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Performance of traditional household drinking water treatment methods used in rural Amazon

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Residents of remote areas in the Amazon often lack access to a water supply system and thus need to produce their potable water at home. This study examined the efficacy of household water treatments traditionally used by these communities to treat rainwater and river water, their predominant water sources. Samples of untreated, treated, and stored drinking water were collected from 18 households in three communities in Central Amazon, Amazonas State, Brazil. We describe the materials and practices involved and traditionally used in each treatment technique – cloth filtration (water straining), chlorination, and sedimentation, and their efficiency. In the samples we evaluate water quality analyses, as free chlorine, color, coliforms, and turbidity. The treatment steps for the separation of solids in river water were effective only for removing turbidity and apparent color. Straining river water after sedimentation had no relevant effect on water quality. Chlorination of rainwater was efficient in inactivating *Escherichia coli*; however, all samples showed some level of contamination by *E. coli*. We found a significant difference ($p < 0.05$) between untreated and treated river water turbidity, reduced by up to 22%. Untreated rain and river waters showed similar levels of microbiological contamination, close to 3.5 log CFU/100 mL of *E. coli*. Chlorine effectively removed microbiological contaminants in rainwater (median removal of 100, 44.5% of samples with <1 CFU/100 mL). Yet, this treatment was less effective for river water (94% median removal, with 11% of samples with <100 CFU/100 mL and only 5.5% with <1 CFU/100 mL found in treated water), showing a significant reduction in both cases when the Wilcoxon test was applied. Sodium hypochlorite treatment showed the best results among the techniques evaluated in this study. It can be used in remote areas where rainwater is available for consumption. Microorganism concentration increased after water underwent water straining and sedimentation processes. These results suggest that the improper handling of water containers and materials used during treatment processes leads to contamination of water. Thus, more robust outreach and educational efforts are recommended to improve remote communities' water collection, treatment, and storage practices.

KEYWORDS

waterborne diseases, SDG6, rainwater, river, water safety, Amazonia, riverine people

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1 Introduction

Universal and equitable access to safe drinking water across the globe is an international priority and is part of Sustainable Development Goal number 6, as established by the United Nations (UNICEF, 2019). In different regions of the world, urban and rural populations lack access to drinking water. In Northern Brazil, home to the Amazon biome, 25% of households are not connected to a water supply network; this is well above the national average of 8% (IBGE, 2019). Rainwater and river waters are rural populations' main drinking water sources (Cardoso, 2021; Gomes et al., 2022). The Amazon hosts high levels of biodiversity and provides ecosystem services globally, including carbon sequestration (Strand et al., 2018; Joly et al., 2019). Sustainable development is the most viable strategy for biodiversity conservation and maintaining ecosystem services. This development model concurrently seeks to improve the quality of life of local populations (Campos-silva et al., 2018; Franco et al., 2021).

The riverine people, recognized as traditional communities in Brazil, exist in a challenging environment for human development due to the annual flood pulses, waterway-only transport, long distances from urban centers, and a lack of infrastructure (de Andrade et al., 2021). Most of them live in wood-made stilt houses along the main rivers, with gain income from extractivism, fishing, agriculture, and services. Access to safe drinking water is fundamental to quality of life and is urgent for Amazonian populations.

Since the beginning of COVID-19, actions to prevent emerging diseases and new global pandemics have been urgent. Households in remote areas are in contact with wild animals, and populations are subject to zoonoses from the crossover of pathogenic organisms from wild and domestic non-human and human species (Ellwanger et al., 2020). In this context, high-quality water is a barrier to emerging diseases, as the pollution of waters, soils, and other objects also promotes widespread exposure to pathogenic microorganisms (O'Brien and Xagoraraki, 2019).

Household or point-of-use (POU) water treatment is encouraged in the absence of safe water supply systems to reduce diarrheal diseases (WHO, 2017). Nevertheless, positive effects depend on correct, effective, consistent, and continued use of these methods (Bivins et al., 2019). POU treatments are only effective when more than 90% of water consumed at home is being treated (Brown and Clasen, 2012) – or, in other words, great adherence to these practices is sustained (UNICEF, 2019). The quality of treated water is used to classify the risk level for health diseases (WHO, 2012). In the Central Amazon, many families use traditional POU practices, such as sedimentation, cloth filtrations, and hypochlorite. Sodium hypochlorite is employed by 43% of all households as the only treatment technique, and it is combined with other techniques at 25% of households (Gomes et al., 2022). Despite the widespread use of POU, its efficiency in improving water quality is unknown. Thus, this study aimed to evaluate the effectiveness of removing solids and microbial contamination of household water treatments in riverine communities from Central Amazon.

In this study we sampled water untreated and treated (through traditional household water treatment), from river and rainwater. Thus, we have identified cases where treatment techniques, and handling practices have not been effectively utilized to make the water potable and propose specific efforts that the government and institutions should undertake to enhance water quality.

2 Materials and methods

We collected POU-treated water from 18 residences belonging to three communities (Caburini, Sítio Fortaleza, and Várzea Alegre) located in a floodplain area in the middle Solimões region, Amazonas State, Central Amazon, Brazil (Figure 1). Here, we also conducted observations to learn more about household treatments.

Rainwater samples were collected during the rainy season (Dec/2021 to Feb/2022). River water samples were collected during the dry season (July to October 2022) – when families rely more heavily on this water source.

For rainwater, we evaluated three treatment techniques: cloth filtration (C), chlorine disinfection (Cl), and cloth filtration + chlorine disinfection (C + Cl). For river water, five-technique combinations were tested (all of which included at least one sedimentation step): sedimentation (S); sedimentation + cloth filtration (S + C); sedimentation + cloth filtration + chlorine disinfection (S + C + Cl); sedimentation + chlorine disinfection (S + Cl); flocculant + chlorine disinfection (F + Cl). The commercial flocculant *Water Purifier* P&G® was used as a reference, as some families in the region have had access to this treatment type since 2017 (FAS, 2019). Sodium hypochlorite, distributed by the Brazilian government, has a concentration around 2.38% of active chlorine (Ministério da Saúde, 2018).

Residents were asked to carry out daily water treatment techniques as usual. Water samples were collected at each step of the treatment process, and details about the practice were described and recorded. Drinking water samples were collected from household containers readily available for drinking, and residents described the origin and type of water treatment conducted.

Samples were placed inside sterile flasks and bags containing sodium thiosulphate when containing chlorine, transported at 4°C to the laboratory at the Mamirauá Institute (Tefé/AM) in thermal boxes, and packed and processed within 48 h after collection.

2.1 Water quality analyses

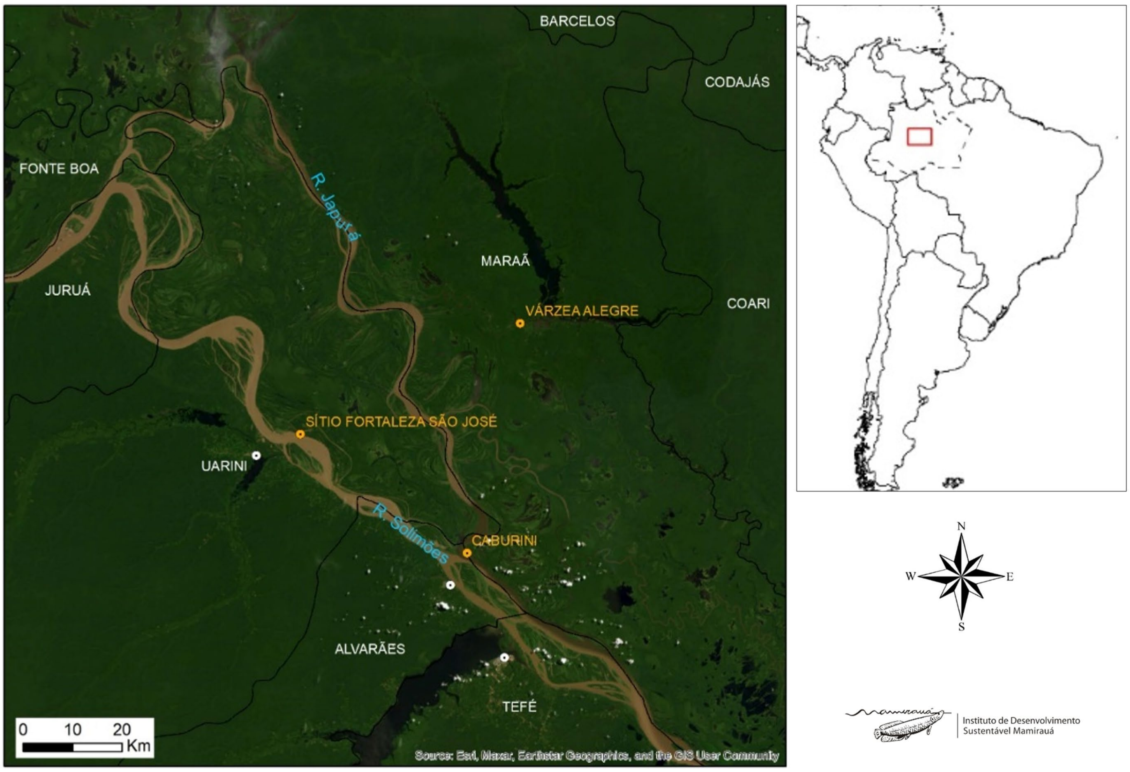
The free chlorine concentration was measured (photometer Hanna® HI 97710) between 25 and 30 min after adding sodium hypochlorite and between 20 and 30 min after mixing P&G® flocculant, as recommended by the manufacturers.

In the laboratory, we evaluated the following: true and apparent color (Hach® DR3900 spectrophotometer, 465 nm); total coliform and *Escherichia coli* [Method 9222 membrane filtration (APHA, 2005)]; turbidity (turbidimeters *Policontrol® AP2000* for rainwater and *Hanna® HI93793* for river water).

2.2 Data analysis and statistics

The concentration *of E. coli* in treated water was classified according to health risk levels, from "No Risk" to "Very High Risk" (WHO, 2012).

Data distribution was evaluated using Normal Probability charts and Shapiro–Wilk adherence test. The Wilcoxon test for paired data comparison was used to analyze the differences in quality between untreated and treated water pairs, with each type of treatment evaluated separately for river water and rainwater. A 95% confidence



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

FIGURE 1
Location map of study area in the Central Amazon with yellow points at the communities where samples were collected.

interval was considered (significant $p < 0.05$). Statistica10 software was used in the analyses.

2.3 Ethical aspects

The study was approved on ethical grounds and presented no risk to participant groups (Certificate of Presentation of Ethical Appreciation No. 42236920.7.0000.8117). Participants signed a Free and Informed Consent Form to participate in the research.

3 Results

The initial results comprise a description of the household water treatments based on the observations, followed by an assessment of their effectiveness in enhancing the quality of river and rainwater.

3.1 Description of traditionally used water treatment techniques

Cloth filter (*straining*): Rainwater is filtered at its source or POU (Figure 2A). Residents used the following fabrics: old T-shirts, cotton kitchen towels, bed linen fabrics, non-woven fabric, and cloth coffee filters; most used a single layer (no folds) of these materials. Some fabrics are used exclusively for filtering water, while others are used to dry kitchen utensils and surfaces. Families use buckets, plastic bottles, and pans as water containers. Buckets and pans are generally used for water collection and other household uses.

Chlorination: Water is treated with sodium hypochlorite solution, usually added to drinking water receptacles (buckets, bottles, etc.) or sometimes directly to the tank used to collect rainwater (Figure 2B). The chlorinated water is left to stand for at least 30 min before consumption. Doses of 0.25–1.5 drops per liter in rainwater and 1.0–2.5 drops per liter in river water were used. Some participants reported that adding more chlorine would result in a bad taste in the water.

Sedimentation: In this process, river water is collected in buckets or plastic gallons of up to 20 L in the afternoon. The water then sits at rest for 15–17 h (most commonly) up to 36 h. Water is then poured into a large storage container and is strained with a cloth filter. Water collection and sedimentation containers are not used exclusively for these purposes and may be used for other domestic activities. The recipient has a lid or is covered with cloth (Figure 2C).

Water Purifying Flocculant (P&G)®: The contents of the sachet (5 g) are added to a bucket of 10 L of water and mixed with a spoon. After mixing, residents wait for the water to settle until it becomes clear – being left for up to one night. Water is then strained into the water storage. No particular attention was paid to the recommended mixing and rest time of 20 min after straining (Figure 2D).

3.2 How effective are the household water treatment methods?

In riverine communities in Central Amazonia, river and rainwater collected by families have a high concentration of total

FIGURE 2
Household water treatments: **(A)** straining water with cloth filter C, **(B)** addition of chlorine Cl, **(C)** sedimentation process S, **(D)** P&G Water Purifier F + Cl.

coliform and *E. coli* (Table 1) and need to be treated before consumption. Raw rainwater and river water showed similar patterns concerning *E. coli* concentration, being close to 3.5 log CFU/100 mL (Table 1).

Table 2 summarizes the efficiency of the methods for each contamination. The treatment steps for the separation of solids in river water were partially effective only for removing turbidity (12–22% of turbidity) and apparent color (18–26% of apparent color). Pouring rainwater through cloth filters (water straining) (C) did not reduce any of the evaluated parameters (Table 1).

The combined sedimentation and cloth filtration method (S + C) of river water had a median removal of 12% of the initial turbidity, with a minimum value of 33 NTU for treated water (Table 1). Comparison between the S and S + C methods indicates that straining river water after sedimentation had no relevant effect on water quality; in fact, it increased turbidity concentration (from 36 to 39 NTU). Also, an increase in microorganisms was observed after sedimentation processes.

Chlorination of rainwater (Cl) was efficient in changing the water quality ($p < 0.05$) by inactivating *E. coli*, with a median of 3.46 log CFU/100 mL in untreated water and 0 log CFU/100 mL in chlorinated water. Eighty-nine percent of the chlorinated rainwater samples obtained No Risk and Low Health Risk levels (Figure 3). The median dose of Cl applied to river water was 1.2 mg/L. Chlorine was effective for rainwater disinfection (median 100%) but not for river water (median 94%).

Regarding health risks for local water consumption (Figure 3), rainwater samples treated with chlorine were classified as No Risk, Low Risk, and Medium Risk. In contrast, the other samples were distributed in the highest risk levels. Importantly, C + Cl treated rainwater samples also significantly reduced *E. coli* ($p < 0.05$).

The application of sodium hypochlorite to decanted river water (S + Cl) reduced total coliforms by 95% (Table 1) and did not result in disinfection, with 11% of the samples having <100 CFU/100 mL and 5.5% having <1 CFU/100 mL (Figure 4). The addition of the cloth filtration step (S + C + Cl) did not change the turbidity, color, or coliforms (Table 1) compared to its absence (S + Cl).

The Water Purifier® (F + Cl)—used as a comparative reference in this study—was the most effective water treatment technique. It removed 99% of turbidity (0.3 NTU in treated water), 94% of true color, and 2.39 log CFU/100 mL of *E. coli* (Table 1).

Despite the predominant preference for rainwater for drinking purposes (Table 3), with only one resident in a study household using a mixture of river and rainwater, the quality of this drinking water was unproper. Drinking water ($n = 15$) showed a level of contamination similar to that of untreated rainwater (2.9 and 3.5 log *E. coli*/100 mL). Notably, all samples, including samples treated with chlorine, showed some level of contamination by *E. coli* (Figure 3).

TABLE 1 Efficacy of traditional rainwater and river water treatments in study area.

Variables		Household water treatment type										
		Rainwater				River water						
	Measurements	Raw (*n* = 9)	C (*n* = 9)	Cl (*n* = 9)	C + Cl (*n* = 9)	Raw (*n* = 9)	S (*n* = 9)	S + C (*n* = 9)	S + C + Cl (*n* = 9)	S + Cl (*n* = 9)	F + Cl (*n* = 9)	Consumption (*n* = 16)
Turbidity (NTU)	Median (min–max)	0.3 (0–1.8)	0.8 (0–1.6)	0.4 (0–1.6)	0.8 (0–1.3)	44 (33–82)	36 (31–44)	39 (33–46)	40 (30–44)	36 (33–45)	0.6 (0.3–1.8)	0.8 (0–6.5)
	Efficiency	–	1%	6%	6%	–	16%	12%	22%	14%	99%	–
	p value*	–	0.5	0.61	0.75	–	0.01*	0.01*	0.01*	0.01*	0.01*	–
Apparent color (uC)	Median (min–max)	12 (5–43)	13 (2–42)	9 (6–13)	11 (6–23)	403 (237–565)	298 (247–387)	318 (248–401)	309 (247–377)	308 (237–379)	4.5 (0–22)	9 (0–49)
	Efficiency	–	−18%	17%	8%	–	25%	18%	26%	23%	99%	–
	p value	–	0.21	0.13	0.48	–	0.01*	0.02*	0.02*	0.01*	0.01*	–
True color (uC)	Median (min–max)	1 (0–3)	1 (0–3)	0 (0–4)	0 (0–3)	29 (24–36)	30 (18–55)	30 (20–70)	22 (16–45)	23 (16–58)	Two (0–4)	1 (0–9)
	Efficiency	–	67%	100%	100%	–	11%	7%	19%	7%	94%	–
	p value	–	0.35	1.00	0.83	–	0.81	0.64	0.09	0.44	0.01*	–
Total coliform (log CFU/100 mL)	Median (min–max)	5.43 (4.1–7.5)	5.53 (4.3–6.7)	1.00 (0–2.5)	1.11 (0–2.7)	4.2 (3.3–5.3)	4.5 (4.2–6.3)	4.7 (3.8–6.2)	2.9 (1.8–3.2)	3 (1.6–4.8)	1.4 (0–3.3)	5.4 (2.1–7.1)
	Average efficiency	–	−0.14 log −40%	4.20 log 100%	4.53 log 100%	–	−0.33 log −115%	−0.48 log −199%	1.28 log 95%	1.25 log 94%	1.45 log 99.8%	–
	p value	–	0.33	0.01*	0.01*	–	0.11	0.14	0.01*	0.02*	0.01*	–
E. coli (log CFU/100 mL)	Median	3.46 (2.7–5.2)	3.60 (2.5–5.3)	0 (0–1.4)	0 (0–1.9)	3.5 (2.3–4.0)	3.8 (3.1–4.4)	4 (2.7–5.0)	2.3 (0–3.7)	2.1 (0.9–3.3)	0.7 (0–2.6)	2.9 (0–5.9)
	Average efficiency	–	0.09 log 18%	3.46 log 100%	3.13 log 100%	–	−0.23 log −71%	−0.08 log −20%	1.24 log 94%	1.30 log 95%	2.39 log 99.4%	–
	p value		0.33	0.01*	0.01*	–	0.17	0.21	0.02*	0.01*	0.01*	–
Chlorine added (mg/L)**	Median (min–max)	–	–	1.01 (0.59–1.19)	1.01 (0.59–1.19)	–	–	–	1.19 (1.19–2.97)	1.19 (1.19–2.97)	2.18 (2.18–2.18)	–
Free chlorine (mg/L)**	Median (min–max)	–	–	1.01 (0–1.5)	1.01 (0–1.53)	–	–	–	0.08 (0.03–1.89)	0.05 (0–1.09)	0.01 (0–0.38)	0 (0–0.1)

C, cloth filtration; Cl, chlorination; S, sedimentation; F, flocculation.

*Significant *p*-values ($p < 0.05$) in the Wilcoxon test. **Untreated water (Raw), C, S, and S + C did not receive chlorine.

TABLE 2 Summary of the efficiency of traditional rainwater and river water treatments in study area.

Efficiency	Household water treatment type							
	Rainwater			River water				
	C	Cl	C + Cl	S	S + C	S + C + Cl	S + Cl	F + Cl
No/low efficient for: (0–20% turbidity and color; 0–50% microbiological)	Turbidity Apparent color True color Total coliform *E. coli*	Turbidity Apparent color	Turbidity Apparent color	Turbidity True color Total coliform *E. coli*	Turbidity Apparent color True color Total coliform *E. coli*	True color	Turbidity True color	–
Medium efficient for: (21–50% turbidity and color; 51–99% microbiological)	–	–	–	Apparent color	–	Turbidity Apparent color Total coliform *E. coli*	Apparent color Total coliform *E. coli*	–
Very efficient for: (50–100% turbidity and color; 99–100% microbiological)	True color	True color Total coliform *E. coli*	True color Total coliform *E. coli*	–	–	–	–	Turbidity Apparent color True color Total coliform *E. coli*

C, cloth filtration; Cl, chlorination; S, sedimentation; F, flocculation.

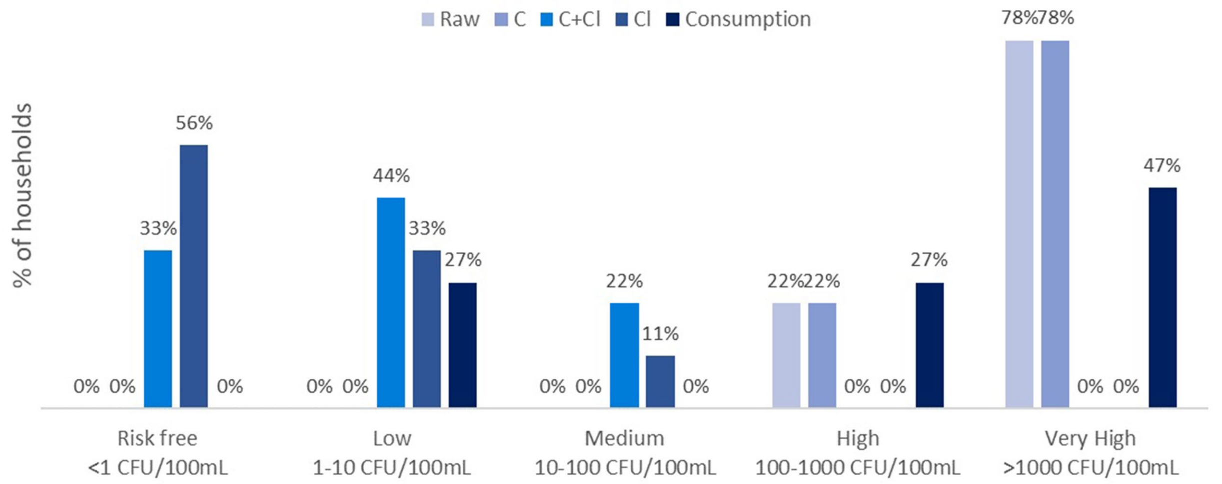


FIGURE 3
The concentration of *E. coli* in rainwater collected in the study area, grouped by WHO (2012) health risk levels.

4 Discussion

Fecal contamination of untreated rainwater (median 3.46 log CFU/100 mL *E. coli*) can occur during water collection and storage. Rainwater can become contaminated when running off roofs and into gutters (or uncovered reservoirs) by animals (bats, rats, possums, vultures) or through atmospheric pollution (Novaes and Cintra, 2013; Ahmed et al., 2014; Hamilton et al., 2019). *E. coli* bacteria deposited on rooftops in animal feces only remain active for 2 h on sunny days; however, they survive from 9 to 53 h in cloudy conditions (Ahmed et al., 2014) and can be carried to household water reserves when it rains. In water reservoirs (tanks), 90% of bacteria will become inactive (Ahmed et al., 2014) after 38–72 h, and recontamination may also occur during this period.

Water straining (C), a common POU, was ineffective and eventually damaging (Table 1) for microbiological water quality. The absence of larger suspended solids in rainwater, such as plankton (Colwell et al., 2003) for adhesion of microorganisms (Ali et al., 2011) potentially retained in the straining process, may have negatively affected the effectiveness of this method. Kotlarz et al. (2009) also reported that straining water with a single layer of fabric showed low effectiveness in reducing the turbidity of slightly turbid water. Enterobacteria are typically 2–3 μm in length and 0.6 μm in thickness (Rogers et al., 2016) – and are not removed during cloth filtration.

Positive results in straining efficacy could be obtained in the field for surface waters (rivers and lakes), with a 50% removal of turbidity using 16 layers of fabric or four folds (Ali et al., 2011). Old fabrics, which have been

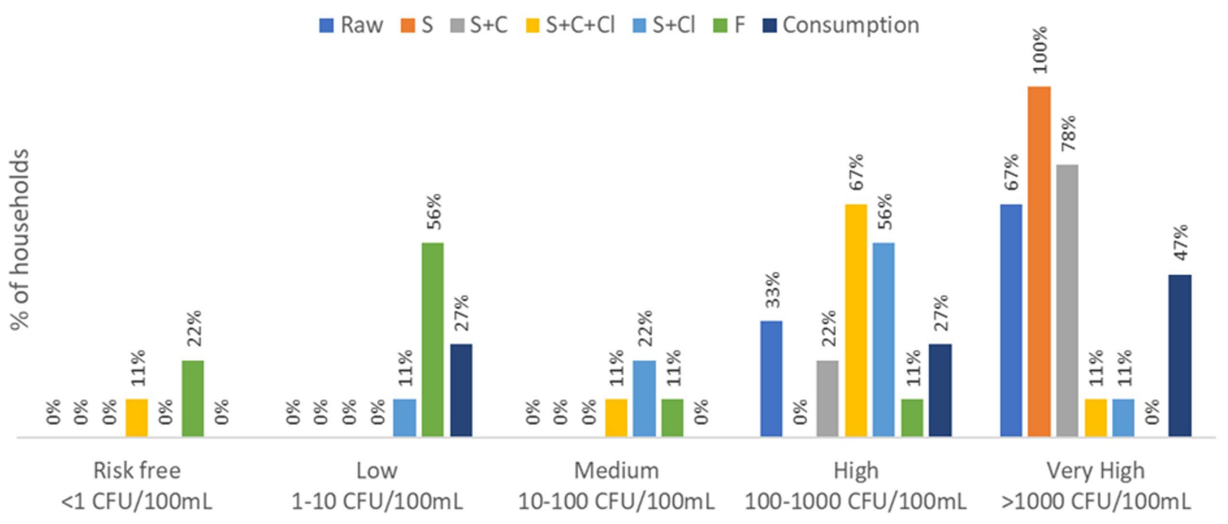


FIGURE 4
Concentration of *E. coli* in river water samples collected in the study area, grouped by WHO (2012) health risk levels.

TABLE 3 Drinking water characteristics ($n = 15$).

Feature	Values
Drinking water origin	94% rain ($n = 14$) 6% mixture of river and rain water ($n = 1$)*
Chlorine use in drinking water**	82% did not use chlorine ($n = 9$) 18% used chlorine ($n = 2$)
Chlorine dose added**	0.3–1.0 drops/L ($n = 2$) (0.3–1.2 mg/L Cl)
Presence of free residual chlorine	92% without residual chlorine ($n = 11$) 8% with residual chlorine ($n = 1$)

*Mixture of rain and river waters in the sample whose turbidity was 6.5 NTU. **According to information from the resident.

washed several times, are more effective in treating water due to the reduction in pore size (Huq et al., 2010). In this study, since fabric wear does not negatively impact the straining process of river water, the use of a single layer of fabric is likely to explain the results found. Nonetheless, as total coliform and *E. coli* quality indicators could be abundant on surfaces, objects, and fabrics under inadequate hygienic conditions, the water handling potentially altered the results of water straining (Zimmer and Dorea, 2023). For example, better fabric hygiene could be achieved by rinsing with chlorinated water or heating.

Natural sedimentation (S), for 16–18 h (overnight), reduced the apparent color (11%) and turbidity of the river water ($p < 0.05$) but had only 16% efficacy and a final value of 36 NTU above the 0.5 NTU portability limit (Ministério da Saúde, 2021). Longer settling times could change the results. With controlled values of 10–300 NTU for untreated water, sedimentation for 24 h had a 79–87% efficacy rate in reducing turbidity (Kotlarz et al., 2009).

The increased number of microorganisms after the sedimentation processes was also observed in previous studies about water storage for domestic use (Mintz et al., 1995; Yi et al., 2019). Despite the coverage of storage containers, contact with unhygienic hands and objects can lead to contamination of treated and untreated water. Microorganisms in biofilm covering the surfaces of containers, such as buckets and bottles, can survive for more than 48 h. They can also detach, becoming a continuous source of water contamination (Momba and Kaleni, 2002). Other microorganisms such as *E. coli*, *Salmonella* sp. and coliphages persist during water storage and display little growth (Momba and Kaleni, 2002). *E. coli* is a commensal bacterium that lives in the intestinal tract of humans and vertebrate animals (Berthe et al., 2013). Researchers are studying the possibility of the multiplication of these bacteria outside the intestinal tract in the case of phylogenetic groups that contain strains adapted to the conditions of the aquatic environment (Nowicki et al., 2021).

Water turbidity provides suitable conditions for bacterial multiplication through the association of nutrients with organic carbon (Momba and Kaleni, 2002; Yi et al., 2019). It is likely that, after the proliferation of bacteria immediately following water straining (with contaminated cloth), a decay process would begin due to nutrient and oxygen reduction, in addition to changes in temperature, and other factors (Allwood et al., 2003; Blaustein et al., 2013).

Removing turbidity from water before disinfection influences its efficacy, as it reduces the demand for chlorine by reducing oxidizable components in the water (Kotlarz et al., 2009). Removing turbidity through sedimentation processes and other simplified techniques can guarantee the maintenance of residual free chlorine for up to 24 h after chlorination (Kotlarz et al., 2009). Free chlorine, in turn, prevents recontamination of water during storage (WHO, 2017).

Adding sodium hypochlorite did not effectively disinfect river water due to its high turbidity (more than 31 NTU). In decanted river water (S + Cl treatment), chlorination substantially reduced *E. coli* by 95% (Table 1), but only 5.5% of the samples measured <1 CFU/100 mL (Figure 4). However, the correct chlorination dose for this turbidity level is 3.75 mg/L of chlorine (Lantagne, 2008), representing 4 drops/L addition. The Brazilian Ministry of Health recommends a standard dose of 2 drops/L – and in practice, smaller doses are used (median 1.2 mg/L). Considering that the local population rejects the taste of chlorine, it is likely that residents would disregard the recommendation to use even higher doses of chlorine.

The household treatment of river water with the best result of the risk of water consumption was sedimentation, followed by sodium hypochlorite (S + Cl) (Figure 4). This technique had the highest percentage of samples (33%) in the No risk to Medium risk classes (WHO, 2012).

The Water Purifier (F + Cl) method combines coagulation of sediments and water disinfection by the simultaneous use of ferrous sulfate and calcium hypochlorite (Souter et al., 2003), thus having advantages over the simple and natural techniques used in this study. Chemical coagulants and combination products are challenging to purchase compared to sodium hypochlorite, which is distributed free of charge by the Brazilian government. Its relative inaccessibility makes it less sustainable to use in the long term. Studies have reported a 44% reduction in *per capita* consumption of treated water 2 months after the delivery of flocculant sachets despite intensive follow-up (Shaheed et al., 2018). Using devices like filters results in greater adherence and prolonged use (Sobsey et al., 2008). Promoting a technique that depends on the continuous distribution of the product is not a viable medium/long-term solution, being more suitable for emergencies (Ariel Branz et al., 2017).

While in the region, 67% of families had reported using chlorine for water treatment (Gomes et al., 2022), this study found that only 18% of families reported using chlorine for this purpose; we detected the presence of residual chlorine in a mere 8% of samples. Brown and Sobsey (2012) also found a difference between families who stated that they boiled water (>90%) and those who boiled it (31%). In rural Peru, only 23% of the families who had reported POU water treatment consistently did so, which may indicate a failure to collect "good" data (Rosa et al., 2014), but also poor adherence to treatment or its inappropriate use.

The sodium hypochlorite distribution program (around 2.5% active chlorine solution) in Brazil is widespread and involves Community Health Agents (CHAs). Considering its wide reach and impact, we recommend further training of CHAs to raise public awareness on the proper use of chlorine. This would enhance the effectiveness of the investment and promote public health by reducing diseases and health consequences like malnutrition and child mortality. Improving and monitoring the quality of drinking water in riverine communities in Amazonia is urgent to promote the well-being of the local population. Additionally, it would improve preparedness for water access during emergencies, such as extreme droughts and heavy rainfall events, which are increasingly common in the Amazon (Flores et al., 2024).

5 Conclusion

The riverine population lives in scarcity of drinking water despite individual efforts to treat water at home. Considering the analyzed parameters, the water available could not be classified as safe for human consumption even after treatment. Therefore, emergency investment in the topic is needed, thus contributing to quality of life and health barriers for unknown emerging pathogens.

Improving the techniques used, particularly the use of hypochlorite and the straining of water (cloth filter), could potentially promote greater water treatment efficacy. Treating rainwater with sodium hypochlorite had the best results despite observing that residents were using doses below the recommended level. This thus represents the most recommended treatment of all those evaluated. No treatment effectively removed turbidity or disinfected river water. Therefore, investments are needed to improve the efficacy of removing solids from water; improvements to filters or coagulants may show promise.

Investing in education and outreach initiatives to teach proper cleaning of utensils and containers used in water treatment and storage is imperative. These measures are recommended to enhance treatment efficacy for local families, along with investments in adequate water supply infrastructure delivering potable water.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Comitê de Ética em Pesquisa Instituto de Desenvolvimento Sustentável Mamirauá Plataforma Brasil/CONEP. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MG: Writing – original draft, Writing – review & editing. LA: Writing – review & editing. MB: Writing – review & editing. BL: Writing – review & editing. CM: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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