BALNEABILITY OF THE MUNICIPALITY OF SÃO LUÍS – MA AND THE INFLUENCE OF RAINFALL OCCURRENCES AS AN EXTERNALITY FACTOR

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ABSTRACT

Objective: To analyze the bathing conditions, that is, the quality of the water intended for primary contact recreation on the beaches of Ponta D’areia, São Marcos, Calhau and Olho d’água located in the municipality of São Luís- Maranhão.

Theoretical framework: This study was conducted based on theoretical reflections on environmental issues, the relationship between society and nature. Issues of water use for recreation, environmental policies regarding bathing and externalities that interfere with the quality of water for bathing and their impacts on the health of the population were analyzed.

Method: To select beaches and water collection sites, the most intense flow of bathers and the risks of interference with water quality were taken into account. Data on bathing ability and average monthly precipitation were obtained to verify bathing conditions, in addition to information on effluent release points and urban drainage.

Results and conclusion: It was observed that the main influence on the incidence of thermotolerant coliforms is the presence of sanitary effluents on beaches, this factor becomes visible in the rainy season and with the lack of sanitary infrastructure.

Implications of the research: This research will contribute to public policy measures, helping decision-making to improve public and environmental health in the city of São Luís- MA.

Originality/value: This study has socio-environmental and scientific value, as it relates bathing ability to externalities such as the lack of environmental sanitation and high rainfall in the region.

Keywords: Fecal Coliforms, Bathers, Recreation, Public Health.

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BALNEABILIDADE DAS PRAIAS DO MUNICÍPIO DE SÃO LUIS – MA E A INFLUÊNCIA DA OCORRÊNCIA DE CHUVAS COMO UM FATOR DE EXTERNALIDADE

RESUMO

Objetivo: Analisar as condições de balneabilidade, ou seja, na qualidade da água destinada a recreação de contato primário nas praias de Ponta D’Areia, São Marcos, Calhau e Olho d’água localizadas no município de São Luís-Maranhão.

Referencial teórico: Esse estudo foi conduzido com base nas reflexões teóricas acerca das questões ambientais, da relação sociedade e natureza. Foram analisadas questões de uso da água para recreação, políticas ambientais referentes a balneabilidade e as externalidades que interferem na qualidade das águas para banho e seus impactos a saúde da população.

Método: Para a seleção das praias e dos locais de coleta de água levou-se em consideração o fluxo mais intenso de banhistas e os riscos de interferência na qualidade da água. Obteve-se dados de balneabilidade e de precipitação média mensal para verificação das condições para banho, além de informações sobre pontos de lançamento de efluentes e drenagem urbana.

Resultados e conclusão: Observou-se que a principal influência na incidência dos coliformes termotolerantes é a presença de efluentes sanitários nas praias, esse fator se torna visível no período chuvoso e com a falta de uma infraestrutura sanitária.

Implicações da pesquisa: Esta pesquisa contribuirá para medidas em políticas públicas, auxiliando a tomadas de decisão para melhoria na saúde pública e ambiental do município de São Luís- MA.

Originalidade/valor: Este estudo possui um valor socioambiental e científico, pois relaciona a balneabilidade com externalidades como a falta de saneamento ambiental e altos índices pluviométricos da região.

Palavras-chave: Coliformes Fecais, Banhistas, Recreação, Saúde Pública.

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1 INTRODUCTION

This research aims to analyze the seaworthiness conditions of the main beaches of the municipality of São Luís-MA. This research was based on the fact that historically the most frequented beaches for leisure in the municipality are: São Marcos, Ponta D'Areia, Calhau and Olho d'Água, and it is necessary to investigate the seaworthiness conditions of these beaches. Thus, the bathing conditions were studied in the years 2009, 2011, 2015, 2016 and 2017, by surveying the microbiological indices and the externalities that can influence the bathing conditions, such as the increased surface runoff caused by precipitation, being a contributor to changes in the quality of the waters of the beaches.

Water quality is a relevant factor in establishing the health of a population and can lead to the incidence of various diseases potentially related to low water quality and consequently to the proliferation of water resources. The main water-related diseases are acute diarrhoeal diseases, cholera, shigellosis, typhoid fever, amebiasis and hepatitis A and E (CORREIA et al., 2021). The identification of risks associated with contact with or consumption of water has been increasingly relevant to improving the quality of life of populations.

The classification of a beach in relation to quality for primary contact recreation makes it a tool for checking its use, through statistical data analysis. In addition, it is a quality control
instrument that allows a visualization with more clarity and better water inspection (CAMPOS; CUNHA, 2015 apud MARTINS et al., 2017, p. 118).

Bathing is an important water quality monitoring to analyze the sanitation policy implemented by the responsible environmental body (CAMPOS; CUNHA, 2015 apud MARTINS et al., 2017, p. 118). According to Peleja (2015, p. 06), the purpose is to monitor water quality to analyze "the risk of contamination of bathers, and the relatively short time between contamination and bacterial decay".

**2 THEORETICAL FRAME**

With regard to the quality of the water used for recreation activities, be it inland or oceanic water, the Bathing Index (IB) was developed. This index is an important parameter for measuring the level of contamination by bacteria and toxic substances in aquatic environments used for leisure activities such as swimming, diving and water skiing, during which direct and prolonged contact of the body with water occurs, which can be ingested involuntarily, leading to contamination by microorganisms and toxic substances (CONAMA, 2000).

Among some parameters measured by the Water Quality Index (AQI), the most used to make IB (Bathing Index) is the density of fecal coliforms on beaches (VASILIO, 2006). The use of fecal coliforms as indicators of water body pollution refers to the possibility of the presence of other harmful microorganisms (bacteria, viruses and protozoa), which can cause diseases for those who have contact with water during recreation (SOUTO, 2015).

Resolution CONAMA No 274/2000, on the quality of fresh waters, brackish waters and salt pans intended for seaworthiness, establishes an assessment by means of two categories, which are themselves and improper. The waters estimated as proper are subdivided into satisfactory, very good and excellent. Classification shall be according to the densities of fecal coliforms (thermotolerants), Escherichia coli (in marine waters) shown for five consecutive weeks or five samples with an interval of at least 24 hours between them.

Also, according to CONAMA Resolution 274/2000, waters that have a high bacteriological index and incidence of diseases that can be transmitted via water, with residues such as sewage, oils, greases and other substances capable of posing health risks, algal blossoming or the presence of potential transmitters of schistosomiasis and other water-borne diseases are considered inappropriate.

The actions employed to ensure a good Balneability Index in Brazil are legally linked to the National Environment Policy (PNMA); National Water Resources Policy (PNRH) and the National Coastal Management Plan (PNGC) programs. With regard to the quality aspect of marine and brackish waters, there are two resolutions of the National Council for the Environment (CONAMA) pertinent to the subject: Resolution CONAMA 357/05 defining classes of waters and maximum standards for the main pollutants; and Resolution CONAMA 274/00 specific on bathing (CETESB, 2010).

Thus, the use of beaches for leisure is recurrent in Brazil, and some studies have been developed to research the seaworthiness conditions of bodies of water, such as the study by Martins et al. (2017) that carried out an evaluation of the seaworthiness conditions on the beaches of the municipalities of João Pessoa and Cabedelo -PB. The authors noticed that the concentrations of bacteria found were on a scale well below the values indicated by Resolution 274/2000 of CONAMA. Therefore, they concluded that according to the microbiological results, the beaches of Cabo Branco and Intermares, during the collection period, are classified as excellent. In the work of Fernandes et al. (2021), a study of seaworthiness was carried out on four beaches of the archipelago of Fernando de Noronha-PB, two in the sea portion of the island and two in the sea outside. The authors concluded that, from the point of view of the coliform analyzes, the beaches were classified as excellent seaworthiness, as indicated by
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Resolution no. 20 of CONAMA, and that the highest value recorded was above 5,000 NMP/100g1 for the beach of Porto, in period of high tourist season. Alves, Machado & Oliveira (2020) investigated the influence of precipitation on E.coli densities of beaches located on the coast of Salvador-BA. The results indicated the influence of precipitation on E.coli densities of 17 beaches and it was possible to conclude that although there is an influence of precipitation on E.coli dynamics, the intake of bacteria is associated with multiple factors arising from the environment. Costa et al.’s work (2019) aimed to analyze the conditions of seaworthiness on beaches in Natal/RN by means of a bibliographic survey and monthly analysis of seaworthiness in the period 2010-2016 on the beaches of Redinha and Forte, taking as a parameter resolution CONAMA No. 274/2000. The results indicated that the analyzed sites had a good environmental quality, except for the beach of Redinha - Rio Potengi. It was also found that there was a relationship between the increase in precipitation as the increase in the quantity of thermotolerant coliforms, and this increase did not occur only in the rainy period, but also in the dry period.

3 METHOD

3.1 Field of Study

The island of São Luís is located in the urban micro-region of São Luís, being constituted 57% of the total municipality, with an estimated population of 1,037,775 inhabitants, in a territorial area of 583,063 km². It belongs to the northern Maranhão mesoregion, bordering the municipalities of Paço do Lumiar, São José de Ribamar and Raposa. It is bathed to the north by the Atlantic Ocean; to the east it is bordered by São José de Ribamar; in the western part it is between the rivers Bacanga and Anil; in the western zone with the Bay of São Marcos and to the south it is bordered by the Mosquito Strait (IBGE, 2022; SILVA, 2015).

The climatic type of the island of São Luís, according to the classification of Köeppen-Geiger is tropical and rainy - AW, with annual precipitation totals around 2,000mm and with temperatures ranging between 25 and 32º C (WEATHER SPARK, 2023). It has beaches that are an attractive point of tourists, being one of the most visited places where stimulates more and more economic business (SANTOS et al., 2022), however as to basic sanitation is relatively precarious and does not serve the whole population.

Six monitoring points were selected for the main beaches of the municipality, starting from the Jaguaréma River and extending to the Ponta d'Sandy beach, totaling about 12,594 km of coastline (Figure 1). The first monitoring point called P-1 PONTA D'AREIA is located near Fort Santo Antônio (Meeting of Av. Nina Rodrigues with Rua das Bonitas), with coordinates 2º30'06,56“ S / 44º19'06,76” W 04 02. The second point P-2 PONTA D'AREIA - In front of the Bather Service Center - Praça do Sol. 2º29’39.96” S/ 44º18’28.70” W 03 02, the third point P-3 PRAIA DE SÃO MARCOS - Av. Coastal - In front of the Sea Battalion Group. 2º29’12.45” S / 44º17’04.95” W 05 27, the P-4 PRAIA DO CALHAU - Av. Coastal - The right of Lift Station 2222 (EE 22222) CAEMA. 2º28’55.78” S / 44º15’35.01” W 01 08, the P-5 OLHO D'ÁGUA - Between the perimeter access to the beach (Rua São Geraldo) and the Rio Pimenta. 2º28’47.97” S/ 44º14’15.75” W 01 01 and the last point P-6 EYE OF WATER - The right of the Yemanjá Sewage Lift Station. 2º28’39.65” S / 44º13’33.50” W 00 09
3.2 Data Collection and Analysis

This study was based on a qualitative and quantitative research strategy, of an exploratory nature, to obtain information about baths and one of its factors of influence: rainfall. For the data on seaworthiness, according to Table 1, the data for the year 2009 were obtained in the works of Barros et al. (2009) and Almeida et al. (2012) whose analyzes of seaworthiness were carried out in the Laboratories of Environmental Microbiology and at CEUMA University. The results were obtained through an on-site collection and laboratory analysis following Conama No. 274/00 and in section 9060 of the 21st edition of the standard methods.

Figure 1 Study Monitoring Points on the island of São Luís-MA.
Source: Prepared by the Authors (2023)
for the examination of water and wastewater analysis of APHA (2005) with the Most Likely Number Technique. The procedures for collecting, storing and transporting the samples followed the specifications established by CONAMA Resolution 274/00 and in section 9060 of the 21st edition of the Standard Methods for The Examination of Water and Wastewater Analysis (APHA, 2005).

The water samples were collected weekly, always during the tide and at the approximate isobath of 1 (one) meter, which represents the region most used for recreation. The sampling method consisted of collecting the waters in sterile flasks, duly identified, at a depth of 30 cm below the water surface. All the samples collected were kept in a thermal box with recyclable ice, and a temperature of 10ºC at the most, and at the end, were taken immediately to the Laboratory, for microbiological determinations. The time elapsed between the collection of the samples and the start of the bacteriological examination was at most 8 hours (APHA, 2005).

Bacteriological examination of the waters coming from the urban beaches of the municipality of São Luís/MA was carried out for thermotolerant coliforms using the method of Fermentation in Multiple Tubes using LC (Lactosed), EC (EC medium) and filter membranes (NICOLAU, 2014).

For the year 2011, the data were obtained by means of a documentary survey of the reports of the laboratory analysis department of the state of the dial., and for the years 2015 to 2017, data was obtained from the reports of baths presented by the Secretary of State for the Environment and Natural Resources - SEMA, in which a basic descriptive analysis of the results presented by the laboratory analysis department available, obtained on the website of the state secretariat for the environment and natural resources - SESMA.

The data on rainfall were obtained from the portal of the National Meteorological Institute - INMET.

<table>
<thead>
<tr>
<th>Year</th>
<th>Considered Months</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>April to September</td>
<td>They were obtained in the works of Barros et al. (2009) and Almeida et al. (2012) whose analyzes of baths were carried out in the Laboratories of Environmental Microbiology and at CEUMA University. On-site collection and laboratory analysis following Conama 274/00 and section 9060 of the 21st edition of standard methods for the examination of water and wastewater analysis of APHA (2005). Most likely number technique</td>
</tr>
<tr>
<td>2011</td>
<td>February to October</td>
<td>Basic descriptive analysis of the results presented by the laboratory analysis department of the state of the dial.</td>
</tr>
<tr>
<td>2015/2016/2017</td>
<td>January to December</td>
<td>Basic descriptive analysis of the results presented by the laboratory analysis department available on the website of the state secretariat for environment and natural resources - SESMA</td>
</tr>
</tbody>
</table>

Source: Prepared by the Authors (2023)

4 RESULTS AND DISCUSSIONS

This study considered the proportion of fecal coliforms in a sample of 100 ml, for the determination of the bathing conditions of the beaches of São Luís -MA in the years 2009, 2011, 2015, 2016 and 2017, finding the points as suitable or unsuitable for bathing. And it was compared with data on rainfall to find out whether the incidence of rainfall leads to an improvement or a worsening in the region's baths.
4.1 Bathing Conditions of the Beaches of São Luís - MA

First, a visit was made to the sites in order to observe what factors could influence the change of local baths, such as the quantity of sewage release points, and to storm drainage points. Thus, Table 2 shows the amount of geo-referenced points of sewage releases and rainwater drainage present in the studied area, from the sewage survey conducted in 2009.

Table 2 - Release points sewage and storm drainage

<table>
<thead>
<tr>
<th>Points</th>
<th>Location</th>
<th>Geographical Coordinates</th>
<th>Sewage Launch Points Quantity</th>
<th>Amount of Rain Drain Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>PONTA D'AREIA - Near Fort Santo Antônio (Meeting of Nina Rodrigues Avenue with Rua das Bonitas)</td>
<td>2º30'06.56&quot; S / 44º19'06.76&quot; W</td>
<td>04</td>
<td>02</td>
</tr>
<tr>
<td>Q2</td>
<td>PONTA D'AREIA - In front of the Bather Service Center - Praça do Sol</td>
<td>2º29'39.96&quot; S / 44º18'28.70&quot; W</td>
<td>03</td>
<td>02</td>
</tr>
<tr>
<td>Q3</td>
<td>PRAIA DE SÃO MARCOS - Coastal Av. - In front of the Sea Battalion Group.</td>
<td>2º29'12.45&quot; S / 44º17'04.95&quot; W</td>
<td>05</td>
<td>27</td>
</tr>
<tr>
<td>Q4</td>
<td>PRAIA DO CALHAU - Coastal Av. - The right of the Elevatoria Station 22 (EE 22) of the CAEMA.</td>
<td>2º28'55.78&quot; S / 44º15'35.01&quot; W</td>
<td>01</td>
<td>08</td>
</tr>
<tr>
<td>Q5</td>
<td>OLHO D'AGUA- Between the perimeter access to the beach (Rua São Geraldo) and the Pimenta River.</td>
<td>2º28'47.97&quot; S / 44º14'15.75&quot; W</td>
<td>01</td>
<td>01</td>
</tr>
<tr>
<td>Q6</td>
<td>EYE OF WATER - The right of the Yemanjá Sewage Elevation Station.</td>
<td>2º28'39.65&quot; S / 44º13'33.50&quot; W</td>
<td>00</td>
<td>09</td>
</tr>
</tbody>
</table>

Source: Adaptado de Barros et al. (2009) and Almeida et al. (2012)

Next, starting from the information collected, one can observe in Figure 2 the percentages of points considered "proper" for the bath. In the year 2009, the beaches analyzed had in the points of analysis P2, P3, P4 a percentage of 50% of the time as proper for bathing, the rest of this period being improper. At the P1 and P5 points, it was 70% of its own time and the rest improper, the P6 point was the whole period in itself (Figure 2(a)).

Figure 2(b) shows that in 2011, the rates of bathability considered "unsuitable" were higher compared to all the years studied, with the points P1, P2, and P5 considered 100% "unsuitable" for bathing, during the whole period analyzed.

Also in Figure 2(c), it can be observed that in the year 2015 all points were less than 50% of the time "proper" for bathing, as well as in the year 2016 (Figure 2(d)). In this year the points P2, P4 and P5 only 25% of the period analyzed, the beaches were "suitable" for bathing.

In 2017, there was an improvement in the bathability of the points of the beaches studied, reaching 75% of the period in P4 the "proper" point for bathing.
Figure 2: Comparative percentage of beaches proper and improper of the municipality of São Luís - MA, per year studied

Source: Adaptado de Barros et al. (2009), Almeida et al. (2012) and SEMAS (2017)

4.2 Balneability Comparison for Each Point Studied

Figure 3 presents the comparison of the percentage of the balneability of the sampling points studied in the years 2009, 2011, 2015, 2016 and 2017.

It can be observed in Figure 3(a) and 3(b) that for points P1 and P2 the year 2009 was the year that presented the highest percentage of time with proper water for bathing, being 67% and 50% of the time, respectively. In 2011, for these same points, they presented water unsuitable for bathing in 100% of the time studied.
For point P3 (Figure 3(c)), the year 2011 presented almost 80% of the time waters unsuitable for bathing, and in the year 2017 this point was about 60% of the time with waters suitable for bathing.

In Figure 3(d), it was observed that for the point P4, in the year 2011 the point was approximately 90% of the time unsuitable for bathing, but in 2017 it was 75% own. Still in Figure 3(e), for the point P5 in the year 2009 the percentage of waters suitable for bathing was higher than 65%, but in the year 2011 the percentage was 100% unsuitable for bathing.
In the year 2009, the P6 was 100% of the time studied proper for bathing, however in the years 2011, 2015 and 2016 only 35% of the period studied the waters were suitable for bathing (Figure 3(f)).

It was found with this study that the year 2011 presented a higher percentage of points unsuitable for bathing and that the point P2 was the most critical point with regard to bathing presenting an average of 75.6% of the time as unsuitable for bathing, followed by the point P5 with 70.6% of the time improper, P4(63.4%), P3(61.4%), P1(60.2%) and the point P6 (48.6%). Table 2 shows that at point P6 there is no effluent discharge point which may lead to better water quality for recreation.

4.3 Externalities that Influence Bathing in the Municipality of São Luís-MA

Lack of sanitation is one of the externalities that can influence the conditions of seaworthiness. The pollution of the beaches through the quality of the urban rivers that keep their mouth in the coastal zone is a clear example of the importance of advancing the development of sanitation (Rossi et al., 2012). Exposure of people to contaminated water can lead to diseases such as diarrhea, typhoid fever, hepatitis, cholera, gastroenteritis and others due to susceptibility, children and the elderly are among the most likely individuals to acquire diseases from water transport (Pond, 2005; Guercio and Ulbricht, 2013).

With the accelerated population growth, the supply systems are not expanded concomitantly, causing a deficit in the basic sanitation sector and causing the transmission of diseases to the population and high public health expenditures. In addition, the lack of planning and sanitation policies also affects the use of water (MELO, 2017).

The Instituto trata Brasil (2021) presents some data on sewage in the state of Maranhão for the year 2019, showing that only 27% of municipalities are served with sewage collection, and of these only 11.8% present adequate treatment. For the municipality of São Luís-MA only 19.8% of its sewage is collected and treated appropriately.

Surface runoff caused by precipitation is another externality that can influence seaworthiness conditions. Studies in coastal regions, such as Hirai and Porto (2014) and Alves (2019) describe the increased incidence of unsuitable beaches in the face of rainfall, and highlight the importance of alerting the community about the risks of microbiological contamination when coming into contact with water. The results of the research of Alves, Machado and Oliveira (2020), pointed out the influence of precipitation on E.coli densities of 17 beaches on the coast of Salvador-BA, and conclude that although there is an influence of precipitation on E.coli dynamics, the intake of bacteria is associated with multiple factors arising from the environment.

To verify the influence of rain on the seaworthiness of the municipality of São Luís-MA, we considered the percentage of time of beaches unsuitable for bathing during the months for each year studied (2009, 2011, 2015, 2016 and 2017), and compared with the monthly rainfall rates obtained on the website of INMET, the São Luís-MA meteorological station.

He observed in Figure 4 that the months with lower rainfall rates (from September to December) the percentage of unsuitable beaches decreased significantly, reaching 100% suitable for bathing in the months of October and November in the years 2015 (Figure 4(c)) and 2016 (Figure 4(d)). With the exception of the year 2011 (Figure 4(b)), which presented four months with beaches 100% unfit for bathing.
5 FINAL CONSIDERATIONS

From the study it was observed that there is influence of environmental variants and the incidence of thermotolerant coliforms in the waters of the main beaches of the municipality of São Luís - MA. The beaches of Ponta d’Areia, Calhau, Olho D’Água and São Marcos may present risk to primary contact of bathers, because during the weeks of monitoring all were considered unsuitable at some point of the monitoring, and the monitored points of the beaches of Olho D’Água and Ponta d’Areia were the ones with the highest incidence of thermotolerant coliforms.

There is an undeniable association between the basic sanitation system and the pollution of the beaches of the municipality of São Luís. Sewage discharged directly into streams and
rivers discharging directly into beaches strongly contribute to such pollution. This shows that the main influence on the incidence of thermotolerant coliforms is the presence of sanitary effluents on the beaches, being accentuated by the incidence of rainfall and constituting a situation that extends to the present day demonstrating the lack of a sanitary infrastructure of the beaches of São Luís.

By monitoring the quality of the waters of the beaches of São Luís, classifying them as "proper" or "improper" for the use for which they are intended, there is a strong instrument for signaling the need for actions relating to basic sanitation. These include the installation of sewage collection systems and their treatment. On the other hand, when implementing such actions, the effectiveness of the expected results can be monitored with them.

The main attractions of São Luís, which consolidated it as a tourist destination, are the beaches. For this reason, frequent periods of unfit bathing conditions can negatively impact tourists to return to visit it. On the other hand, for the resident population of the municipality, this leads to the need to seek other beaches out of leisure, moving it away from an inherent relationship to those who inhabit regions of beaches, which is their frequent use.

Investments in basic sanitation stand out as urgent and necessary to maintain the beaches in proper conditions for bathing and, consequently, to eliminate the need for treatments for diseases associated with the use of polluted beaches.

REFERENCES


