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Environmental perception of riverine people on pollution and water quality of the middle Tocantins River, Maranhão

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ABSTRACT

The Tocantins River is essential for the sustenance of the population in Maranhão; however, despite its importance, the region faces environmental degradation problems due to rapid urban growth, such as deforestation of hillsides, intense exploitation of fishery resources, air and water pollution, siltation, dredging, and lack of sanitation. The objective was to investigate the environmental perception of riverside dwellers regarding the water quality of the middle Tocantins River through the application of structured questionnaires. The research was conducted between August and December 2023, with a sample universe of 50 respondents. Additionally, a multimethod approach was used to integrate quantitative and qualitative data. The affected population consisted of riverside families distributed among four questionnaire application points along the middle Tocantins River (P1: Beira Rio - urban area, P2: Bananal village, P3: Embiral village, and P4: Cidelândia village). The majority of riverside dwellers involved in the study have been residing in the region for a significant period, predominantly over 10 years (88%). Furthermore, 34% of respondents consume and market native fish, while 62% use them only for their consumption, and 4% do not consume them. It is also important to highlight that 84% of participants claim not to have a sewage system in their homes. These data highlight the importance of fishery resources and river water for this population, emphasizing the need for measures to promote environmental conservation and access to basic sanitation services.

Keywords: Environment; Pollutants; Fishing resources.

Percepção ambiental dos ribeirinhos sobre a poluição e qualidade da água do médio rio Tocantins, Maranhão

RESUMO

O rio Tocantins é essencial para o sustento da população maranhense, porém, apesar de sua importância, a região enfrenta problemas de degradação ambiental pelo crescimento urbano acelerado, como desmatamento de encostas, exploração intensa de recursos pesqueiros, poluição do ar e água, assoreamento, dragagem e falta de

saneamento. Objetivou-se investigar a percepção ambiental dos ribeirinhos quanto à qualidade da água do médio rio Tocantins através da aplicação de questionários estruturados. A pesquisa foi realizada entre os meses de agosto e dezembro de 2023, contando com um universo amostral de 50 entrevistados. Ainda, foi utilizada uma abordagem multimétodo para a integração de dados quantitativos e qualitativos. A população atingida foi composta por famílias ribeirinhas distribuídas entre quatro pontos de aplicação de questionário ao longo do médio rio Tocantins (P1: Beira Rio – zona urbana, P2: povoado Bananal, P3: povoado Embiral e P4: povoado Cidelândia). A maioria dos ribeirinhos envolvidos no estudo reside na região há um período significativo, predominantemente acima de 10 anos (88%). Além disso, 34% dos entrevistados consomem e comercializam peixes nativos, enquanto 62% os utilizam apenas para consumo próprio, e 4% não os consomem. É importante destacar também que 84% dos participantes afirmam não possuir rede de esgoto em suas residências. Esses dados evidenciam a importância dos recursos pesqueiros e da água do rio para essa população, destacando a necessidade de medidas que promovam a conservação ambiental e o acesso a serviços básicos de saneamento.
Palavras-chave: Meio ambiente; Poluentes; Recursos pesqueiros.

Percepción ambiental de los riberanos sobre la contaminación y la calidad del água del medio río Tocantins, Maranhão

RESUMEN

El río Tocantins es esencial para el sustento de la población en Maranhão; sin embargo, a pesar de su importancia, la región enfrenta problemas de degradación ambiental debido al rápido crecimiento urbano, como deforestación de laderas, intensa explotación de recursos pesqueros, contaminación del aire y el agua, sedimentación, dragado y falta de saneamiento. El objetivo fue investigar la percepción ambiental de los habitantes ribereños con respecto a la calidad del agua del río Tocantins medio mediante la aplicación de cuestionarios estructurados. La investigación se llevó a cabo entre agosto y diciembre de 2023, con un universo muestral de 50 encuestados. Además, se utilizó un enfoque multimétodo para integrar datos cuantitativos y cualitativos. La población afectada consistió en familias ribereñas distribuidas entre cuatro puntos de aplicación de cuestionarios a lo largo del río Tocantins medio (P1: Beira Rio - área urbana, P2: aldea Bananal, P3: aldea Embiral y P4: aldea Cidelândia). La mayoría de los habitantes ribereños involucrados en el estudio han estado residiendo en la región durante un período significativo, predominantemente más de 10 años (88%). Además, el 34% de los encuestados consumen y comercializan pescado nativo, mientras que el 62% los utilizan solo para su consumo propio y el 4% no los consume. También es importante destacar que el 84% de los participantes afirman no tener un sistema de alcantarillado en sus hogares. Estos datos resaltan la importancia de los recursos pesqueros y del agua del río para esta población, enfatizando la necesidad de medidas para promover la conservación ambiental y el acceso a servicios básicos de saneamiento.
Palabras clave: Meio ambiente; Contaminantes; Recursos pesqueros.

INTRODUCTION

The Tocantins River is a watercourse that crosses the Brazilian states of Maranhão, and Tocantins, and has its mouth in Pará; hence, it is also named Araguaia-Tocantins. This body of water is the second largest entirely Brazilian, with a length of 2.400 km, with a potential for electricity generation of approximately 11,500 MW, the third largest in Brazil (Agência Nacional De Águas, 2020). However, this river has been facing environmental degradation, directly affecting the traditional communities living in its surroundings, including riparian communities (SANTOS, 2019).

Water is the main renewable natural resource and is of significant interest for maintaining life on planet Earth. Although abundant, part of this resource presents physical-chemical parameters different from those required by the Ministry of Health for population consumption and agricultural services (RIBEIRO, 2017). In this sense, maintaining water quality becomes a concerning factor due to rapid urban growth near watercourses, resulting in the accumulation of pollutants (CHIDIAC, 2023).

The absence and precariousness of environmental sanitation are reasons for global concern, being essential for maintaining ecological integrity, well-being, and human health, having been included as a goal of the United Nations Agenda 2030 (BRITO *et al.*, 2021). Several studies have observed situations where adverse effects on human health arise from the consumption of contaminated fish and seafood by emerging pollutants, and some known diseases have been associated with trace metals, such as recurrent episodes of mercury poisoning in areas where mining has occurred in Brazil (ALVARIÑO *et al.*, 2023; JOB *et al.*, 2023; RAKIB *et al.*, 2021; MILHOMEM *et al.*, 2016).

Human contamination through fish becomes significant when considering the preference of Amazonian riverside dwellers for this protein source over other types of food (JUNIOR *et al.*, 2020). For local communities, the Amazon region is crucial for daily diet, recognized for its rich aquatic biodiversity. According to Corrêa *et al.* (2023), the main source of heavy metal contamination, such as mercury (Hg), lead (Pb), and cadmium (Cd) for humans, is through the consumption of fish and other aquatic organisms. Additionally, riverside communities live in close connection with the river, using its waters for daily routines and even for human and animal consumption.

The municipality of Imperatriz is the second most populous municipality in the state of Maranhão, with 273.110 inhabitants and an area of 1.369.039 km², located in the Northeast Region, extending along the right bank of the Tocantins River (IBGE, 2022). Faced with this proximity, the population has been influenced by the activities of the river in its social, economic, cultural, and environmental context. Their environmental perception is of utmost importance, as they are the first to notice any change or impact that occurs in the environment they live in. Based on their intimate knowledge of the region, their perceptions can provide valuable information about environmental problems, such as water contamination, pollution, and changes in local ecosystems (PARENTE, 2019).

By sensitizing and educating riverside populations, the aim is to encourage sustainable practices and the protection of Brazilian rivers. It is expected that these actions will also encourage the government and other institutions to engage in the development of awareness and remediation programs, promoting more effective and collaborative environmental management. Ultimately, they may inspire similar initiatives across Brazil, benefiting the preservation of water resources, the quality of life of riverside populations, and the health of the local ecosystem (MATSUOKA, 2019). In this sense, it can be observed that the objectives of Agenda 21 seek to promote sustainability, including sustainable management (SCHIEBELBEIN, 2018).

> The elaboration of Agenda 21 was one of the main outcomes of this meeting and defined objectives for promoting sustainable development of human settlements, including providing adequate housing for all; improving the management of human settlements; promoting sustainable planning and management of land use; and promoting integrated provision of environmental infrastructure, considering water, sewage, drainage, and solid waste management issues (SCHIEBELBEIN, 2018, p. 67).

Anthropogenic actions have been altering the natural dynamics of the environment and accelerating environmental impacts, leading to the acceleration of processes that alter watersheds and river courses (COLOMBO *et al.*, 2019). Negative impacts have been the cause of physicochemical degradation such as decreasing water volume, and contamination of surface and groundwater. Additionally, water is a source of consumption for animals, and humans, as well as for tourism, and it is crucial for future generations, thus requiring preservation and conservation efforts from governments and the population (RIBEIRO *et al.*, 2017).

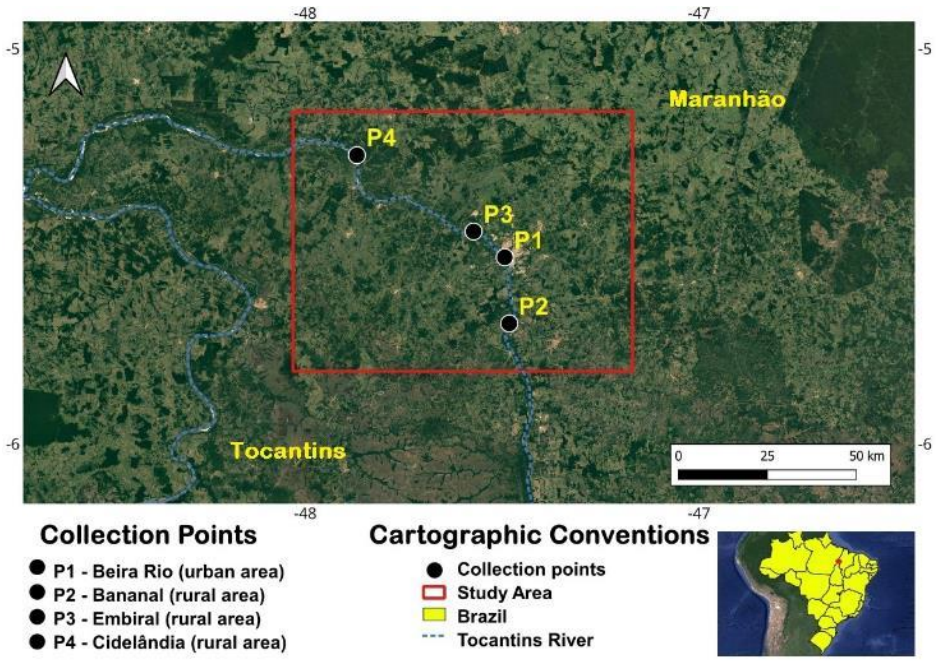
This socio-environmental study aims to take the first step towards diagnosing, understanding, and sensitizing riverside populations about pollution and water quality in the middle Tocantins River, in Maranhão. More specifically, it seeks to investigate the environmental perception of riverside dwellers regarding the water quality of the middle Tocantins River through the application of structured questionnaires, sensitizing and guiding them towards environmental conservation and restoration. By sensitizing and educating riverside populations, we understand the importance of encouraging sustainable practices and the protection of Brazilian rivers.

METHODOLOGY

Characterization of the study area

The research was conducted in sections along the middle Tocantins River, located in the municipality of Imperatriz and surrounding regions, with riverside residents from the Beira Rio (urban area), Bananal village, Embiral village, and Cidelândia village (Figure 1), by the Advanced Morphophysiological Studies Center (NEMO) of the State University of the Tocantina Region of Maranhão (UEMASUL). The city of Imperatriz borders the state of Tocantins and is bordered by the Tocantins River (IBGE, 2022). It is noteworthy that, due to the proximity of this population to the river, people have been influenced by river activities and have incorporated riverside life into their social, economic, cultural, and environmental context.

Figure 1 - Points of application of the environmental perception questionnaire to riverside dwellers of the middle Tocantins River, Maranhão.



Source: Author (2024, p. 04).

Urban occupation in the vicinity and, consequently, negative environmental externalities disrupt the environment and aquatic ichthyofauna of the region, resulting in deforestation of slopes, intense exploitation of fishery resources, destruction of habitats, siltation, and contamination of river waters. Consequently, anthropogenic activities elevate levels of environmental degradation, altering the balance of the ecosystem and causing harmful effects on the resident population. The first sampling point (P1) around the middle Tocantins River is about 600 m away from Beira Rio, a region potentially contaminated and urbanized (Figure 2). It is a location intensely populated by traders, tourists, riverside fishermen, and citizens seeking leisure on the banks of the river. Additionally, the area is characterized by the presence of animals, boats, dumping of waste, and sewage directly into the water body.

Figure 2 – Beira Rio (P1), the first point of the questionnaire application, exhibits evidence of waste and sewage dumping directly into the river body, the presence of animals, boats, and riverside dwellers.

Source: Author (2024, p. 05).

The second study point (P2) is located in the Bananal village, at Praia Talismã, approximately 30 km away from the municipality of Imperatriz (MA). It is considered a more remote area from the urban perimeter, with some boat traffic coming from fishing activities (riverside dwellers) and leisure (river beach) (Figure 3).

Figure 3 – Bananal village (P2), the second point of the questionnaire application, with the presence of riverside dwellers and boats in the vicinity of the middle Tocantins River.

Source: Author (2024, p. 06).

The third questionnaire application site (P3) is located in the Embiral village, a rural area of Imperatriz and approximately 40 km away from the municipality of Cidelândia (MA). This area is frequently used for recreational activities on the Tocantins River (river beaches and country estates), as well as for fishing activities by riverside dwellers (Figure 4).

Figure 4 – Embiral village (P3), the third point of the questionnaire application, with the presence of riverside dwellers and boats in the vicinity of the middle Tocantins River.

Source: Author (2024, p. 06).

The last questionnaire application point (P4) is located in the region of Praia da Viração, which is 20 km away from the center of the municipality of Cidelândia (MA). This area belongs to the rural zone of Imperatriz (MA) and concentrates a large number of riverside dwellers who depend on the river water for a significant portion of their domestic activities. It is a region considered prominent due to intense dredging, fishing, and leisure activities, which may contribute to the contamination of the water resources of the Tocantins River (Figure 5).

Figure 5 – Praia da Viração in the village of Cidelândia (P4), the fourth point of the questionnaire application, with the presence of active dredges and boats belonging to riverside dwellers.

Source: Author (2024, p. 07).

Methodological procedures

Application of questionnaires on environmental perception of riverside dwellers

The research was conducted between August and December 2023, with a sample universe of 50 respondents. A multimethod approach was employed to integrate quantitative and qualitative data, aiming to obtain complementary information about the study object (PINHEIRO and GÜNTHER, 2008). The questionnaire consisted of 23 questions about the respondents' perception regarding environmental quality/contamination, water resources, and fisheries, distributed among closed-ended (14) and open-ended (9) questions (Table 1).

Table 1 - Questionnaire on environmental pollution perception and water quality of the middle Tocantins River, Maranhão.

Respondent's Name: Gender: ( ) Female ( ) Male Age: Region Name:	
Educational Level: ( ) Incomplete Elementary School ( ) Complete Elementary School ( ) Incomplete High School ( ) Complete High School ( ) Incomplete Higher Education ( ) Complete Higher Educatior	
Length of time living in the area: Number of people living in the household:	
Occupation/Profession:	
Average monthly income: ( ) Up to one minimum wage ( ) Up to two minimum wages ( ) Above two minimum wages	
Do you have a sewage system? ( ) Yes ( ) No. Where does the sewage produced in your residence go?	
1. Do you use water from the river in your daily life? If yes, what are the uses?	
2. Do you know which organization is responsible for monitoring and protecting the Tocantins River and its surrounding area?	
3. In your experience in the region, do you believe that the Tocantins River has changed over time? What were the main changes?	
4. Do you believe that the water of the Tocantins River may be somehow polluted?	
5. In your opinion, what are the main impacts caused by human activity on the Tocantins River? () Dredging; ( ) Pollution from soap and fuel; ( ) Urbanization; ( ) Burnings and improper occupation; ( ) Discharge of garbage and sewage into the river; ( ) Siltation and deforestation; others _____	
6. What recovery and preservation actions could be developed on the river?	
7. Do you consume or sell fish from the Tocantins River? For personal consumption? If you sell, where? What are the main species (types of fish)?	
8. What do you think of the water quality of the Tocantins River in your region? (appearance, smell, hygiene, taste, etc.) ( ) Very good; ( ) Good; ( ) Fair; ( ) Poor; ( ) Very poor.	
Legend for questions 9 to 15: 1 – Strongly disagree; 2 – Disagree; 3 – Neither agree nor disagree; 4 – Agree; 5 - Strongly agree.	
9. Do you believe that urbanization in the region influences the quality of the river water?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
10. Do you consider that activities near the river (or in the river) can contribute to the pollution and contamination of the Tocantins River?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
11. Do you think the Tocantins River is polluted?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
12. Do you believe that the use of water from the Tocantins River can transmit diseases?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
13. Are you satisfied with the water quality of the river in this region?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
14. Do you consider the water in this area of the river unsuitable for consumption?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
15. Are you satisfied living in the region where you reside?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
Legend for questions 16 to 20: 1 – Never; 2 – Rarely; 3 – Sometimes; 4 – Often; 5 – Always.	
16. How often do you use river water for drinking? If you do, do you treat it before drinking or for cooking? How?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
17. How often do you use the water from this region of the river for recreational activities (bathing, for	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

example)?	
18. Have you participated, or do you currently participate, in any program/activity aimed at conserving or preserving the area along the Tocantins River?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
19. How often do you consume fish from the Tocantins River?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
20. Do you use water from the Tocantins River for agriculture or livestock?	( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5
21. If the river ceased to exist (dried up), how would it interfere with your life? What would you do to continue your activities that depended on the river water?	
22. Do you believe that the river will remain for future generations of your family (grandchildren, great-grandchildren)?	
23. What activities of yours do you think could harm the quality of the river? Which ones?	

Source: Author (2024, p. 8).

Among the closed-ended questions analyzed through descriptive statistics, twelve (12) were constructed according to the Likert scale model, with five response levels, while two (2) were in a simplified model. The objective is to calculate the percentage frequency for each response alternative. The Likert scale consists of a series of statements or items to which participants respond by indicating their level of agreement or disagreement (GÜNTHER, 2003). This scale, which ranges from 'strongly disagree' to 'strongly agree', with intermediate points, was chosen due to its ability to provide a quantitative measure of participants' opinions or attitudes. This allows for a more detailed analysis and a more precise understanding of the perceptions of the sample under study.

Participant selection criteria

As inclusion criteria for participant selection, questionnaires were administered to individuals residing in the vicinity of the Tocantins River, aged 18 years or older. The application was conducted randomly with residents present during the interviews, aiming to reach primarily the population engaged in fishing activities. The confidentiality and privacy of the interviewees were ensured, who agreed to participate voluntarily in the research, consenting to the objectives of the study described in the Informed Consent Form (ICF).

Sample composition

The targeted population consisted of riverside families, distributed across the four questionnaire application points. The questionnaire's axes aimed to gather information on education level, water quality, environmental monitoring, fish species consumed, perception of pollution, chronological changes, and future perceptions regarding the water body.

RESULTS AND DISCUSSION

Characterization of the study population

A survey of the profile of riverside dwellers along the middle Tocantins River was conducted to characterize the population, which was subsequently analyzed regarding their environmental perception. The respondents had an average age of 44 years, ranging from 18 to 82 years, with 60% being male and 40% female (Table 2). The vast majority had a monthly family income of up to one minimum wage (86%) and an educational attainment level of up to incomplete primary education (42%), followed by complete secondary education (32%).

Table 2 - Profile of riverside dwellers interviewed at points along the middle Tocantins River, Maranhão.

Variable	Category	n (%)
Sex	Female	20 (40%)
	Male	30 (60%)
Education Level	Incomplete Primary	21 (8%)
	Complete Primary	4 (42%)
	Incomplete Secondary	3 (6%)
	Complete Secondary	16 (32%)
	Incomplete Higher	6 (12%)
Length of Residence	Less than 1 year	1 (2%)
	1 - 5 years	3 (6%)
	6 - 10 years	2 (4%)
	More than 10 years	44 (88%)
Number of Residents	1 person	4 (8%)
	2 – 5 people	42 (84%)
	More than 6 people	4 (8%)
Profession	Self-employed	9 (18%)
	Homemaker	6 (12%)
	Fisherman	18 (36%)
	Others	17 (34%)
Average Monthly Income	Up to one minimum wage	43 (86%)
	Up to two minimum wages	7 (14%)
Sewage System	Yes	8 (16%)
	No	42 (84%)

Source: Author (2024, p. 10).

The majority of riverside dwellers involved in the study have been residing in the region for a significant period, predominantly over 10 years (88%) (Table 2). This data is relevant as it indicates a lasting connection of these communities with the local environment. The long-term residency in the region may have significant impacts on the environmental perception of the inhabitants, the knowledge acquired about natural resources, and the relationship of the communities with the Tocantins River over time. This prolonged connection can influence the attitudes, practices, and perspectives of riverside communities regarding the environment around them.

The occupational category "Fisherman" was the most cited in the study, representing a significant portion of 36% (Table 2). These riverside dwellers are the citizens who reside near the river and directly depend on it for the sustenance and food security of their families. Other

professions mentioned include "Self-employed", "Homemaker", "Waiter", "Farmer", "Student", "Janitor", and "Retired". This reveals a great diversity of income-generating activities, with them being the main actors involved in the study, and their perceptions and actions are crucial for the success of proposed socio-environmental activities. After all, perception can be judged as something selective that is vulnerable to a series of factors such as meanings, memories, and experiences lived by the individual regarding that object (PINTO *et al.*, 2016).

The absence and precariousness of environmental sanitation conditions represent a global concern, having been the subject of discussions and included as a goal of the UN's Agenda 2030 (BRITO *et al.*, 2021). In this context, 8 respondents (16%) reported having a sewage system at their residence, while 42 respondents (84%) stated not having one (Table 2). When questioned about the type of sanitation structure, the following situations were mentioned: septic tank (6%), open-air (6%), CAEMA (Environmental Sanitation Company of Maranhão) (2%), direct sewage discharge into the river (70%), or did not know how to inform (16%). In this sense, it is observed that the sewage collection system is inefficient in the region, corroborating with Silva (2022) who reported that 440 billion liters of sewage are spilled into watercourses in the state of Maranhão and that the city of Imperatriz has an index of 70.8% regarding the lack of sewage collection system.

Environmental perception about the water quality of the middle Tocantins River of the study population

Among the riverside dwellers interviewed, the vast majority use water from the river in their daily lives (94%), whether for domestic use (56%), recreational activities (15%), or income generation (26%). It is noteworthy that domestic use involves everything from cooking, drinking, and bathing, to laundry; which is a concern, as the population directly discharges large amounts of garbage and domestic sewage into the river. The UN recognizes that water rights are interdependent with other rights since the scarcity or precariousness of this resource directly impacts the health and quality of life of citizens (BRITO *et al.*, 2021).

In question 02, respondents were asked: "Do you know which organization is responsible for monitoring and protecting the Tocantins River and the surrounding area?" The majority responded that they do not know (56%), while some government agencies were mentioned: IBAMA (14%), Navy (28%), and Civil Defense (2%). The Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) performs various essential functions for the protection and preservation of the environment in Brazil, including environmental inspection and control, management of conservation units, environmental licensing, and environmental education/public awareness.

According to Fernandes *et al.* (2019) and Nascimento *et al.* (2021), the absence of environmental information and policies for popular awareness is harmful to the common good. Therefore, for environmental education to contribute to awareness and the formation of a new citizen, the principles of environmental educational action must be respected. These principles include participation, critical-reflexive thinking, ecology of knowledge, awareness,

collectivity, responsibility, continuity, equality, emancipation, and social transformation (GONZALEZ *et al.*, 2007).

In the perception of the majority of riverside dwellers interviewed, the middle Tocantins River is somehow polluted (84%). Furthermore, in response to question 03 "In your experience in the region, do you consider that the Tocantins River has changed over time?" most respondents observe changes in the river over the years, especially those who have been living in the studied regions for more than 10 years (88%). Among the most cited changes are a decrease in the river level (dry season), a smaller quantity of fish (mainly during the dry season), and polluted water (Table 3).

Table 3 − Environmental quality issues perceived by riverside dwellers in sections of the middle Tocantins River, Maranhão.

Study Point	What were the main changes observed in the Tocantins River over time?	What are the main impacts caused by human action on the Tocantins River?
Beira rio (Urban Area)	Decrease in river level; river siltation; higher water temperature; fewer fish; polluted water	Disposal of garbage and sewage into the river; urbanization and siltation
Bananal Village	Decrease in river level; polluted water	Disposal of garbage and sewage into the river; siltation and deforestation
Embiral Village	Decrease in river level; fewer fish	Disposal of garbage and sewage into the river; damming of the river by the Estreito Dam, Maranhão
Cidelândia Village	Decrease in river level; polluted water	Disposal of garbage and sewage into the river

Source: Author (2024, p. 12).

Interviewee 37 states, "The river has changed a lot, lately the water is polluted, the river is drier, and the city is hotter." In addition, the impacts caused by humans on the Tocantins River mentioned were "Disposal of garbage and sewage into the river" (50%), "Urbanization" (30%), "Siltation and deforestation" (14%), "Damming" (2%), "Dredging" (2%), and unable to inform (2%). These data are valuable for the development of public policies, environmental conservation programs, and the implementation of sustainable practices. Furthermore, understanding the environmental perception of local communities is crucial for promoting the active participation of these communities in environmental management and preservation.

In question 06, when asked "What actions for recovery and preservation could be developed in the river?" the most cited were "Not dumping garbage and sewage into the river" (34%), "Sewage treatment" (18%), "Monitoring and awareness" (12%), and "Avoiding deforestation" (8%); while 8% mentioned other options (garbage collection, banning the use of dredges for sand extraction, and implementing supportive public policies) and 20% were unable to inform (Table 2). Braga *et al.* (2023) also observed a wide variety of responses regarding proposals suggested by the population to improve the river's quality, with an emphasis on monitoring and raising awareness through Environmental Education actions. The authors reinforce the importance of the community mobilizing itself for improvements to occur and reflect in their daily lives.

It is worth noting that the discharge of untreated sewage directly into the river can compromise the biota and water quality (SOUZA and GASTALDINI, 2014), both for domestic purposes and income generation. Pádua (2021) states that the release of untreated sewage seriously impacts the receiving body, leading to a decrease in dissolved oxygen levels, intensification of eutrophication, and changes in aquatic biota. Thus, the relationship between the river's water quality and the socio-economic subsistence of riverside dwellers is interdependent, and environmental degradation can have direct impacts on these people's family income (ADGER, 2006).

> Article 3 of Resolution No. 430/2011, of the National Environment Council (CONAMA), establishes that effluents from any polluting source may only be discharged, directly or indirectly, into water bodies after proper treatment and only after meeting the conditions, standards, and requirements outlined in said Resolution (BRAZIL, 2011, p. 01).

In question 07, respondents were asked about the consumption and commercialization of native fish from the Tocantins River, and it was observed that 34% consume and commercialize, 62% use only for personal consumption, and 4% do not consume. The riverside fishing families in the Imperatriz region (Maranhão) have fish as the main protein source in their diet, consuming both predator and non-predator species (FILHO *et al.*, 2016). In this perception study, the main species consumed and commercialized are Avoador (*Brycon pesu*) (mentioned by 62% of respondents), Branquinha (50%) (*Steindachnerina amazonica*), Tambaqui (26%) (*Abramitis hypselonotus*), Curimatá (18%) (*Prochilodus nigricans*), Tucunaré (16%) (*Cichla kelberi*), Mapará (14%) (*Hypophthtalmus marginatus*), and Sardinha (12%) (*Lycengraulis batesii*).

When asked about the water quality of the river in their region, the majority consider it "Good" (44%), followed by "Fair" (26%), "Poor" (14%), and "Very good" (16%). However, if this quality deteriorates over the years, 87.5% state that they would not be able to continue in the region, as their family income would be severely affected. Interviewee 39 says, "I wouldn't have an option, I would be left without work and even without water to drink." This approach to environmental perception is necessary to identify and understand socio-environmental issues, being the first step towards diagnosis, awareness, and sustainable action.

Frequency of responses as a tool for environmental perception of the study population

The riverside dwellers affirm that urbanization in the region influences the water quality of the middle Tocantins River, as 46% agree and 42% fully agree with the statement (Table 4). Furthermore, the vast majority also agree that activities near the river (or in the river) can contribute to its pollution and contamination (34% agree and 46% fully agree). When asked about the possible pollution of the river, 48% of respondents fully agree, indicating significant concern about water quality. This perception may reflect the environmental conditions observed in the region.

Table 4 - Frequency of responses from respondents on aspects related to urbanization, water pollution in the river, transmission of waterborne diseases, and housing satisfaction.

Questions	Frequency of responses from respondents				
	1	2	3	4	5
For you, does urbanization in the region influence the quality of the river water?	2%	-	10%	46%	42%
Do you consider that activities near the river (or in the river) can contribute to the pollution and contamination of the Tocantins River?	2%	6%	12%	34%	46%
Do you consider the Tocantins River to be polluted?	14%	8%	16%	14%	48%
Do you believe that the use of water from the Tocantins River can transmit diseases?	14%	6%	18%	28%	34%
Are you satisfied with the water quality of the river in this region?	10%	14%	36%	28%	12%
Do you consider the water in this region of the river unsuitable for consumption?	56%	12%	-	8%	24%
Are you satisfied living in the region where you live?	-	2%	10%	62%	26%

1 – Strongly disagree; 2 – Disagree; 3 – Neither agree nor disagree; 4 – Agree; 5 - Strongly agree.

Source: Author (2023, p. 14).

When the focus turns to health safety, 36% of respondents express a neutral position regarding the possibility of the Tocantins River water carrying diseases. This response indicates a considerable portion of the population neither agrees nor disagrees, suggesting uncertainty or lack of information about the risks associated with the use of contaminated water. Surprisingly, despite concerns about possible pollution, 56% of respondents completely disagree that the water in the region is unfit for consumption. This apparent contradiction may suggest a disconnect between perception and reality, highlighting the

importance of awareness and environmental education. An impressive percentage of 88% of respondents agree or strongly agree that they are satisfied living in the region. The high satisfaction of the responses may be attributed to various factors, such as the natural beauty of the region, the local community, or other positive elements that outweigh environmental concerns.

The use of water from the middle Tocantins River to meet the needs of riverside communities is a constant concern, as it may expose these families to contaminants and microorganisms present in polluted waters (OLIVEIRA, 2019). A study conducted at the same collection sites found that the levels of aluminum, copper, iron, magnesium, and selenium in the water exceeded legal standards (ACIOLY et al., 2024). Notably, the urbanized region (P1) showed elevated nitrogen concentrations, raising serious concerns about the quality of water for direct consumption. The analysis of sediments from these same sampling points revealed that the levels of chromium, nickel, copper, zinc, and lead exceeded the limits established by environmental guidelines, with the highest values recorded in the urbanized region (P1) for aluminum and in the Embiral (P3) for nickel and lead (MACHADO DA SILVA ACIOLY et al., 2024). Additionally, there is the possibility of the occurrence of *Salmonella spp.*, the causative agent of salmonellosis, one of the main pathogens transmitted through the consumption of contaminated water (MENDONÇA, 2023). These factors represent a significant risk, especially as 18% of participants and their families reported using river water as their sole source for consumption, including direct ingestion (Table 4).

Table 5 - Frequency of respondents' answers regarding aspects related to participation in conservation activities, future perception of the water body, and polluting activities.

Questions	Frequency of respondents' answers				
	1	2	3	4	5
Frequency of using river water for drinking. If yes, do you treat it before drinking or cooking?	80%	2%	-	-	18%
Frequency of using water from this river region for recreational activities (such as bathing)?	2%	8%	10%	44%	36%
Have you participated or ever participated in any program/activity aimed at conserving or preserving the Tocantins River?	92%	4%	2%	-	2%
Frequency of consuming fish from the Tocantins River?	10%	6%	8%	20%	28%
Do you use water from the Tocantins River for agriculture or livestock?	86%	-	4%	-	10%

1 – Never; 2 – Rarely; 3 – Occasionally; 4 – Often; 5 – Always.

Source: Author (2023, p. 15).

When it comes to the use of water for recreational activities such as bathing, the frequency is notable. A significant percentage of 44% of respondents claim to use water from this region of the Tocantins River very often, while 36% use it always for such activities, highlighting the importance of the river not only as a resource but also as a leisure space. Despite this complex and multifaceted relationship, the research indicates that the vast majority (92%) have never participated or currently do not participate in programs or activities aimed at the conservation and preservation of the Tocantins River (Table 5).

Regarding the consumption of fish from the Tocantins River, there is an active relationship between the local population and natural resources. Most respondents consume native fish from the river, with 20% stating that they do so very often and 28% always. These data correspond to Milhomem *et al.* (2016), who found that out of 59 riverside dwellers interviewed, 90% consumed more than 2 meals, and over 60% consumed over 4 fish meals per week. In this study, mercury (Hg) concentrations in the most consumed fish were within normal limits, but considering that this metal is associated with neurological diseases in humans and abnormal levels have been found in other regions such as Pará and Rondônia, this highlights the importance of constant monitoring of the ichthyofauna. Furthermore, 10% responded that they frequently use river water for agricultural or livestock activities, revealing the importance of monitoring the quality of this water resource.

During the interviews, the hypothetical scenario of the middle Tocantins River ceasing to exist in the future, whether due to drought or any other reason, raised deep reflections on the interdependence between local communities and water resources. For a significant percentage of 32% of respondents, the prospect of losing income is an imminent concern, while 28% fear running out of water for both domestic use and consumption, and another 10% indicated willingness to move to another city in search of better living conditions. Despite this, 84% of riverside dwellers believe that the river will remain for future generations of their families (grandchildren, great-grandchildren) (question 22).

The last question of the survey (question 23) sought to promote critical-reflexive thinking to the respondents by addressing possible human activities that may have negative impacts on the quality of the Tocantins River. A significant majority, represented by 52%, identified the combination of littering and sewage discharge as activities that could be harmful to the river's quality, while 10% mentioned deforestation. There is a noticeable discrepancy between knowledge and behavior, as some respondents are aware of activities harmful to the quality of the Tocantins River, such as improper waste and sewage disposal, while simultaneously admitting to engaging in such practices.

Moreover, factors such as perception of water quality and length of time residents have lived in the region may be correlated. In this regard, 18% of respondents who have lived in the region for 21 to 40 years fully agree that the river water is polluted, and 16% with 41 to 60 years of residence also agree with this statement. Regarding residents over 60 years old in the region, only 2% agree that the river is polluted, and people with residents between 1 and 20 years completely disagree that the water is not polluted (Table 6).

Table 6 - Relationship between length of residence and water quality perception of the middle Tocantins River, Maranhão.

Length of residence in the region (in years)	Response frequency to the question: "Do you consider the Tocantins River to be polluted?				
	1	2	3	4	5
Between 1 – 20 (13)	3 (23,08%)	1 (7,69%)	2 (15,38%)	-	7 (53,85%)
Between 21 – 40 (22)	2 (9,09%)	2 (9,09%)	4 (18,18%)	5 (22,73%)	9 (40,91%)
Between 41 – 60 (14)	2 (14,29%)	1 (7,14%)	2 (14,29%)	1 (7,14%)	8 (57,14%)
Above 60 years (1)	-	-	-	1 (100%)	-

1 – Completely disagree; 2 – Disagree; 3 – Neither disagree nor agree; 4 – Agree; 5 - Completely agree.

Source: Author (2023, p. 17).

CONCLUSIONS

The absence and precariousness of environmental sanitation conditions are concerning, as the majority of respondents claim not to have a sewage system, and they dispose of domestic sewage directly into the river. Almost all respondents indicated using the same water for domestic use, including bathing, washing clothes, or even drinking.

While residents indicate disturbances in the water quality of the river, the significant majority of respondents have never participated or currently do not participate in programs or activities aimed at the conservation and preservation of the Tocantins River. Thus, there is a gap in environmental awareness and community participation in environmental protection initiatives, highlighting the need to promote educational and engagement programs.

Most respondents consume native fish from the river very frequently or always. Meanwhile, some participants and their families always use river water for drinking, which is their only available source. This highlights the importance of the river and its fishery resources for the subsistence of riverside families in the region.

The main impacts caused by humans on the Tocantins River perceived were urbanization, littering, and sewage discharge into the river, while the most recommended recovery and preservation actions by riverside dwellers were to avoid littering and sewage discharge into the river, sewage treatment, and increased monitoring and awareness. It is hoped that these actions will also stimulate the government and other institutions to become involved in the development of awareness and remediation programs, promoting more effective and collaborative environmental management.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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