incidence of severe dengue and an increased case-fatality rate[11].

According to Pereira[14], the geographical area is pivotal to epidemiological action. It indicates the risks to which the population is exposed, allows the spread of diseases to be tracked, provides evidence for causal explanations, defines the priorities of intervention, and evaluates aspects of intervention. In this study, the use of geospatial tools, along with the qualitative analysis conducted on-site, contributed to demonstration of the close relationship between areas of social and environmental vulnerability and dengue deaths in the municipality of São Luis: The worst environmental conditions presented higher concentrations of dengue deaths. In these areas, the level of income is low and basic sanitary conditions are precarious; creating a situation that favors the distribution and dispersion of the *Aedes aegypti* mosquito. The distribution of the disease indicates exposure of the entire population living in areas of high risk of dengue transmission[15]. This study revealed that deaths were concentrated in the most vulnerable environmental areas, those with a higher degree of exposure to vector.

In conclusion, assessment of dengue morbidity and case-fatality rate cannot be achieved in a unilateral and simplistic manner, considering only the affected person. The environment, an integrated system formed by a set of tangible and intangible elements that can provide conditions conducive to the occurrence of dengue death, must also be considered.

Ethical considerations

The project was approved by the Institutional Review Board of the Ceuma University, and was registered on the Brazil Platform (CAAE. 10255613.2.0000.5084).

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Conflict of interest

The authors declare that there are no conflicts of interest.

REFERENCES

1. Ministério da Saúde. Secretaria de Vigilância em Saúde. Departamento de Vigilância Epidemiológica. Diretrizes nacionais para prevenção e controle de epidemias de dengue. Brasília: Ministério da Saúde; 2009. 162p.
2. Tauil PL. Prefácio. *In*: Valle D, Pimenta DN, Cunha RV, editores. Dengue: teorias e práticas. Rio de Janeiro: FIOCRUZ, 2015. p. 11-13.
3. Torres EM. Dengue. Rio de Janeiro: Editora FIOCRUZ; 2005. 344p.
4. Pignatti MG. Saúde e Ambiente: as práticas sanitárias para o controle da dengue no Estado de São Paulo (1985-1995). Dissertação de Mestrado em Saúde Coletiva. Campinas: Universidade Estadual de Campinas; 1996. 144p.
5. Instituto Brasileiro de Geografia e Estatística (IBGE). Centro de Documentação e Disseminação de Informações. Base de informações do Censo Demográfico 2010: Resultados do Universo por setor censitário. Rio de Janeiro, 2011. 125p.
6. Figueiró AC, Hartz ZMA, Brito CAA, Samico I, Siqueira Filha NT, Cazarin G, et al. Óbito por dengue como evento sentinela para avaliação da qualidade da assistência: estudo de caso em dois municípios da Região Nordeste, Brasil, 2008. Cad Saúde Pública. 2011;27(12):2373-85.
7. World Health Organization (WHO). Dengue haemorragic fever: diagnosis, treatment, prevention and control. 2nd edition. Geneva: WHO; 1997. 58p.
8. Vinhal LC. Avaliação da qualidade da assistência hospitalar para os casos graves de dengue. Dissertação de Mestrado em Saúde

Pública. Escola Nacional de Saúde Pública Sergio Arouca. Rio de Janeiro: Fundação Oswaldo Cruz; 2008. 110p.

9. Farias MS. Análise de óbitos por dengue na epidemia de 2007/2008 na Região Metropolitana do Rio de Janeiro. Dissertação de Mestrado em Saúde Coletiva. Rio de Janeiro: Universidade Federal do Rio de Janeiro; 2011. 98p.
10. Instituto Brasileiro de Geografia e Estatística (IBGE). Maranhão, São Luis. Censo Demográfico 2010: resultados da amostra – Características da População. São Luis: IBGE; 2010. Disponível em: http://cidades.ibge.gov.br/xtras/temas.php?lang=&codmun=211130&idtema=90&search=maranhao%7Csao-luis%7Censo-demografico-2010:-resultados-da-amostra-caracteristicas-da-populacao-
11. Escosteguy CC, Pereira AGL, Medronho RA, Rodrigues CS, Chagas KKF. Diferenças, segundo faixa etária, do perfil clínico-epidemiológico dos casos de dengue grave atendidos no Hospital Federal dos Servidores do Estado, Rio de Janeiro-RJ, Brasil, durante a epidemia de 2008. Epidemiol Serv Saúde. 2013;22(1):67-76.
12. Brito CAA, Albuquerque MFMP, Lucena-Silva N. Evidência de alterações de permeabilidade vascular na dengue: quando a dosagem de albumina sérica define o quadro? Rev Soc Bras Med Trop. 2007;40(2):220-223.
13. Secretaria Municipal de Saúde de São Luis. Vigilância Epidemiológica. Orientação sobre coleta, acondicionamento e transporte de amostra de soro para sorologia e isolamento viral. Nota técnica nº 03, de 10 de janeiro de 1997. São Luis: SEMUS; 1997. 4p.
14. Pereira MG. Epidemiologia: teoria e prática. 15th reimpr. Rio de Janeiro: Guanabara Koogan; 2012. 596p.
15. Aquino Jr J. A dengue em área de fronteira internacional: riscos e vulnerabilidades na tríplice fronteira de Foz do Iguaçu. Tese de Doutorado. Curitiba: Universidade Federal do Paraná; 2014. 188p.