Characterization of the Water Supply System of the São Francisco Community in Santarém, Pará, Amazon, Brazil (Paper 601)

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ABSTRACT

The objective was to characterize and analyze the water supply system for human consumption in the São Francisco Community, located in the Lago Grande Agro-Extractive Settlement Project (PAE Lago Grande), in Santarém, Pará. The research adopted a qualitative–quantitative approach of a descriptive and exploratory nature, using questionnaires administered to 15 families, corresponding to approximately 55% of the local population. The results indicated that 93% of residents are served by a groundwater micro-supply system, while about 7% use surface water from the river. It was found that 60% of respondents consume water directly from the distribution network, and 40% use polyethylene storage tanks. Regarding water treatment, 53% of residents consume water without any treatment, while the others adopt alternative practices such as filtration using a clay filter, boiling, straining, or the use of hypochlorite. It is concluded that, although the existence of the micro-system ensures access to water, sanitary weaknesses persist that compromise the quality of the water consumed, highlighting the need for structural improvements, the implementation of adequate treatment, and the strengthening of sanitary education actions within the community.

Keywords: PAE Lago Grande. Rural sanitation. Microsystem. Amazonian community. Sustainable development goal.

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RESUMO

Objetivou-se caracterizar e analisar o sistema de abastecimento de água para consumo humano na Comunidade São Francisco, localizada no Projeto de Assentamento Agroextrativista Lago Grande (PAE Lago Grande), em Santarém, Pará. A pesquisa adotou uma abordagem qualitativa-quantitativa de natureza descritiva e exploratória, utilizando questionários aplicados a 15 famílias, correspondendo a aproximadamente 55% da população local. Os resultados indicaram que 93% dos moradores são abastecidos por um sistema de microabastecimento subterrâneo, enquanto cerca de 7% utilizam água superficial do rio. Constatou-se que 60% dos entrevistados consomem água diretamente da rede de distribuição e 40% utilizam reservatórios de polietileno. Em relação ao tratamento de água, 53% dos moradores consomem água sem qualquer tratamento, enquanto os demais adotam práticas alternativas como filtração com filtro de argila, fervura, coagem ou uso de hipoclorito. Conclui-se que, embora a existência do microssistema garanta o acesso à água, persistem fragilidades sanitárias que comprometem a qualidade da água consumida, evidenciando a necessidade de melhorias estruturais, implementação de tratamento adequado e fortalecimento de ações de educação sanitária na comunidade.

Palavras-chave: PAE Lago Grande. Saneamento rural. Microssistema. Comunidade amazônica. Objetivo de desenvolvimento sustentável.

INTRODUCTION

Access to safe drinking water and the adequate provision of sanitation services constitute an essential, fundamental, and universal human right, indispensable for ensuring a dignified life. It is recognized by the United Nations (UN) as a necessary condition for the full enjoyment of life and other human rights, particularly within Sustainable Development Goal (SDG) 6, which aims to ensure the availability and sustainable management of water and sanitation for all (UN Brazil, 2025).

Within the legislative framework, the New Legal Framework for Sanitation, established by Law No. 14.026/2020, stands out, having updated Law No. 11.445 of January 5, 2007. This legislation aims to universalize water supply and sanitation services by 2033, establishing coverage targets of 99% of the population with access to safe drinking water and 90% with access to sanitation services in Brazil.

In this context, the sustainable universalization of sanitation services on a global scale constitutes one of the major challenges of the early 21st century, especially in developing countries, where access to these services still occurs in an unequal, restricted, and limited manner (Scaramussa; Henkes, 2014).

Furthermore, the New Legal Framework for Sanitation seeks to promote greater efficiency in service provision, ensure economic and financial sustainability, and expand participation and coordination among federal entities (Brazil, 2020). However, if the country maintains the current pace of expansion in access to sanitation, the targets established in the National Basic Sanitation Plan (Plano Nacional de Saneamento Básico -PLANSAB) are unlikely to be achieved, even after the changes introduced by Law No. 14.026/2020.

Among the municipalities with the poorest performance in the latest Sanitation Ranking, Santarém, in the state of Pará, stands out as one of the localities with the most critical indicators. Only 48.80% of the population has access to treated water, 3.81% is connected to the sewage network, and only 9.13% of the generated wastewater is effectively treated (ITB, 2025).

Over the past 10 years, the municipality has remained among the 10 lowest-ranked among the 100 largest Brazilian cities, a situation that more severely affects vulnerable populations, especially those living in rural areas, where the lack of basic infrastructure is even more evident (Sousa *et al.,* 2025a).

According to data from the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística-IBGE), significant inequalities persist between urban and rural contexts. While 93.4% of urban households have access to the water supply network and 78% to the sewage system, in rural areas, these percentages decrease to 32% and 10%, respectively (IBGE, 2024)

In this scenario, many rural communities remain excluded from essential public policies, such as basic sanitation, health, education, and public safety, a situation aggravated by historical and institutional structural constraints (PNRS, 2019). The precariousness of sanitation infrastructure in these areas directly affects public health and the environment and is further intensified by factors such as population dispersion, the lack of appropriate technologies, and the limited availability of specialized technical support (Bernardo *et al.,* 2025).

In this context, the National Rural Sanitation Program (Projeto Nacional de Saneamento Rural - PNSR) stands out as a pioneering initiative aimed at the planning and implementation of sanitation actions in rural areas in Brazil. The PNSR is based on technological, social,

and economic–financial pillars, integrating the implementation of sanitation systems, environmental education actions, and mechanisms for social participation, with the objective of promoting solutions that are appropriate to the specificities and needs of rural communities (Roland; Heller; Rezende, 2022).

The importance of water is also emphasized in the National Water Resources Policy, established by Law No. 9.433/1997, which aims to ensure for present and future generations the availability of this resource in quantities and quality compatible with its different uses (Brazil, 1997).

Furthermore, a water supply system can be understood an integrated set of structures, equipment, processes, and practices intended to ensure the continuous provision of water in adequate quantity and quality for human consumption (Brazil, 2007).

In general, this system involves the stages of water abstraction from surface or groundwater sources, conveyance, treatment, storage, and distribution to points of use, and, must comply with the drinking water quality standards established by current legislation (Brazil, 2020).

In rural contexts and isolated communities, water supply may occur through simplified systems or micro-systems, which present configurations adapted to local conditions, environmental characteristics, and the technical and operational capacities of the community, while maintaining as a fundamental principle the protection of public health and the assurance of the human right to water (Medeiros; Silva, 2025).

In this regard, it is the responsibility of the state to ensure the universal provision of this right and to promote, through legislation and public policies, conditions that enable all individuals to have equitable access to water, thereby contributing to the reduction of socio-environmental inequalities and environmental injustice (Heller, 2017; Maia, 2017).

The realization of this right can generate significant impacts on the health and quality of life of vulnerable populations, reflected in the reduction of infant mortality, decrease in social inequalities, expansion of access to education, improvement of living conditions, and reduction of poverty (Heller, 2017).

In light of these considerations, the present study aimed to characterize and analyze the current situation of the water supply system for human consumption in the São Francisco Community, located on the banks of the Arapiuns River, within the territory of the Lago Grande Agro-Extractive Settlement Project (Projeto de Assentamento Agroextrativista Lago Grande – PAE Lago Grande), in the municipality of Santarém, state of Pará, Brazil.

MATERIALS AND METHODS

Study Area

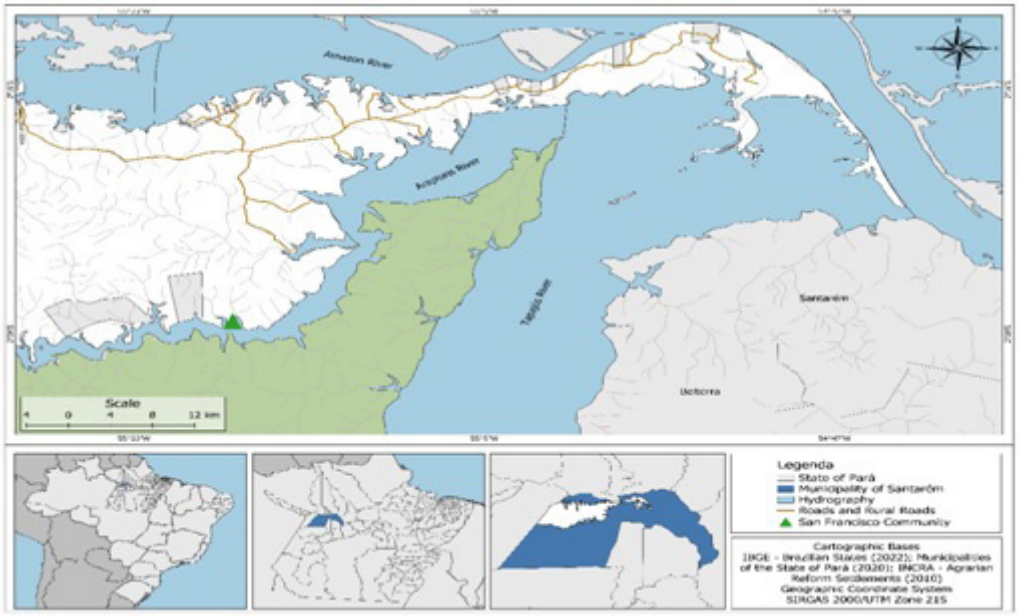
The study area is located within the PAE Lago Grande, situated in the municipality of Santarém, in the state of Pará. Created in 2005, the PAE is located in a lacustrine region between the Tapajós, Amazon and Arapiuns rivers, in western of Pará (Mapa de Conflitos, 2025).

The settlement covers approximately 250.000 hectares, encompassing 144 communities and an estimated population of around 35.000 inhabitants, whose main sources of livelihood include fishing, extractivism (the collection of forest products), agriculture, and other activities that generate low environmental impact (Mapa de Conflitos, 2025).

In addition, the PAE Lago Grande region has another territorial subdivision, being organized into Lower Lago, Middle Lago, and Upper Lago, and also comprising areas along the Arapiuns River, as well as communities associated with the area known as *Arapixuna* (Mendes, 2025).

The São Francisco Community, the study area of this research, is located within the territory of the PAE Lago Grande and lies along the Arapiuns River (Silva; Cruz; Carvalho, 2024), at the geographic coordinates of latitude 2°32'55.2"S and longitude 55°18'01.7"W (Figure 1), with access to the community provided exclusively by river transport.

Figure 1. Geographic location map of the São Francisco Community in the Lago Grande Agro-extractive Settlement Project (PAE Lago Grande), in the municipality of Santarém, Pará, Amazon, Brazil



Source: Authors (2026).

Travel between the municipality of Santarém and the São Francisco Community takes an average of six to eight hours, depending on the speed of the vessel, the number of passengers, and the seasonal conditions of the watercourse. During the dry season, travel time tends to be longer due to reduced river levels, which favor the formation of sandbanks and hinder navigation.

According to information provided and recorded by the Community Health Agent (Agente Comunitário de Saúde- ACS), the locality has 27 families, totaling approximately 80 residents.

Research type

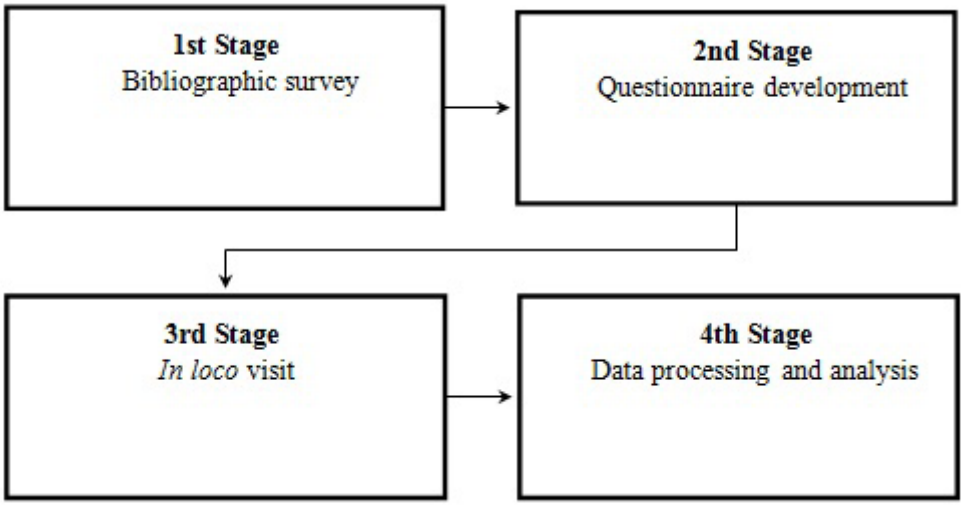
This study is characterized by a qualitative–quantitative approach, as described by Gil, Carlan, and Behling (2015). Regarding its objectives, it is a descriptive and exploratory study, as it seeks to describe and explore a theme, object, population, or phenomenon, providing greater familiarity with the subject and the research problem, considering that the purpose of the study is to expand knowledge about the investigated object and to establish possible relationships among the variables that compose the research context (Gil, 2017).

Regarding methodological procedures, the study adopts the case study method, which, according to Silva (2024), is based on the in-depth observation of a unit of analysis. In this research, the unit corresponds to the São Francisco Community, located within the territory of the PAE Lago Grande, with the purpose of collecting and analyzing the conditions of the local water supply system.

Data collection

Questionnaires were administered to key community stakeholders, including the ACS, the person responsible for the water supply microsystem, and local residents. Thus, the research was developed in four main stages, as illustrated in Figure 2.

Figure 2. Flowchart of the research development stages in the São Francisco Community within the Lago Grande Agro-extractive Settlement Project (PAE Lago Grande), in the municipality of Santarém, Pará, Amazon, Brazil



Source: Authors (2026).

The literature review related to the proposed topic was conducted throughout the entire research period, as it supported the development of the research project, the construction of the theoretical framework, and the discussion of the results obtained.

The questionnaire was developed encompassing different thematic areas, defined according to the research objectives. These axes addressed aspects related to water supply, water transport for human consumption, household water storage, and the treatment processes adopted by the community, as described below:

a) Water supply

The aim was to identify the water sources used in the homes, such as springs, artesian wells, and micro-systems.

b) Household storage of water for consumption

The storage methods used were assessed to support the proposal of improvements in storage conditions.

c) Water treatment process for final consumption

The aim was to identify the methods used or the lack thereof in treatment.

Data collection was conducted through the application of structured questionnaires during an *in loco* visit to the community, conducted on February 1, 2025. A total of 15 questionnaires were administered, corresponding to one per household, resulting in the participation of approximately 55% of the local population.

The collected information was transcribed and subjected to qualitative analysis using the ATLAS.ti software (Version 2022), which enabled the coding of responses and their organization into categories according to the research objectives. Among the main analytical objectives were the identification of the types of water sources used for supply, the forms of water storage, and the treatment methods adopted by the community.

After the coding stage, the software generated reports in Word document format and tables in Excel spreadsheets, allowing for data organization and the use of pivot tables to produce graphs and tables, thereby enabling a clearer and more systematized visualization of the results.

RESULTS AND DISCUSSION

Type of Water Supply System

Based on the data collected, it was identified that the São Francisco Community has a micro water supply system, characterized as a Collective Alternative Solution (CAS), adopted as the form of water supply for the local population.

According to Medeiros and Silva (2025), water supply arrangements can be classified into three categories:

a) Water Supply Systems (WSS), which comprise complete structures with abstraction, treatment, storage, and distribution through a network;

b) Collective Alternative Solutions (CAS), which include collective forms of supply without a conventional distribution network; and

c) Individual Alternative Solutions (IAS), intended for isolated household units, such as wells or cisterns.

The adoption of CAS has been a recurrent practice in the region. As demonstrated by Mendes (2025), in a diagnostic study conducted in 51 communities within the PAE Lago Grande, a widespread presence of micro water supply systems was identified, representing a positive aspect by ensuring access to water in adequate quantities in communities located along the Arapiuns (77%), Arapixuna (79%), and Middle Lago Grande (69%) rivers. In contrast, populations in Upper and Lower Lago Grande show greater dependence on artesian wells, corresponding to 32% and 49%, respectively. Complementarily, a study conducted by Medeiros and Silva (2025) in a non-demarcated Indigenous village in the PAE Lago Grande region (Esperança Village) showed that 96% of the population is served by this type of water supply system.

Although CAS may meet basic water supply needs, challenges related to the public management of these systems are recognized, as well as a greater likelihood of non-compliance with drinking water quality standards. Thus, a significant portion of the Brazilian rural population remains served by services that do not fully ensure the human rights to safe drinking water and sanitation (Raid *et al.*, 2022).

This scenario also diverges from the fundamental principles established by the New Legal Framework for Basic Sanitation, which defines as national guidelines the universalization of access, comprehensiveness, safety, quality, and regularity of service provision, as well as the promotion of partnerships and investments in the sector (Brazil, 2020).

At the national level, experiences such as the São José Project, described by Silva and Sousa (2025) and focused on water supply in the context of the semi-arid region of Ceará,

demonstrate that the partnership between the Government of the State of Ceará and the World Bank achieved positive results in expanding access to treated water in rural areas.

Notably, one of the prerequisites for the implementation of WSS within the São José Project was the adoption of an associative management model by the beneficiary communities, with the aim of preventing the deterioration of infrastructure over time. To ensure implementation in accordance with the proposed planning, the project relied on the support of partner institutions responsible for technical assistance, project management, training activities, and internal and external audits (Silva; Sousa, 2025).

In conclusion, Silva and Sousa (2025) indicated that, despite the limitations that still exist, the São José Project was able to serve a significant population with treated water in rural areas of the state of Ceará, promoting mechanisms that encouraged the active participation of beneficiaries, as well as fostering awareness among the population regarding their responsibility for the maintenance of the collective benefit.

In this regard, it is worth noting that the system implemented in the São Francisco Community dates back to 2004 and was made possible by the Saúde e Alegria Project (PSA), a non-governmental organization funded by the National Bank for Economic and Social Development (BNDES), with a total investment of R$ 38.048.28.

Similar results have been observed in other communities in the Amazon region. A study conducted by Ramos (2021) reported that, in communities and villages of the Tapajós/Arapiuns Extractive Reserve, 78% indicated the participation of NGOs in the installation and maintenance of micro water supply systems.

Description of the supply system

The community's micro water supply system has infrastructure composed of a groundwater abstraction unit, consisting of a tubular well 60 meters deep with piping of 75 mm in diameter, equipped with a 12 HP pump.

Initially, the system operated using a diesel generator, responsible for driving a motor–pump set composed of an Agrale M90 engine and a 7.5 kW (7500 W) generator. However, in 2023, the microsystem underwent a modernization process, with the replacement of the energy source by a photovoltaic system consisting of 16 solar panels, in addition to the restructuring of the storage area.

The adoption of photovoltaic technology represents one of the most promising alternatives for supplying water to populations located in remote areas without access to the conventional electrical grid. Among its main advantages are the availability of solar resources, the reduction of operational costs, and the decrease in environmental impacts, provided that the system is properly sized (Boitrago *et al.,* 2016).

The replacement of the diesel generator contributed to the elimination of pollutant gas emissions and noise pollution, reducing recurring expenses related to the purchase and transportation of fuel, thereby promoting improvements in the community's well-being (Boitrago *et al*., 2016).

Furthermore, this practice is aligned with the Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action), by promoting more efficient, sustainable, and resilient solutions (UN Brazil, 2025).

Although photovoltaic energy is classified as a "clean source", it may generate environmental impacts when its components are improperly disposed of at the end of their life cycle, which may cause harm to both environmental and human health (João, 2025). Nevertheless, such impacts are not comparable to the environmental damages associated with non-renewable energy sources (Costa; Jurubeba, 2025).

In this context, the importance of reverse logistics for photovoltaic panels is highlighted, especially considering their estimated service life of 25-30 years, as a strategy to ensure the environmentally appropriate disposal of modules at the end of their life cycle (João, 2025). The adoption of this practice enables the reuse and recycling of materials such as glass, aluminum, and silicon, and contributes to mitigating the environmental impacts resulting from improper disposal (João, 2025).

The abstraction of water used in the water supply system of the São Francisco Community is performed by suction and directed directly to the reservoir. According to Tsutiya (2006), regarding the type of water source supplying the system, its selection and the selection of potential sources for use should be preceded by a preliminary analysis of the main technical, economic, and environmental aspects involved, to support the formulation and presentation of feasible alternatives for the system in question.

Furthermore, the system includes fiberglass reservoirs with a storage capacity of 20.000 liters and a distribution network extending 2.750 meters, in addition to system automation through level control floats, ensuring greater operational efficiency.

The reservoirs are intended to ensure that water demand is met even in situations of supply interruption. For this function to be properly fulfilled, it is essential that their structures are adequately protected to prevent contamination of the stored water (Ventura; Guimarães, 2022).

When they do not receive adequate maintenance and sealing, these reservoirs may favor the presence and proliferation of pathogenic microorganisms and, additionally, function as environments conducive to the development of mosquito larvae, contributing to the spread of vectors and increasing risks to public health (Ventura; Guimarães, 2022).

During the *in loco* visit, no system or device intended for water disinfection was identified. In conventional water supply systems, the treatment of abstracted water is mandatory, including the disinfection stage, between abstraction and storage, before its distribution to consumers.

According to Simas *et al.* (2005), groundwater treatment processes vary according to the source of the water, the required quality standards, technical and economic conditions, environmental impacts, and the characteristics of the distribution system, with raw water quality being a determining factor in the definition of the treatment stages (Pereira, 2017).

Ventura and Guimarães (2022) highlight that, among water disinfection methods, the dosing of granular calcium hypochlorite and liquid sodium hypochlorite stands out, with household bleach being a diluted solution of sodium hypochlorite. However, the use of household bleach presents limitations, since product adulteration may result in actual chlorine concentrations lower than those indicated on the label, compromising the efficiency of the disinfection process (Ventura & Guimarães, 2022).

In this context, a device that can be used is a tablet chlorinator, which operates with granular calcium hypochlorite containing, on average, 65% available chlorine. It consists of a set of components made of PVC pipes and valves, designed to force the passage of water through a compartment containing chlorine tablets (Ventura & Guimarães, 2022).

Notably, that the number of tablets to be used depends on water quality analyses, and continuous bacteriological monitoring throughout the service life of the supply system is essential to ensure the effectiveness of disinfection and the sanitary safety of the water distributed to the population (Ventura & Guimarães, 2022).

To cover operational expenses, including system maintenance, a monthly fee of R$ 15.00 per user is charged in the São Francisco Community, in the PAE Lago Grande. This fee can be interpreted as a mechanism to strengthen community-based management, as it encourages users' sense of shared responsibility for the operation of the microsystem and reinforces the understanding of water as a common good that requires collective management.

This practice is consistent with the general principles established by the New Legal Framework for Basic Sanitation, which emphasizes the need for the economic and financial sustainability of sanitation services and the adoption of tariff mechanisms to ensure their continuity and efficiency (Brazil, 2020).

It is important to emphasize that, for populations living in settlements resulting from agrarian reform, inequalities in access to drinking water are exacerbated due to structural and institutional factors, such as the lack of coordination among the federative entities responsible for ensuring fundamental rights, as well as the legal and administrative challenges associated with the classification of these territories, which contribute to the persistence of situations of vulnerability for an indefinite period (Machado *et al.*, 2023).

Evaluation of the supply system from the users' perspective

Based on the collected data, approximately 93% of the residents used the micro water supply system implemented in the locality as their main source of water, while the remaining 7% rely on surface water from the river. Notably, no household with an artesian well was identified in the community under study.

These results corroborate the study by Medeiros and Silva (2025), in which the authors found that, in the Aldeia Esperança community, the main source of water supply corresponds to the microsystem installed by the public authorities, being used by 96% of the respondents as the primary source for domestic consumption. Only 4% of the residents reported using a combination of the microsystem and household wells to meet their water needs.

Data from the Demographic Census indicate that, in rural areas of Brazil, 72.5% of the population obtains water from alternative sources, while only 27.5% is served by a public distribution network (Raid *et al.*, 2022), a scenario that differs from that observed in the community under study, where collective supply through a microsystem predominates.

In rural areas, the drilling shallow groundwater wells generally constitutes the first alternative for locations that do not have surface water abstraction, due to the ease of construction, operation, and maintenance (Ventura & Guimarães, 2022), which also differs from the context analyzed, in which this solution was not identified.

Furthermore, in the Northern Region, the lowest proportion of households connected to the public water supply network is observed, at 54.5%, highlighting regional inequalities in access to this essential service (IBGE, 2011).

In order to understand water storage practices in the community, respondents were asked about the type of reservoir used in their households. The results indicated that 60% of

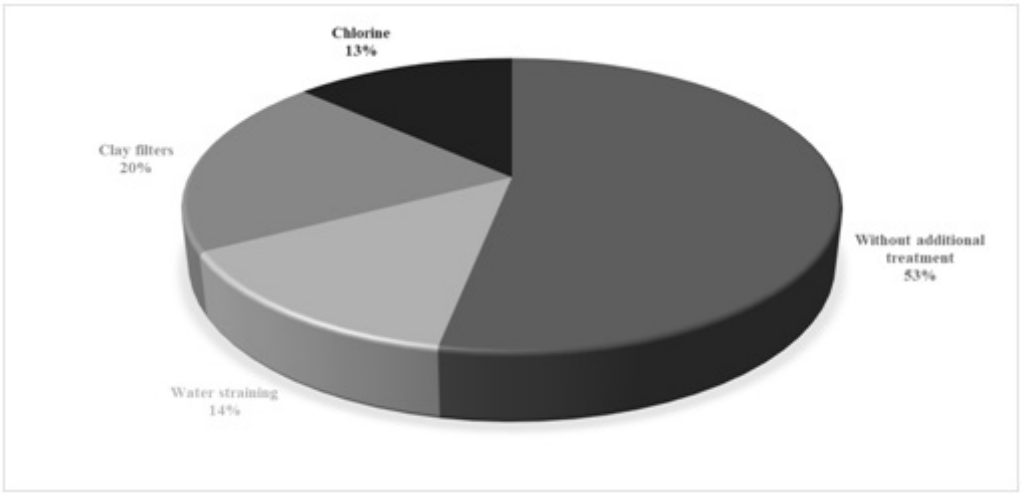
the residents consume water directly from the distribution network, without the use of intermediate storage, whereas 40% use polyethylene tanks for storage before consumption.

Residents who use storage tanks demonstrate a more effective strategy for ensuring the continuity of water supply, especially during temporary system interruptions. This practice is reflected in the report of one of the respondents, who highlighted the prior communication provided by the person responsible for the microsystem during maintenance or cleaning periods, allowing families to store water in containers such as buckets and basins.

Similar results were identified by Figueira and Guimarães (2021) in the Arapiranga community, on the Arapiuns River, where residents reported the adoption of different forms of storage, such as water tanks, jerry cans, bottles, and other containers, as a strategy to cope with possible interruptions in supply.

Regarding the treatment procedures adopted by residents after water distribution for final consumption, a predominance of low-cost and operationally feasible alternatives for the community context was identified. The treatment methods used by the users of the micro water supply system are presented in Figure 3.

Figure 3. Water treatment methods for human consumption adopted by users of the water supply system in the São Francisco Community, in the Lago Grande Agro-Extractive Settlement Project (PAE Lago Grande), municipality of Santarém, Pará, Amazon, Brazil.



Source: Authors (2026)

The majority of residents (53%) consume water without performing any additional treatment, indicating a high level of dependence on the quality of the water supplied directly by the distribution system. This situation reflects a sensitive scenario regarding water and sanitary safety, as possible inadequacies in the supply process may expose the population to health risks, especially in contexts marked by structural vulnerabilities and limitations in basic sanitation services.

Santos, Paes, and Pessoa (2023) emphasize that a portion of the population associates good water quality with its sensory characteristics, such as the absence of color, smell and taste; however, these attributes alone do not guarantee the potability of water intended for human consumption, as sanitary safety requires the complete absence of pathogenic microorganisms.

In this context, Ordinance GM/MS No. 888/2021 is highlighted, as it establishes drinking water quality standards for human consumption in Brazil. The regulation determines that all water intended for consumption must meet specific quality requirements, encompassing physical, chemical, microbiological, and organoleptic parameters, in addition to the monitoring cyanobacteria, cyanotoxins, and radioactivity.

The relevance of drinking water quality is directly related to the prevention of waterborne diseases, which represent a significant public health problem, as the presence of pathogenic microorganisms, such as bacteria, viruses, protozoa, and helminths, may result in various clinical manifestations, including acute diarrhea, dysentery, intestinal infections, fever, body aches, headache, general malaise, loss of appetite, and different types of helminth infections, reinforcing the need for strict control of the quality of water intended for human consumption (Santos; Paes; Pessoa, 2023).

In scenarios characterized by precarious sanitation infrastructure, individual or decentralized alternatives may play a relevant role in mitigating these risks (Cunha *et al*., 2024). In this context, Social Technologies (ST) emerge as promising strategies, as they are based on the collective construction of knowledge, integrating technical expertise and local experiences, and fostering community ownership of the adopted solutions, thereby promoting processes of social innovation, inclusion, and strengthening socio-environmental justice (Batista; Neu, 2024).

These technologies have central purpose addressing the needs of socially vulnerable populations through the development of solutions based on participatory processes that prioritize social inclusion and the creation of technoproductive arrangements compatible with the socioeconomic, cultural, and territorial conditions of the communities involved, and have been especially disseminated in countries in Asia, Africa, and Latin America (Tahin; Silva; Lobo, 2022).

An example of this approach is the initiative "Water security and decentralized basic sanitation through social technologies in the Insular Region of Belém," analyzed by Batista and Neu (2024). Developed through university research and extension activities, the experience integrated scientific and traditional knowledge to address the challenges of basic sanitation in the riverside community of Furo Grande.

Over more than a decade of implementation, ST was applied to ensure safe water supply and treat domestic wastewater, highlighting the potential of these solutions to strengthen the relationship between Science, Technology and Society (STS) and promote context-specific responses to local demands (Batista; Neu, 2024).

Among users who adopt any water treatment method, the use of clay filters was the most frequently reported (20%), followed by water straining (14%) and the use of chlorine or sodium hypochlorite (13%).

The clay filter, as described by Fernandes *et al*. (2015), operates by gravity, allowing water to pass through the filter candle and be stored in the lower compartment, with advantages including low cost, operational simplicity, and cultural acceptance.

Silva (2023) identified, in communities and villages located within a protected area in Santarém, Pará, the predominant use of sodium hypochlorite as a method of water treatment, applied mainly in the community distribution system, in addition to practices such as sedimentation and boiling carried out at the household level.

A study conducted by Gomes *et al*. (2022) identified that, in riverside communities of the Central Amazon, simple household water treatment practices are still widely used, with filtration through cloth being particularly notable, either combined with or without the use of sodium hypochlorite. According to the authors, approximately 20% of households adopt the combination of cloth straining and chemical disinfection, while about 12% rely exclusively on cloth filtration as a treatment method.

The technique of cloth filtration, traditionally employed in Asian countries, has the capacity to remove particles larger than 20 µm and, when performed using multiple layers (up to 12), can reduce water turbidity by approximately 50% (Gomes *et al*., 2022).

In this context, this practice is recommended as a pre-treatment step, especially when combined with subsequent disinfection methods, such as solar disinfection (Gomes *et al*., 2022). Thus, for families that rely on cloth straining as a treatment strategy, the adoption of a complementary disinfection step after filtration becomes essential to ensure greater efficiency in the removal of microorganisms and enhance the safety of water intended for human consumption.

In alternative collective supply systems, such as rural microsystems, Ventura and Guimarães (2022) highlight that although treatment techniques can be adopted by the population itself, there is always a risk that the procedures will not be carried out properly or consistently, thereby compromising their effectiveness.

This limitation reinforces the need for structured actions to ensure the quality of the water consumed, especially in communities that rely exclusively on this type of system. In this context, it becomes essential not only to carry out systematic monitoring of the water used in the São Francisco Community, but also to implement educational strategies that promote awareness, particularly in the school environment, about the risks associated with the consumption of contaminated water and safe water use practices.

As highlighted by Silva Neto *et al.* (2025), educational actions play a strategic role in fostering a preventive culture, contributing to the reduction of health problems and strengthening collective responsibility regarding water use.

From this perspective, university extension projects developed by Higher Education Institutions (HEIs) play a central role in the production and dissemination of scientific and technological knowledge aimed at local development, as they act as a link between the results of academic research and the real demands of society and, also constitute important spaces for practical and civic training for students (Sousa *et al*., 2025a).

Such actions are aligned with the principles of the National Environmental Education Policy, established by Law No. 9.795 of April 27, 1999, and updated by Law No. 14.926 of July 17, 2024, which advocates the democratization of environmental information, the promotion of social participation, interinstitutional cooperation, and the integration of science, technology, and education, encompassing both formal and non-formal education.

The relevance of the integration of extension activities into the curriculum and the continuity of projects that articulate science, education, and social commitment are reaffirmed. Initiatives of this nature constitute effective pathways for consolidating critical environmental education aimed at promoting socio-environmental justice and strengthening university engagement committed to the transformation of local realities (Sousa *et al*., 2025b).

FINAL CONSIDERATIONS

The results of this study showed that the existence of the water supply microsystem in the São Francisco Community represents a significant advance in terms of physical access to water for human consumption, especially in a rural Amazonian context historically marked by structural limitations and exclusion from public sanitation policies. However, the findings demonstrate that quantitative access to water alone does not ensure adequate conditions of water and sanitary safety, as technical, operational, and institutional weaknesses persist that compromise the quality of the water consumed by the population.

The absence of a treatment and disinfection system integrated into the microsystem constitutes the main vulnerability identified, especially considering that more than half of the residents consume water directly from the distribution network without adopting any form of household treatment. This condition increases the community's exposure to risks associated with waterborne diseases, particularly in a context characterized by the absence of systematic water quality monitoring and the high dependence on the collective system as the sole source of supply.

It was also observed that a portion of households does not have domestic storage tanks, which increases the system's sensitivity to operational interruptions and limits the capacity to cope with emergency situations. Although alternative treatment practices are adopted by some residents, these strategies have limited sanitary effectiveness when applied in isolation or without technical guidance and are not sufficient to continuously ensure the potability of the water consumed.

Given this context, it becomes essential to incorporate a simplified water treatment system into the existing microsystem, with emphasis on disinfection by chlorination, combined with the implementation of periodic water quality monitoring routines, in accordance with Ordinance GM/MS No. 888/2021. Additionally, strengthening community management is recommended, with technical and institutional support from public authorities, in order to ensure the operational, financial, and sanitary sustainability of the system over time.

The results also highlight the importance of continuous sanitary and environmental education actions, especially within community and school settings, as a fundamental strategy for building a preventive culture, increasing risk perception associated with the consumption of untreated water, and promoting the proper use of low-cost social technologies. In this context, the strategic role of Higher Education Institutions and university extension projects stands out in articulating science, technology, and social demands, contributing to the development of contextualized and socially appropriate solutions.

It should be noted that the results presented must be interpreted in light of the limitations inherent to the methodological design adopted. As this is a case study, the findings reflect a specific reality conditioned by the socio-environmental, institutional, and operational characteristics of the São Francisco Community and are not directly generalizable to other rural or riverside communities in the Amazon. In addition, the sample included approximately 55% of the community's families, which, although representative of the local context, may not encompass the full range of existing perceptions and practices.

Additionally, the study did not include laboratory analyses of water quality, being limited to the structural assessment of the system and to users' perceptions regarding the forms of supply, storage, and treatment adopted. This limitation highlights the need for future studies that incorporate physicochemical and microbiological monitoring of the distributed

water, as well as comparative approaches across different communities, in order to enhance the robustness of the results and support more comprehensive public policies aimed at rural sanitation.

Finally, the study shows that the realization of the human right to safe drinking water in rural Amazonian communities requires not only the implementation of physical infrastructure, but also the integration of public policies, community management, sanitary education, and continuous technical support. In this regard, the results contribute to the debate on rural sanitation in Brazil by providing technical and social evidence that may guide more equitable and sustainable strategies aligned with the Sustainable Development Goals, particularly SDG 6.

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