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PHYSICOCHEMICAL AND MICROBIOLOGICAL CONDITIONS OF THE BLUE LAKE IN ARAGUAÍNA, BRAZIL

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ABSTRACT

The relationship between urban development, gentrification and impacts on aquatic environments can be analyzed in the context of the urban lake "Lago Azul" in the city of Araguaína, State of Tocantins, in northern Brazil. We aim to characterize the quality of urban waters at different points of Lago Azul, using chemical and microbiological analyses, to contribute to a deeper understanding of the environmental condition of the lake, especially in view of the accelerated process of urbanization in the vicinity. The microbiological survey was carried out by means of multiple tubes, in which total coliform bacteria, Escherichia coli, heterotrophic bacteria, molds and yeasts were identified, in addition to the presence of Salmonella spp/Shigella spp in the water. This work analyzed samples from Lago Azul in June 2021. The results obtained were compared with the maximum values allowed by the legislation in force in CONAMA Resolution 430/2011 and CONAMA Resolution No. 357/2005. It was concluded that the waters of Lago Azul, under study during the period evaluated, are not recommended for recreation with primary contact and direct consumption without previous treatment.

Keywords: Coliforms. Recreation. Pollution. Water Quality.

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INTRODUCTION

The water crisis of the twenty-first century, related to the availability and management of water resources, is derived from several environmental, economic and social problems of the past that last until the present. Intense urbanization is one of the motivating elements of the imbalance inherent to accelerated territorial growth, thus, management needs to consider not only the immediate needs of urban supply, but also the well-being of the citizen, according to the criteria of sustainable development (TUNDISI; MATSUMURA-TUNDISI, 2015; TUNDISI et al., 2015; LIMA, LOPES, FAÇANHA, 2019; ROCHA, 2021; PEREIRA, RODRIGUEZ, 2022).

In addition, changes resulting from the phenomenon of gentrification, which accompanies the reconfiguration of urban spaces, causing a change in the social and economic profile of a given region, are observed. According to Lauriano (2015), this process seeks real estate appreciation, but has impacts on the displaced population of these areas, thus characterizing itself as a two-way dynamic, in which the right to the city neglects the participation of the displaced community.

With the increase in population, the management of water resources becomes a priority, challenging not only the excessive use of water, but also the need for management that addresses both quantity and quality. The complexity of this challenge is accentuated when considering the processes of eutrophication and the alterations in the hydrological cycle due to global changes, as indicated by Tundisi (2008).

The decrease in water availability is closely linked to patterns of land use and occupation, agricultural and livestock production processes, urbanization, and the generation of domestic and industrial waste (SANTOS et al., 2017; BORDALO, PERET; SILVA, 2018). In this context, Jacobi, Empinotti and Schmidt (2016) highlighted that the UN's Sustainable Development Goal (SDG) number six, which aims to ensure the availability and sustainable management of water and sanitation for all. Previous studies indicate that continuous monitoring of the quality of water bodies is a crucial indicator of the conditions of the aquatic system, covering both natural conditions, which guide actions to avoid eutrophication or water degradation (JARDIM; SILVA, 2006; BRITO; LUZ, 2015), as well as anthropogenic issues, such as the disposal of sewage and effluents associated with agricultural, urban and industrial activities (Ribeiro et al., 2010; Bordalo; Peret; Silva, 2018).

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Among the anthropic actions, irregularities and deficiencies in the processes of urban drainage and garbage collection and disposal represent factors that contribute to the degradation of the aquatic environment of urban regions, which makes the deterioration of water quality an inevitable event (Tucci; Spanish; Cordeiro Neto, 2000). Thus, the waters of rivers and lakes present in the urban environment can become a source of diseases for people who live close to water bodies, which further emphasizes the importance of constant evaluation of microbiological quality (SOUZA NETO, 2013). This relationship between aquatic bodies and waterborne diseases is closely associated with the lack of environmental sanitation, which leads to the presence of several pathogenic microorganisms and compromised water quality for human supply (PEDROZO; KAPUSTA, 2010). Egito et al. (2007) revealed that the pollution of water bodies by physical and chemical elements, in addition to biological ones, becomes an even more serious problem, because in addition to being harmful to living organisms, it can also make several important human activities unfeasible. Also according to these authors, the pollution of surface water courses and sediments occurs due to the indiscriminate release of various waste of industrial, urban and even agricultural origin

By taking into account that aquatic environments are easily contaminated, the importance of monitoring physical, chemical and biological parameters is highlighted, especially in urbanized and industrial areas (Oliveira et al., 2008).

In Brazil, monitoring surveys are carried out according to the quality standards for water bodies determined by Resolution No. 357 of the National Council for the Environment (CONAMA), of 03/17/2005 (CONAMA, 2005), in addition to CONAMA Resolution No. 430/2011 (CONAMA, 2011). These resolutions address environmental guidelines for the framing of waters, in addition to establishing maximum conditions and characteristics for physical, chemical and microbiological aspects.

The creation of urban parks is necessary, since this is one of the main strategies used to minimize anthropogenic impacts and achieve the conservation of natural environments (Ribeiro et al., 2010). For this, the type of the various uses of these aquatic bodies is determined: protection of biological diversity, recreational activities, cultural aspects, scenic beauty, human consumption, among others, and studies on water quality (Strieder et al., 2005), such as those arising from monitoring the quality of surface waters and environmental management, enabling a systematic and integrated perception of the environmental reality (SILVA; JARDIM, 2006).

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These questions, together with the authors' daily observations, motivated the research to be carried out in Lago Azul (Fig. 1), which belongs to the city of Araguaína, a medium-sized city in the state of Tocantins, located in the northern region of the country.

Fig. 1 A. General view of the area in which Lago Azul is located, in Araguaína, TO, on different dates, showing: A. the lake before its emptying in July 2012; B. after emptying in December 2012; C. earthworks of the area for the construction of Via Lago (2017); D. access roads and works of the Beira Lago sports complex (2017); E. Aerial view of Via Lago and Lago azul (2018); F. Via Lago beach (2019).

Sources: Marcos Sandes (2012, 2017, 2018, 2019).

The history of the existence of this lake shows that it arose from the damming of the reservoir, in the hydrographic basin of the Lontra River, as the Small Corujão Hydroelectric Power Plant, which began its activities in 1971 and was deactivated in 2012 to be rebuilt from 2014, thus emerging the so-called "postcard" of the city, next to the waterfront called Via Lago. According to the Technical Report of the Review of the Master Plan of Araguaína (ARAGUAÍNA, 2017), the following were found: 1) the devastation of significant

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areas of forests and in the urban area; 2) the landscape potential of the shores of Lago Azul and 3) the numerous risks of pollution and siltation of rivers and streams; The report warns about the need for more adequate planning for watersheds, urban expansions and densification of existing occupation.

In view of the above, the present work aimed to carry out an investigative study in the geographic space of Lago Azul, located in the city of Araguaína, Tocantins, in order to characterize the water quality based on physical-chemical and microbiological parameters.

METHODOLOGY

FIELD OF STUDY

The city of Araguaína is located in the northern region of the state of Tocantins (Fig. 2); it began in 1876, with the installation of the first inhabitants on the banks of the Lontra River, reaching the condition of municipality in 1958. According to the Technical Report of the Review of the Master Plan of Araguaína (2017), its development was driven by the construction of the BR-153 highway, better known as the Belém-Brasília highway, in the early 60s of the twentieth century (ARAGUAINA, 2017).

The Master Plan determines, in its Article 8, "The protection and enhancement of the natural and built environment, particularly that for tourist appeal", aiming at the effective implementation of Environmental Protection Areas, recovery of environmentally degraded areas, promotion of environmental education, protection of water and natural resources, fauna, flora and the cerrado biome, and the protection of built environments of social interest, however, it does not define what they are. Along with this, the plan determines compliance with the Environmental Policy of the Municipality of Araguaína, which was defined by Municipal Law No. 1,659 of December 30, 1996.

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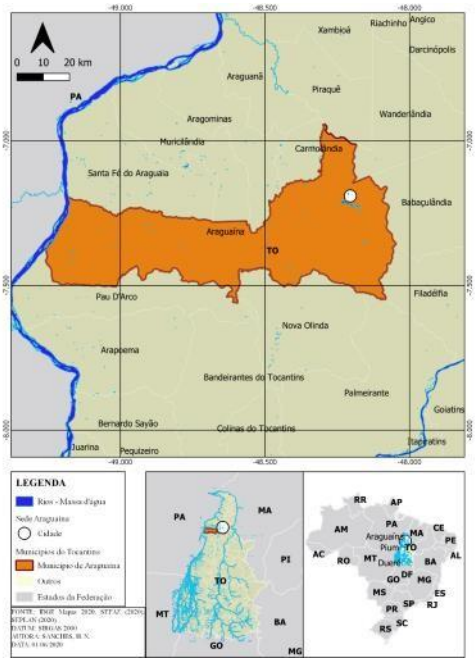
Fig. 2. Geographical location of the state of Tocantins and the municipality of Araguaína.



Fonte: Sanches, H. N (2021).

The city of Araguaína is located on the banks of the Lontra River and is intersected by several streams, the most relevant being the Neblina Stream, which drains the region of the city's most occupied nucleus and where there is the occurrence of deep wells with large flows. The area of the municipality is inserted in the basin of the Araguaia River (Fig. 3), which has as its main tributary the Lontra River, where the Corujão Hydroelectric Power Plant was built, the first to supply electricity to Araguaína. Several rivers and streams also comprise the Araguaína Hydrographic Basin, among them: the Preto and Lontra Rivers and the Lavapés, Prata, Raizal, Xixebal, Cará, Jacubinha, Tiúba, Jacuba and Ribeirão de Areia streams, all located in the urban perimeter (PEREIRA, 2013).

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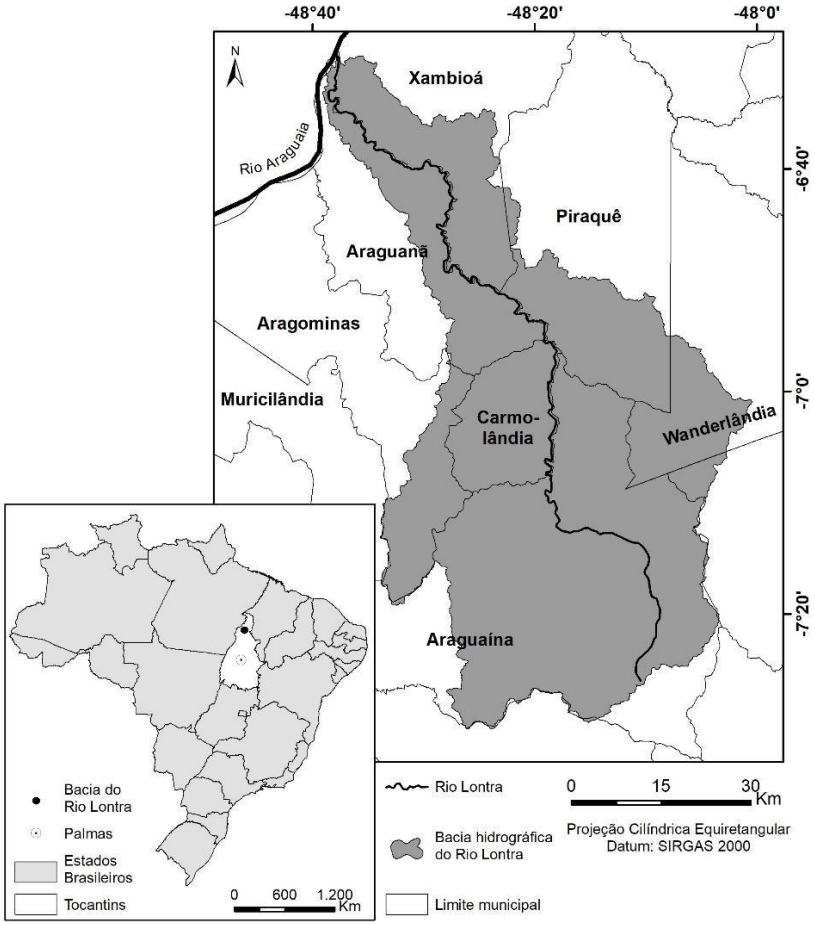
Fig. 3 Map of Brazil highlighting the state of Tocantins; on the larger map we have the northern region of the state, in gray the basin of the Lontra River and the municipalities are highlighted.



Fonte: Silva et al. (2021).

STUDY DESIGN

The analysis of the water quality of Lago Azul was carried out for nine demarcated points (Fig. 4) and classified as high, low or no population density (Chart 2). The sampling was carried out during the month of June 2021, in the morning, at nine points in Lago Azul. All sampled points were georeferenced using GPS, model 60CS x Garmin, and using the multiparameter equipment (POL-60), where the measurement is made through a probe, pH and temperature values were measured. Values closer to zero indicate a higher concentration of hydrogen ions (H+) and are considered acidic, while values closer to 14 indicate a lower concentration of hydrogen ions (H+) considered alkaline, and the neutral value is considered when the sample result is 7. To collect the samples for laboratory analysis, glass vials with a capacity of 250 ml were used, labeled and closed with plastic caps (FAL, 2009); then they were packed in a refrigerated Styrofoam box and transported

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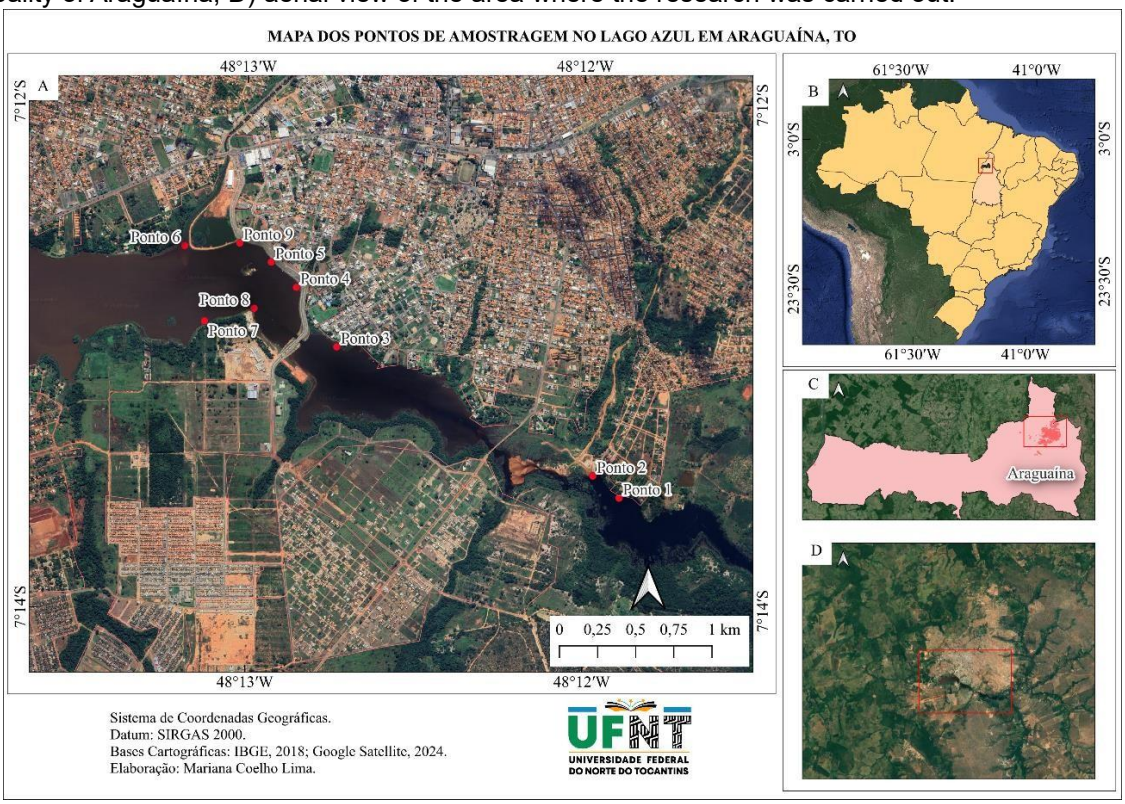
to the Biology laboratory of the Federal University of Northern Tocantins, Araguaína campus for analysis.

Fig. 4. A) Aerial view of Lago Azul, the vegetation and part of the urban fabric of Araguaína, TO; highlighting the location of the nine water sample collection points; B) map of Brazil highlighting the state of Tocantins; C) municipality of Araguaína, D) aerial view of the area where the research was carried out.



Source: Prepared by Mariana Coelho Lima (2024).

Table 2. Identification of the collection points along with the names of the neighborhoods, in Araguaína, TO, near Lago Azul and the number of inhabitants and number of blocks.

Stitches	Locations	Population density (number of inhabitants/number of blocks)
1	Itaipu	34,81
2	Jardim Paulista	46,83
3	Mansions of the Palm Trees Garden	24,98
4	Philadelphia Garden	20,15
5	Jardim Beira Lago	26,12
6	Itatiaia Garden	10,06
7	Preserved Area	0,00
8	Preserved Area	0,00
9	Itatiaia Garden	10,06

Source: Table prepared by the authors based on data provided by the Center for the Control of Zoonoses of Araguaína, TO (CCZ, 2020).

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LABORATORY TESTS

In the microbiological analyses for the determination of *Escherichia coli* (EC), total coliforms (TC) and yeast fungi-, 1 mL aliquots of the sample were transferred to Petrifilm® plates (3M Company, St. Paul, MN, USA), according to the technique used by the 3M Interpretation Guide (3M, 2014; 2020). To verify the presence of heterotrophic bacteria, the methodologies of Silva et al. (2017) and the National Health Foundation (FUNASA, 2013) were used; where Petri dishes with Plate Count Agar medium were used, using the depth plating technique (pour plate). For the isolation and differentiation of *Salmonella spp/Shigella spp*, the hydrated culture medium in CEFAR flasks, Agar SS, was used.

The data obtained were analyzed descriptively, organized in tables that facilitated the visualization and interpretation of the results. In addition, an analysis of the conformity of the parameters with the Resolution of the National Council for the Environment (CONAMA) No. 357/05 (BRASIL, 2005) was carried out.

RESULTS AND DISCUSSION

Despite the landscape aspect of preservation, this lake has served to highlight an important avenue, called a postcard, the "Via Lago", which apparently aims at real estate exploration and as an economic tourist stimulus-for the city, with bars and restaurants on its banks. Adorno et al. (2016) described the Lontra River as a tributary of the Araguaia River, which was partially dammed to build the Corujão Hydroelectric Power Plant, which is currently deactivated. According to the city's history, at the time, there was no type of sewage or rainwater collection and all those drained would go to the watercourses, determining the high contamination of this aquatic environment. Currently,-there is a collection network that covers approximately 30% of the city, concentrated mainly in the central areas.

Over the years, debris, chemical and organic effluents were released into the lake and caused a marked erosion, which determined the concern of local environmental entities, such as the Nature Institute of Tocantins (Naturatins), which culminated in the origin of the State Hydrographic Basin Committee. Thus, Fernandes (2017) describes that this seizure was revitalized in 2014 and fits into the municipality's environmental preservation programs.

According to Fernandes (2017), on the shores of Lago Azul, high-end residences are established, therefore, with the character of private appropriation of a body of water

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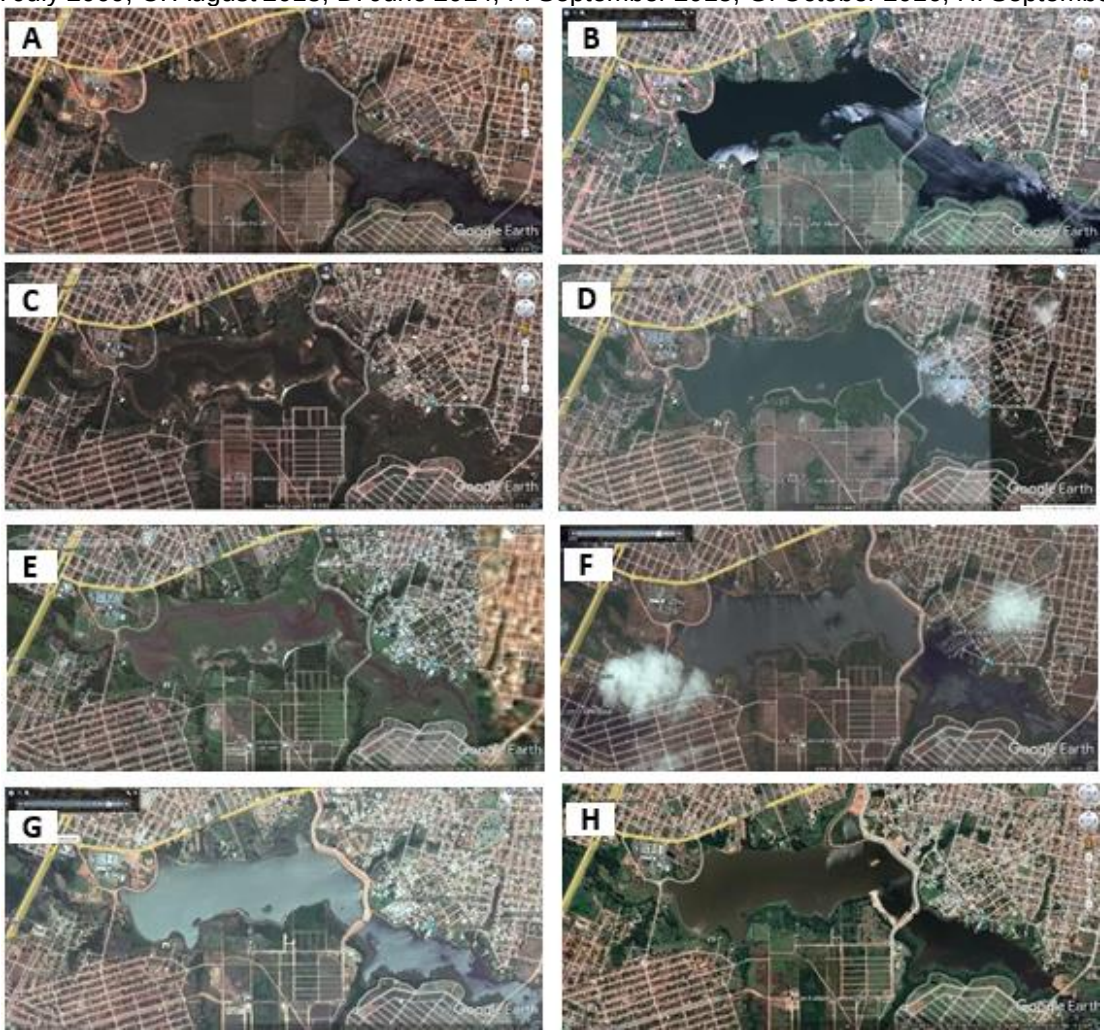
that should be conceived and managed as public, since, at the beginning of the city,-a Hydroelectric Power Plant (Corujão Plant) behaved. This author describes the negative environmental effects arising from the revitalization procedures, which included the dredging of the sediment, impacting the quality of life of the fish species existing in the lake and the native plants in the surroundings. Currently, the Lake is in a rapid process of siltation affected by the process of urban growth without planning. The temporal evolution of the surroundings of Lago Azul can be observed in Figure 4.

Fig. 4. Temporal evolution of the landscape in the vicinity of Lago Azul in Araguaína, Tocantins: A: February 2005; B: July 2009; C: August 2013; D: June 2014; F: September 2015; G: October 2016; H: September 2022.



Fonte: Google earth (2023).

In his work, Fernandes (2017, p. 57) highlights information released by the city hall of the city of Araguaína itself:

> The bridge is within the second stage of the work, which includes the paving of the road, including sidewalks and landscaping; electrification and the bridge. Via Lago

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will be 1.56 km long, starting at the end of Marginal Neblina (at the intersection with Avenida Filadélfia) and continuing to the Lago Azul, Cidade Nova and Nova Morada sectors, with three double lanes, bike path and pedestrian pavement. At the end of the avenue, there will be the bridge. Within the project, an island near Via Lago is also planned, where a restaurant will be built and access will be by boats, with boarding and disembarking decks.

As for the laboratory analyses, Table 1 presents the results from the physicochemical analyses-. According to CONAMA Resolution No. 430/2011 (CONAMA, 2011), for the protection of aquatic life, the pH must be between 6 and 9, which indicates that the samples analyzed would be within the parameters suggested for the protection of aquatic life. As well as the solubility of oxygen, which can decrease as the temperature increases, considering that the minimum value of dissolved oxygen (DO) for the preservation of aquatic life, established by CONAMA Resolution 357/2005, is 5.0 mg/L.

Table 1 – Sampling points, geographic location and physicochemical parameters-measured in Lago Azul in Araguaína, TO.

POINT	GPS*	pH*	Volume A*	Tº H2O*	Time for collection	Oxygen mgL^{-1}
1	S 07°13.362' W 045°11.919'	6,56	28,5°	26,8°	8:46	-
2	S 07°13.273' W 048°12.006'	6,32	29,3°	26,1°	9:00	-
3	S 07°12.870' W 048°12.881'	6,41	28,2°	28,4°	10:00	4,4
4	S 07°12.657' W 045°13.022'	6,31	28,0°	28,8°	10:19	4,6
5	S 07°12.580' W 048°13.127'	6,19	28,3°	28,9°	10:25	4,2
6	S 07°12.507' W 048°13.428'	6,90	27,4°	27,2°	10:36	7,5
7	S 07°12.793' W 048°13.355'	6,14	26,6°	29,0°	10:47	3,8
8	S 07°12.737' W 048°13.195'	7,46	26,0°	29,2°	10:57	5,0
9	S 07°12.491' W 048°13.242'	7,40	28,2°	29,2°	11:21	10

*GPS: Global positioning system; pH: hydrogen potential; TºA: ambient temperature; TºH2O: water temperature. Samples were collected from 8 am to noon. Source: Prepared by the authors.

Table 1 also presents the Dissolved Oxygen (DO) values, although some points present concentrations lower than those recommended by the Resolution, approximately 50% of the samples with determined DO, hypoxia values were not detected, lower than 2 mg/L, as indicated by Cetesb (2022), in an article that describes the survival of some fish species in extreme DO values. Considering the water temperature during collections, from

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26.1ºC to 29.2ºC, the solubility of oxygen decreases as the temperature increases, which may explain the low DO indices identified.

Apparently, the DO values may be influenced by the amount of aquatic mass for dissolution, as well as the presence of organic matter, as indicated by research carried out by Paula, Mesquita and Mendes (2013) in urban lakes in Catalão, GO, where they indicate that depth and wind could have influenced the DO measurements, and indicate that places with low DO content may indicate a high presence of organic matter, This is in agreement with the results found in the present study, since the collection-took place on the shores of the lake, generally with the presence of macrophytes and silt.

After the laboratory procedures were carried out respecting the incubation time, the readings of the Colony Forming Units (CFU) were performed for total coliforms and *E. coli*, as well as for heterotrophic bacteria and presence/absence and *Salmonella spp/Shigella spp* and *C. violaceum,* which occurred at the time of the color change of the culture media for coliforms and the presence of violet colonies (Table 2).

Table 2. Results of microbiological analyses of water samples from Lago Azul, Araguaína, TO.

Samples	Total coliforms CFU/mL	*E. coli* UFC/mL	CFU/mL Heterotrophic Bacteria	Molds and Yeasts CFU/mL	(*Cromobacterium violaceum*) P/A*	SS Agar - *Salmonella* / *Shigella* Agar P/A*
1	1	0	6,3x102	0	+	+
2	2	0	7x102	0	+	-
3	5,4x101	24	4,8x102	8x101	+	-
4	1,5x101	5	1,7x102	1x101	+	-
5	3,2x101	0	3x103	2x101	+	-
6	2,4x102	41	9,2x103	4x101	-	+
7	1,5x101	3	4,6x102	6x101	+	-
8	2,8x101	0	3,4x102	1x101	+	-
9	3,4x102	0	4,2x103	0	-	-

*P: presence (+) / A: absence (-) Source: Prepared by the authors.

According to CONAMA Resolution No. 274, of November 29, 2000, human health and well-being may be negatively affected if they do not present adequate bathing conditions provided for by this resolution (CONAMA 2000). After carrying out the collected analyses, the results were compared in relation to this CONAMA provision, and the waters of this lake are characterized as bathing waters, appropriate for this use, especially at the

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points located on the beach of the Lake, since the disposal for class 1 fresh waters, CONAMA Resolution No. 357 (CONAMA 2005), defined for recreational waters, to be-considered as of Excellent level, there must be a maximum of 250 fecal coliforms (thermotolerant) or 200 *Escherichia coli* or 25 *Enterococci* per l00 milliliters, and the limit index for total coliforms is 1,000 per 100 milliliters. Thus, the samples from points 3 and 6 are outside the bathing limits, with 240 and 410/100mL, respectively.

According to Table 2, it -was observed that the highest counts for total coliform bacteria and *E. coli* were from the samples from points 6 and 9, revealed as the most contaminated points. This was expected, since point 6 corresponds to the tributary of the Neblina stream, in the Itatiaia sector, to Lago Azul. It is worth noting that the stream crosses the city of Araguaína, in whose course it is common to observe pipes that discard tributaries from surrounding households, among which are hospitals,-car washes, old homes with pipes in inappropriate places, whose wastewater is discharged along with rainwater. It is important to note that point 9 is located near point 6, but it was dammed for the construction of the city hall's works, which may add to its contamination.

The sampling points named 1, 2 and 7 were the ones with the lowest counts of total coliform bacteria and *E. coli,* places considered to be more preserved and with low housing density (Table 2).

In relation to heterotrophic bacteria, the quality standards of Resolution No. 274/2000 (CONAMA, 2000) limit the count of heterotrophic bacteria to a maximum of 500 Colony-Forming Units per milliliter (CFU/mL). Thus, the counts of this parameter in the samples vary from 1.8x102 to 3.1x103 CFU/mL, which indicates that some points would be outside the recommended parameters, calling attention to point 6 (corresponding to the one where the tributary between the Itatiaia sector and the Neblina stream would be). It is-relevant to point out that sudden or above-usual changes in the heterotrophic bacteria count should be investigated to identify irregularities, and measures should be adopted to restore the integrity of the distribution system (reservoir and network), recommending-that the limit of 500 CFU/mL should not be exceeded. In points 1 and 6, the presence of *Salmonella spp/Shigella spp* was identified, which indicates the need for greater monitoring, since these are bacteria of importance to public health (CUNHA et al., 2017; OLIVEIRA, 2021). Similar studies, such as those by Marcondes et al. (2016) identified the presence of *Salmonella* spp and Total Coliforms in streams in São Caetano do Sul/SP with nearby houses and a Sewage Treatment Plant, as well as Forsythe (2013)

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and Paredes-Aguilar; Rivero-Montes (2023) identified *Salmonella* and *Shigella species* as common pathogens involved in foodborne toxicoinfections, found in the intestinal flora of animals and humans, so their presence in two samples of the research may reaffirm the hypothesis of contamination of the lake by domestic sewage.

In points 1, 2, 3, 4, 5, 7 and 8 (Table 2), the presence of *Chromobacterium violaceum*, a Gram-negative bacillus, which according to Levinson (2011) is frequently found in water and soil, especially in tropical and subtropical regions, this bacterium recognized as an opportunistic pathogen can cause infections in wounds.

CONCLUSION

Through the analyzes carried out during the survey of the physicochemical-and microbiological conditions of the lake, it can-be concluded that the waters under study during the period evaluated, although they can be intended for recreation, are not recommended for primary contact, such as swimming and diving, nor for direct consumption without prior treatment, according to CONAMA Resolution No. 357/2005 (CONAMA, 2005).

The importance of this study is due to the fact that it is a strategic area for the city hall, configured as a postcard of the city and which has potential future projects, including revitalization, with the insertion of fish and leisure areas and municipal infrastructure and other enterprises. In view of this,-it is important to consider the results, such as those presented in this study, in the environmental planning of this site.

It is-necessary to periodically analyze the quality of the water, in its physical, chemical and microbiological parameters, although these last measurements, at the different points of the lake, did not present very high numbers of microorganisms indicating its quality. Due to the geographical location-, special attention should be paid to the monitoring of Lago Azul, since urban occupations close to a body of water can bring problems of increased sedimentation and serve as a source of nutrients for organisms that participate in eutrophication processes that, according to the degree of trophy, could cause a decrease in dissolved oxygen in the water, not allowing the survival of organisms that use oxygen to survive. such as the case of fish, among other negative consequences for the environment and its surroundings.

Thus, this study aimed to contribute to scientific research, and although it is not conclusive, it can open perspectives for the deepening of the theme by other researchers

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in the construction of data that can serve as support for the elaboration of a study that results in the formulation of a sustainability policy for the management of the lake. aiming at mitigating its environmental degradation.

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