WATER FOR LIFE: CONTAMINATION, VULNERABILITY AND SOCIAL DETERMINANTS IN PERIPHERAL TERRITORIES OF EUNÁPOLIS AND PORTO SEGURO

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Abstract: Water insecurity in peripheral territories, settlements, and traditional villages represents a persistent challenge to the guarantee of the human right to water and to public health. This study, developed as part of a scientific extension initiation project, aimed to evaluate the quality of water intended for human consumption at twelve points located in rural and Indigenous communities in the municipalities of Eunápolis and Porto Seguro, Bahia. The objective was not only to identify the

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level of contamination but also to understand the social and environmental determinants that shape sanitary risks in these contexts. This is an observational, cross-sectional study with a quantitative and qualitative approach. Data were obtained through physicochemical and microbiological analyses of water, in accordance with the parameters established by Ordinance GM/MS No. 888/2021, and through structured interviews conducted with residents of the territories. The samples revealed a high presence of total and fecal coliforms in most of the investigated points, as well as nonconformities in pH, turbidity, residual chlorine, consumed oxygen, and alkalinity. The interviews revealed the absence of sanitation infrastructure, inadequate water storage and treatment practices, and a low perception of sanitary risk. The findings highlight the interrelationship between precarious socio-environmental conditions and the prolonged exposure of populations to waterborne diseases, reinforcing the need for integrated interventions in sanitation, environmental surveillance, and health education.

Keywords: water quality; environmental health; sanitary risks; coliforms; water vulnerability.

INTRODUCTION

Access to drinking water is an inalienable human right, recognized by the United Nations since 2010 and reinforced by Brazilian health regulations, such as Ordinance GM/MS No. 888/2021. However, this guarantee remains a distant ideal for large portions of the Brazilian population, especially in peripheral, rural and traditional territories. In the North and Northeast regions, the historical deficits of investment in sanitation, added to racial inequality and state negligence, produce critical scenarios of socio-environmental injustice. In municipalities such as Eunápolis and Porto Seguro, located in the extreme south of Bahia, this reality is manifested in alarming numbers that reveal the sanitary abyss and the deleterious effects on public health, especially in settled communities and indigenous villages.

According to the Instituto Trata Brasil (2024), Eunápolis has 7,825 people without access to drinking water (6.9% of the population), while more than 101 thousand inhabitants live without sewage collection. In Porto Seguro, 38,817 people are deprived of adequate supply (23.1%), with an even more alarming rate among indigenous populations: 57.4% do not have regular access to water. The scenario is marked by racial inequality: while 13.8% of the brown population of Eunápolis does not have access to treated water, in Porto Seguro this number exceeds 33% for the same racial category, reaching 35.3% among whites and 29.9% among blacks (INSTITUTO TRATA BRASIL, 2024).

These conditions directly impact the health of populations, especially through the spread of waterborne diseases, such as viral hepatitis, giardiasis, rotavirus infections, Escherichia coli, Vibrio cholerae, as well as toxoplasmosis and other diseases associated with fecal contamination of water. In Eunápolis, the data point to 84 hospitalizations due to water diseases, 43 of which due to diarrhea, with a mortality rate of 0.35 per 10 thousand inhabitants. In Porto Seguro, there are 59 hospitalizations and 18 due to diarrhea, with a rate of 0.24 deaths per 10 thousand inhabitants (INSTITUTO TRATA BRASIL, 2024). These numbers corroborate the analysis by Pasini and Damke (2020), according to which up to 60% of hospital infections in Brazil can be attributed to the lack of adequate sanitation.

The scientific literature shows that failures in water management, even in urban contexts with formal supply coverage, result in recurrent contamination. Araújo and Andrade (2020) highlight that the poor conservation of household reservoirs and the deterioration of the distribution network are potential sources of risk. In studies conducted by Lima et al. (2024), it was observed that, even in locations with apparently treated water, the microbiological parameters were outside the recommended limits. Thus, it is not only a matter of the lack of access to water, but also of its sanitary inadequacy for human consumption, which reinforces the urgency of systematic monitoring.

The present research starts from this reality to investigate, in an integrated way, the quality patterns of the water consumed by communities of high social vulnerability, including settlements of the Landless Rural Workers Movement (MST) and the indigenous villages of the Jaqueira and Juerana Reserves. The methodology includes physical-chemical and microbiological analyses of the water, application of questionnaires on sanitation conditions and community perception, in addition to georeferenced mapping of critical areas. The objective is not only to identify the level of contamination, but above all to understand the social and environmental determinants that structure the health risks in these territories.

As a subsequent step, the research proposes to deepen the analysis of the clinical and epidemiological impacts associated with the consumption of contaminated water, with emphasis on waterborne diseases. The approach adopted articulates science, extension and popular education, aiming at the construction of an intervention plan that involves the subjects of the researched territories.

As Porcy et al. (2020) argue, access to water should be understood as a common good threatened by social disputes, territorial conflicts, and structural inequalities. From this perspective, studying water quality in vulnerable territories is more than a technical exercise: it is an act of confronting historical asymmetries of power. By focusing its attention on invisible territories and neglected populations, this research is aligned with Sustainable Development Goal No. 6 (SDG/UN, 2010), promoting knowledge applied to health promotion, health risk reduction, and the strengthening of environmental equity.

THEORETICAL FOUNDATION

The quality of drinking water represents one of the main environmental determinants of public health and is a central element in strategies for the prevention of diseases and the promotion of social well-being. Access to safe water, in addition to being a fundamental human right, is a sanitary prerogative provided for in Brazilian legislation, especially in Ordinance GM/MS No. 888/2021, which establishes the standards of potability and the physical-chemical, microbiological, and radioactive parameters to be followed in alternative supply systems and solutions. However, as pointed out by the Instituto Trata Brasil (2024), the deficit in access to quality water still affects millions of Brazilians, especially those living in traditional communities, settlements, and rural areas where the public sanitation system is precarious or non-existent.

Several studies reinforce and qualify this concern. With regard to technical-sanitary criteria, authors such as Libânio et al. (2005) and Oliveira et al. (2015) highlight the importance of systematic monitoring of microbiological parameters, such as total coliforms and Escherichia coli, which are direct indicators of fecal contamination and potential health risks. In the direct relationship between contaminated water and infectious diseases, Barta et al. (2021), Costa et al. (2024), and De Oliveira (2023) point to the prevalence of waterborne diseases, such as gastroenteritis, giardiasis, and hepatitis A, in places with poor sanitation. In the characterization of the research territories, documents such as the CPT booklet (Brasil, 2023), the Santos report (2022) and the dissertations of Souza (2023) and Sobreira (2017) offer ethnographic, socioeconomic and environmental data on the Maravilha and Aristeu Carvalho settlements and on the Juerana and Jaqueira villages, revealing contexts marked by the absence of sanitary infrastructure, use of untreated water sources and institutional invisibility.

The implications of the non-potability of water extend beyond the sanitary field, affecting dignity, human development and territorial rights. In the context of the Maravilha and Aristeu Carvalho settlements, located in the municipality of Eunápolis, the booklet prepared by the Pastoral Land Commission (Brasil, 2023) shows that the absence of systematic laboratory tests and the use of alternative sources such as shallow wells and wells expose the local population to various risks. Such practices, often accompanied by lack of technical knowledge, perpetuate silent contamination, especially in groups with immunological vulnerability such as children, pregnant women, and the elderly.

Studies such as the one by Barta et al. (2021) reinforce the urgency of effective measures to ensure the monitoring and surveillance of water quality in non-urbanized areas. The authors point out that the absence of basic sanitation, associated with inadequate storage and consumption practices, favors the spread of waterborne diseases, such as infectious diarrhea, hepatitis A, giardiasis, and cholera. Such diseases, although largely preventable, are still present in the morbidity indicators of marginalized regions, reaffirming the correlation between water precariousness and health inequities.

The socio-environmental vulnerability of populations living in traditional communities is also present in the study by Sobreira (2017), which analyzes the Juerana Village, in Porto Seguro. The text reports not only the use of natural water sources without any type of treatment, but also the absence of institutional support for local environmental management. The conjunction between political invisibility, sanitary abandonment and structural violence reveals a reality in which access to drinking water is mediated by territorial struggles and collective resistance, and not guaranteed by universal public policies.

In the context of the Jaqueira Reserve, located in the municipality of Porto Seguro, studies point to a complex relationship between cultural practices of environmental protection and external pressures that compromise water quality. According to Souza (2023), the Pataxó indigenous community maintains a socio-territorial organization focused on the defense of the environment, articulating traditional knowledge and educational actions aimed at the conservation of water resources. However, the presence of tourist enterprises and urban growth around the reserve generate indirect impacts on the springs used by the population, including the possibility of contamination by sewage and solid waste. This reality highlights the need for accurate diagnoses and continuous monitoring to ensure local water security.

In a complementary way, the records of Santos (2022) highlight the role of indigenous youth as socio-environmental multipliers in the Jaqueira Reserve, promoting environmental education actions, sustainable water management, and recovery of degraded areas. These efforts, although significant, occur in a scenario marked by institutional asymmetries and scarce presence of the State, which limits the effectiveness of preventive actions in the face of water contamination. In this sense, the technical investigation of the water consumed in the community becomes fundamental to subsidize public policies and strengthen territorial autonomy.

Exposure to water contaminants, especially of fecal origin, represents one of the most serious threats to public health in contexts of health exclusion. Studies such as De Oliveira (2023) and Da Silva (2020) show how changes in the aquatic microbiota can indicate processes of ecological imbalance, often associated with the presence of fecal coliforms, pathogenic protozoa, and enteric bacteria. These microorganisms, in contact with the human body by ingestion or dermal contact, are related to the emergence of diseases such as gastroenteritis, viral hepatitis, leptospirosis and other opportunistic infections, especially in children, pregnant women and the elderly. Thus, the absence of adequate water quality control systems becomes a vector of continuous cycles of illness.

The assessment of water potability follows specific technical and legal standards, such as those established by Ordinance GM/MS No. 888/2021, which updates microbiological, physicochemical, and radiological parameters, replacing the guidelines of Ordinance No. 518/2004 (BRASIL, 2004; 2021). As discussed by Libânio et al. (2005), these parameters constitute the basis for defining the health risk and the type of treatment needed. The authors point out that, even with advanced legislation, implementation still faces technical and financial limitations, especially in rural areas and traditional communities. This gap between norm and practice reinforces the need for local studies that identify the predominant types and sources of contamination, contributing to localized diagnoses and more effective actions.

Studies carried out by Costa et al. (2024) and Mota et al. (2024) reinforce that the absence of continuous laboratory monitoring compromises the early diagnosis of water contamination, in addition to limiting the adoption of preventive measures. Costa et al. (2024), when analyzing the presence of Escherichia coli in surface and groundwater, demonstrated that seasonal variability, associated with geographic and socio-environmental factors, directly affects potability levels. Mota et al. (2024) validated the effectiveness of rapid diagnostic kits (Alfakit) for initial water quality screening in communities with difficult access to laboratories. Such resources are fundamental for contexts such as those studied in this research, where territorial mapping combined with the use of low-cost technologies can favor agile responses to health risks.

In addition to technical analyses, it is necessary to understand the territories investigated as spaces marked by conflicts and inequalities. The booklet produced by the Pastoral Land Commission (2023), which describes the daily life of the Maravilha Settlement, reveals the infrastructure challenges faced by the settled families, such as dependence on artesian wells and untreated springs. A similar situation is pointed out in the document on the Aristeu Carvalho pre-settlement, which integrates the same logic of exclusion from basic services. The absence of continuous public sanitation policies, combined with land insecurity and the difficulty of access to safe technologies, perpetuates the health vulnerability of these populations.

In the indigenous communities of Juerana and the Jaqueira Reserve, the context is equally critical. Works such as those by Sobreira (2017) and Souza (2023) expose the direct relationship between territory, culture, and environmental health. Indigenous families often resort to natural springs, such as rivers and springs, whose banks are pressured by monocultures, irregular occupations or high-impact tourist activities. The loss of traditional territories, the use of pesticides in the surroundings and the absence of government control compromise the water and cultural security of these peoples. In this sense, the protection of water is not only a sanitary demand, but an imperative of civilization and environmental justice.

In the records of the Juerana Village, also located in Porto Seguro, a reality of historical exclusion is observed with regard to access to safe water. As Sobreira (2017) points out, indigenous people face institutional invisibility and the precariousness of basic infrastructure, such as sanitation and supply. Dependence on natural sources, without treatment, puts the population at permanent risk of waterborne diseases, especially when added to environmental contamination from nearby urban and agro-industrial activities. The study highlights the absence of specific public policies aimed at the water reality of traditional communities, a fact that aggravates the impacts on local health and health security.

The absence of drinking water in communities like Juerana directly compromises the exercise of other fundamental rights, such as health, food and education. The strategies adopted by the families, such as storage in improvised containers and direct capture from streams, do not eliminate microbiological risks, as highlighted by Oliveira et al. (2015), when they warn that visibly clean sources may be contaminated by Escherichia coli, enteroviruses and other invisible pathogenic agents. The lack of systematic laboratory analysis and the distance from Vigiagua's actions in these areas reinforce the health vulnerability faced by native peoples.

In the Maravilha and Aristeu Carvalho settlements, located in the rural area of Eunápolis, the structural challenges in access to drinking water are also widely documented. According to a booklet produced by the Pastoral Land Commission (2023), the settlers mostly depend on artesian wells, dams and surface sources without any form of treatment. In addition, there is no record of periodic laboratory monitoring, which makes it impossible to control the potability parameters established by Ordinance GM/MS No. 888/2021. Such a scenario increases the population's exposure to contaminants of fecal origin, nitrates and agricultural residues.

The trajectory of these settlements, as described by Santos (2021), reveals a history of struggle for territory and agroecological production, but also of abandonment by public sanitation policies. Investments in basic infrastructure, such as adequate reservoirs and decentralized treatment systems, are practically non-existent. The conditions of home storage of water, often in open buckets or boxes without regular hygiene, aggravate the risks of proliferation of vectors and parasitic diseases. The absence of basic sanitation thus compromises not only individual health, but also productivity and community development.

On the other hand, the studies by Costa et al. (2024) point out that, even in the face of such adverse contexts, communities develop autonomous forms of water management and collective health. Such strategies range from boiling practices and artisanal filtering to mobilizing to claim rights from public agencies. This resilience, however, does not replace the need for evidence-based structuring policies that consider epidemiological data, environmental indicators, and local knowledge in the formulation of surveillance and health promotion programs.

The literature also highlights the importance of water quality surveillance in areas of alternative supply, such as wells, fountains and cisterns, common in the settlements and villages of Bahia. The Vigiagua Report (BRASIL, 2009) already warned of the need to include these systems in municipal surveillance plans, emphasizing that the lack of attention to these sources exposes populations to pathogens such as Salmonella, Giardia and thermotolerant coliforms. In the same vein, Libânio et al. (2005) argue that microbiological parameters, especially the presence of Escherichia coli, should be a priority in rural areas, since they are sensitive indicators of recent fecal contamination, directly associated with outbreaks of diarrheal diseases.

The absence of continuous monitoring policies and the lack of local technical training for water analysis constitute persistent obstacles to the effectiveness of environmental health promotion actions. As Mota et al. (2024) argue, it is essential to strengthen the installed capacity of municipalities for the use of field analysis kits and the decentralization of health surveillance. The authors highlight that the combination of screening tools and community participation increases the scope of water quality control actions in peripheral and traditional territories. This decentralization does not replace reference laboratory tests, but allows for immediate and educational actions with a direct impact on prevention.

The work of De Oliveira (2023), when conducting a systematic review on the aquatic microbiota, reinforces that changes in water ecosystems caused by organic and inorganic contaminants directly influence the cycle of pathogens. The study associates the environmental degradation of watersheds with the proliferation of potentially pathogenic microorganisms, such as cyanobacteria and protozoa. These effects intensify in contexts of climate change, increased water temperature, and nutrient overload, which makes the integration between environmental health and public policies for climate adaptation even more urgent.

In this sense, authors such as Porcy et al. (2020) advocate the construction of territorial sanitation indicators that take into account the socioeconomic, cultural, and ecological aspects of vulnerable communities. In addition to formal coverage, indicators must express the effectiveness of access, quality, continuity, adequacy, and allow the assessment of the real health risk. The settlements studied by these authors show that even communities with minimal physical structure can present alarming indicators of water vulnerability, if consumption is based on contaminated or poorly managed sources.

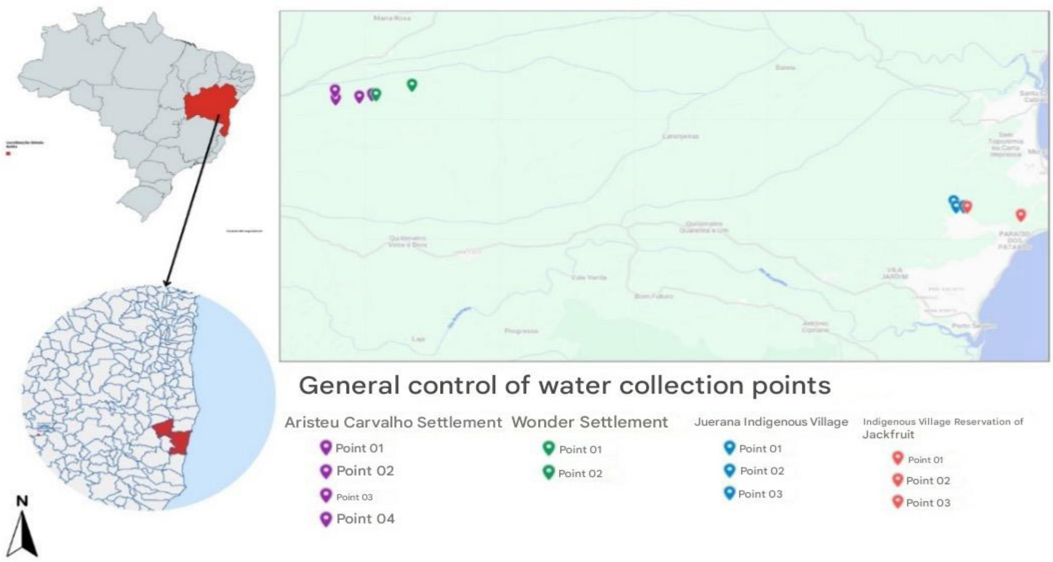
Finally, the studies systematized here converge to the understanding that the lack of access to drinking water cannot be reduced to a technical deficit, but must be interpreted as an expression of structural inequalities, institutional omission and fragility of intersectoral health, environment and human rights policies. The present study, by focusing on communities made invisible by the traditional surveillance system, proposes to fill these gaps through the production of primary data, community engagement, and the articulation between scientific evidence and health justice. This theoretical framework is the foundation for understanding the severity of the risks associated with contaminated water and for supporting effective and contextualized interventions.

METHODOLOGY

The present study is characterized as an observational, cross-sectional research, with a quantitative-qualitative approach and applied nature, focused on the analysis of the quality of water for human consumption in vulnerable territories in the extreme south of Bahia. The data were obtained through physicochemical and microbiological analyses of the samples collected, following the parameters established by Ordinance GM/MS No. 888/2021. The investigation also integrated geospatial and perceptual elements, in order to promote a broader understanding of the health risks present in the territories studied, articulating environmental, social and cultural dimensions in a way that is committed to collective health.

The locus of the research comprises four communities distributed between the municipalities of Eunápolis and Porto Seguro, two of which are rural settlements of the Landless Rural Workers Movement (MST): Maravilha Settlement and Aristeu Carvalho Pre-Settlement; and 2 (two) indigenous villages: Pataxó da Juerana Indigenous Village and Jaqueira Reserve Village.

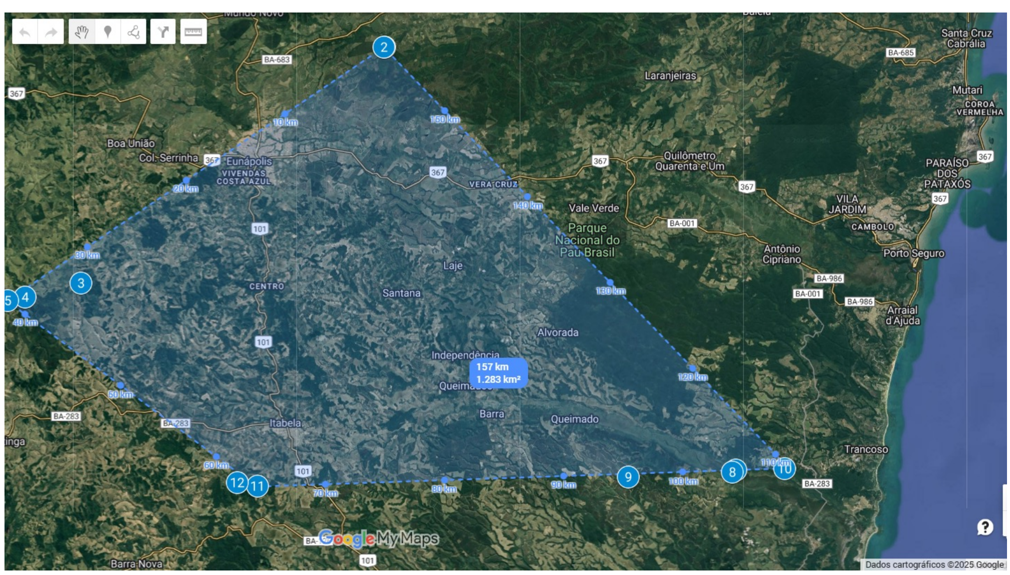
Figure 1 – Cartographic Map of the Collection Points



Source: Field Research, 2025.

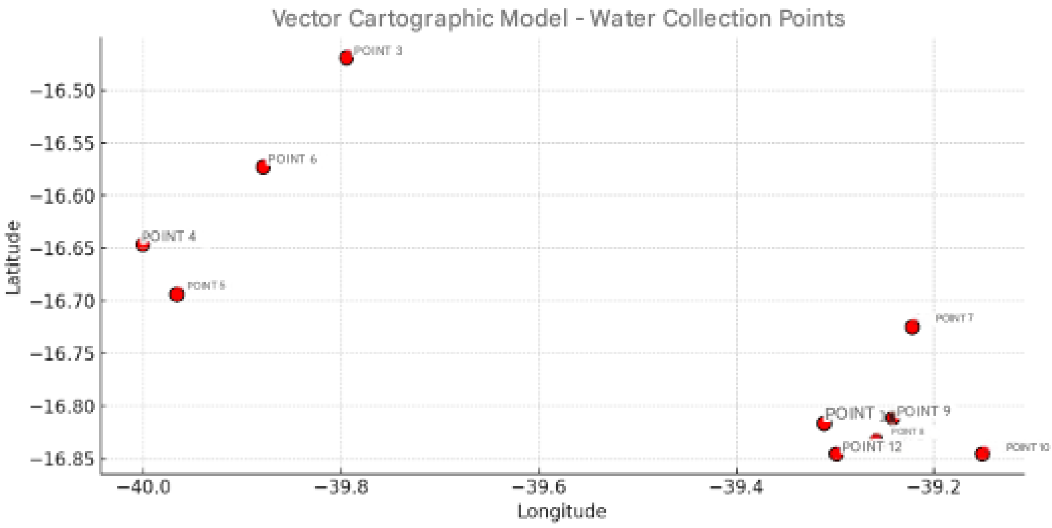
(*) Due to the proximity of some points, the marking is superimposed.

Figure 2 – Cartographic Map – Territorial Coverage of Collection Points



Source: Field Research, 2025.

Figure 3 – Vector Cartographic Map – Water Collection Points



Source: Field Research, 2025.

Each territory was contemplated with three collection points, totaling 12 georeferenced points, previously defined in conjunction with community leaders, based on the location of the main sources used for human consumption, such as community and individual artesian wells, as well as containers with water from springs collected and stored by the residents themselves. The identification of these points had the support of the Mother Earth Institute (IMT), an institutional partner of the research, which enabled access to the territories and mediated contact with local leaders to present the objectives of the investigation, build collective acceptance and define the areas of interest. This collaboration was fundamental to ensure the legitimacy of the study with the communities and to respect their socio-territorial dynamics.

Chart 1 – Details of Collection Points

WATER FOR LIFE PROJECT-IC					
Municipality: Eunápolis/BA and surrounding area - Porto Seguro/BA					
N.	CATEGORY	Location	Point Order	Specification	Detailed Description
1	Settlement Occupations	Aristeu Carvalho	Point 1	Individual Point	Torneira of the Association
2	Settlement Occupations	Aristeu Carvalho	Point 2	Community Peace	Direct Tap from Artesian Well
3	Settlement Occupations	Wonder	Point 3-Neura	Individual Point	Direct piping from the water hole
4	Settlement Occupations	Wonderful	Point 1 - Antonia	Individual Point	Direct piping from individual artesian well
5	Settlement Occupations	Aristeu Carvalho	Point 2 Ivanir	Individual Point	Water collected from the spring and stored in a bottle
6	Settlement Occupations	Aristeu Carvalho	Point 3 Valmira	Individual Point	Direct piping of individual artesian part
7	Unworthy Village	Pataxó Juerana Village	Point 1	Community Peace	Community artesian well
8	Unworthy Village	Pataxó Juerana Village	Point 2	School	Indigenous Village School
9	indigenous village	Pataxó Juerana Village	Point 3	Individual Point	Plumbing in the house of a local indigenous person
10	indigenous village	Jaqueira Reserve Village	Point 1	Individual Point	Drinking Fountain in the Main Hut
11	indigenous village	Laqueira Reserve Village	Point 2	Individual Point	Torneira from the Reserve Community Kitchen
12	indigenous village	Jaqueira Reserve Village	Point 3	School	School drinking fountain

Source: Field Research, 2025.

The selection of points followed the logic of territorial representativeness, taking into account the degree of use of the source, the proximity to housing and agricultural activities, as well as the history of reported water diseases. The geographic coordinates were obtained by portable GPS and used in the construction of a simplified cartographic map, with visualization of the georeferenced points. The vector composition included only basic localization elements, due to the technical limitation of overlapping with environmental or sanitary data.

The laboratory analyzes followed the parameters defined by Ordinance GM/MS No. 888/2021, which establishes the criteria for the potability of water intended for human consumption. Microbiological examinations were carried out, focusing on the identification of total coliforms and Escherichia coli, and physicochemical analyses that included pH, turbidity, apparent color, electrical conductivity, nitrate, chlorine and total dissolved solids (STD). Part of the physicochemical parameters was evaluated using the AlfaKit technique, which uses specific chemical reagents applied directly to the water samples, allowing the visual or spectrophotometric reading of the results, according to the standards and instructions provided by the manufacturer.

Before the start of collection, the researchers were previously trained through technical workshops conducted at the Pitágoras Faculty of Medicine of Eunápolis, addressing the proper use of Personal Protective Equipment (PPE), the procedures for collecting, packaging and preserving the samples, as well as the analytical protocol with AlfaKit. This preparation was essential to ensure methodological standardization, the safety of those involved, and the reliability of the results obtained. The collection was carried out using sterile vials, duly identified, and the samples were kept under controlled refrigeration until the time of analysis in the institution's laboratory.

In parallel with the water collection, a structured questionnaire was applied to the families using the analyzed sources, totaling 12 interviews. The form, previously prepared by the researchers, was divided into three sections: the first addressed sociodemographic and structural data of the house; the second dealt with water use and storage practices; and the third collected perceptions about health risks and collective care actions. The construction of the questions was guided by the objectives of the research and validated based on previous studies on water surveillance and environmental health.

Due to the limitation of internet access in many of the collection areas, the application of the questionnaires was carried out in printed form, with subsequent digitization and systematization of the answers on the Google Forms platform. This strategy allowed the secure storage of data and the generation of graphs and spreadsheets for later descriptive statistical analysis, maintaining the traceability of information and the confidentiality of participants.

Data analysis combined quantitative and qualitative methods. The laboratory parameters were compared with the maximum values allowed by the current legislation, identifying non-conformities and patterns of recurrent contamination. The answers to the questionnaires were submitted to thematic content analysis, making it possible to understand the cultural, cognitive and practical dimensions related to water and health risk in the territories studied.

The cartographic mapping allowed the visualization of the spatial distribution of the collection points, without, however, performing geospatial overlapping analysis of environmental factors. The coordinates collected by GPS were inserted into a vector-based visualization system, facilitating the identification of the sources in their respective territories. The technical limitation at this stage indicates a possibility of future deepening with the more robust use of Geographic Information Systems.

Finally, the results were systematized in technical-scientific reports and presented to the communities in feedback meetings. This stage not only promoted the transparency of the research, but also fostered the dialogue between academic knowledge and popular knowledge, favoring the collective construction of strategies for water care and advocacy on public sanitation and health policies.

The research was previously submitted to and approved by the Research Ethics Committee of the Pitágoras School of Medicine of Eunápolis, according to the protocol registered in Plataforma Brasil. All participants were duly informed about the objectives, risks and benefits of the study, in accessible and respectful language, with space for clarification of doubts. After the clarification, the Informed Consent Form (ICF) and the Authorization Term for the Use of Image and Voice were signed, ensuring full compliance with the ethical precepts provided for in CNS Resolution No. 466/2012.

The methodology adopted thus articulates technical-scientific rigor and social commitment, giving the research not only empirical validity, but also ethical and political relevance. The interdisciplinary nature of the proposal, combined with the qualified listening of the communities, allows us to understand water not only as a physical resource, but as a symbolic good, a human right and a structuring element of environmental health in the territories investigated.

ANALYSIS AND DISCUSSION OF RESULTS

The results obtained in the physicochemical and microbiological analyses of the water samples collected at the 12 points investigated reveal a panorama that requires attention, especially in view of the non-conformities observed in the microbiological parameters. In addition to the technical verification of potability levels, the analysis of the data allows a direct confrontation with the theoretical foundation, expanding the understanding not only of the degree of water contamination, but also of the social and environmental determinants that structure the health risks in the evaluated territories. By examining indicators such as pH, turbidity, coliforms, and metals, it becomes possible to identify patterns of vulnerability associated with the type of water source, the absence of adequate treatment, water management and storage practices, as well as socioeconomic conditions that hinder access to basic sanitation services. In this way, the discussion of laboratory parameters is articulated with basic studies and with the reality experienced by the communities, shedding light on the factors that perpetuate exposure to waterborne diseases and environmental inequality.

Table 2 – General Result of the Laboratory Parameters of the 12 Points

Resultados das Coletas															
N.	Ponto de Coleta	Categoria	Descrição/Localização	ALCALINIDADE (mgL-1 CaCO3)	AMONIA (mgL-1 NH3)	CLORO (mgl-1 Cl2)	CLORETOS (mgl-1 Cl)	COR (mgL-1 Pt/Co)	Dureza Total (mgl-1	FERRO (mgl-1 Fe)	TURBIDEZ (NTU)	Oxigênio Consumido (mgL-1 O2)	pH (un.pH)	COLIFORMES TOTAIS (UFC/100m	COLIFORMES FECAIS (UFC/100mL
				***	1,2 mgL-1 NH3	5 mgl-1 Cl2	250 mgl-1 Cl	15 mgL-1 Pt/Co	500 mgl-1 CacO3	mgl-1 Fe	5 NTU	3 mgL-1 O2	6 - 9,5	Ausência	Ausência
1	Torneira Coletiva (associação)	Assentamento	Assentamento Aristeu Carvalho - Torneira da Associação	0	0	0,1	50	3	10	0	20	**3**	**5**	**51.200**	0
2	Poço Artesiano Comunitário	Assentamento	Assentamento Aristeu Carvalho - Poço Artesiano Comunitário	0	0	0	40	3	10	0	0	**3**	**5**	0	**32.000**
3	Cacimba	Assentamento	Assentamento Maravilha - Residência Neuza da Silva (Cacimba)	0	0	0	40	0	10	0	0	1	**4**	**54.400**	0
4	Poço Artesiano Individual	Assentamento	Assentamento Maravilha - Residência Antonia de Jesus	0	0	0,1	30	0	10	0	0	0	**5**	**25.600**	0
5	Armazenada em Garrafas (Residência)	Assentamento	Assentamento Aristeu - Residência Evanildes (Ivanir)	10	0	0	30	0	10	0	0	**3**	**5**	**64.000**	**25.600**
6	Torneira Individual (residência)	Assentamento	Assentamento Aristeu - Residência Valmira de Souza Dias	0	0	0	30	0	10	0	0	0	**4**	**9.600**	**16.000**
7	Poço Artesiano Comunitário	Aldeia	Poço Artesiano Comunitário da Aldeia Pataxó Juerana	200	0	6	40	0	10	0	0	**3**	6	0	**3.200**
8	Bebedouro Escolar	Aldeia	Escola Indigena Pataxo Juerana - kijetxawe txihihãe pataxó juerana	20	0	0	40	0	10	0	0	**3**	**5**	0	0
9	Torneira Individual (residência)	Aldeia	Casa da Aldeia Juerana - Encanação direta do poço	300	0	10	50	0	10	0	0	**3**	6	**9.600**	0
10	Bebedouro Coletivo	Aldeia	Bebedouro da Oca Principal - Reserva da Jaqueira	0	0,1	0	40	0	10	0	0	**3**	**4**	0	0
11	Torneira da Cozinha Comunitárian	Aldeia	Cozinha Comunitária da Reserva Pataxó da Jaqueira	0	0	0	40	0	10	0	0	**3**	**4**	**41.600**	0
12	Bebedouro Escolar	Aldeia	Bebedouro da Escola Indigena Pataxó da Jaqueira	0	0,1	0	40	0	10	0	0	**3**	**4**	**9.600**	0

Source: Field Research, 2025.

(***)Ordinance GM/MS No. 888/2021 does not establish a maximum value for this indicator

Total alkalinity, expressed in mg/L of $CaCO_3$, is a fundamental parameter to evaluate the buffering capacity of water, that is, its resistance to pH variations. Although Ordinance GM/MS No. 888/2021 does not establish a maximum value for this indicator, the technical literature recommends values between 75 mg/L and 200 mg/L as ideal to ensure the chemical stability of water and prevent corrosive or fouling effects in hydraulic installations. In the present study, there was great variability in alkalinity levels among the points analyzed, with values ranging from 0 mg/L to 300 mg/L. Four points stood out with high levels: point 5 (10 mg/L), point 7 (200 mg/L), point 8 (20 mg/L) and point 9 (300 mg/L). The significant increase in alkalinity at point 9, for example, suggests the possible presence of bicarbonates or carbonates in expressive concentrations, which may be related to the local geological origin or the type of source used.

According to Araújo and Júnior (2016), excessive alkalinity values, when associated with high hardness, can increase fouling in pipes and compromise the palatability of water. On the other hand, the low alkalinity recorded at points such as 1, 2, 3, 4, 6 and 10 to 12 (with a record of 0 mg/L) indicates a lower capacity to neutralize acids, making the water more vulnerable to sudden pH fluctuations and increasing the risk of corrosivity. This condition, when combined with slightly acidic pH, as observed in some of the samples, can accelerate the wear of pipes and the release of metals such as iron and copper, with potential toxic effects on prolonged exposures.

The presence of ammonia (NH_3), an indicative parameter of recent organic contamination, was recorded in only two of the twelve points analyzed, specifically in points 10 and 12, both with a concentration of 0.1 mg/L. These values do not exceed the maximum limit allowed by Ordinance GM/MS No. 888/2021, which is 1.5 mg/L for water intended for human consumption. However, the detection of the substance, even at low levels, can signal processes of decomposition of organic matter, such as plant remains or animal excreta, especially in environments with little sanitary protection at the sources of abstraction.

According to Lima et al. (2024), the presence of nitrogenous compounds in raw water samples, even within legal parameters, requires attention, especially in rural and traditional areas with poor access to sanitation. The persistence of nitrogen residues may be related to the use of fertilizers, the presence of rudimentary cesspools near the collection points or the accumulation of organic waste in the surroundings. Although it is not an acute risk, the presence of ammonia should be considered a marker of environmental vulnerability, and it is recommended that monitoring continue in future research cycles.

In agreement, Araújo and Júnior (2016) argue that the detection of nitrogenous compounds in community environments should be interpreted as an alert to the need to evaluate sanitary infrastructure and water management conditions, since such elements, even if isolated, can compromise the effectiveness of disinfection processes. Systematic monitoring of ammonia, therefore, can help in the screening of diffuse sources of contamination and in the preventive assessment of water quality in vulnerable territories.

The parameter free residual chlorine, measured in mg/L of Cl_2 presented different values in four of the twelve points analyzed. The samples from points 1 and 4 recorded discrete concentrations of 0.1 mg/L, while points 7 and 9 showed high values of 6.0 mg/L and 10.0 mg/L, respectively. This finding requires attention, as Ordinance GM/MS No. 888/2021 establishes that, to ensure the effectiveness of disinfection and the microbiological safety of water, free residual chlorine must be between 0.2 mg/L and 5.0 mg/L at the points of consumption. Thus, a situation of absence or insufficiency of chlorination is observed in most of the points and, on the other hand, a significant excess in at least two of them.

According to Lima et al. (2024), the absence or deficiency of residual chlorine in water intended for human consumption is directly associated with greater microbiological vulnerability, especially in areas without systematic treatment. Chlorine is an essential disinfectant not only for the inactivation of pathogenic microorganisms, but also for maintaining sanitary quality throughout the storage and transportation of water. At points where chlorine was detected at levels above the permitted levels, such as in points 7 and 9, the excessive concentration is related to attempts at domestic or community treatment, without adequate technical control of the dosage.

Araújo and Andrade (2020) emphasize that, although the use of chlorine is essential for water safety, its application must respect technical limits, as excess can compromise the taste and odor of water, in addition to generating undesirable byproducts such as chloramines. Such effects were not measured in the present study, but the concentration of 10.0 mg/L at point 9 exceeds twice the maximum allowed limit, indicating the need for technical guidance in the water disinfection practices used by the residents. At the same time, the points with 0.0 mg/L reinforce the absence of treatment and the risk of recontamination, especially in unsealed containers and in contexts with precarious sanitary infrastructure.

The heterogeneity in chlorine levels observed among the points analyzed shows not only the inequality in access to water treatment, but also the absence of effective public policies for environmental health surveillance. As Araújo and Júnior (2016) point out, the instability of chlorine concentration can compromise the effectiveness of disinfection, even when the water source is considered safe. This reality imposes the need for guidance strategies on treatment and home storage, as well as the strengthening of water quality surveillance actions in vulnerable territories.

Based on the data in the confirmed table, it is observed that the chloride parameter (mg/L Cl^-) varied between 30 and 50 mg/L in all 12 points analyzed. This range is below the maximum value allowed by Ordinance GM/MS No. 888/2021, which is 250 mg/L, indicating, therefore, that no non-conformities were identified regarding this parameter in the samples collected. According to Araújo and Andrade (2020), the presence of chlorides at moderate levels is expected in groundwater and does not, in itself, constitute a health risk. However, high levels can impart a saline taste to the water and accelerate the corrosion of metal structures, affecting the durability of pipes and reservoirs. In the case of this research, the levels detected remained within the range considered safe, thus not presenting adverse impacts on potability or domestic use of water in the territories investigated.

The apparent color, expressed in Pt/Co units, was within the potability standards at all points analyzed. Points 1 and 2 recorded values of 3 mg/L Pt/Co, while the remaining 10 points presented a value of zero, indicating a complete absence of perceptible staining. According to Ordinance GM/MS No. 888/2021, the maximum allowed limit is 15 mg/L, which confirms the adequacy of all samples analyzed for this parameter. The color of the water, although it does not represent a direct health risk, is an important indicator of sensory acceptance and can signal the presence of dissolved organic substances when above the ideal. As Araújo and Andrade (2020) point out, significant color changes can hinder disinfection processes and form harmful byproducts, such as trihalomethanes, depending on the quality of the organic matter present. In the present study, however, the absence of non-standard apparent color indicates visually clear waters, suggesting good aesthetic condition and compatibility with human consumption in this specific aspect.

Based on the confirmed results spreadsheet, the total water hardness, measured in mg/L of $CaCO_3$, showed homogeneous values among the 12 points analyzed, all registering exactly 10 mg/L, which represents a level of hardness considered very low. According to the criteria of Ordinance GM/MS No. 888/2021, there is no mandatory minimum limit for this parameter, but values below 50 mg/L are generally classified as "soft water", which can have relevant technical and sanitary implications.

According to Lima et al. (2024), low hardness, although it does not represent a direct health risk, can increase the potential for water corrosion, especially when associated with acidic pH and low alkalinity, conditions also identified in some points of this research. This corrosivity can affect the integrity of pipes, favor the leaching of metals, and negatively impact the quality of the water consumed over time. Araujo and Júnior (2016) highlight that waters with low mineral salt content require special attention regarding the durability of hydraulic structures and the chemical stability of water, especially in contexts of unmonitored household supply. Thus, although hardness itself does not represent an immediate warning factor from a microbiological point of view, its continuous monitoring is relevant to ensure the safety of the facilities and prevent secondary changes in the potability of the water.

Based on the laboratory data obtained at the 12 collection points, the iron parameter (Fe), measured in mg/L, showed a result equal to zero in all samples analyzed. This indicates the absence of detection of the metal at the minimum concentrations established for the methods used. According to Ordinance GM/MS No. 888/2021, the maximum allowed limit for iron in drinking water is 0.3 mg/L, a value that, when exceeded, can cause not only sensory problems (such as metallic taste and reddish color), but also pose a health risk if associated with chronic ingestion in vulnerable populations.

Araújo and Andrade (2020) discuss that, although iron is an essential element in human metabolism, its presence in high concentrations can generate technosanitary implications, such as fouling in pipes and reactions with chlorine, compromising the disinfection process. However, the lack of detectable iron in the samples collected, as verified in the present study, indicates a good quality in this specific aspect, especially in alternative supply systems. This result reinforces that, at least with regard to the presence of iron, there is no compromise of potability or risk associated with direct ingestion or domestic use of water in the territories evaluated.

Based on the consolidated data from the results spreadsheet, it was observed that the turbidity parameter, measured in NTU units (Nephelometric Turbidity Unit), showed alteration only in Point 1, located in the collective tap of the Aristeu Carvalho Settlement, where a value of 20 NTU was recorded. This value significantly exceeds the maximum limit of 5 NTU established by Ordinance GM/MS No. 888/2021 for water intended for human consumption.

High turbidity directly compromises the sanitary quality of the water, as it interferes with the effectiveness of the disinfection process, especially with chlorine, as evidenced by Lima et al. (2024). According to the authors, the presence of suspended particles makes it difficult for the disinfectant to come into contact with microorganisms, favoring the survival of pathogens even in treated waters. Although only one of the 12 points presented non-standard turbidity, the finding should not be minimized, since prolonged exposure to turbid water, especially in communities with deficiencies in domestic treatment, can favor outbreaks of waterborne diseases. Araújo and Andrade (2020) also point out that high levels of turbidity are indicative of suspended organic matter, sediments, or microorganisms, all associated with increased health risk, especially when associated with the absence of residual chlorine, as was the case at that point.

Oxygen consumed (OC), expressed in mg/L of O_2, is a parameter that reflects the presence of organic matter in the water, being an important indicator of the sanitary quality of the sources, especially in contexts not monitored by public treatment networks. As recommended by Ordinance GM/MS No. 888/2021, the maximum value allowed for this parameter is 3 mg/L. In the present study, this limit was reached in nine of the twelve points analyzed (1, 2, 5, 7, 8, 9, 10, 11, and 12), suggesting a possible accumulation of organic matter in these sources. Only points 4 and 6 presented a value equal to 0 mg/L, and point 3 recorded 1 mg/L.

Araujo and Andrade (2020) point out that the presence of organic matter in community water sources may indicate improper waste disposal or the absence of effective sanitary barriers, increasing the risk of microbiological contamination. Costa et al. (2024) reinforce that high levels of oxygen consumed, even within the legal limit, should be interpreted with caution, especially when associated with other markers of organic contamination, such as ammonia. The recurrence of values within the limits of the legislation in 75% of the points analyzed reinforces the need for community control of water quality, with educational and sanitary measures to avoid the accumulation of debris in the vicinity of the sources.

The hydrogen potential (pH) is one of the most relevant indicators for the evaluation of the potability of water, since it directly influences the solubility of chemical compounds and the effectiveness of disinfection processes, such as chlorination. According to the criteria established by Ordinance GM/MS No. 888/2021, the acceptable pH range for drinking water is between 6.0 and 9.5. Values below this limit indicate acidity and may pose risks to human health, in addition to structural compromises in the distribution and storage networks.

In the present analysis, the results revealed that 10 of the 12 sampled points had pH below the minimum allowed. Specifically, points 3, 6, 10, 11 and 12 recorded a value of 4; points 1, 2, 4, 5 and 8 presented pH 5. Only points 7 and 9 reached the minimum required, with pH 6. This trend of widespread acidity is a warning sign, especially in contexts of continuous and domestic use. As Araújo and Júnior (2016) discuss, waters with a pH lower than recommended tend to be corrosive, increasing the risk of heavy metal leaching into pipes, which can intensify toxicological risks, especially when combined with low levels of alkalinity, as observed in other points of this analysis.

In addition to the physicochemical impacts, Araújo and Andrade (2020) reinforce that acidic pH enhances the ineffectiveness of chlorination, as the biocidal action of chlorine is strongly dependent on the pH range. Acidity, therefore, compromises the sanitary barrier against pathogenic microorganisms, aggravating the risk of waterborne diseases. In communities with decentralized supply and home storage practices, as is the case of the villages and settlements investigated, the absence of continuous treatment, added to the acidity of the water, represents a critical combination of sanitary vulnerability.

Thus, the finding of pH below the recommended limits in most of the points analyzed requires attention from health authorities and local leaders. The adoption of corrective measures, such as the application of alkalizing agents, as well as the promotion of community water quality surveillance practices, are urgent strategies to mitigate risks and ensure the human right to safe water.

The microbiological analysis of the samples revealed that only the points corresponding to the drinking fountain of the Indigenous School of Aldeia Juerana (Point 8) and the community drinking fountain of the Indigenous Reserve Village of Jaqueira (Point 10) were free of the presence of total and fecal coliforms, according to the standards defined by Ordinance GM/MS No. 888/2021. The other ten samples were contaminated by at least one of the groups, indicating a health risk situation. More specifically, fecal coliforms were identified in points 2, 5, 6 and 7, which correspond to a domestic storage bottle (Point 5), the direct connection of the well of the Aristeu Settlement (Point 2), the tap of one of the residences of the Aristeu Carvalho Settlement – Individual Artesian Well (Point 6), and finally, the community artesian well of Aldeia Juerana (Point 7). These sites, although they represent different forms of access to water (individual storage, shared use, and underground sources), shared the same diagnosis: the presence of microorganisms indicative of active fecal contamination.

According to Araújo and Júnior (2016), coliforms, especially fecal coliforms, are considered sentinel indicators of the microbiological quality of water, functioning as indirect markers of the presence of enteric pathogens. This group of microorganisms not only denounces the possibility of recent fecal contamination, but also evidences structural deficiencies in the processes of collection, storage or distribution of water. Porcy et al. (2020) reinforce that in traditional communities and rural settlements, the persistence of these indicators is associated with the precariousness of sanitary infrastructure, inadequate waste management, and the lack of effective drinking water treatment systems.

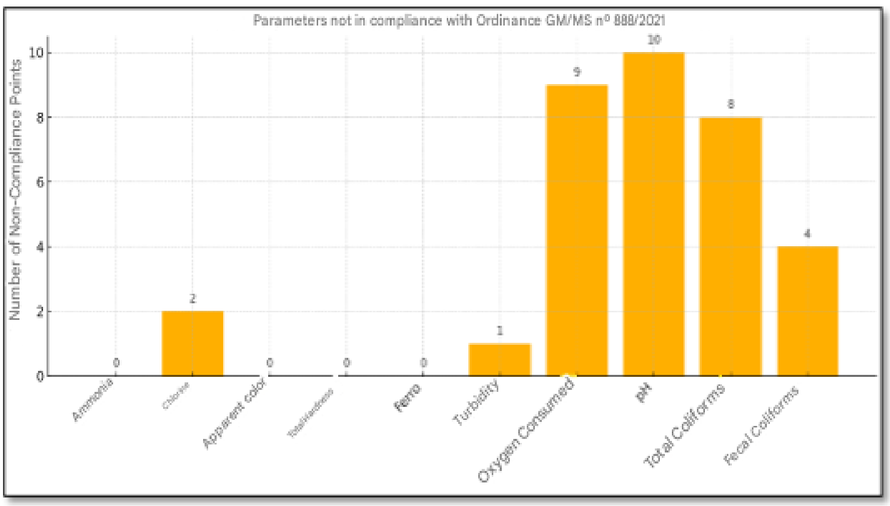
From this perspective, Souza et al. (2006) warn that microorganisms such as Escherichia coli, belonging to the group of fecal coliforms, can play an important pathogenic role, generating severe infectious conditions, especially in more susceptible populations, such as children and the elderly. The detection of these bacteria should be interpreted as an epidemiological alert, requiring urgent interventions. As Araújo and Júnior (2016) point out, coliforms act as sentinels not only of biological contamination, but of the social and environmental precariousness that structures access to water in these territories. In view of this, it is essential not only laboratory control, but also the implementation of integrated public policies that articulate sanitation, health education and low-cost social technologies.

The detection of total coliforms in 8 of the 12 points analyzed (1, 3, 4, 5, 6, 9, 11 and 12) reveals a scenario of wide exposure to microbiological contamination in the sources of supply of the communities investigated. As highlighted by Souza et al. (2006), the presence of these microorganisms is used as a sentinel parameter in water quality surveillance, indicating the existence of decomposing organic matter and the possibility of contamination by pathogens of fecal origin. Although they are not necessarily pathogenic, total coliforms function as indirect indicators of the effectiveness of the water treatment and storage system, in addition to denouncing the contact of the source with organic waste or with inadequate post-collection management. Araújo and Júnior (2016) reinforce that the identification of total coliforms, even in the absence of Escherichia coli, is a warning for the fragility of sanitary conditions and a strong indication of exposure to microbiological risks, especially when associated with acidic pH, absence of residual chlorine and poor conservation of storage containers.

The presence of total and fecal coliforms in the analyzed samples poses a direct risk to public health, especially in communities with low sanitation coverage and alternative supply systems. Souza et al. (2006) point out that the ingestion of water contaminated by these microorganisms can cause outbreaks of acute diarrheal diseases, viral hepatitis, typhoid fever and other gastrointestinal infections, compromising the nutritional and immunological status of vulnerable populations. The situation is aggravated when there is daily consumption of contaminated water without proper treatment, as is common in rural and traditional areas, where access to safe solutions and disinfection technologies is limited or non-existent. For this reason, the detection of these indicators should be considered more than laboratory data: it is an epidemiological marker of exposure to infectious agents.

In addition to gastrointestinal diseases, studies such as those by Araújo and Júnior (2016) highlight that the permanence of fecal coliforms in supply sources compromises preventive actions in public health and indicates the need for structural and educational actions. In young children, recurrent exposure to enteric pathogens is associated with severe dehydration, developmental delay, and increased mortality from preventable causes. In adults and the elderly, the consequences include worsening of chronic diseases and overload of the immune system.

Graph 1 – Summary of the Number of Points in Non-Conformities

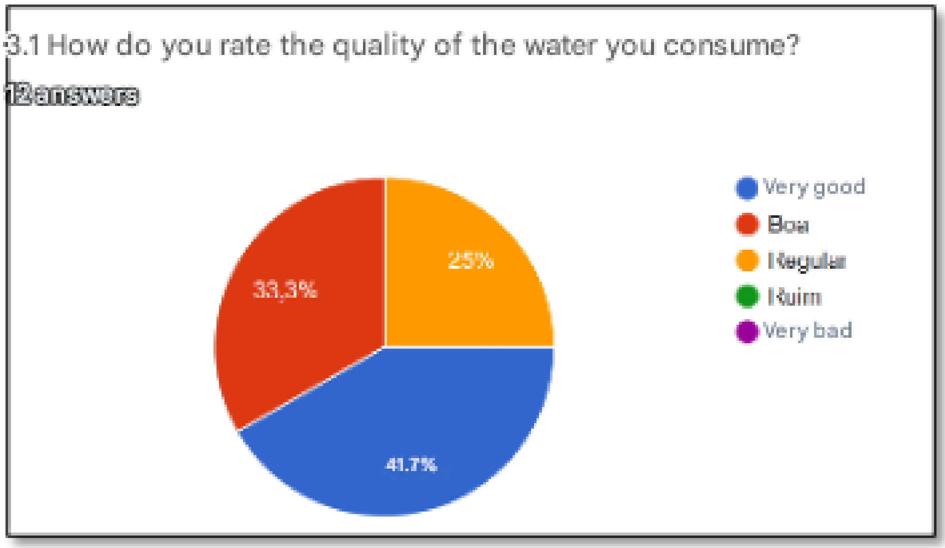


Source: Field Research, 2025.

Porcy et al. (2020) reinforce that the occurrence of indicative microorganisms in communities such as those studied here is a reflection of a broader scenario of socio-environmental inequities, requiring integrated approaches between health surveillance, policies for access to safe water, and strengthening of primary health care in rural and indigenous territories.

The graphs present the results obtained in the interviews with the residents of the territories investigated in the research.

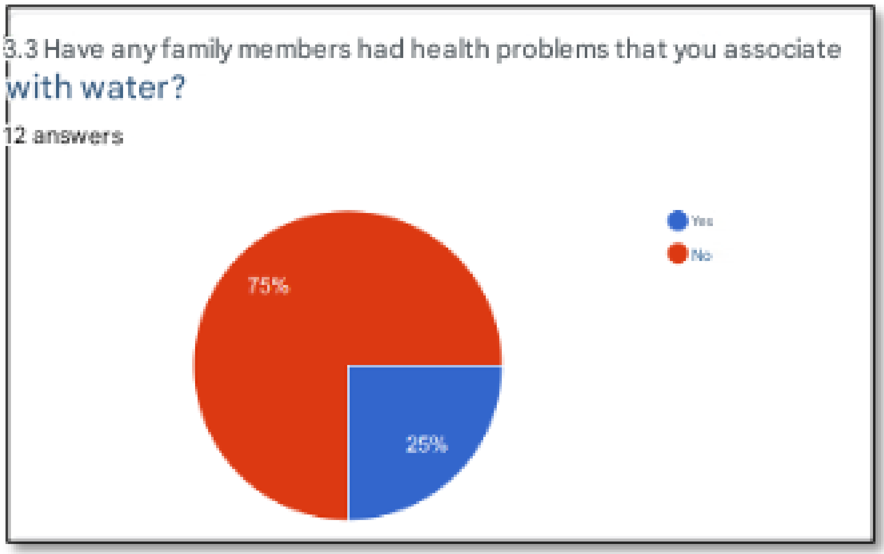
Graph 2 – Assessment of water quality by communities



Source: Field Research, 2025.

Perceptions about water quality reveal an apparent dissociation between sensory evaluation and the actual sanitary parameters observed. Although 41.7% of the interviewees classified the water consumed as "very good" and 33.3% as "good", the laboratory results pointed to the presence of total and fecal coliforms in 10 of the 12 points analyzed, in addition to physicochemical imbalances such as acidic pH and absence of residual chlorination. This contradiction reveals a deficit of information and health education, an aspect already discussed by Araújo and Júnior (2016), who point out the risk of invisibility of pathogenic agents when the appearance of the water does not denounce its contamination. The absence of visual parameters of contamination, such as turbidity or odor, can generate a false sense of security and hinder the adoption of water treatment practices in daily domestic life.

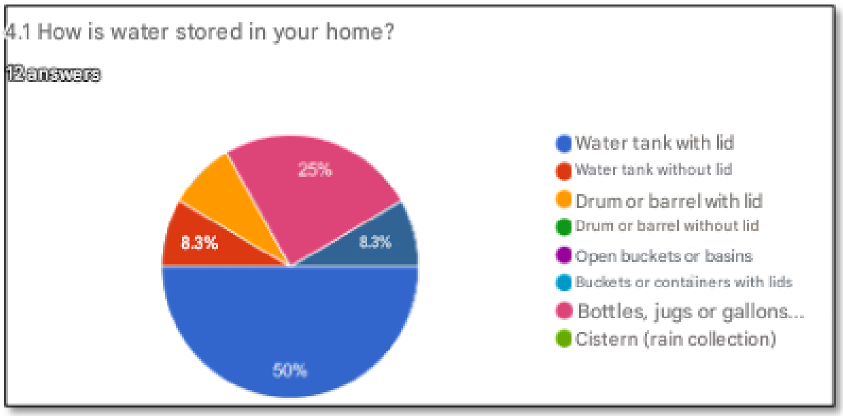
Graph 3 – Disassociation of Symptoms and Diseases



Source: Field Research, 2025.

Another critical fact is that 75% of respondents do not associate symptoms or diseases with the consumption of available water. This perception reflects the naturalization of water sickness in vulnerable communities, as observed by Souza et al. (2006), for whom contaminated water becomes, paradoxically, part of the daily landscape, even when related to diarrhea, gastrointestinal infections and other waterborne diseases. This dissociation between cause and consequence represents one of the greatest challenges for environmental health surveillance, as it reduces community mobilization for change in practices and minimizes pressure on public sanitation policies.

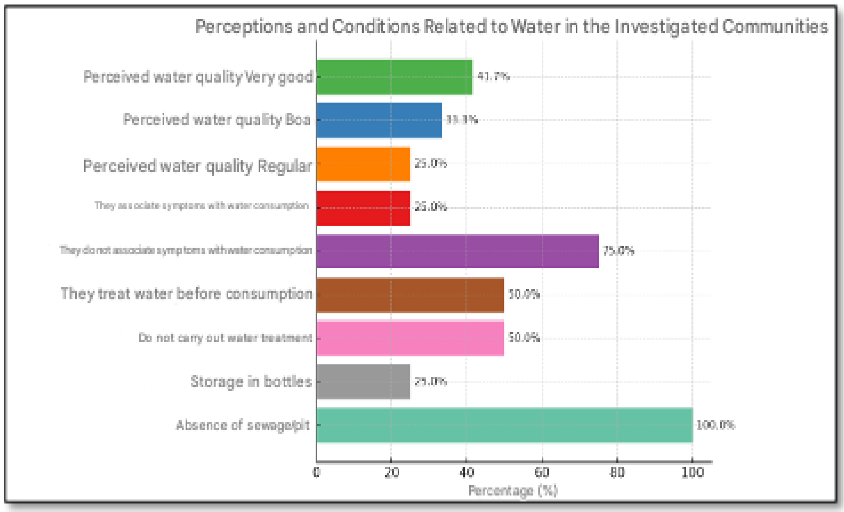
Graph 4 – Forms of Water Storage by the participants



Source: Field Research, 2025.

The forms of storage identified are also worth mentioning. Although 25% use plastic bottles, the data indicate that a significant portion uses drums, barrels and unsealed containers, facilitating the recontamination of water after collection. According to Araújo and Andrade (2020), inadequate storage represents one of the main critical points in the household water cycle, and can cancel out the effects of any previous treatments. The absence of sealing and the frequent handling of water for various purposes increase the microbiological load at the point of consumption, which is in line with the high prevalence of coliforms in the microbiological analyses performed.

Graph 5 – Summary of the main points of the Interview



Source: Field Research, 2025.

Finally, the total absence of sanitary sewage or septic tanks, reported by 100% of the interviewees, is an alarming finding that requires urgent intersectoral articulation. As Porcy et al. (2020) indicate, inadequate sanitation is a structural determinant of water and sanitary vulnerability. Direct contact with human feces and the proximity between water sources and waste areas exponentially increase the risk of fecal contamination, which was confirmed in laboratory data. In addition, the fact that only 50% of the participants declared that they underwent some type of treatment before consumption reinforces the need for continued educational actions, associated with the expansion of access to social technologies for sanitation and water purification.

Final Thoughts

The empirical evidence collected reveals a worrying sanitary scenario in settled communities and indigenous villages in the municipalities of Eunápolis and Porto Seguro, marked by multiple weaknesses in the quality of water intended for human consumption. The physicochemical and microbiological analyses, based on Ordinance GM/MS No. 888/2021, exposed a high rate of non-compliance in the parameters evaluated. The presence of total coliforms in 8 of the 12 points investigated and fecal coliforms in 4 samples stand out, alarmingly, signaling the presence of contamination of fecal origin and exposing populations to waterborne diseases such as diarrhea, hepatitis A and intestinal parasitosis.

From the point of view of physicochemical parameters, significant deviations were found in the levels of pH, turbidity, oxygen consumed, free residual chlorine and alkalinity, compromising not only the potability of the water, but also the effectiveness of the disinfection processes. The presence of ammonia, even if punctual, suggests recent sources of organic pollution, which, associated with the systematic absence of chlorination in most of the points, increases the health risks observed. These indicators, taken together, point to the fragility of the local water infrastructure, aggravated by alternative supply systems and without permanent technical supervision.

The interviews with the residents reinforced the socio-territorial dimension of the identified risks. The general perception that the water is “very good” or “good”, although not supported by laboratory results, reveals a mismatch between community experience and technical quality criteria, which hinders preventive and educational actions. The absence of sanitary sewage in 100% of the households interviewed and the use of open containers for storing water accentuate sanitary vulnerabilities, in addition to exposing populations to a constant cycle of contamination and recontamination.

In this sense, the findings of the study not only document the level of water contamination, but also highlight the structural conditions that sustain prolonged exposure to health risks, including the lack of public policies aimed at water security, the insufficiency of permanent environmental health surveillance actions, and the invisibility of the demands of these territories in municipal and state basic sanitation plans.

In view of the seriousness of the results, the urgency of intersectoral interventions that combine the supply of low-cost technologies for water treatment with the implementation of health education and social participation strategies is reinforced. In addition, it is recommended that the data produced in this study be incorporated into environmental health surveillance actions, as a technical-scientific subsidy for the territorialized planning of public policies for supply, sanitation and health protection of vulnerable populations.

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