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RESEARCH ARTICLE OPEN ACCESS

INDICATORS OF FECAL POLLUTION IN STREAMS LOCATED IN THE ITAQUI-BACANGA DISTRICT, SÃO LUÍS, MARANHÃO, BRAZIL

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ABSTRACT

Escherichia coli is a pathogenic microorganism that can be introduced into the human body through contaminated water and food, causing gastrointestinal or urinary tract infections, being a bioindicator of water quality and risk to human health. The aim of the present research was to analyze the water quality of streams located in the Itaqui-Bacanga district using bacteriological indicators and establish a correlation between cause and effect considering the housing conditions, sanitation, healthcare aspects of local residents. The Vila Isabel neighborhoods, which is drained by Macaca Creek, had better sanitation and housing conditions but presented the worst indicators of water quality due to disordered urban growth as well as a lack of sanitary and environmental awareness, which are factors that contribute considerably to the aggravation of health problems in the local population.

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INTRODUCTION

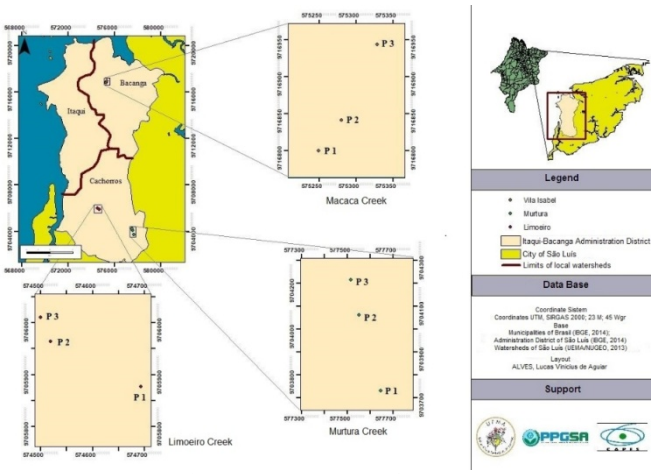
Bacteria of the coliform group are commonly used as bioindicators of the quality of aquatic environments. Known as pathogenic intestinal bacteria, the occurrence of coliforms in aquatic environments is due to the presence of feces from warm-blooded animals, although coliforms may be found in the soil and vegetation (HACHICH*et al*., 2012). *Escherichia coli* belongs to the subgroup of thermotolerant coliforms and is the main microorganism that represents this class of etiologic agents, indicating fecal contamination of the environment (PARUCH; MAEHLUM, 2012; EDBERG *et al*., 2000).The introduction of this agent in the human organism occurs through the ingestion of contaminated water and food or contact with the skin. These pathogenic agents commonly occupy the large intestine, causing infections and giving rise to symptoms, such as diarrhea. Coliforms can also infect other parts of the body, such as the urinary tract, and can cause meningitis, pneumonia and other illnesses (BUSH*et al*., 2018). Water-borne diseases include diarrhea, cholera, typhoid fever and dysentery, which are mainly attributed to contaminated water and inadequate hygiene practices (MAHMUD *et al*., 2019). Direct runoff from urbanized surfaces and sewage discharges not connected to a wastewater treatment plant (WWTP) has emerged as a serious threat, not only to the ecological values of water ecosystems but also to the provision of good quality water required for all socioeconomic functions (BRION *et al*. 2015; GOTKOWSKA-PŁACHTA *et al*. 2016).The treatment of residual waters is part of the sanitation system, contributes decisively to ecological balance and is an important aspect of the hygiene and health of the population (POORTVLIET*et al*., 2018). Approximately 2.2 billion people in the world do not have access to potable water and 4.2 billion do not have safely managed sanitation services. In northeastern Brazil, only 34.1% of sewage is treated and the collection rate is only 30.3%. This difference is more accentuated when considering urban and rural areas within the same region (VENTURA *et al*., 2017).In the state of Maranhão, 49.65% of the

population are connected to the sewage system, whereas sewage treatment rate is only 22.23% (BRASIL, 2021). The capital of the state – São Luís – occupies the 80th position in the ranking of the 100 best cities, with the water supply reaching 83.25% of the population. However, the sewage collection rate is only around 50% (47.43% in rural areas and 52.57% in urban areas). Despite the existence of sewage treatment stations in the city, the volume of treated sewage corresponds to 22.23% of the volume of water consumed (BRASIL, 2021).In this context, the aim of the present study was to analyze water quality in creeks that drain neighborhoods in the Itaqui-Bacanga district of São Luís using bacteriological indicators and establish a correlation between cause and effect considering the housing conditions, sanitation, healthcare aspects and lifestyle of the local residents.

Study Area: The Itaqui-Bacanga sanitary district is one of the most populated regions in the city of São Luís, with a contingent of approximately 250,000 residents (CONCEIÇÃO*et al*., 2017) distributed among 60 neighborhoods encompassing both urban and rural areas of the city. The neighborhoods included in the present study were Limoeiro, Murtura and Vila Isabel, the first two of which are in rural areas. Limoeiro is located near the village of Taim, where an extratavist reserve is planned, and Murtura is close to the neighborhood of Pedrinhas. Vila Isabel is situated between the neighborhoods of Alto da Vitória, Dom Luís and Vila Embratel, which pertain to the urban zone of the city.

MATERIAL AND METHODS

Sampling: Data were obtained through four collections at three-month intervals between May 2017 and February 2018, encompassing the dry and rainy periods. Collection points denominated P1, P2 and P3 were defined for each water body (Figure 1) and distributed spatially as a function of the declivity of the creeks. The following are the coordinates of each point in each creek: Limoeiro, P1: 02°39'34''S and 44°19'47''W; P2: 02°39'15''S and 44°19'47''W; P3: 02°39'39''S and 44°19'4''W. Murtura, P1: 02°40'49"S and 44°18'.05''W; P2: 02°40'.38''S and 44°18'08''W; P3: 02°40'33''S and 44°18'.09''W. Vila Isabel, P1: 02°33'43''S and 44°19.23''W; P2: 02°33'42''S and 44°19'22''W; P3: 02°33'38'S' and 44°19'20''W (CABRAL *et al.,* 2020). Samples were collected following the recommendations of *Fundação Nacional de Saúde* (FUNASA [National Health Foundation], 2014) and stored in 500-mL polyethylene flasks previously disinfected with a cleaning solution containing 5% NHO_3 (v/v).



(Source: CABRAL, *et al* 2020)

Figure 1. Location of study area and sampling points

Bacteriological Analysis: The multiple tube method was adopted for the determination of the most probable number (MPN) of coliforms, as described by the American Public Health Association (2005). The analyses were conducted at the Technological Pavilion of *Universidade Federal do Maranhão* (UFMA) and obeyed the following steps: Presumptive test; confirmative test for the estimate of the most probable number of total coliforms (MPN/mL); confirmative test for the estimate of the most probable number of coliforms at 45 °C (MPN/mL); and the identification of *E. coli.*

Lifestyle and healthcare aspectsof population: For the analysis of the housing conditions, sanitation, healthcare aspects and lifestyle of individuals who reside in the study area, interviews were held involving the administration of questionnaires. One of the inclusion criteria was a minimum age of 18 years. The sample size was determined using proportional sampling for a finite population. The reference was the number of residents in the neighborhoods within the census sector in which the interviews were held (COCHRAN, 1977; ZAR, 2010; BAYE *et al.*, 2020). The sample size was determined using the following formulas:

$$\text{no} = \frac{z\,p\,q}{e^2} \text{ and } \quad n = \frac{n}{1 + \frac{(n-1)}{N}}$$

in which:
n_o = initial sample size
n = final sample size
z = value of normal curve for desired confidence level (1-α)
p = estimated proportion of attribute in population
q = 1- p
e = maximum acceptable error
N = size of population

Ethical aspects: This study received approval from the UFMA institutional review board (certificate number: 2290033).

RESULTS

Bacteriological analysis: During the collections, Macaca Creek had high concentrations of total coliforms and thermotolerant coliforms at all sampling points and *E. coli* was detected throughout the entire stretch of the creek. In Limoeiro Creek, the most probable number (MPN/mL) for both total coliforms and thermotolerant coliforms was lower than maximum limit established by current legislation, except at P1, where *E. coli* was detected in August 2017. In Murtura Creek, coliform bacteria and *E. coli* predominated in the rainy period, whereas the occurrence of these bacteria varied among the different sampling points in the dry period (Table 1).

Lifestyle and healthcare aspects of population

- ***Sociodemographic characteristics:*** No accentuated differences were found among the interviewees in the neighborhoods analyzed regarding schooling, occupation or income. Most interviewees in all three locations were women. Age ranged from 19 to 94 years. The lowest level of schooling was found in the neighborhood of Limoeiro, as all interviewees had only a primary school education and only 33% had a complete primary school education. The neighborhoods of Murtura and Vila Isabel also had residents with only a primary school education. However, Vila Isabel had individuals with a higher level of schooling, as 12.5% of the interviewees had a complete (4.2%) or incomplete (8.3%) higher education.The main occupations of the residents interviewed in the neighborhood of Limoeiro were homemaker and self-employed, with the residence itself serving as the place of work. In the neighborhood of Murtura, the individuals interviewed reported activities related to farming located in the neighborhood itself, followed by domestic activities executed in the residence. The most cited occupation in the neighborhood of Vila Isabel was homemaker (33.3%); other occupations cited were cook, business owner, real estate agent, dietician, student and craftworker. All families interviewed lived on an income of one to two times the minimum monthly wage and received some type of benefit from a social program (Figure 2).

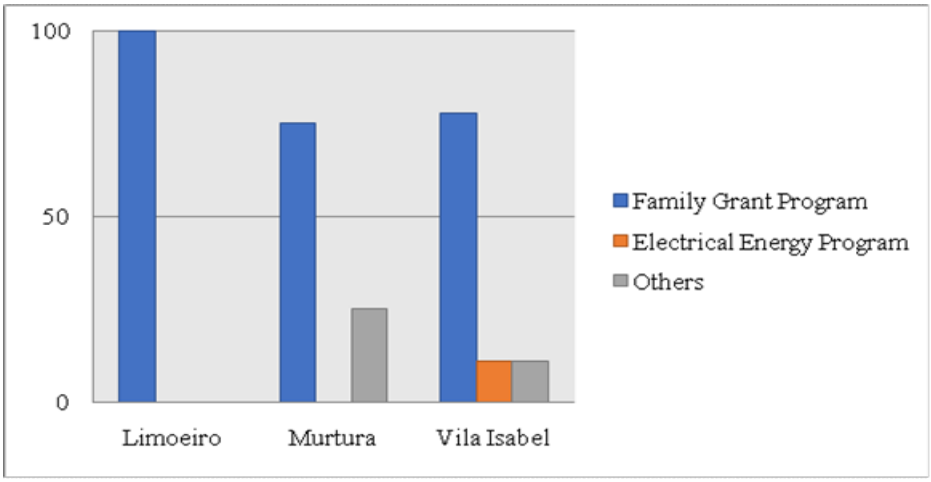


Figure 2. Social programs benefiting families interviewed in neighborhoods of (a) Limoeiro, (b) Murtura and (c) Vila Isabel

Figure 3. Depositing of garbage on banks of Macaca Creek

Figure 4. Changes in landscape of Macaca Creek during study period(a) May 2017; (b) August 2017; (c) November 2017; (d) February 2018

Table 1. MPN/mL of total coliforms (35°C), thermotolerant coliforms (45°C) and presence of *Escherichia coli* in creeks investigated

		Limoeiro Creek		Murtura Creek		Macaca Creek	
		Total C.	Therm C.	Total C.	Therm C.	Total C.	Therm C.
May 2017*	P1	240	240 (b)	2400	2400 (a)	2400	2400 (a)
	P2	240	240 (b)	2400	2400 (a)	2400	2400 (a)
	P3	240	240 (b)	2400	2400 (a)	2400	2400 (a)
Aug 2017**	P1	2400	1100 (a)	2400	< 3 (b)	2400	2400 (a)
	P2	43	43 (b)	2400	43 (b)	2400	2400 (a)
	P3	23	< 3 (b)	2400	93 (b)	2400	1100 (a)
Nov 2017**	P1	240	240 (b)	93	93 (b)	2400	2400 (a)
	P2	240	240 (b)	2400	2400 (a)	2400	2400 (a)
	P3	93	93 (b)	2400	2400 (a)	2400	2400 (a)
Feb 2018*	P1	460	460 (b)	2400	2400 (a)	2400	2400 (a)
	P2	23	23 (b)	240	240 (b)	2400	2400 (a)
	P3	23	23 (b)	2400	2400 (a)	2400	2400 (a)

MPN: most probable number; * rainy period; ** dry period; (a) presence of *Escherichia coli* in sample; (b) absence of *E. coli* in sample.

•***Aspects of healthcare:*** In Limoeiro, the majority of interviewees reported having access to public healthcare services, for which the greatest difficulties were scheduling appointments and exams. As this neighborhood is in a region of difficult access and distant from other neighborhoods, public transportation constituted another difficulty, which could be attenuated if the family had a private vehicle. The closest primary care unit to Limoeiro is the Yves Parga Health Center located in the community of Vila Maranhão. In cases of illness, the residents first sought the Urgent Care Unit of Itaqui-Bacanga. Once per month, the residents received visits from community health agents and made regular appointments. The residents assessed the healthcare services as deficient and in urgent need of improvements.The residents of Murtura reported not having access to healthcare services and 83.3% reported having some difficulty seeking such services. Among the reasons presented, transportation to the healthcare service corresponded to the greatest difficulty (38.9%), followed by the lack of healthcare providers (33.3%). The closest primary care unit is the Pedrinhas Health Unit, although the Urgent Care Unit of Itaqui-Bacanga was the most sought in cases of illness (83.3%), followed by Socorrão I Hospital (22.2%) and, lastly, the healthcare unit nearest to their homes. The community rarely receives visits from a community health agent, except in cases of pregnancy. Under such circumstances, follow-up continues through to the first days of life of the child. Assessments of the healthcare services ranged from good to very poor, with the majority classified as fair.In Vila Isabel, 58% of the individuals who participated in the study reported having access to healthcare services, whereas 70.8% reported difficulties in seeking care. The principal complaint was related to the scheduling of appointments, return visits and exams. As the neighborhood is situated in the urban zone, there are more primary care options near the residents, such as Itaqui-Bacanga Mixed Unit, Women's Hospital, Nossa Senhora da Penha Maternity, Urgent Care Unit of Itaqui-Bacanga and Clodomir Pinheiro Costa Health Center. Among these establishments, the Mixed Unit is the first option in cases of illness, followed by the Urgent Care Unit. A large part of the families received visits from community health agents once per month (45.8%), whereas 29.2% of the individuals interviewed reported rarely receiving visits. The interviewees classified the healthcare services as very good to very bad, with the highest percentages found for the fair (33.3%), poor (29.2%) and very poor (25%) categories.

•***Perception of health and reported morbidities:*** In the neighborhood of Limoeiro, 66.7% of the interviewees assessed their health as good to very good. A minority (33.3%) had some health problem, such as high blood pressure, liver disease or blood disease. Among these problems, hypertension was found in older people, whereas liver and blood diseases were found among individuals in the adult phase. A low percentage of individuals answered the question regarding water-borne diseases. However, the results revealed cases of malaria, dengue and, more commonly, giardiasis, the latter of which, according to the residents, is related to the daily consumption of well water.In Murtura, the residents interviewed assessed their health as good to poor, with the fair category accounting for the highest proportion (66.7%). When asked about diseases, the majority reported hypertension (greater occurrence among older people), followed by skin, liver, kidney, heart and respiratory diseases. Regarding water-borne diseases, the occurrence of dengue and malaria were reported. When asked if they had recently been affected by fecal-oral diseases transmitted by the water, the majority reported the occurrence of intestinal parasites, followed by amebiasis and gastroenteritis/ diarrhea/vomiting.In the neighborhood of Vila Isabel, most residents assessed their health as good (37.5%) or fair (41.7%). There were reports of heart disease, respiratory disease, stroke, liver disease, depression, impaired vision, diabetes and skin disease and the majority (especially older people) reported hypertension. One-third (33.3%) of the interviewees reported having dengue. Among fecal-oral diseases, 12.5% reported amebiasis and 37.5% reported occurrences of gastroenteritis/diarrhea/vomiting in recent months.

• ***Housing conditions and sanitation:*** In the neighborhood of Limoeiro, all homes at which the interviews were held were owned by the families. Two-thirds (66.7%) had precarious construction and only one-third (33.3%) was made of bricks and mortar. The homes had pets, especially dogs, and all respondents reported the occurrence of synanthropic animals, mostly flies as well as the existence of mice/rats. There are only six residences in the location, which belong to two distinct families and all residents had lived in the location since the establishment of the community. Thus, the reported length of residence in both the home and region was more than 40 years. The origin of water for consumption was a well and treatment consisted of filtration. There was no basic sanitation. All sewage was dumped either into a cesspit or on the ground. There was also no garbage collection. Thus, all garbage generated was burned. All homes had a gas stove. Fruits and vegetables were acquired from small shops and farmer's markets. In the neighborhood of Murtura, 88.8% of the homes were owned by the families and made of brick and mortar. Homes of adobe sustained by clay and wood were also found. Domestic and wild animals were found, with dogs in 66.7% of the homes, followed by cats and chickens. The majority of respondents (88.9%) confirmed the occurrence of synanthropic animals, the most cited of which, in decreasing order, were flies, cockroaches, mice/rats and mosquitoes. Most respondents (88.9%) reported living in the region for more than eight years and some had lived there for more than 30 years. Water for consumption and cooking came from a well. The type of well was not specified. Treatment consisted of filtration or boiling. A small portion of the population did not submit their water to any type of treatment. The sewage generated by the homes was dumped into cesspits with dirt (44.4%), collected by the sewage

system (33.3%) or dumped on the ground in the open air (16.7%). One-third (33.3%) of the respondents reported an absence of garbage collection. Most residents used a gas stove (83.3%), which was combined with other types, such as charcoal (50%), wood (16.7%) and kerosene (11.1%). The neighborhood had a community vegetable garden, which was a source of food for 33.3% of the families. Other sources included a small shop/market/grocery store (44.44%), supermarket (16.7%) and farmer's market (5.6%).In the neighborhood of Vila Isabel, 91.7% of the individuals who participated in the study owned their homes and all residences were made of brick and mortar. A total of 70.8% of the homes had some type of domestic or wild animal, with preferences for dogs (found in the half of the homes) and cats. The most cited synanthropic animals, in decreasing order, were rats/mice, cockroaches, flies, mosquitoes, ants and ticks. Most interviewees had lived in their homes and in the region for more than 30 years. Drinking water was provided by the Maranhão Water and Sewage Company in 66.7% of the homes. Besides treatment performed by the distributor, home treatment consisted of filtration or boiling. Another portion of the population (33.3%) purchased bottled drinking water. Most of the respondents used water from the Maranhão Water and Sewage Company for cooking purposes. The sewage generated by the homes was dumped into cesspits with dirt (33.3%), collected by the sewage system (20.8%) or dumped on the ground in the open air (12.5%). There were also reports of sewage dumped directly into the stream. Regular garbage collection occurred two to three times per week. Despite this, some residents dumped garbage onto empty lots and into dumpsters or burned it. A total of 91.3% had gas stove, with some reports of wood and charcoal stoves in combination with gas stoves. A large portion of the fruits and vegetables consumed were obtained from the farmer's market (54.2%), supermarket (29.2%) and small shop/market/grocery store (20.8%).

• ***Environmental perceptions regarding water quality in creek and risks to health:*** In the neighborhood of Limoeiro, the residents used water from the creek to wash clothes and dishes, swim, fish and even drink at the time of the establishment of the community. Currently, most local residents no longer use the water and those who do report that that the water is used for swimming. Those who reported not using the water from the creek would not do so even if there were no water in their homes. Those who reported some use of the creek water said they would use the water to wash clothes and dishes if they had no water in their homes. When asked about the definition of contamination, most said that they had empirical knowledge and also state that Limoeiro Creek is not contaminated. Those who stated that the creek may be contaminated were unable to state the focus of the contamination. The harm caused by possible contamination of the creek was reported to be provoked by the population. When asked about the possibility of the creek transmitting some type of disease, most answered affirmatively, citing stomach diseases.No residents of the neighborhood of Murtura currently make any use of the creek and would not do so even if there were no water in their homes. A total of 94.4% of the respondents said that the water of the creek was contaminated and identified the main source of contamination to be sewage from the Pedrinhas Penitentiary Complex, which is discharged directly into the creek. The respondents also identified an oil spill that occurred in the creek. When asked about what they used to do with the water of the creek and no longer do, the main activities reported were swimming, washing clothes and dishes, watering plants and vegetable gardens, cooking and drinking. The harm to the environment cited was pollution, contamination and deforestation. The harm to health was the transmission of diseases, allergies, itching, intestinal parasites, skin diseases and schistosomiasis.No residents of the neighborhood of Vila Isabel currently make use of the creek and would not do so even if there were no water in their homes. All were convinced that the water was contaminated, identifying the source of the contamination to be sewage discharged directly into the creek. There were also reports of garbage, feces, urine and even dead animals dumped directly into or around the creek. The harm identified was a bad smell, harm caused to fishes and dammed water in some stretches of the creek. Regarding harm to health, the residents identified the proliferation of diseases, such as dengue, intestinal parasites, diarrhea and skin problems. Regarding past uses of the water body, the respondents reported swimming, washing clothes and recreational practices.

DISCUSSION

Bacteriological analysis: The bacteriological analyses conducted with water from Limoeiro Creek demonstrated no considerable changes in the MPN/mL of coliforms in the two periods of the year. Despite this, the residents demonstrated fear regarding the constant use of the creek by swimmers on weekends. Indeed, the presence of *E. coli* was found at one sampling point. In contrast, a significant difference was found between the two periods (dry and rainy) in Murtura Creek, with an increase in the MPN/mL of *E. coli* in the rainy period. This patter has also been reported in previous studies and indicates a direct association between the rainy period and an increase in the number of bacteria of the coliform group (PADOVAN *et al*., 2010; KOLM *et al*., 2016), as rainfall can lead to the transport of organic matter from the surface of the soil to adjacent creeks. Although the neighborhood of Murtura is located in the rural zone, the residents state that the Pedrinhas Penitentiary Complex is the major cause of contamination, as its sewage is discharged into the creek, producing local contamination.*E. coli* was identified in Macaca Creek in all periods of the year, likely due to the fact that the location is exposed to the depositing of garbage on the ground and the discharge of sewage directly into the creek (Figure 3) by the residents as well as inadequate land use, which accelerates the erosive process on the banks (Figure 4). The consequence of these actions is the degradation of the creek bed and poor water quality, confirmed by the results of the bacteriological analyses, which revealed higher contamination rates by *E. coli* compared to the other creeks investigated.Comparing the three water bodies investigated in the present study, Limoeiro Creek had the best quality. According to the water quality criterion for recreational purposes established by Brazilian legislation (BRASIL, 2000), this creek can be classified as excellent, with a small variation in the maximum number of total coliforms and thermotolerant coliforms permitted only at P1 in both collection periods (August 2017 and February 2018). In contrast, the Murtura and Macaca Creeks are improper for swimming according to legislation (BRASIL, 2005). Recent studies conducted in environments close to the locations investigated in the present study showed the presence of *E. coli* in the surface water of Cachorros River (SANTOS*et al*., 2017) and in deep tubular wells used for daily consumption in the rural communities of São Benedito, Porto Grande, Inhaúma and Estiva (OLIVEIRA *et al.,* 2016).

Lifestyle and health of population: Regarding the profile of the residents, the neighborhood of Vila Isabel had higher levels of schooling compared to the other two locations. One hundred percent of the interviewees in the neighborhood of Limoeiro had only a primary school education, this proportion ranged from 50 to 60% in Murtura and Vila Isabel. Data from the United Nations Development Programme (2017) confirm this proportion, as 60% of the adult urban population have a complete primary school education compared to 26.5% of the rural population. Other information generated by this program refers to residential income *per capita*, which demonstrates that the urban population generates more income than the rural population. The low level of schooling among most interviewees in the present study may be an indicator of the low income on which the families depend to survive. According to information provided by the interviewees regarding occupation, most were homemakers or exercised some activity near their homes, such as small businesses and farming activities. Regarding sanitation, Ventura and Lopes (2017) found that access to sanitation services decreases from the urban zone to the periphery. In the present study, both neighborhoods located in the rural zone (Limoeiro and Murtura) had practically no sanitation services. The residents of these locations consume well water, are not connected to the sewage collection system and do not have regular garbage collection. *Instituto Trata Brasil* [Treat Brazil Institute] [6] states that "investing in basic sanitation can reduce the number of hospitalizations in the public healthcare network due to

gastrointestinal diseases". The greatest risks to health in the neighborhood of Vila Isabel is the lack of education related to sanitation and disordered growth, which is compromising the water quality of the creek. According to Ventura and Lopes (2017), the education regarding sanitation is fundamental to combatting water-borne diseases. The residents of the three neighborhoods investigated in the present study reported being affected by dengue; cases of malaria were reported in the neighborhoods of Limoeiro and Murtura and all three locations had recent cases of diseases caused by the lack of sanitation. One of the aims of this study was to analyze water using bacteriological parameters. Cases of gastroenteritis, diarrhea and vomiting were reported in Vila Isabel and Murtura. Moreover, the presence of helminths and protozoa in the water was recorded during the administration of the questionnaires. These organisms caused diseases, such as giardiasis in the neighborhood of Limoeiro, amebiasis in Murtura and Vila Isabel and intestinal parasitosis in Murtura. Yamaguchi *et al.* (2013) also report that the pathogenicity of microorganisms is often associated with health conditions in the host. These findings underscore the importance of a healthy environment for the population. As urban growth occurs in a disordered way and without due monitoring, the result is clearly seen through the "[...] accumulation of every type of waste resulting from the unbridled consumption of materials and natural resources, burdening the environment, which will directly or indirectly affect the majority of residents" (AYACH *et al*., 2012). As a neighborhood situated in the urban zone, Vila Isabel has better sanitation conditions compared to the two other locations investigated and also has a primary care unit – the Mixed Unit of Itaqui-Bacanga. Other health establishments are also found near the neighborhood, such as the Women's Hospital, Clodomir Pinheiro Costa Health Center and Nossa Senhora da Penha Maternity located in the neighborhood of Anjo da Guarda and the Embrião Health Center and Urgent Care Unit in the neighborhood of Vila Bacanga. The other neighborhoods investigated have access to primary care units for simple procedures, such as the Yves Parga Health Center located in the neighborhood of Vila Maranhão and the Pedrinhas Health Unit (SEMUS, 2016). Regarding the perceptions of the residents of the current situation of the creeks, the interviewees in the neighborhoods of Murtura and Vila Isabel know that the water bodies are contaminated and are the sources of the proliferation of diseases. In Limoeiro, the residents were concerned with the use of the river by sporadic swimmers on the weekends and the fact that the water is dammed at a particular point.

Another concern was that, despite having knowledge that the creeks are contaminated, the interviewees could not quantify the magnitude of the risk. Although contamination by metals was beyond the scope of this study, it may be another situation of risk to which the residents are subjected and do not perceive, as they live near industries, especially the neighborhoods of Limoeiro and Murtura.The majority of the interviewees owned their homes, which were mainly constructed with brick and mortar. In the three locations studied, most interviewees reported residing in the neighborhood for many years. Vila Isabel is the only one of the three neighborhoods with water provided by CAEMA [Maranhão Water and Sewage Company]. As Limoeiro and Murtura are not connected to the water distribution system, treatment of water for consumption consists of filtration and/or boiling, which can avoid diseases such as cholera. All sewage generated in these two neighborhoods is discharged into cesspits or directly on the ground. Most of the garbage produced by the residents is burned. Thus, the residents of Murtura raised concerns due to the existence of individual and community gardens, which are sources of fruits and vegetables consumed by the local population, increasing the risk of contracting water-borne diseases, which can be transmitted through contaminated water and/or food.

CONCLUSION

The Murtura and Macaca Creeks are contaminated, with *E. coli* values above the maximum limited established by legislation (CONAMA N° 274 from 2000), characterizing these environments as improper for swimming. Environmental authorities need to monitor the situation of public calamity in Murtura Creek.Sanitation conditions in Murtura and Limoeiro are inadequate, as these locations are not connected to the water and sewage systems and do not have garbage collection, which poses health risks, as the population may be consuming contaminated water and food. In the neighborhood of Vila Isabel, the major factor is the lack of sanitary and environmental awareness. Thus, environmental education interventions with the residents are needed. The present results show that being connected to the sewage collection system is not an assurance of environmental quality, as solid waste and raw sewage are still discharged directly into the environment, which causes serious harm. The consequences are changes in water quality indicators, such as the presence of *E. coli,* especially in the location that has such services. Although the number of appointments and hospitalizations at nearby healthcare units due to diarrhea was not investigated in the present study to test associations with housing and sanitary conditions, the information generated from the bacteriological analysis and the administration of the questionnaires demonstrate the possibility of such associations. The probability of acquiring water-borne diseases is higher in neighborhoods that do not have treated water and are not connected to the sewage collection system, as the residents may be using contaminated water and, consequently, contaminated food.

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