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Water quality of Guamá river in the surroundings of an insular environmental protection area in Belém - Pará, Brazil

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***Keywords*— Environmental protection, Water quality, Guamá river.**

***Abstract*—** *The current research has as objective analyze the water quality of Guamá river in the surroundings of Combu island, insular area of Belém - Pará, through the following parameters: thermotolerant coliforms, E. coli and chlorophyll a. Six samples were collected in low tide, in rainy periods and in strategic points of the river, near tourism areas. After the collection were submitted to quantitative test technique with enzymatic substrate to the result of more probable number (MPN) to thermotolerant coliforms and E. coli. To chlorophyll a, the samples were submitted to the method of extraction and reading in the visible spectrophotometer. The results showed values above of the legal limits of 1,000 MPN/100 ml determined by CONAMA 357/2005 for thermotolerant coliforms and E. coli, with mean of 7,001 MPN/100 for the first and 2,330 MPN/100 ml for the second. About the chlorophyll a, although the values do not pass the legal limit of CONAMA 357/2005 of 30 µg/L in all collection points, with mean of 4,73 µg/L, the index of trophic state - ITS result in indication of river eutrophication. It can be highlighted the deficiency in basic sanitation services in Combu island, which interferes both in the quality of Guamá river, with high concentration of coliforms indicatives of fecal contamination, and in the health of local population, which demands the use of water for survival , but that has the potential risk of waterborne diseases in the most vulnerable communities.*

I. INTRODUCTION

The regular normalization for protection of environmental areas in Brazil emerged in 1981 with the National Politic of Environment and posteriorly the law 9,985/2000 that created the National System of Nature Conservation Units - SNUC, which determine that it is objects of protection inside the Units of Conservation - UC's the spatial territories and its environmental

resources, including the inherent water resources conservation.[1] [2]

Considering that the maintenance of water quality are related with the sanitation condition of communities that use that resource, insular areas demands attention for the relation with water resources that surrounding it, and in that sense, the insular area of Belém have 42 islands with 332.04 km² spread in the Amazon estuary and among them the Combu island was considered through the Ordinary Law 6,083/1997 a Environmental Protection Area - EPA of sustainable use, allowing the human occupation for use of the natural resources with condition of equilibrate use and economic viable.[3] [2] [4]

However, despite being legally supported as an EPA, the Combu island suffers from several problems related to the inefficiency of basic sanitation, mainly related from the sanitary sewage and provide of potable water for the population. Although existing treatment of the waters of Guamá river for population supply, the water with quality do not reaches the insular regions, forcing the riparian population to use the water resource of direct form or through the onerous acquisition from unknown origins.[5] [6]

In front of this relation of the island with the river, the evaluation of hydric quality through the parameters which can indicate if the water resources are adequate for use becomes central, following that, when the locality involves problems with sanitation, analysis of microbiological agents becomes relevant because help as contamination indicators, highlighting the necessity of prevention related to waterborne diseases.[7]

In this perspective, it can be highlighted the necessity of the implantation of basic sanitation services, through the Law of Basic Sanitation n° 11,445/2007 which points sanitation services as “water supply, sanitary sewage, urban cleaning and management of solid residues performed in adequate way for public health […]”.[8]

When the sanitation don’t follow the population increasing, negative ramifications both in water resources and population’s health can emerge and, in this context, the irregular disposal of sewage in waters constitute in a source of pollution which can interfere not only in the microbiological quality but also in the irregular growth of algae because of the enrichment of nutrients, compromising even more its use.[9]

Thus, it is clear the necessity of instruments of monitoring the receptor body, aiming to evaluate the pollution impacts and hydric contamination through field activities in the area, surrounding population study and laboratorial analysis of physical-chemical and microbiological parameters.[10]

In Brazil, the CONAMA regulates the maximum limits that the water body can reach according with each parameter, being as principal the Resolution 357/2005, however, despite of uncountable legal references exist to be followed, the deficiency of monitoring associated with basic sanitation represents health risks to population and others living beings.[11]

Therefore, the following research aims to evaluate if the Guamá river, in the surroundings of Combu island, insular area of Belém capital, has been showing negative results in superficial water quality through analysis of microbiological parameters (thermotolerant coliforms and E. coli), the chlorophyll a and its index of trophic state - ITE.

II. MATERIAL AND METHODS

2.1 Research locality

The study area was Guamá river, near the Combu island, with 06 points of collection, embracing both the river and the Combu igarapé, a Environmental Protection Area - EPA that is part of the insular area of Belém, located in the outfall of the Guamá river, bordered in north for the river, in the south for Furo São Benedito, east by the Furo Paciência and west by Guajará bay, in a area of 16 km², according to Fig. 1. [12] [13]

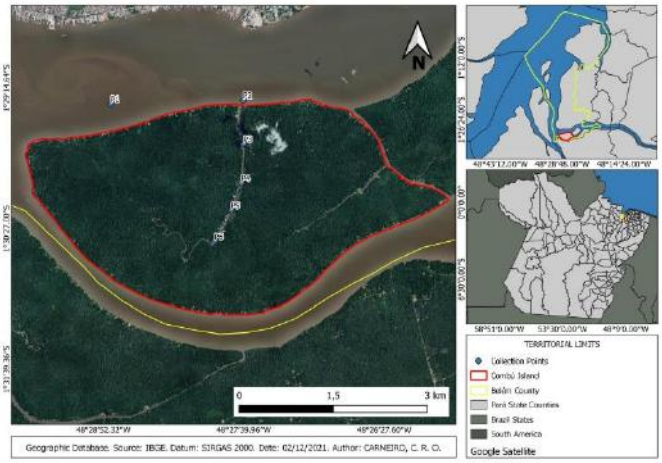

Fig 1: Combu island, insular area from Belém county, Pará. Source: Authors, 2021.

In relation of Guamá river, with 700 km of extension approximated, the research focused in the waters of the EPA, in the sub-basin of the lower Guamá, where the river border Belém by south, with right border corresponding to the city rim and the left border is the place of Combu island. [14]

The Combu island is a touristic point due to its many istilts restaurants, with a population of 1,800 inhabitants, mainly vegetation of mangrove and other part of economics performed by extractivism of products as açaí, cupuaçu, chocolate between others.[15] [16]

2.2 Research approach

The initial methodology was focused in the theoretical research in the scientific literature inherents of water resources, basic sanitation and water quality. In parallel, it was performed an exploratory research *in loco* to collection of data related to the water samples for analysis. The approach was quantitative to the organization of the first data acquired.

2.3 Collection and data analysis

The collected data aims at the results which could indicate the water quality relating them to the legislation limits - CONAMA 357/2005. The criteria for choosing the points are related to the existence of economic activities, in case of touristic points and presence of nearby communities, which are potential sources of sanitary sewage.

The acquisition of the samples occurs from technique activities in the studied area, for water collection in 06 points of the river, with location presented in table 1, embracing the Guamá river and Igarapé of Combu, where it is located the restaurants in stilts form, where the locomotion is by small boats.

Table 1: Geographic localization of the collection points

Point	Geographic Coordinates UTM	
P1	01° 29' 22.7" S	048° 28' 48,5" W
P2	01° 29' 20.8" S	048° 27' 40.2" W
P3	01° 29' 43.4" S	048° 27' 40.0" W
P4	01°30' 03.5" S	048°27' 41.2" W
P5	01°30' 17.4" S	048° 27' 46.5" W
P6	01°30' 33.5" S	048° 27' 55.0" W

Source: Authors, 2021.

The field research was conducted in 2021, rainy period in low-tide, with observance of storage and conditioning following the methodology of Cetesb (2013)[17] and following the protocol of sampling water, according to Standard Methods for Water and Wastewater. The flasks with samples for analysis of chlorophyll *a* were with 1 L of capacity in amber glass e for the bacteriological essays it was used collectors of 100 ml.

The sample analysis were from the following parameters: thermotolerant coliforms and E. coli, where the More Probable Number (MPN) was determined by the technique of quantitative test with enzymatic substrate, performed by the Central Laboratory of Pará - LACEN and analysis of chlorophyll *a* concentration, through the spectrophotometric method, where the samples were vacuum filtered and the chlorophyll extraction obey the method described by Cetestb (2014)[18], performed by the Laboratory of Amazon Water Quality - Labágua.

With the results of chlorophyll *a*, it was possible to perform the classification of the Index of Trophic State - ITS of the sampling points, following the methodology by Lamparelli (2004)[19], adapted for tropical environments adopted by Carlson (1977)[20], for temperate climates. As the studied area being a river, the equation used for obtaining the Index of Trophic State is according to lotic environments:

IET (CL) = 10x (6-((-0.7-0.6x(ln 2)) - 20

Where

CL: chlorophyll *a* content measured in the water surface, in μg.L-1;

ln: natural logarithm

For the ITS classification, it were follow the limits of the six differents trophic level for rivers: ultraoligotrophic (IET ≤ 47); oligotrophic (47 < TSI ≤ 52); mesotrophic (52 < TSI ≤ 59); eutrophic (59 < ETI ≤ 63); supereutrophic (63 < ETI ≤ 67); hypereutrophic (IET > 67).

The results treatment was performed through descriptive statistics and comparative graphics between the obtained concentrations and the established legal limits. It was used for the graphics elaboration the Microsoft Excel 2010 and for map elaboration the Arcgis program.

III. RESULTS AND DISCUSSION

The table 2, through descriptive statistics, compares the obtained data with the legal scope according to CONAMA 357/2005, presenting the mean values, standard error, maximum and minimum values.

Table 2: Obtained results of thermotolerant coliforms, E. coli and chlorophyll a parameters

	Mean	Standard error	Minimum	Maximum	MVA
CT nmp/100ml	**7.001**	2.076	3.736	17.109	1000 nmp/100ml
E.Coli nmp/100ml	**2.330**	1.829	947	5.811	1000 nmp/100ml
Clorofila *a* µg/L	**4.73**	1.018	2.81	8.55	30 µg/L

**MVA – Maximum value allowed. Source: Authors, 2021.*

It can be noticed that the thermotolerant coliforms and E. coli, in the majority of the samples, the bacteria concentration results in values above the permissible by the legal limits of 1,000 MPN/100 ml, according the Fig. 2 below:

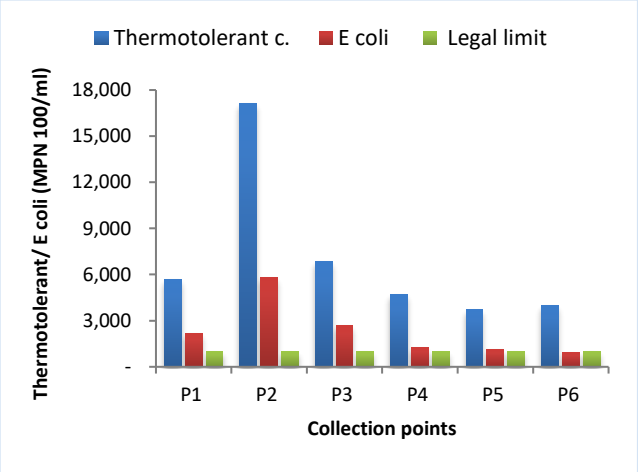

Fig. 2: Results of thermotolerant coliforms and E. coli Source: Authors, 2021

In the thermotolerant coliforms group, the central characteristics is the subgroup that constitute the total coliforms, whose bacteria can ferment the lactose in 44-45° C (±0.2) in 24 hours, and the E. coli that highlight itself in this group for being the unique species with exclusive habitat in the human intestine or in homeothermic animals, thus, both parameters are indicators of fecal contamination, however, the last one with higher specificity.[11] [21]

The chlorophyll results indicate the biomass quantity of algae, relationing the water quality analyzed with the excessive growth of algae. The results showed that the quantity of Chlorophyll *a* in the collection points presented results below of the established limits according the legislation, that is 30 µg/l.[22]

3.1 Thermotolerant coliforms

In relation to the thermotolerant coliforms, all the samples showed concentrations above the limit for freshwater, class 2, according to the legislation (1,000 MPN/100 ml), with mean of 7,001 MPN/100 ml, reaching the maximum value in point 2 with 17,109 MPN/100 ml and minimum value in point 5 with 3,736 MPN/100 ml.

Thermotolerant coliforms are important water quality indicators, because points in a water sample the probable bacteria concentration existed, and these ones are different from the total coliforms, because ferment lactose produces gasses in 24 hours with temperatures varying between 44.5 and 45.5 °C. Its presence is mostly found in fezes, soil and vegetation, thus, its presence in superficial waters could be related with sanitary sewage.[23]

In the study area, one of its characteristics is it proximity with the collection points with touristic areas, where the local possess commercial establishment, as restaurants in stilts form, as Fig. 3:

Fig. 3: Restaurants in stilts in Combu island. Source: Authors, 2021.

Furthermore, the existence of riparian communities in the area increase the domestic sewage production, that jointly with the poor infrastructure of sanitation potencialize the load of pollution released in Guamá river. This fact is corroborated with other surveys about rivers near riparian communities, with precary sanitation.[24] [25] [26]

Important issue that comes up in riparian communities is that their living way is direct related with the necessity in having water for many uses, as for consumption (potability) and recreation of primary contact (bathing), that leads to the concern of legal limits adequation for these uses.[27]

Besides CONAMA 357/2005, that classifies the water bodies and gives environmental guidelines, the Healthy Ministry, through the ordinances regulates the threshold parameters for water potability for human consumption, nowadays regulated by Ordinance GM/MS n° 888 of may 4th, 2021, which changed the attachment XX of the Consolidation Ordinance GM/MS n° 5, of september 28th, 2017, where it determine that the bacteriological standard of water for human consumption, both general coliformes and E. coli must be absent of these microorganisms, ie, for human consumption the water must be absent of any bacteria of the coliforms group.[28]

About the bathing, freshwater rivers class 2 can be destined to recreation of primary contact, since respecting the bathing limits of CONAMA 274/2000. This resolution classifies the water for bathing as Proper, subdivided in Excellent, Very Good and Satisfactory, and the Impropry category, the obtained values in the last sampling mustn't be above of 2,500 MPN/100 ml for thermotolerant coliforms, therefore, it can be noticed that for all the highlighted uses, the results showed that the waters can be impropry, due to the fact that the concentration mean for thermotolerant coliforms (7,001 MPN/100 ml) perpass the legal limits.[29]

In general, Amazon river receivers of domestic sewage are marked by the presence of thermotolerant coliforms. As the Guajará bay is a important receiver of Belém county, surveys showed values of this parameter above the legal limits according to CONAMA 357/2005, both in rainy and non-rainy period, with maximum reaching 486,775 MPN/100 ml.[30]

In the urban border of Guamá river, it can be registered many points of anthropic activities, as touristic shores, open air fair, private ports, universities, communities and others [31]. Ergo, the domestic sewage load received from the many activities is released direct in the river, and in that sense, results with elevated concentration of thermotolerant coliforms also were found in points of releasing of urban sewage in the Guamá river, with values reaching 629.4 x 10^4 MPN/100 ml.[32]

3.2 Escherichia Coli

Beyond the thermotolerant coliforms, it was analyzed the *E. coli* parameter, that is included in the thermotolerant group, however is considered a high enteric bioindicator, because the bacteria has its primary habitat in the human intestine and in warm-blood animals.[23]. This parameter also presented concentrations above the value determined by legislation (1,000 MPN/100 ml) in 5 of the 6 points.

With a mean of 2,330 MPN/100 ml, it reached maximum value in point 2, with 5,811 MPN/100 ml and minimum value in point 6 with 947 MPN/100 ml. The analysis of *E. coli* showed contamination in superficial waters, once it possesses high fecal specification, where its presence indicates the water body contact with non-treated water, because these microorganism survive for only a few days out of its primary habitat, respectively 1 day in superficial waters, 1.5 days in sediments and 3 days in soil. [33]

It can be observed that beyond the contamination indicate recent time, the results mean of *E. coli* are out of the parameters not only for CONAMA 357/2005, but also for bathing parameters (2,000 MPN/100 ml) and potability (absence), where bathing, 50% of the points was above 2,000 MPN/100 ml.[28] [29]

High concentrations of *E. coli* were equally found for surveys in rivers that supply riparian communities in Moju county, Pará state and that have multifunctionality for the community, with results pointing 2,755 MPN/100 ml with detection of strong anthropic pression, and situation of sanitary risk without potability and potential of waterborne diseases.[34]

A survey about parasitic infections through parasitological exams was performed in riparian communities in Santarém county also in Pará state, which results indicates that the communities are exposed to infection risk due to the deficiency of sanitation and the socio-environmental conditions, whose water for consumption generally don't have treatment, with origins directly from the river or shallow wells with inadequately storage, situation similar to the studied area from this study. [35]

The impasses from the precarity of the sanitation and its relation with the microbiological quality of the water has been boosting surveys not only for microorganisms concentration detection, but also has been promoting the search for solutions about the qualitative scarcity and minimizing the problems presented through disinfection techniques.

In this sense, the surveys about disinfection techniques as chlorination and its negative effects (cancerogenous subproducts presence), has been directing researchers for

alternative techniques of disinfection, but more advanced, as the microfiltration, advanced oxidation processes and electrodialysis, however, the implementation suffers from impasses due to the absence of investments, making its applicability limited and often leading communities to the use of social technologies.[36] [37]

Thus, it can be observed that the impasses in riparian communities are huge in reason of the distance from urban centers and the transportation, usually using river ways. Therefore, the problems are mostly because the sanitation condition absence, water use necessity that generally are contaminated and the creation of ways for containing the problems from contamination through accessible techniques of disinfection that generally in underdeveloped countries its implementation is harder.

3.3 Chlorophyll a and Index of Trophic State – ITS

About the concentration of chlorophyll *a*, the results presented values below the legal limit (30 µg/L for freshwater rivers, class 2) as shown in Fig. 4.

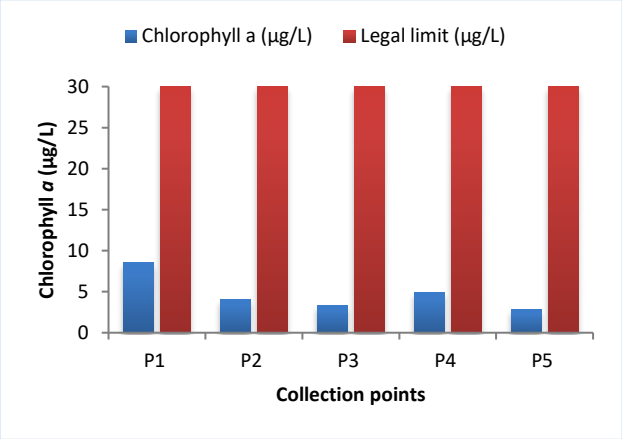

Fig. 4: Chlorophyll a. Source: Authors, 2021.

The concentration mean of chlorophyll *a* between the points was 4.73 µg/L, with maximum value in point 1, with 8.55 µg/L and minimum in point 5, with 2.81 µg/L. It can be highlighted that in point 6, although the collection performed, it did not reach the limit of detection by the spectrophotometer.

The results demonstrated coherency with other surveys in similar study areas, that in the same river in Belém county, it was concluded that the low values of chlorophyll *a* was related with the characteristics of muddy water, with low transparency, clayish material in suspension, turning the water blurred and promoting the decreasing of photic layer, which limits the increase of phytoplankton mass.[38]

In other surveys in the area, the values do not perpass the legal limits, which suggests that in the rainy period the results were associated to the superficial flow of waters from precipitation, favoring the carrying of sediments to the water body.[39]

However, with regard to the trophic state, the mean of the Index of Trophic State - ITS, between the points was 62.85, whose most points were classified as eutrophic, with the exception of point 1, whose result was hypereutrophic and the point 4 which was supereutrophic, according to Table 3:

Table 3: Index of trophic state in collection points.

Collection points	Chlorophyll *a* (µg/L)	ITS	Classification
P1	8.55	68.67	**Hypereutrophic**
P2	4.07	62.25	**Eutrophic**
P3	3.31	60.46	**Eutrophic**
P4	4.91	63.87	**Supereutrophic**
P5	2.81	59.04	**Eutrophic**
P6	*U.D	-	-

**U.D. – undetectable.* Source*: Authors, 2021.*

These classifications followed the limits of the six different trophic levels for the rivers, namely: ultraoligotrophic (IET ≤ 47); oligotrophic (47 < TSI ≤ 52); mesotrophic (52 < TSI ≤ 59); eutrophic (59 < ETI ≤ 63); supereutrophic (63 < ETI ≤ 67); hypereutrophic (IET > 67), where each level seeks to assess the availability, quality and effect of the inclusion of nutrients present in the water, responsible for the disorderly and excessive growth of algae or macrophytes in the aquatic environment.[19]

The trophic state classified as eutrophic was the index with the highest incidence in the collection points, which indicates that the Guamá river in the region that bathes the Combu island, has been affected by anthropic activities, is eutrophic and with negative influences on the water quality, interfering with the multiple uses it has.

In surveys about Amazon waters, index classified as eutrophic were found in rivers as the Guajará Bay, with mean of 62.47 and supereutrophic in Bolonha lake, important spring within a urban environmental protection area in Belém, with values reaching 66.86.[40] [41]

High values of ITS suggest origins in the use and occupation of soil and loads of sewage discharged in the river without treatment, contributing to the increase of nutrients, causing eutrophication. Thus, improvement in the sanitation services are necessary aiming to minimize the found problems.[42]

IV. FINAL CONSIDERATIONS

The study area has been undergoing changes in the quality of water that serves the riparian community, where despite being an insular region, the disorderly growth of the nearby urban population has potentiated the increase in the load of effluents in the Guamá River.

Regarding the Brazilian normative of CONAMA 357/2005, the average of the parameters Thermotolerant Coliforms and E. coli presented legal non-compliance, and as both are bioindicators of contamination of fecal origin, the sanitary issue of the Island raises an alert. Descriptive statistics showed that the nonconformity of these parameters reach high values of bacteriological concentration in the waters that bathe the island, far beyond the legal limit allowed.

Regarding the uses of water resources for human consumption and for primary contact leisure, the results ended up showing that the Guamá River is also in disagreement with the legislation on bathing and drinking. As for the chlorophyll *a* values, in addition to complying with current legislation for freshwater rivers, class 2, the results are also consistent with the characteristics that the rivers in the region carry, such as the presence of sediments that end up limiting the photic layer in the river waters, an important factor for the growth of algae and other aquatic photosynthetic organisms.

Although these values are legally adequate, the average of the Trophic State Index indicates that the river is eutrophic, so attention turns again to the health issue of the island, since the increase in nutrients in the water intensifies the eutrophication process of rivers.

Thus, considering that the city of Belém has low coverage of basic sanitation, especially sewage collection and treatment, the polluting load that goes directly to the receiving body, associated with the lack of sanitation also on the island of Combu, are factors that can be relate to the results found, raising a concern about the need to monitor and verify the impacts both on the society that uses the water resource, and on the quality of the river itself.

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