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Quality and access to water for human consumption: a look at the state of Amazonas, Brazil

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Abstract *Surveillance indicators of the quality of water for human consumption in the Amazon were analysed from 2016 to 2020 using 185,528 samples from 11 microregions. Of the samples analysed, 93.20% were from urban areas, 66.65% were from the public water supply system (WSS), 31.02% were from the Collective Alternative Solution-CAS, and 2.33% from the Individual Alternative Solution-IAS. There was an increase in the number of records by the WSS, with a downwards trend and fluctuations in records for the CAS and the IAS. The quality indicators of chemical and physical parameters for urban areas were higher than those for rural areas and traditional communities. Most of the samples presented pH values below the recommended level. In the quantification of microbiological parameters, a higher presence of total coliforms and E. coli was identified in samples from rural areas and in traditional communities. In conclusion, there were inadequacies in the chemical, physical and microbiological parameters as well as problems related to the supply, storage and surveillance of water distributed for human consumption. These findings indicate the need to build an agenda for public management to address water insecurity and its likely effects on food insecurity in the region.*

Key words *Drinking water, Water insecurity, Water supply, Health information systems, Environmental health surveillance*

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Introduction

Drinking water is a fundamental human right and is included in the sixth objective of the Sustainable Development Goals (SDGs) of the 2030 Agenda, proposed by the United Nations in 2015, of which Brazil is a signatory; the objective consists of the universal guarantee of the sustainable management of water and sanitation[1]. Amazonas fits not this general context; despite being one of the Brazilian states with the greatest abundance of water resources, there is a lack of sufficient public service to allow equal access to water for the population[2], compromising quality parameters (chemicals, physical and microbiological) based on the criteria recommended by regulatory agencies[3,4].

Since 1997, the right to equal access to water has been protected by the Water Resources Policy (PNRH) (Federal Law No. 9,433/1997), which established actions to mitigate problems related to access to drinking water in sufficient quantity and of compatible quality with the expected potability standard (Consolidation Ordinance GM/MS No. 5, of September 28, 2017, and Ordinance GM/MS No. 888, of May 4, 2021)[5]. The National Program for the Surveillance of the Quality of Water for Human Consumption (Vigiagua) is notable, and its main instrument is the Surveillance Information System of the Quality of Water for Human Consumption (Sisagua), which allows local managers to monitor data on the quality of water for human consumption and the management of health risks[5,6].

In addition to Sisagua, information on water supply is available via the National Sanitation Information System (SNIS) or through population surveys, such as the National Household Sample Survey (PNAD) and, recently, the National Survey on Food Insecurity in the Context of the COVID-19 Pandemic in Brazil[2], which revealed that in 2022, there was a 12% restriction of access to household water (water insecurity – WI). Notably, 65% of these households also lived with moderate and severe food insecurity (quantitative food restriction), with a greater impact in the North region (48.3%)[2].

According to the Organic Law on Food and Nutrition Security (LOSAN – No. 11,346, of September 15, 2006), access to water and measures to minimize the risk of shortage of drinking water are premises for the promotion of Food and Nutrition Security (FNS) and for the guarantee of the Human Right to Adequate Food[7]. Based on the guidelines of the Unified Health System (SUS), water surveillance is based on the construction of an information system that enables the monitoring of indicators and facilitates social participation in ensuring water quality, which is one of the major monitoring challenges[3].

The interrelationship between WI and FI harbours potential threats to safe access to food, increasing the chances of occurrence of foodborne diseases (FBDs)[8] and damage to physical and mental health and nutrition[9], compromising the prevention, treatment, and control of COVID-19[10,11]. Furthermore, water security, an incipient concept in the field of food and nutrition, plays an important role in guaranteeing HRAF[12]. Thus, monitoring the quality of water for human consumption in Brazil is strategic for managing the conditions of access to this natural resource by monitoring agents harmful to potability[3,13].

The objective of this study was to analyse surveillance indicators of the quality of water for human consumption in the State of Amazonas from 2016 to 2020, seeking to identify connections with WI in this population.

The unprecedented nature of this study lies in the fact that it is the first to discuss population water security in terms of microbiological, supply, distribution and surveillance aspects using information available in national public databases. It starts from the premise that the availability of water, in quantity and quality, is an important protective factor against food insecurity, especially in vulnerable populations in the state of Amazonas, already subjected to such a situation. This investigation, therefore, makes it possible to fill a knowledge gap by revealing the paradox of the inexistence of sufficient drinking water for human consumption in the region with the greatest water abundance in the country.

Methods

Study design

This was a cross-sectional, exploratory-descriptive and analytical study with secondary data from samples of water distributed for human consumption in the state of Amazonas, covering the period from 2016 to 2020.

Study area

The state of Amazonas has a territorial area of 1,559,167.878 km^2, with an estimated population of 4,269,995 inhabitants in 2021 [14], distributed among 62 municipalities.

Database

Open access public Sisagua databases made available by the Ministry of Health were used. The dataset and the dictionary of Sisagua variables were obtained by consulting and searching the Brazilian Open Data Portal (available at https://dados.gov.br/dataset?tags=SISAGUA – accessed on 12/13/2021 and 12/15/2021). Data from 185,528 samples were available for 2021, the time of data collection (Figure 1).

Statistical analyses [

Descriptive analyses, i.e., calculation of absolute (N) and relative (%) frequencies, were performed for the variables, which were categorized into form of supply (water supply system – WSS; collective alternative solution – CAS; and individual alternative solution – IAS); area (urban, rural, traditional community and unidentified); location (public/private institutions, households, commercial establishments, other and unidentified); origin of collection (water treatment plant, intrahousehold/building, collection point, distribution system and alternative solution); reason for collection (routine, complaint, disaster and outbreak); and institution responsible for management where the sample was collected (public, private, nongovernmental organization – NGO and unidentified).

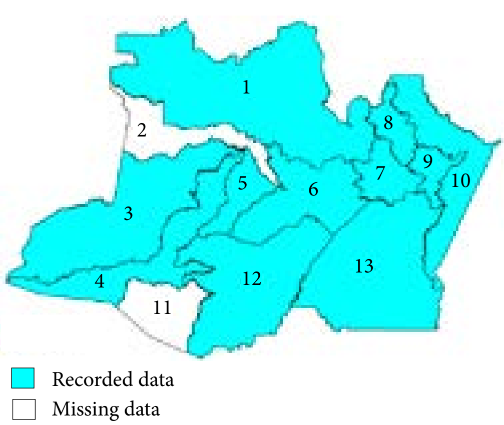

Figure 1. Microregions of the state of Amazonas with information records in the Surveillance Information System of the Quality of Water for Human Consumption – Sisagua – from 2016 to 2020. Amazonas, Brazil, 2023.

Source: Authors.

The chemical, physical and microbiological parameters selected were consistent with those established in Consolidation Ordinance No. 5/2017 (Brasil, 2017), and the following classifications were used:

A) Free residual chlorine (mg/L) – adequate, between 0.2 mg/L and 5 mg/L; inadequate, \lower than 0.2 mg/mg or above 5 mg/L;

B) Fluoride (mg/L) – adequate, between 0.6 mg/L and 1.5 mg/L; inadequate, lower than 0.6 mg/L or above 1.5 mg/L;

C) Apparent colour (uH) – adequate, maximum of 15 uH; inadequate, greater than 15 uH;

D) Turbidity (uT) – adequate, maximum of 5 uT; inadequate, greater than 5 uT;

E) pH – adequate, between 6.0 and 9.5; inadequate, lower than 6.0 or above 9.5;

F) Total coliforms –absence or presence of microorganisms; and

G) *Escherichia coli* –presence or absence of microorganisms.

The chemical and physical parameter data did not follow a normal distribution, as verified by the Shapiro-Wilk tests. Therefore, to measure the difference between the medians of the parameters, the Mann-Whitney test was applied.

A Prais-Winsten generalized linear regression model was used to evaluate the temporal variation trends for the percentages pertaining to water supply and area. In the design of the regression models, the classifications of supply and area were defined as dependent variables, and year of registration was defined as the independent variable. The annual percentage change and 95% confidence interval (95%CI) were calculated to estimate trends, considering the coefficients *b minimum* and *b maximum*, using the following equations:

$EPV = [-1+e^{b}] * 100\%$

$95\%\ CI = [-1 +^{\text{minimum } 10\ b}] * 100\%\ [-1 +^{\text{maximum } 10b}] * 100\%$

All statistical analyses were performed using Stata software, version 15.1 (StataCorp – College Station, Texas, USA), adopting a significance level of 5% ($p \leq 0{,}05$).

Ethical aspects

Because the data in this study were obtained from secondary databases in the public domain, without the possibility of individual identification, this study was exempt from approval by the Committee of Ethics in Research with Human Beings/National Committee for Ethics in Research (CEP/CONEP), in accordance with Resolution No. 510/2016 of the National Health Council.

Results

Characteristics of water samples recorded in Sisagua

From 2016 to 2020, 185,528 samples of water for human consumption from the 11 microregions of the state of Amazonas were analysed; no records were found for Japurá (2) and Boca do Acre (11) (Table 1). Most samples were from urban areas (93.20%), with only 2.74% from rural areas and 1.25% from traditional communities. Regarding the form of supply, the WSS – public system – accounted for 66.65% of the samples, the CAS accounted for 31.02%, and the IAS accounted for 2.33%.

The trend analysis showed an increase in the number of WSS records, with an annual percentage variation (APV) of 2.57%, and a decrease in the number of CAS records, with an APV of 2.58%) in the same period. There were also fluctuations in the number of IAS records, for both urban and rural areas, and a decrease in the number of sample collection records for traditional communities (Table 1).

Quality of water samples recorded in Sisagua based on chemical, physical and microbiological parameters

Table 2 shows the classifications of the chemical and physical parameters of the water samples collected in the Amazon, stratified by area and form of supply. There was a high percentage of samples classified as unsuitable for free residual chlorine, especially in rural areas (83.22%) and in traditional communities (74.11%). The samples collected via the WSS and CAS showed adequacy percentages of 52.16% and 52.26%, respectively. For the WSS samples, 72.41% were adequate for fluoride concentration, unlike those obtained from the CAS, 99.83% of which were inadequate for the same parameter. For the evaluation by location, 65.04% of the samples from urban areas had adequate fluoride levels. There were no records for fluoride in samples from rural areas and traditional communities (Table 2).

Regarding the physical parameters of water potability, the IAS samples had higher percentages of suitability for apparent colour (98.59%), with lower percentages for WSS (996.73%) and CAS (94.62%) samples. In the analysis by location, 97.10% of the samples collected in urban areas had adequate apparent colour; in rural areas and in traditional communities, 82.01% and 89.13% of the sample had adequate apparent colour, respectively (Table 2)

For the turbidity analyses, 95.47% of the WSS samples had adequate values. In the evaluation of the same parameter for CAS and IAS samples, 95.18% and 94.62%, respectively, had adequate values. Most samples from urban areas (96.34%) had adequate turbidity (Table 2). Most WSS samples (62.15%) and samples from urban areas (59.92%) were not within the pH range recommended by Brazilian legislation (Table 2).

In the quantification of the microbiological parameters of the water samples collected in the Amazon (Table 3), there was a greater presence of total coliforms in samples from the CAS (31.59%) and IAS (32.74%) than in samples from the WSS (16.77%). When the samples were analysed by distribution area, the presence of total coliforms was higher in rural areas (20.86%) and in traditional communities (55.97%). For *E. coli*, the presence was higher in IAS samples (11.79%) and in samples from traditional communities (21.52%).

Discussion

Quality aspects of water distributed for human consumption in the state of Amazonas

Of the 185,528 samples of water for human consumption analysed between 2016 and 2020, in two of the 13 microregions of the state of Amazonas, there was underreporting of information through Sisagua. The location with underreporting included the municipalities of Japurá and Maraã, with approximately 20,979 inhabitants and a population density of 0.3 inhab/km², and the municipalities of Boca do Acre and Pauini, with a population of 53,734 inhabitants and a population density of 0.8 inhab/km²[15]. This finding is a cause for concern, as the recording of information is of particular relevance for guiding actions and decision-making inherent to public management and for ensuring safe access to sufficient water, in physical-chemical and economic

Table 1. Trend analysis of sample collection percentages by type of supply and distribution area of water for human consumption registered in Sisagua from 2016 to 2020. Amazonas, Brazil, 2023.

		Total	2016	2017	2018	2019	2020	APV (%)	95%CI	p value	Trend
Supply method											
WSS*	Total	123,648	16,950	24,753	21,507	35,497	24,941				
	(%)	66.65	60.46	65.83	64.06	66.99	74.83	2.57	0.49; 4.65	0.03	Increase
CAS*	Total	57,550	10,405	12,069	11,269	16.637	7,170				
	(%)	31.02	37.11	32.10	33.56	31.4	21.51	-2.58	-4.88; -0.28	0.04	Decrease
IAS*	Total	4,330	681	779	798	853	1,219				
	(%)	2.33	2.43	2.07	2.38	1.61	3.66	-0.05	-0.17; 0.08	0.25	Fluctuation
Area											
Urban	Total	172,908	26,430	34,982	30,154	49,753	31,589				
	(%)	93.20	94.27	93.03	89.81	93.9	94.78	0.2	-1.40; 1.79	0.72	Fluctuation
Rural	Total	5,089	653	993	1,431	1,403	609				
	(%)	2.74	2.33	2.64	4.26	2.65	1.83	-0.1	-0.87; 0.67	0.72	Fluctuation
Traditional communities	Total	2,328	528	414	594	438	354				
	(%)	1.25	1.88	1.10	1.77	0.83	1.06	-0.18	-0.32; -0.04	0.03	Decrease
Unidentified	Total	5,203	425	1,212	1,395	1,393	778				
	(%)	2.80	1.52	3.22	4.16	2.63	2.33	0.1	-0.94; 1.14	0.77	Fluctuation

*Water Supply System – WSS; Collective Alternative Solution – CAS; Individual Alternative Solution – IAS.

Source: Authors based on the analysis of data from Sisagua, 2023.

Table 2. Classification of chemical and physical-chemical parameters of water quality, according to the form of supply and area, Sisagua from 2016 to 2020. Amazonas, Brazil, 2023.

	WSS				CAS				IAS			
Parameter	No.	Adequate (%)	No.	Inadequate (%)	No.	Adequate (%)	No.	Inadequate (%)	No.	Adequate (%)	No.	Inadequate (%)
Free residual chlorine (mg/L)	8,977	52.16	8,232	47.84	1,536	52.26	1,403	47.74	-	-	-	-
Fluoride (mg/L)	3,569	72.41	1,36	27.59	1	0.17	578	99.83	-	-	-	-
Apparent colour (uH)	12,123	96.73	410	3.27	3,272	94.62	186	5.38	491	98.59	7	1.41
Turbidity (uT)	20,803	95.47	986	4.53	10,701	95.18	542	4.82	949	94.62	54	5.38
pH	6,830	37.85	11,217	62.15	3,281	48.71	3,455	51.29	394	68.64	180	31.36
	Urban				**Rural**				**Traditional communities**			
	No.	Adequate (%)	No.	Inadequate (%)	No.	Adequate (%)	No.	Inadequate (%)	No.	Adequate (%)	No.	Inadequate (%)
Free residual chlorine (mg/L)	10,413	52.97	9,246	47.03	49	16.78	243	83.22	51	25.89	146	74.11
Fluoride (mg/L)	357	65.04	1,919	34.96	-	-	-	-	-	-	-	-
Apparent colour (uH)	15,422	97.1	461	2.9	155	82.01	34	17.99	82	89.13	10	10.87
Turbidity (uT)	30,131	96.34	1,145	3.66	841	84.86	150	15.14	489	92.97	37	7.03
pH	9,465	40.08	14,149	59.92	476	70.83	196	29.17	148	50.68	144	49.32

Source: Authors based on the analysis of data from Sisagua, 2023.

Table 3. Classification of microbiological parameters of water quality in Amazonas based on form of supply and area, Sisagua, 2016 to 2020. Amazonas, Brazil, 2023.

Variables	Total coliforms				P value	E. coli				P value
	N	Absence (%)	N	Presence (%)		N	Absence (%)	N	Presence (%)	
Supply method					<0.001					<0.001
WSS	20431	83.23	4116	16.77		23600	96.79	785	3.21	
CAS	11066	68.41	5111	31.59		15036	93.63	1023	6.37	
IAS	754	67.26	367	32.74		995	88.21	133	11.79	
Area										
Urban	30328	78.14	7992	20.86	< 0.001	36706	96.17	1462	3.83	<0.001
Rural	695	46.68	794	53.32		1263	86.92	190	13.08	
Traditional communities	269	44.03	342	55.97		474	78.48	130	21.52	
Unidentified	959	67.3	466	32.7		1248	88.7	159	11.3	

Source: Authors based on the analysis of data from Sisagua, 2023.

terms, for individual, household and economic use[16].

In the North region, only 57.5% of the population is covered by the public WSS, in contrast, in other regions of the country, approximately 90% of the population is served[17]. As reflected in the results of this study, failures in the water supply and basic sanitation service in the state of Amazonas reveal historical disparities between Brazilian geographic regions, creating challenges in the guarantee of universalization of sanitation services.

Most of the samples analysed were from urban areas, and most samples were from the WSS, followed by the CAS. It is the responsibility of the water supply service providers to report sample information, with the data passed on to the health sector or entered directly into Sisagua. The reporting of IAS data is the responsibility of Vigiagua professionals in municipalities, suggesting the incipient nature of the programme's actions in the state of Amazonas.

A previous study identified a low proportion of records for municipalities in the interior of Amazonas in Sisagua, compared with the proportion of records for the geographical microregion of Manaus, noting technical-operational obstacles, problems related to management, a low number of sample collections, and insufficient data analysis and use of instruments for georeferencing information[4]. Deficiencies in the information records directly affect the construction of indicators for monitoring the SDGs and the goals of the National Basic Sanitation Plan (PLANSAB)[18].

In the Middle Solimões region of the state of Amazonas, the implementation of water supply systems to serve riverside communities has contributed to reducing the spread of waterborne diseases and to promoting improvements in household chores and personal hygiene[19].

In the interior of the State of Amazonas, localities such as the municipality of Benjamin Constant depend on the Amazonas Sanitation Company (Cosama) for the collection, treatment and distribution of water for human consumption. However, the network of old pipelines, the advance of disorderly urban development and the growth of communities have posed challenges for providing an adequate water supply[20]. In a population-based study conducted in the interior of the state of Amazonas that analysed the situation of food insecurity (FI), adversities related to access to water were identified, warning of a scenario of water insecurity, with possible influences on triggering extremely severe levels of FI in the study population[21].

Apparent colour and turbidity are parameters that measure the reflection of dispersed colloid particles and the degree of interference in the passage of light, respectively. These are indicative of the presence of suspended particles, for example, released from domestic or industrial sewage, which can be reduced via sedimentation. Low turbidity facilitates the disinfection process by reducing the shield effect, which favours pathogen-

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ic microorganisms. The increase in turbidity may be caused by poor water quality from the source, through poor treatment and by the formation of sediments and biofilms in the distribution systems[22,23].

Referencing official legislation[24], it is possible to verify noncompliance with regulations that stipulate water quality parameters. Changes in pH can be of natural origin or due to human action, involving the dumping of domestic and industrial sewage. However, water acidification can occur in water courses in the Amazon plain, with values between 4 and 6[22]. The findings of this study corroborate those found in residences located in Brazilian urban slums, i.e., noncompliance with the standards of potable water quality, increasing the risks to the health of populations and constituting a need for public policies[11].

The guarantee of microbial safety of the water supply for human consumption depends on the application of barriers, with the implementation and correct operation of a series of steps for the treatment and management of the distribution system. Disinfection serves as a crucial barrier against numerous pathogens, especially bacteria, for which chemical sanitizing agents based on chlorine are used; these agents generate toxic byproducts, such as trihalomethanes and haloacetic acids[23]. The rules on quality control of water for human consumption may differ in nature and form between countries and regions, and therefore, there is no single method of analysis and evaluation that has been universally adopted[23].

In Brazil, water quality surveillance for human consumption was only consolidated after the creation of the National Environmental Health Surveillance System (Silva), based on Decree No. 3450, of May 9, 2000, through Sisagua. The provision of data on chemical, physical and microbiological parameters theoretically facilitates public management regarding collective and alternative water supply systems, allowing interventions when water nonconformities are detected[13].

The paradox of water (in)security in the state of Amazonas

The Amazon is one of the largest freshwater hydrographic basins in Brazil; paradoxically, this does not imply safe access to water for the population[26]. The State of Amazonas, as well as the other states in the region, is challenged by a set of problems related to the availability of quality water for human consumption; these problems are the result of, among other factors, deforestation, fires, disorderly agricultural activities and mining, which all produce tailings and residues that make these water in the region unhealthy[27]. In this scenario, populations located in water territories, e.g., traditional communities, are especially affected[28]. This finding represents a major challenge that needs to be addressed.

Water insecurity occurs when any person or population group has insufficient physical, social or economic access to safe and sufficient amounts of water for consumption or use on crops, either due to barriers to access to water or due to real unavailability of this natural resource[29]. Water insecurity chronically coexists with food insecurity as the result of environmental stress associated with climate change and human action governed by private interests and population dynamics[29]. Models developed in cross-sectional studies indicate that as the availability and quality of water for domestic consumption decrease, food insecurity increases[30]. In addition, the syndemic nexus between water insecurity and food insecurity can cause harmful outcomes to human health, such as malnutrition, psycho-emotional stress and an increased risk of infectious and chronic diseases[31,32].

Given the existence of millions of people susceptible to water insecurity and food insecurity, the deleterious effects of these preventable phenomena on global public health are considerable. In low- and middle-income countries of the global South, the syndemic repercussions between access to water and food insecurity are recurrent, representing a complex burden on the health infrastructure[33].

In a study conducted in Kenya, water insecurity and food insecurity, in association with diseases such as HIV, were shown to cause depressive disorders[9,32]. Syndemic approaches suggest that food and water issues should be addressed in a combined manner. Koyratty et al.[34] indicate that both dimensions have very discrete indicators and can be evaluated separately. Importantly, water insecurity seems to be a driver of food insecurity, indicating the need for an approach based on combined interventions[33].

Links between water and food insecurity and the 2030 Agenda

We argue herein that very similar links between food and water insecurity occur in the Amazon region and that transversal dimensions are also present and can be portrayed by interdisciplinary frameworks, such as the SDGs of the 2030 Agenda. Brewis et al.[33] propose a model with contextual syndemic links for low- and middle-income countries, supported by fundamental blocks for water security, namely, socioeconomic and environmental aspects and calls for action, considering interdisciplinary dimensions for the design of public policies, such as the governance and integrated management of water resources.

The complexity of water insecurity can be decoded through interdisciplinary indicator systems, such as those present in the 2030 Agenda[1]. The indicator system consists of 17 SDGs and 169 specific targets. Figure 2 summarizes the dimensions of water security and their synergistic connections, tracing links between the two themes and the 169 goals of the 2030 Agenda. In addition, systemic connections between water insecurity and food insecurity are suggested, as well as possible approaches to mitigate this problem.

The macro aspects of the issue, covered by the 2030 agenda, affect access to drinking water (goal 6.1). These dimensions can be categorized into socioeconomic and environmental aspects. From a socioeconomic perspective, we highlight I) efficiency and equity in the use of water resources among different economic sectors (goal 6.4), II) the inclusion of tax incentives in the government agenda (goal 6.a) and III) contextualized and integrated approaches to different population contexts (e.g., rural and urban) (goal 11.1). In the environmental field, we highlight the relationship between availability and access to water and the impacts caused by climate change (goal 13.1), extreme events (goal 11.5), and the sustainable use of surface and underground water resources (goals 6.4 and 15.1).

The macro dimensions connect equitable and universal access to drinking water (goal 6.1) with the main food and nutrition agenda: access to food and means of food production (goal 2.1) and the fight against all forms of malnutrition (goal 2.2). The main systemic connections identified by this study, considering the lens of analysis of the 2030 Agenda, are related to the microbiological parameters of the samples (goals 3.3 and 3.9) and their disproportionate impact in different population contexts (urban, rural, and traditional communities) (goal 11.1), as well as the challenges of water resource management, in line with the preservation of ecosystem services (goal 15.1) provided, in this case, by the tropical forest.

The alignment of the results also indicates ways to reduce the effects of the COVID-19 pandemic, whereby the SDG goals can act as a guiding model for decision-making in public policies. The main relationships identified within the scope of the 2030 Agenda are described by the following SDG 6 goals, which aim to ensure "*the availability and sustainable management of water and sanitation for all*":

Goal 6.1: By 2030, achieve universal and equitable access to affordable drinking water for all;

Goal 6.5: By 2030, implement integrated water resource management at all levels, including through transboundary cooperation as appropriate; and

Goal 6b: Support and strengthen the participation of communities in improving water and sanitation management.

Scope and limitations of the study

In terms of scope, this is the first study to analyse the implications of water insecurity considering the form of supply, location of distribution and water quality in the state of Amazonas using information available in national public databases, a notable strength of the study. Although there was a limited amount of information recorded in Sisagua in the investigated period, it was possible to identify weaknesses in the supply and quality of water available for human consumption at the state level.

There were limitations regarding the recording of information in the Sisagua database, potentially related to the sampling method adopted. Faria et al.[35] found inconsistencies regarding the minimum number of samples collected and the representativeness of sampling points in the distribution system when analysing data from Sisagua for the metropolitan region of the state of Rio de Janeiro.

Studies based on the analysis of secondary data are subject to selection biases related to quality, number of records and ability to extract information. However, these limitations did not weaken the analyses used to evaluate the potability of water samples reported in the Sisagua[36]. In addition, the study of regional indicators favoured the deepening of the discussion on this topic, thus potentially helping in decision-making by public health surveillance services as well as in developing future investigations.

Final remarks

In a broader sense, the water distributed for human consumption in the state of Amazonas presents serious chemical, physical and microbi-

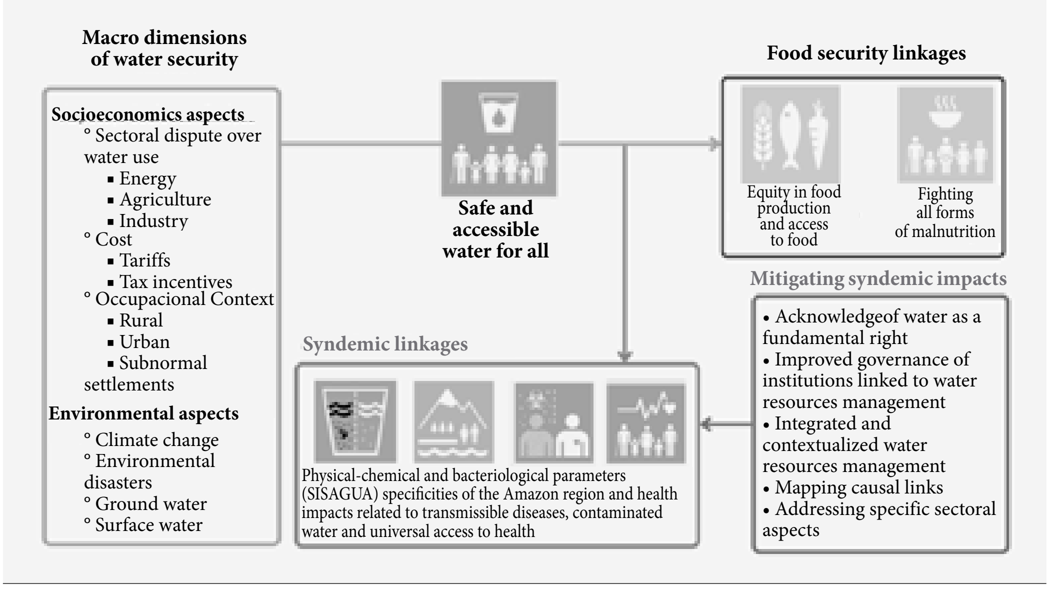

Figure 2. Conceptual model of the syndemic link between water security and food security. Amazonas, Brazil, 2023.

Source: Authors.

ological problems that compromise quality and potability, especially in locations far from urban areas or subject to alternative supply forms other than a public system. In addition, there are obstacles in supply, storage and surveillance, resulting in a scenario of water insecurity, which can negatively affect the serious situation of food insecurity already experienced by this population.

There are disparities regarding territorial coverage and the number of records for water quality surveillance in the state of Amazonas. In addition, the analysis of data obtained from Sisagua shows notable differences in water quality based on type of supply service and location of distribution.

The results presented and discussed in this study can serve as the basis of actions that promote the surveillance and control of water for human consumption, especially for improvements in the number of records and greater territorial coverage in the Amazon. Notably, there is a need for the implementation of programs and the expansion of actions for the water supply by public systems by the municipalities of Amazonas, with a view to reducing regional water insecurity and improving the monitoring of water quality.

Additionally, we suggest the development of new studies using other investigation methods, such as the international scale "*Household Water Insecurity Experiences* (HWISE)", which is capable of identifying and quantifying household water insecurity.

Collaborations

MM Mata participated in the conception, design, analysis, discussion of results, and writing and critical review of the manuscript. ABC Santana participated in the conception, design, analysis, discussion of results, and writing and critical review of the manuscript. F Martins participated in the discussion of the results and in the writing of the manuscript. MAT Medeiros participated in the conception, design, discussion of the results, and writing and critical review of the intellectual content of the manuscript. The authors approved the final version of the manuscript.

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