CAPÍTULO 3

INTERFACES FOR APPLYING THE WATER QUALITY INDEX IN ANALYSES OF THE BURANHÉM RIVER, BAHIA

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ABSTRACT: The aim of this study was to evaluate the water quality data of the Buranhém River through the Water Quality Index (WQI). To characterize water quality, data were collected in 4 fluviometric stations using information from the hydrological data archive (Hidroweb) at the National Water Agency (ANA) website for the most recent year (2021). The tools used in this study included the nine water quality parameters: turbidity, total solids, hydrogen potential, temperature, biochemical oxygen demand, total nitrogen, dissolved oxygen, thermotolerant coliforms, and total phosphorus. The results showed that the variables total phosphorus and thermotolerant coliforms do not comply with the limits established by CONAMA Resolution 357/2005 for class 2 freshwaters. However, it was verified that the other variables complied with the Resolution. In a basin management plan, the discharge of phosphorus and coliforms into river waters can be avoided with specific measures and actions, such as the treatment of domestic sewage.

KEYWORDS: Buranhém River, Water Quality, Dissolved Oxygen.

1 I INTRODUCTION

Until recently, water was considered a public domain resource of infinite quantity and quality. Water resources have always been available to humans precisely for their characteristics of being self-sustaining and resilient (GLORIA; HORN; HILGEMANN, 2017). Currently, water is considered an economic resource with limited supply and growing demand, which, in turn, tends to limit its availability (ARENAS *et al.*, 2017). In this regard, the growth and development of cities and the increase in population lead to higher levels of pollution and degradation of water bodies (ALISEDA, 2016).

In Brazil, Law No. 6,938 of August 31, 1981, establishes the National Environmental Policy that conceptualizes environmental degradation as being adverse changes in the natural characteristics of the environment (BRASIL, 1981). With water pollution and the degradation of water bodies in general, aquatic ecosystems are configured as a deposit of pollutants. In addition, the degradation of water bodies causes damage to living beings and represents a risk to individual and collective health (GLORIA; HORN; HILGEMANN, 2017; GUADARRAMA-TEJAS *et al.*, 2016). In watersheds located in urban environments, pollutants can be carried under the impermeable surface and dumped into rivers, that is, as water cannot penetrate the urban soil, pollutants are taken to the water bodies (CHAUDHRY; MALIK, 2017).

According to the classification by Von Sperling (2005), pollution can be of two types, punctual and diffused. Punctual pollution occurs when pollutants enter the water body at a specific point, while diffused pollution occurs when pollutants reach the water body sparsely along the length of the drainage channel. Actions to reduce these forms of pollution include changes in land management and use and environmental education programs (SCHWEITZER; NOBLET, 2018).

Given the context of the degradation of water bodies and its deleterious effects, the National Water Resources System was created from the Brazilian National Water Resources Policy, established by Law No. 9.433 of January 8, 1997 (BRASIL, 1997). Thus, Water Resources Plans chiefly serve to guide managers and society regarding the conservation, protection, recovery, and development of water resources (ANA, 2013; AMÉRICO-PINHEIRO *et al.*, 2019). According to Law 9.433, Water Resources Plans are long-term master plans that aim to support the implementation of the National Water Resources Policy (PNRH). In this regard, these instruments need to contain a planning horizon that is consistent with the period of operation of their programs and projects (AMÉRICO-PINHEIRO *et al.*, 2019). Nevertheless, the PNRH advocates the need for decentralized management, which, in turn, guarantees the participation of society and users of water resources in decision-making through River Basin Committees (SILVA *et al.*, 2018).

The expression "water quality" refers not only to the state of purity of this resource, but also to the physical, chemical, and biological characteristics of water and its purposes based on these characteristics (GLORIA; HORN; HILGEMANN, 2017). Therefore, the quality of a given body of water must be known to determine its most suitable uses, whether for consumption or non-consumption (MEDEIROS *et al.*, 2016). Water quality is intrinsically related to health and economic growth, which are required to achieve sustainable development and human well-being (CHÁVEZ, 2018).

Thus, the importance of indices in the study of the quality of water bodies is emphasized. These indices were developed to interpret, unify, and disseminate the data from environmental analyses and monitoring. Thus, the indices have fulfilled an important function regarding the characterization of the state and trend of water quality (MEDEIROS *et al.*, 2016). The Water Quality Index (WQI) was created in 1970 by the National Sanitation Foundation in the USA. Subsequently, the Environmental Company of the State of São Paulo (CETESB) began to use the WQI in the mid-1970s. Years later, the same index was adopted in other states of Brazil (ANA, 2017). To calculate the WQI, the most significant parameters are selected from a list and weights are stipulated for each parameter according to its relevance (ANA, 2017; GLORIA; HORN; HILGEMANN, 2017). Therefore, it is critical to evaluate the WQI when managing and monitoring water bodies over time and space (PESSOA; ORRICO; LÔRDELO, 2018). In this regard, the National Environment Council (CONAMA) through Resolution No. 357 of 2005 establishes the classification of water bodies and defines parameters for effluent discharge and water quality.

Thus, the objective of this paper is to study and apply the water quality index in the Buranhém River Basin, conduct a systemic analysis of the WQI parameters, and identify the river's water quality status, which is related to land use and occupation in the basin area. This study is justified by the need for knowledge about the water supply to part of the population living in the South of Bahia. In addition, this study can support state and municipal planning, identify trends, and assist in the (re)elaboration of diagnoses for the inspection and practice of environmental licensing. Regarding the decentralization of water resource management, this study can also contribute to the planning and actions of the Buranhém River Basin Committee.

2 I METHODOLOGY

2.1 Characteristics of the chosen study area

The Buranhém River is the main river draining the Buranhém River Basin (BHRB), located under the geographical coordinates: latitude: -16.2474 north, -16.7137 south, and longitude -49.3495 west, -39.0633 east. The Buranhém River extends through four municipalities, namely Santo Antônio do Jacinto, Guaratinga, Eunápolis, and Porto Seguro, the first of which is located in the state of Minas Gerais and the others in Bahia, respectively. The BHRB has an area of 2,504.83 km^2 bordered to the north by the João de Tiba and Mangues river basins and to the south by the Jucuruçu River Basin (AZEVEDO; GOMES; MORAES, 2016). The Buranhém River springs from Pedra do Cachorro, in the Serra dos Aimorés, in Santo Antônio do Jacinto, in the state of Minas Gerais. Also known as the Peixe River or Porto Seguro River, it runs for 30.5 kilometers in Minas Gerais and 215.5 kilometers in Bahia, to its mouth in the Atlantic Ocean, in the city of Porto Seguro. It is the water source of cities in the Far South of Bahia, supplying a population of more than 250,000 inhabitants

(Figure 1).

BHRB is also inserted in the Water Planning and Management Region IV (IV RPGA), which, among other planning regions of the state of Bahia, is delimited by the Institute of Environment and Water Resources (INEMA) due to the complexity of the hydrographic network of the state and to enable the implementation of the water resources policy (BAHIA, 2009).

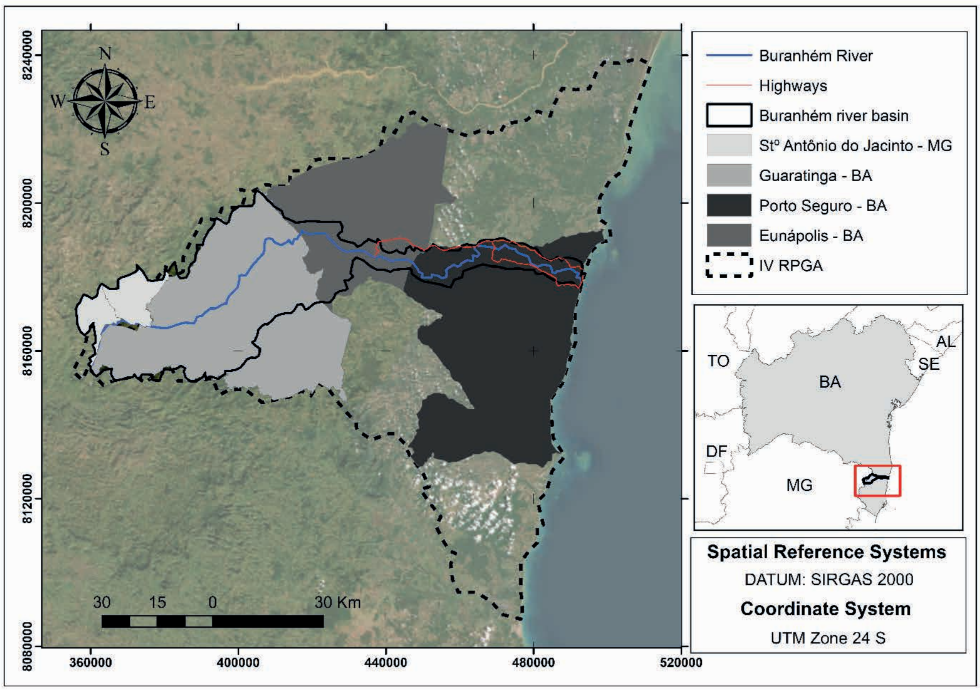

Figure I – Map of the location of the Buranhém River Basin.

Source: From the authors (2023).

2.2 Delimitation of the basin area and the Buranhém River

The basin area and the Buranhém River were delimited using the Digital Elevation Model (MDE) of TOPODATA, which has a spatial resolution of 30 meters. The entire basin delimitation process was carried out in the Geographic Information System (GIS) ArcMap 10.8 and Quantum Gis (Qgis) 3.30. For the delimitation of the BHRB, automatic delimitation was used, with the ArcMap 10.8 geoprocessing tools. The tools and their syntheses suggested by Di Luzio *et al.* (2002) are listed below:

Fill: correction of depression and errors in the MDE;

Flow direction: direction of flow;

Flow accumulation: water accumulation flow;

Stream definition: the number 50 was used as the minimum cell number;

Basin: delimitation of the basin;

Raster to polygon: conversion of the raster file into a vector file in Shapefile format.

2.3 Collection and analysis of water quality data

The water quality of the Buranhém River was studied using secondary data obtained from the National Water Agency (ANA) website. This website provides official and public data online and free of charge at http://pnqa.ana.gov.br/pnqa.aspx. The data come from the National Water Quality Program (PNQA), which extends the study on surface water quality in Brazil. PNQA data are obtained through the on-site collection of water samples in fluviometric stations monitored along the drainage channels. Subsequently, minimum water quality and collection parameters are established and standardized for all Federation Units, as well as sample management and analysis. After collection, the samples are taken to laboratories that specialize in water quality analysis. The results are submitted to the national database, published on a website, and made available free of charge to the general public.

The water quality data were obtained according to the following search criteria: i) monitoring stations located along the Buranhém River, ii) most recent water quality data (2021), iii) all nine WQI parameters included in the analysis, and iv) all fluviometric stations. After collection, the data were organized in tables and graphs and analyzed for consistency. Subsequently, four collection points were identified for four distinct stations, which were duly georeferenced and attributed to an altitude quota (Table 1 and Figure 2).

Points	P01- Guaratinga	P02 - EMBASA Captchment	P03 - BR 101 Bridge	P04 - Lemon Tree Farm
Latitude	-16,59	-16,41	-16,41	-16,46
Longitude	-40,14	-39,59	-39,59	-39,35
Altitude (m)	573	86,3	128,8	22,6

Table I – Collection points of georeferenced water samples in the Buranhém River.

Source: From the authors (2023).

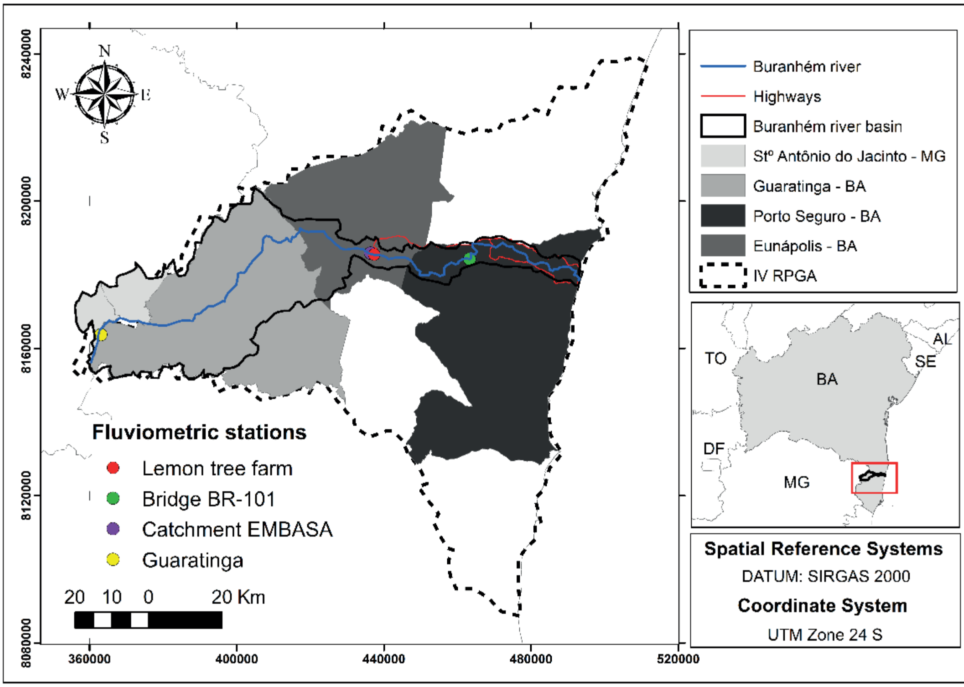

Figure II– Spatial representation of water sample collection points in the Buranhém River.

Source: From the authors (2023).

The WQI was applied to the collected data and calculated according to the parameters thermotolerant coliforms, pH, biochemical oxygen demand, total nitrogen, total phosphate, temperature, turbidity, total residue, and dissolved oxygen. Each parameter is assigned a weight due to its degree of importance (Table 2).

Parameters	Unit	Weight (W)
Dissolved Oxygen (DO)	% saturação	0,17
Thermotolerant Coliforms (TCer)	NMP/100 ML	0,15
Hygrogenic Potential (pH)	-	0,12
Biochemical Oxygen Demand (BOD)	mg O_2/L	0,10
Total Nitrogen (TN)	mg N/L	0,10
Total Phosphorus (TP)	mg P/L	0,10
Temperature (Ta)	ºC	0,10
Turbidity	UNT	0,08
Total Waste (TW)	Mg/L	0,08

Table II – Weights assigned to the parameters that make up the WQI.

Source: Adapted from ANA (2017).

When obtaining the data, the WQI was calculated since this index is obtained by the weighted productivity of the water qualities corresponding to the parameters of the following formula (PINTO *et al., 2012)*:

$$IQA = \prod_{I=1}^{9} qi^{Wi}$$

Where:

WQI: Water Quality Index, a number ranging from 0 to 100;

qi: quality of the i-th parameter. A number between 0 and 100, obtained through the average curvature, depending on its concentration or measurement;

wi = weight corresponding to the i-th parameter fixed to the detriment of its importance for the overall conformation of the quality, being a number between 0 and 1;

The results obtained for the WQI range from 0 to 100, and the value obtained within this range will qualify the water as very bad, bad, medium, good, or excellent (Table 3).

IQA quality bands	Range
Great	80 - 100
Good	52 - 79
Average	37 - 51
Bad	20 - 36
Too bad	0 - 19

Table III – WQI quality ranges for the state of Bahia, Brazil.

Source: Adapted from ANA (2017).

3 I RESULTS AND DISCUSSION

3.1 Evaluation of physical parameters

Table 4 shows the results of the physical parameters of the WQI (turbidity and temperature). These parameters are based on CONAMA Resolution No. 357/2005, which provides for the classification of water bodies and environmental guidelines for their classification and establishes the conditions and standards for the discharge of effluents, and other measures. All results for the turbidity parameter showed levels within the standard for class 2 rivers.

It is noteworthy that turbidity is caused by the presence of suspended materials in the water body, such as organic and inorganic matter, silt, and clays. Thus, high turbidity values and total residues can reduce the photosynthesis of rooted vegetation and algae. Moreover, the interrupted development of aquatic flora can affect fish productivity (GÚZMAN *et al.*, 2013; SANTOS *et al.*, 2020). Given the data presented in Table 4, point 04 – Fazenda Limoeiro presented the lowest value for turbidity due to the little anthropic influence at this point.

WQI Parameters	P1- Guaratinga	P2 - Embasa Captchment	P3- Brigde Buranhém river	P4- Fazenda Limoeiro	Unidade
Turbidity	11,4	24,6	18,2	7,15	UNT
Temperature	28,7	23,9	18,2	20,3	mg N/L

Table IV – Results of the physical parameters of the WQI for the collection points.

Source: ANA, 2021

The temperature parameter complies with the provisions of CONAMA Resolution No. 357/2005 for freshwater. In the Buranhém River, the temperature does not present great amplitude along the points, so the temperatures recorded at each point are consistent with the temperature variations of the local climate. In the analyzed points, P04 - Fazenda Limoeiro showed the lowest temperature value. This is justified due to the point being in a forest fragment with dense vegetation; thus, a part of the solar radiation is intercepted by the riparian areas. Temperature, when altered, directly affects various physicochemical parameters of water, such as the viscosity and surface tension of water. Aquatic organisms are also affected by temperatures outside the standard of the Resolution, which causes impacts on growth and reproduction (FIORENSI *et al.,* 2021).

3.2 Evaluation of chemical parameters

Table 5 shows the data of the chemical parameters of the WQI, namely hydrogenionic potential (pH), dissolved oxygen (DO), biochemical oxygen demand (BOD), total nitrogen (TN), and total phosphorus (TP). CONAMA Resolution 357/2005 recommends pH values for class 2 freshwater within the range of 6 to 9. The pH values found at all collection points are within the value established by the Resolution, and the average pH of the samples is 6.45 ± 0.27. In this regard, the pH of the waters is influenced by the amount of allochthonous and autochthonous organic matter that needs to be decomposed, as the greater the amount of organic matter, the lower the pH.

WQI Parameters	P1- Guaratinga	P2 - Embasa Captchment	P3- Brigde Buranhém river	P4- Fazenda Limoeiro	Unidade
Dissolved oxygen	6,7	8,19	8,8	8,7	% saturação
pH	6,39	6,61	6,7	6,1	-
Biochemical oxygen demand	7	6	2	2	mg O_2/L
Nitrogen Total	1	1	0,14	0,1	mg N/L
Total Phosphorus	0,3	0,1	0,08	0,03	mg P/L
Total residue	72	140	114	51	Mg/L

Table V – Results of the chemical parameters of the WQI for the collection points.

Source: ANA, 2021.

When assessing the level of DO in the Buranhém River, the four sampling points had a minimum value of 6.7 $mgO_2.^{L-1}$ and a maximum value of 8.8 $mgO_2.^{L-1}$ (with a mean of 8.0 ± 0.97 $mgO_2.L^{-1}$). These values are above the limit established by CONAMA Resolution 357/2005, which recommends that the DO values should not be lower than 5 $mgO_2.^{L-1}$ for class 2 freshwater. Regarding total residues in the analyzed points, the P02 - Embasa presented 140 mg/L. According to Souza and Gastaldini (2014), values close to, equal to, or greater than 200 mg/L may indicate the release of direct sewage into the water body.

When analyzing the BOD values, points 01 and 02 presented values of 7 and 6 mg/L, respectively. The minimum BOD value was 2 mg/L and the maximum 7 mg/L (with a mean of 4.25 ± 2.63 mg/L). CONAMA Resolution 357/2005 considers values of up to 5 mg/L. Thus, in point 01 the microorganisms used more oxygen to decompose organic matter, which requires greater oxygen consumption, corroborating the DO result. BOD is the amount of oxygen consumed by microorganisms in a given effluent or water sample, thus, polluted water is considered to have a lower concentration of DO and a higher BOD (JÚNIOR *et al.*, 2018).

Regarding the chemical parameter of nitrogen, the analyzed points are within the acceptable limit of the aforementioned Resolution, which is up to 2.18 mg N/L for lotic environments. In the water samples, the minimum nitrogen value was 0.1 mg N/L and the maximum value was 1 mg N/L (with a mean of 0.56 ± 0.51). The highest nitrogen concentration values are from points 01 and 02, which, according to Von Sperling (2014), indicate anthropic influence due to the release of domestic, industrial, and fertilizer effluents. In this case, the latter is the most likely cause, given that point 01 is in a rural area.

CONAMA Resolution 357/2005 establishes the maximum permissible value (MPV) for total phosphorus of 0.10 mg/L in a lotic environment. The results of the analysis demonstrate that the presence of phosphorus exceeded the MPV at point 01. The minimum phosphorus value in the samples was 0.03 mg P/L and the maximum was 0.3 mg P/L (with a mean of 0.51 ± 0.12 mg P/L). The value of 1 mg N/L at point 01 corroborates the phosphorus concentration result. It is worth noting that high concentrations of P and N can result in the phenomenon of eutrophication.

3.3 Evaluation of the biological parameter

CONAMA Resolution No. 357/2005 determines that the limit range of thermotolerant coliforms for class 2 water must be less than 1,000 $NMP.100mL^{-1}$. Of the four samples, only two were within the limit established by the Resolution (Table 6). At points 02 and 04, the coliform values are above the allowed limit, with point 02 presenting 16,000 $NMP.mL^{-1}$ and point 04 with 24,196 NMP. $100mL^{-1}$. In general, all points showed a mean of 10,139 ± 11,976.63.

WQI Parameters	P1- Guaratinga	P2 - Embasa Captchment	P3- Brigde Buranhém river	P4- Fazenda Limoeiro	Unidade
Thermotolerant coliforms	130	16.000	230	24.196	NMP/100 ML

Table VI – Results of the biological parameter of the WQI for the collection points.

Source: ANA, 2021.

Points 02 and 04 are highlighted as the main reasons for high values of coliforms thermotolerant to the presence of fecal pollution from animal and human feces. Point 02 is closer to the urban area, which indicates contamination by domestic sewage in the river, while point 04 is located in the rural area near the mouth of the river, where contamination occurs due to the waste of animals, such as cattle. The presence of contamination by thermotolerant coliforms reveals that sewage was recently discharged at the point. This increases the probability of pathogens that may cause infectious and intestinal diseases through the consumption of low quality or untreated water (SANTOS *et al.,* 2017).

3.4 Evaluation of WQI

Table 7 shows the results of all the parameters for the analyzed points and their respective WQI values. In general, all points were classified as “good” and within the quality ranges established by the WQI. Points 02 and 04 both presented the lowest value of 58 due to the high values of thermotolerant coliforms, and all points presented a mean of 65.25 ± 8.4.

The use and occupation of land influence the quality of water bodies. Figure 3 shows the classes of land use and occupation in the Buranhém River Basin. According to the data in Figure 3, the predominant land use class is pasture, with 60.35% of the total area of the basin (1511.68 km^2). The forest formation class, which occupies 21.30% (533.60km^2) of the area, is distributed in the landscape with smaller fragments of vegetation along the basin. In the upstream section of the Buranhém River, there is a predominance of eucalyptus culture.

WQI Parameters	P1- Guaratinga	P2 - Embasa Captchment	P3- Brigde Buranhém river	P4- Fazenda Limoeiro	Unidade
Dissolved oxygen	8,8	8,7	6,7	8,19	% saturação
Thermotolerant coliforms	230	24.196	130	16.000	NMP/100 ML
pH	6,7	6,1	6,39	6,61	-
Biochemical oxygen demand	2	2	7	6	mg O_2/L
Nitrogen Total	0,14	0,1	1	1	mg P/L
Total Phosphorus	0,08	0,03	0,3	0,1	mg N/L

Temperature	18,2	20,3	28,7	23,9	ºC
Turbidity	18,2	7,15	11,4	24,6	UNT
Total residue	114	51	72	140	Mg/L
WQI	**74**	**58**	**71**	**58**	-

Table VII. Results of the parameters of the collection points and the respective WQI values.

Source: ANA, 2017.

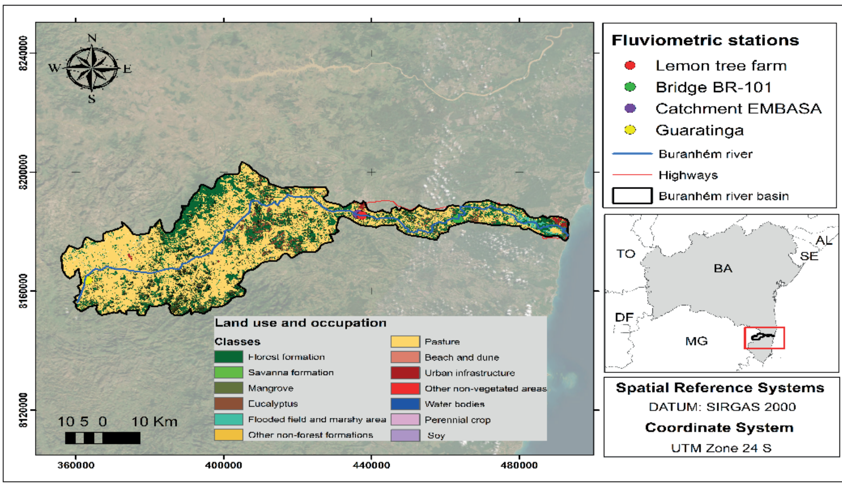

Figure III – Land use and occupation in the Buranhém River Basin.

Source: From the authors (2023).

The forest formation areas of the Atlantic Forest are concentrated in isolated and very small fragments in relation to the pasture class, which is a concern in the protection and conservation of water resources. Rainfall contributes to contamination precisely by dragging the organic matter deposited on the river slopes into the water body, which corroborates the data of thermotolerant coliforms presented in the study.

4 I CONCLUSIONS

The study showed that according to the 9 (nine) parameters that make up the Water Quality Index, the water of the Buranhém River can be classified as "good", given that most of the parameters are in accordance with CONAMA Resolution No. 357/2005 and that the activity in the largest extent of the river is rural. Regarding the disposal of domestic sewage, IBGE data (2010) showed that the supplied population is approximately 250,000 inhabitants. With an average river flow of 38.87m^3/s (ANA, 2021) and considering a daily per capita flow of 150 L/inhabitant, the sewage flow reached 1m^3/s. Therefore, the river manages to self-purify along its route.

The determined parameters revealed that the thermotolerant coliform concentration was far above the legal MPV in fluviometric stations 02 and 04. Therefore, the treatment of domestic sewage must be prioritized to prevent pollution of the Buranhém River.

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