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Data analysis of the Water Quality Surveillance Information System for Human Consumption (Sisagua) in the state of Amazonas, 2016-2020

Análise de dados do Sistema de Informação de Vigilância da Qualidade da Água para Consumo Humano (Sisagua) no estado do Amazonas, 2016-2020

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ABSTRACT

Introduction: The evaluation of water quality parameters is fundamental for public health and disease prevention in the population. **Objective:** To perform an analysis of surveillance data of chemical, physical, and microbiological parameters to evaluate the quality of water for human consumption in the State of Amazonas, based on the Information System of Water Quality Surveillance for Human Consumption (Sisagua). **Method:** An exploratory-descriptive study based on quantitative research was carried out to analyze the quality of human consumption water and chemical, physical, and microbiological parameters, measured in water samples in the State of Amazonas, from 2016 to 2020. Nonparametric statistical tests were performed to compare differences in the proportion of each category and adequacy according to the geographic microregion. **Results:** Inland micro-regions have a lower proportion of municipalities with data recording of water quality parameters. The water samples from the microregion of the capital presented lower free residual chlorine content, higher fluoride concentration, and higher values for apparent color and turbidity. Trend analyses showed improvements in parameters for apparent color in samples obtained in the capital microregion and, for free residual chlorine, total coliforms and *Escherichia coli* in water samples collected in the interior of Amazonas. **Conclusions:** There were differences in the profile of chemical, physical, and microbiological parameters of the samples evaluated according to the locality. The need for improvements in the management of water quality surveillance is emphasized, especially related to looking carefully at the actions of analysis and supervision in the State of Amazonas.

KEYWORDS: Water; Water Supply; Basic Sanitation; Public Health Surveillance; Public Policy; Information Systems

RESUMO

Introdução: Avaliar os parâmetros de qualidade da água é fundamental para a vigilância em saúde pública e o direcionamento de ações de prevenção de doenças no âmbito populacional. **Objetivo:** Realizar a análise dos dados de vigilância de parâmetros químicos, físicos e microbiológicos para avaliação da qualidade da água de consumo humano no estado do Amazonas, com base no Sistema de Informação de Vigilância da Qualidade da Água para Consumo Humano (Sisagua). **Método:** Estudo exploratório-descritivo baseado em pesquisa quantitativa para a análise da vigilância da qualidade da água de consumo humano e de parâmetros químicos, físicos e microbiológicos nas amostras de água no estado do Amazonas, no período de 2016 a 2020. Testes estatísticos não paramétricos foram realizados para comparar diferenças na proporção de cada categoria e adequação de acordo com a microrregião geográfica. **Resultados:** As microrregiões do interior apresentam menor proporção de municípios com registro de informações sobre a qualidade da água. As amostras da microrregião da capital apresentaram menor teor de cloro residual livre, maior concentração de fluoreto, e valores superiores para coloração aparente e turbidez. As análises de tendências evidenciaram melhorias nos parâmetros para cor aparente em amostras obtidas na microrregião de capital e, para cloro residual livre, coliformes totais e *Escherichia coli* em amostras de água coletadas no interior. **Conclusões:** Houve diferenças no percentual de inadequações dos parâmetros das amostras avaliadas de acordo com a localidade. Ressalta-se a necessidade de melhorias na gestão da vigilância da qualidade da água, no que se refere ao olhar atento para as ações de análise e fiscalização no estado do Amazonas.

PALAVRAS-CHAVE: Água; Abastecimento de Água; Saneamento Básico; Vigilância em Saúde Pública; Política Pública; Sistemas de Informação

INTRODUCTION

Maintaining the safety and quality of water for human consumption, with a view to guaranteeing the right to access a product with acceptable levels of chemical and microbiological substances, is essential to providing quality of life for the Brazilian population and reducing mortality and the incidence of pathologies associated with water contamination[1,2,3].

To regulate these indices at a national level, Annex XX of Consolidation Ordinance No. 5, of September 28, 2017, of the Ministry of Health, establishes data on the potability and control and surveillance procedures of water for human consumption, as well as the powers and responsibilities of public authorities. According to this legislation, the criteria and parameters for drinking water quality must be free of pathogenic microorganisms, acceptable levels of inorganic and organic chemical substances and contain previously established physical parameters of apparent color, turbidity and acidity[4].

Water-borne diseases have caused a series of epidemiological and social disorders that can be directly related to poor hygiene and sanitation conditions, a possible reflection of the lack of compliance with public policies, limited knowledge and supervision of care with the improper disposal of contaminants and solid waste in the environment, a common scenario in developing countries such as Brazil[5,6,7,8].

Inadequate drinking water parameters constitute a risk to the population's health, as well as reflecting environmental problems, a lack of appropriate technological approaches for supply systems and a lack of active public policies. Among the risks is microbiological contamination, which can lead to parasites, acute diarrheal disease (ADD) and hepatitis[3].

In Amazonas, most of the cities are surrounded by rivers, and this natural resource is the source of survival and consumption for the population. However, research has shown that this water resource made available to the population is not always suitable for consumption, with the presence of microbiological, chemical and physical-chemical levels being diagnosed that are outside the standards set by the regulatory bodies[9,10,11].

Proposals to monitor indicators are underway, analyzing anthropogenic impacts on water quality and raising awareness of the medium- and long-term consequences of neglecting this natural resource[12,13,14].

Within the scope of public health policies, there is a confluence of bodies, public policies, agendas and normative acts that establish a network of actions and services to ensure the monitoring of the supply, quality and regulation of water for human consumption in Brazil. The National Program for Environmental Health Surveillance Related to the Quality of Water for Human Consumption (Vigiagua) follows the guidelines and guiding principles of the Unified Health System (SUS) and is articulated with the National Environmental Health Surveillance System (Sinvas), for public and private actions and services aimed at monitoring water for human consumption[15,16].

The Information System for the Surveillance of Water Quality for Human Consumption (SISAGUA) is part of Environmental Health Surveillance and is the computerized system that enables regional managers to monitor data on water quality, including the profile of areas supplied by concessionaires. The organization of this system makes it possible to take decisions on corrective and preventive measures whenever changes are noticed in the parameters assessed to indicate the areas with the greatest risk of compromised water quality[3,17].

Sisagua data is routinely obtained by health professionals working in surveillance and by managers responsible for water supply and quality control services. In this way, SISAGUA contributes to managing the risks that water contamination can cause by providing access to information on microbiological, chemical and physical-chemical reports on the potability of water throughout the country[17].

Based on the context presented, the diagnosis of the chemical, physical and microbiological parameters of water quality could contribute to the planning of monitoring actions and the prevalence and control of pathologies related to water contamination, so that a more comprehensive view can be taken of the drinking water situation in the cities of Amazonas.

The aim of this article was to analyze data on chemical, physical and microbiological parameters recorded in Sisagua to assess the quality of water for human consumption distributed in the state of Amazonas, comparing the micro-region of the capital with the other micro-regions located in the interior.

Study design

An exploratory-descriptive study based on quantitative research was carried out to analyze the chemical, physical and microbiological parameters of water samples distributed for human consumption in the state of Amazonas.

General description of the location

The state of Amazonas is made up of 62 municipalities belonging to 13 micro-regions (Rio Negro, Japurá, Alto Solimões, Juruá, Tefé, Coari, Manaus, Rio Preto da Eva, Itacoatiara, Parintins, Boca do Acre, Purus and Madeira), with an estimated population of 4,207,714 inhabitants[18]. The Manaus micro-region includes seven municipalities: Autazes, Careiro, Careiro da Várzea, Iranduba, Manacapuru, Manaquiri and Manaus. The other municipalities are part of the micro-regions that cover locations in the interior of the state.[19]

Database

Sisagua open-access public databases made available by the Ministry of Health were used, covering the period from 2016 to 2020. The data set and 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 12/02/2021 and 13/02/2021). Data from 181,198 samples from the Water Supply System - SAA (68.24%) or from the Collective Alternative Solution - SAC (31.76%). Data from samples obtained from the Individual Alternative Solution (SAI) was not included, due to the lack of control by Sisagua[20]. In addition, the samples from SAI represented only 2.34% of the samples, with more than 70% missing data for the parameters of interest in the study, including the absence of data for free residual chlorine, fluoride, apparent color and pH.

Chemical, physical and microbiological parameters

The basic water quality parameters included in Annex XX of Ordinance No. 5/2017[4] were selected for analysis, as follows: a) Free residual chlorine (mg/L); b) Apparent color (uH); c) Fluoride (mg/L); d) Turbidity (uT); e) pH; f) Heterotrophic bacteria (CFU/mL); g) Total coliforms; h) *Escherichia coli*.

Measurements involving continuous variables on chemical, physical and microbiological parameters were classified according to the median values of the parameters assessed, following the rules in Annex XX of Consolidation Ordinance No. 5/2017[4].

The free residual chlorine content was classified into three categories: (i) below recommended, with values below 0.2 mg/L; (ii) ideal recommended range with values between 0.2 mg/L and 5 mg/L; (iii) above recommended, with values above 5 mg/L.

Regarding fluoride content, the following classifications were considered: (i) below recommended, for values below 0.6 mg/L; (ii) ideal recommended range, corresponding to values between 0.6 mg/L and 1.5 mg/L; (iii) above recommended, considering values above 1.5 mg/L.

In the water potability classifications for apparent color and turbidity, samples with a maximum permitted value of 15 uH and 5 uT, respectively, were classified in the ideal recommended ranges.

The pH range of the samples was divided into three categories: (i) below recommended, with values below 6.0; (ii) in the ideal recommended range, for values between 6.0 and 9.5; (iii) above recommended, for values above 9.5.

For total *coliforms* and *E. coli*, the percentages of samples with absence of these microorganisms in the collected samples were analyzed, considering the tolerance of absence in 100 mL in 95% of the samples examined in the month[4].

Statistical analysis

The data for the chemical and physical parameters did not show a normal distribution, as verified by the Shapiro-Wilk tests. Therefore, Mann-Whitney tests were applied to measure the difference between the medians of the parameters, in order to assess possible differences between the samples analyzed according to geographical micro-region.

The Prais-Winsten generalized linear regression model was used to assess trends in temporal variation for the percentages of chemical, physical and microbiological parameter classifications. In addition, the Durbin-Watson test was applied to verify the serial autocorrelation of the percentages of each parameter analyzed. The application of this regression model is essential to prevent minor variations from being mistakenly identified as significant in water quality analysis[21]. In designing the regression models, the classifications of the chemical, physical and microbiological parameters were defined as dependent variables, while the year of recording was defined as the independent variable.

Taking these assumptions into account, the annual percentage variation was calculated for the quantitative trend estimate and determination of the 95% confidence interval (95%CI), considering the *minimum b* and *maximum b* coefficients, using the equations respectively:

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

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

Where: (APC) Annual percentage change; (*b*) beta coefficient estimated by Prais-Winsten regression to infer the annual percentage change.

The results of the statistical analyses were evaluated on the criterion of a probability of significance level of less than or equal to 5% (p ≤ 0.05). All statistical analyses and georeferenced projections using the shape file provided by the Brazilian Institute of Geography and Statistics (IBGE) were carried out using the Stata program, version 15.1 (StataCorp - College Station, Texas, USA).

Ethical aspects

According to Brazilian legislation, research using secondary data in the public domain without the possibility of individual identification will not be evaluated by the Research Ethics Committee/National Research Ethics Commission (CEP/Conep) system, according to Resolution No. 510, of April 7, 2016, published by the National Health Council. Thus, the criterion of approval by the CEP for carrying out this research does not apply.

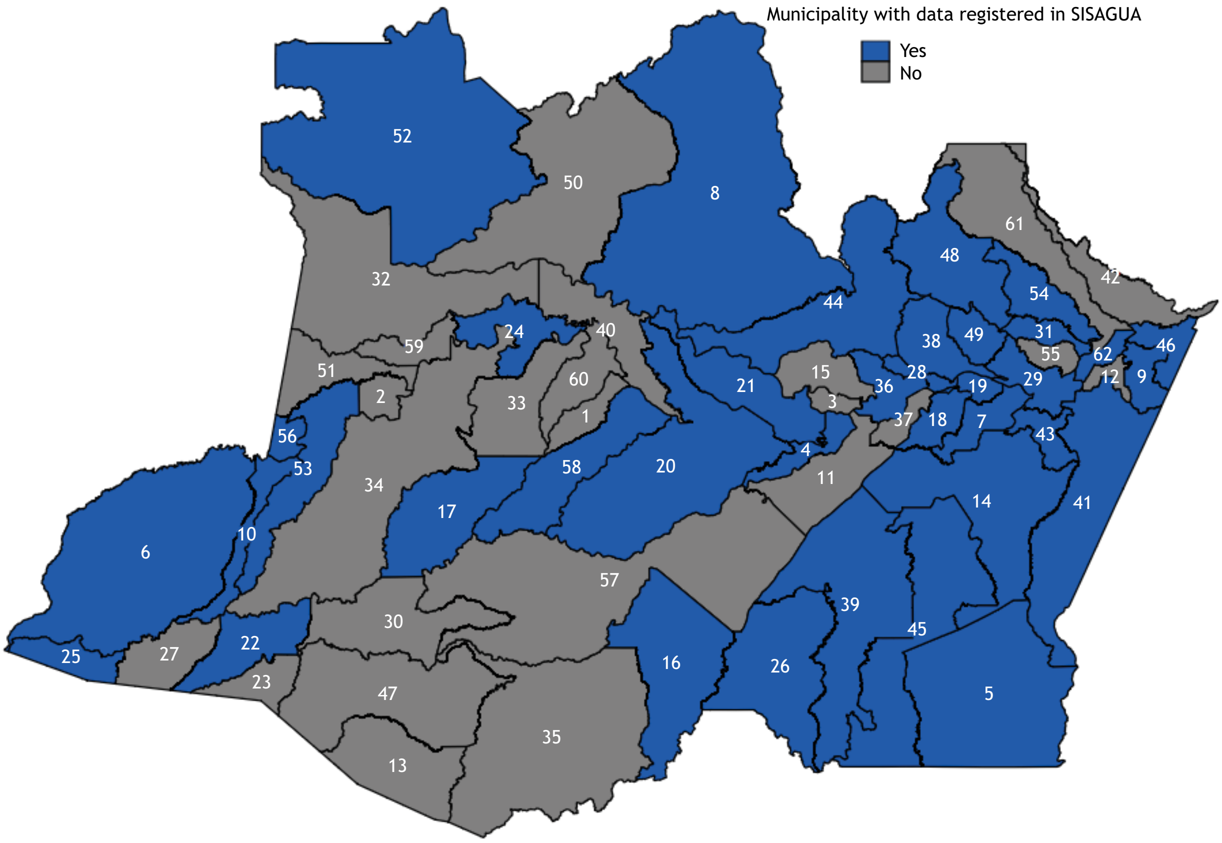
RESULTS

It was possible to see that all the municipalities in the Manaus micro-region had data recorded for monitoring basic water quality parameters (Table 1 and Figure). In contrast, only 30 municipalities (54.56%) in the inland micro-regions had data recorded in SISAGUA (Table 1 and Figure).

Table 1. Distribution of municipalities with surveillance data on basic water quality parameters registered on SISAGUA. Amazonas, 2016-2020.

Variable	Amazonas		Geographical micro-region of Manaus		Inland micro-regions	
	Total	%	Total	%	Total	%
Registered municipalities	37	59,68	7	100,00	30	54,56

Source: Prepared by the authors, 2021.



Source: Prepared by the authors, 2021.
1: Alvarães; 2: Amaturá; 3: Anamã; 4: Anori; 5: Apuí; 6: Atalaia do Norte; 7: Autazes; 8: Barcelos; 9: Barreirinha; 10: Benjamin Constant; 11: Beruri; 12: Boa Vista do Ramos; 13: Boca do Acre; 14: Borba; 15: Caapiranga; 16: Canutama; 17: Carauari; 18: Careiro; 19: Careiro da Várzea; 20: Coari; 21: Codajás; 22: Eirunepé; 23: Envira; 24: Fonte Boa; 25: Guajará; 26: Humuaitá; 27: Ipixuna; 28: Iranduba; 29: Itacoatiara; 30: Itamarati; 31: Itapiranga; 32: Japurá; 33: Juruá; 34: Jutaí; 35: Lábrea; 36: Manacapuru; 37: Manaquiri; 38: Manaus; 39: Manicoré; 40: Maraã; 41: Maués; 42: Nhamundá; 43: Nova Olinda do Norte; 44: Novo Airão; 45: Novo Aripuanã; 46: Parintins; 47: Pauini; 48: Presidente Figueiredo; 49: Rio Preto da Eva; 50: Santa Isabel do Rio Negro; 51: Santo Antônio do Içá; 52: São Gabriel da Cachoeira; 53: São Paulo de Olivença; 54: São Sebastião do Uatumã; 55: Silves; 56: Tabatinga; 57: Tapauá; 58: Tefé; 59: Tonantins; 60: Uarini; 61: Urucará; 62: Urucurituba.

Figure. Distribution of municipalities with registered data for surveillance of basic parameters of SISAGUA. Amazonas, 2016-2020.

Table 2 shows the quantifications of the chemical and physical parameters of the water samples collected in Amazonas, including analyses stratified by micro-region. In general, the water samples collected in the Manaus micro-region have a lower concentration of free residual chlorine, a higher concentration of fluoride, a higher intensity of apparent coloration and a higher turbidity than the samples obtained in the inland micro-regions.

Table 3 shows the trends in the percentages relating to the classification of the chemical, physical and microbiological parameters of water samples collected in the micro-region of Manaus. There are fluctuations in the parameters for free residual chlorine, fluoride, pH, absence of total coliforms and *E. coli*. In 2020, there was a high proportion of samples with free residual chlorine content below the recommended values. In the same year, all the samples analyzed had fluoride concentrations below the recommended values. It should be noted that during the period analyzed, most of the samples had pH values below the recommended values. There was also an upward trend in the proportion of samples within the recommended range for apparent color.

The results shown in Table 4 show fluctuations in the proportions of samples classified according to the parameters for fluoride, turbidity and pH in water samples collected in the interior of the state of Amazonas. In these locations, it was possible to observe a downward trend in the proportions of samples with a free residual chlorine concentration above the recommended level and a downward trend in the proportion of samples in the recommended range for apparent color. Considering the period from 2016 to 2020, all the samples analyzed had fluoride concentrations above or below the

Table 2. Quantification of the chemical and physical quality parameters of the water distributed to the population. Amazonas, 2016-2020.

Parameter	Amazonas			Manaus micro-region			Other micro-regions			p-value
	N	Med	IQ	N	Med	IQ	N	Med	IQ	
Free residual chlorine (mg/L)	20.148	0,20	(0,00; 0,40)	12.377	0,10	(0,00; 0,27)	7.771	0,20	(0,04; 0,6)	< 0,001*
Fluoride (mg/L)	5.508	0,72	(0,37; 0,88)	5.378	0,73	(0,44; 0,89)	130	0,00	(0,00; 0,00)	< 0,001*
Apparent color (uH)	15,991	2,40	(0,20; 5,10)	10.892	2,90	(1,40; 5,60)	5.099	0,00	(0,00; 5,00)	< 0,001*
Turbidity (uT)	33.032	0,79	(0,18; 1,60)	16.595	0,85	(0,30; 1,40)	16.467	0,66	(0,10; 2,08)	< 0.001*
pH	24.783	5,78	(5,13; 6,30)	13.635	5,60	(5,10; 5,92)	11.148	6.22	(5,20; 6,85)	< 0.001*

Source: Prepared by the authors, 2021.
N: Number of samples; Med: Median; IQ: Interquartile range: 25th percentile; 75th percentile.
(*) Mann-Whitney test used to compare the medians of the parameters evaluated in the Manaus micro-region and the other micro-regions.

Table 3. Trend analysis of the percentages for classifications of chemical, physical and microbiological parameters according to the potability standard of the water distributed in the Manaus micro-region. Amazonas, 2016-2020.

Parameter	Samples (%)					Annual variation (%)	p-value	Trends
	2016	2017	2018	2019	2020			
Free residual chlorine								
Below recommended	60,31	34,40	10,06	72,12	66,06	5,40 (-13,90; 24,71)	0,44	Oscillation
Recommended range	39,69	65,60	89,94	27,88	33,91	-5,73 (-24,80; 13,35)	0,41	Oscillation
Above what is recommended	0,00	0,00	0,00	0,00	0,04	0,01 (-0,00; 0,02)	0,14	Oscillation
Fluoride								
Below recommended	38,14	20,97	18,82	38,11	100,00	13,97 (-16,31; 44,25)	0,24	Oscillation
Ideal range	61,86	78,75	60,97	0,00	0,00	-13,99 (-42,87; 14,90)	0,22	Oscillation
Above what is recommended	0,00	0,28	2,50	0,93	0,00	0,07 (-0,83; 0,97)	0,81	Oscillation
Apparent color								
Ideal range	94,49	94,78	93,77	98,36	98,81	1,27 (0,43; 2,12)	0,02	Increase
Turbidity								
Ideal range	98,79	99,04	97,87	98,64	99,23	0,03 (-0,41; 0,47)	0,85	Oscillation
pH								
Below recommended	63,88	84,91	72,71	83,22	78,71	2,08 (-0,26; 4,40)	0,07	Oscillation
Ideal range	36,01	15,09	27,29	16,78	21,29	-2,05 (-4,36; 0,25)	0,07	Oscillation
Above what is recommended	0,11	0,00	0,00	0,00	0,00	-0,02 (-0,06; 0,02)	0,19	Oscillation
Total coliforms								
Absence	82,88	83,86	77,88	82,59	89,54	1,16 (-2,46; 4,77)	0,38	Oscillation
E. coli								
Absence	93,13	96,77	95,90	97,27	96,89	0,21 (-0,04; 0,47)	0,08	Oscillation

Source: Prepared by the authors, 2021.

Table 4. Trend analysis of the percentages for classifications of chemical, physical and microbiological parameters according to the potability standard of the water distributed in the interior of the state. Amazonas, 2016-2020.

Parameter	Samples (%)					Annual variation (%)	p-value	Trends
	2016	2017	2018	2019	2020			
Free residual chlorine								
Below recommended	41,64	65,22	45,69	36,15	19,86	-8,81 (-20,39; 2,77)	0,09	Oscillation
Recommended range	58,08	34,66	54,16	63,77	80,14	8,17 (-2,50; 18,85)	0,09	Oscillation
Above what is recommended	0,28	0,11	0,16	0,08	0,00	-0,05 (-0,08; -0,03)	0,01	Fall
Fluoride								
Below recommended	-	50,00	100,00	100,00	66,67	18,20 (-18,67; 55,07)	0,21	Oscillation
Recommended range	-	25,00	0,00	0,00	0,00	-4,60 (-13,15; 3,95)	0,19	Oscillation
Above what is recommended	-	25,00	0,00	0,00	33,33	1,52 (-15,92; 18,96)	0,80	Oscillation
Apparent color								
Recommended range	100,00	98,79	97,41	91,23	98,05	-2,12 (-2,76; -1,47)	0,005	Fall
Turbidity								
Recommended range	97,85	90,08	91,71	89,70	95,13	-0,52 (-3,23; 2,19)	0,58	Oscillation
pH								
Below recommended	25,62	52,13	19,21	49,17	31,53	0,35 (-4,26; 4,95)	0,83	Oscillation
Recommended range	74,38	47,87	80,61	50,80	68,42	-0,36 (-4,90; 4,18)	0,82	Oscillation
Above what is recommended	0,00	0,00	0,18	0,03	0,05	0,01 (-0,04; 0,06)	0,46	Oscillation
Total coliforms								
Absence	61,12	65,99	67,43	77,19	81,60	5,26 (4,11; 6,40)	0,001	Increase
E. coli								
Absence	93,52	94,02	94,31	94,90	94,73	0,40 (0,35; 0,44)	0,001	Increase

Source: Prepared by the authors, 2021.

recommended range. However, it was possible to observe an upward trend in the proportion of samples without total coliforms and *E. coli*.

DISCUSSION

This study evaluated Sisagua's surveillance data for basic parameters in the state of Amazonas, showing differences between the Manaus micro-region and the other regions in terms of the number of municipalities registered and quality measurements for chemical, physical and microbiological water potability standards.

The low proportion of municipalities in the interior of the state with information in SISAGUA in relation to the geographical micro-region of Manaus highlights aspects previously discussed in the literature, such as technical and operational obstacles to the efficient management of VIGIAGUA, possibly due to shortcomings in the registration of the various forms of water supply and in the surveillance of water supply installations, low numbers of samples collected, deficiencies in data analysis and geo-referencing tools[15]. More specifically in Amazonas, the results suggest a predominant concentration of health resources and structures in the capital, indicating management problems for health surveillance and health issues arising from the health regionalization scheme in Amazonas[22].

According to the study carried out by Vasconcelos et al.[2] on the quality of drinking water in the Legal Amazon, less than 50% of the municipalities between 2009 and 2013 concurrently carried out surveillance of water registration and quality control. During this period, 80.64% of the municipalities in the state of Amazonas were classified as highly vulnerable areas in terms of low scores in water quality and supply indicators, based on an analysis of data from Sisagua2.

Furthermore, the unsatisfactory performance of health surveillance in health regions in Amazonas, due to insufficient human and financial resources, is aggravated by the difficulty in integrating efforts and services due to the long distances between municipalities and dependence on precarious river transportation[23].

The basic quality parameters analyzed are considered the minimum criteria for water to be consumed by humans. However, from the results presented, it can be seen that, as well as being absent, many parameters do not comply with the criteria established by current legislation[4].

The amount of residual chlorine in water in the ideal recommended range is one of the main ways of disinfecting water. In the samples verified for the Manaus micro-region, there were significant fluctuations in the concentration of free residual chlorine, with a high percentage of samples in 2020 below the lower limit of the ideal range recommended for this parameter. This evidence deserves attention, since, with a low cost and great efficiency in eliminating bacteria, the absence or inadequacy of this parameter can contribute to the proliferation of micro-organisms in waterways[1].

Fluoridation is one of the main and most important forms of collective prevention in the control of dental caries, as long as the levels in the water are adequate. Excess fluoridation can cause a risk to oral health by compromising the dentition and insufficient fluoridation does not enable prevention as an effective population method[8].

Fluoride concentrations were observed in all the samples analyzed in the inland micro-regions of the state in 2018 and 2019, with a high proportion of samples in 2017 and 2020 outside the appropriate range for this chemical parameter. The absence of data for fluoride concentration in 2017 reflects the existing gap in the control of this parameter in Brazil and is shared by other studies applied in different regions of the country. According to Frazão et al.[24], Brazil does not offer indicators to monitor fluoridation longitudinally, nor does it offer visibility to all those who have the right to information. To this end, the dosage of fluoride in water has been monitored both by institutions linked to the government, known as heterocontrol, and by sanitation and water supply companies that feed the Vigifluor system of Sisagua, with the aim of ensuring the effectiveness of fluoride use at adequate levels and reducing fluorosis[12,24].

In 2020, more than 98% of the samples collected in Amazonas had apparent color intensity in the range recommended by current regulations. However, for the micro-regions located inland, there was a downward trend in the proportion of samples with adequate color levels. On the other hand, the Manaus micro-region has seen an upward trend in the proportion of samples classified in the recommended range for the parameter in question. According to the World Health Organization, water for human use and consumption should not be visibly colored. This perception is associated with the presence of organic matter (humic and fulvic acids) and minerals from natural impurities or industrial waste25,26. Most individuals can perceive levels of color in water above 15 uH[25]. High levels of color denote a high propensity for the generation of undesirable by-products in water disinfection processes[26]. Natural waters have color intensities ranging from 0 to 200 uH, and the chlorination of waters with a high intensity is subject to the formation of carcinogenic compounds such as trihalomethanes.[26]

Despite the fluctuations, the percentages of samples in the recommended turbidity range were high. This parameter is useful for signaling the dispersion of chemical and biological particles in suspension, such as clay, sludge, chemical precipitates of iron and manganese, plant remains and micro-organisms, and is a target for indicators of environmental events and pollution that compromise the potability of water[27]. Increased turbidity can also be caused by failures and loss of integrity in the distribution network, such as pipe breaks, or by biological events, such as the formation of biofilms that encourage the growth of pathogens such as *Legionella*, *Pseudomonas* and mycobacteria[27]. Thus, achieving low turbidity is a criterion for guaranteeing safe drinking water and is an indication of the removal of pathogens and undesirable particles and the effectiveness of flocculation, filtration and disinfection processes.[27]

The turbidity and acidity of the water are related to its chemical composition, deposited sediments and the geological environment in which they were formed, and are directly influenced by the collection site. The waters of the rivers and streams of central Amazonia are chemically distinct from each other. The Rio Negro has a higher quantity of soluble organic substances and a higher acidity (pH between 4.0 and 5.0) due to a lower quantity of minerals and dissolved fulvic and humic substances. By comparison, the waters of the Solimões River, or Amazon River, as it is called in some regions, Amazonas, Madeira and Purus, classified as "white water", are turbid due to the amount of suspended material and dissolved salts such as Ca^{2+} and HCO_3^-, making the waters weakly acidic to neutral (pH between 6.0 and 7.0) and more conductive[28,29].

The high proportion of samples collected in the Manaus micro-region with pH values below the recommended range is worrying. As well as directly affecting consumers, water with pH values outside the recommended range can become highly corrosive or cause fouling in the distribution network[25,26].

The analysis of microbiological parameters, although it is used as an indirect/auxiliary indicator of water quality, monitors the performance of filtration processes, disinfection and general conditions of the plumbing systems and distribution of water from the public or private supply to the consumer, showing the failure in disinfection, colonization and presence of biofilms in the distribution system of this water resource[5,20,21,22].

The upward trends in the proportions of absent samples for total coliforms and *E. coli* are positive indicators for improving the potability of the water distributed in the micro-regions of inland Amazonas. The microbiological parameters of the water related to total coliforms and *E. coli* show the presence of bacteriological contamination that can cause diarrheal diseases that cause mortality in different age groups. In the results, the downward trend in these parameters is evidence of the improvement in the control process of the inspection bodies related to the collection, transportation, storage and processes for obtaining this water resource.

The absence of precise and standardized information on the pre he presence of heterotrophic bacteria in this study is a factor this parameter is considered to be of paramount importance in drawing conclusions about the microbiological quality of drinking water[30], as it can diagnose changes in the microbial colony count pattern, and provides an early indication of deterioration and integrity of the supply system, as well as detecting important *Xantho- monas* and *Aeromonas*, which are not identified by the other microbiological parameters[31].

Studies in the literature have presented data on the occurrence of fungi, heterotrophic bacteria, salmonella, *E. coli* and total coliforms in a wide variety of water sources and in different regions of Brazil[5,6,1,32]. There is no way of confirming a direct relationship with water consumption, since morbidity and mortality can also be associated with the inefficiency of primary care and/or hospital care in the municipality or region. However, the presence of these microorganisms in water can lead to death through the infection of bacteria that are tolerant to antibiotics and other anti-microbials, as well as pathologies that cause vomiting, diarrhea and other gastrointestinal problems. There is also the risk of indirect contamination during food cooking, hand hygiene, surface hygiene and food hygiene[14].

Research on water from rivers, streams and wells in the municipality of Manaus and in the interior, Coari, Parintins and Humaitá, has been described as inappropriate, with inadequate levels of chemical and biological parameters. This highlights the importance of the quality of drinking water offered by public water and sanitation companies[10,11,33].

These results have been corroborated by other studies in different locations that show the same concern about water contamination. It is known that monitoring water quality is not a problem exclusive to the Northern Region, since research in other states shows that basic sanitation is an obstacle in developing countries.

It is hoped that this information will help to stimulate future research into health surveillance, compliance with existing legislation and public policies and the improvement of water treatment technologies in Brazil, with a view to overcoming the health risks caused by inappropriate drinking water.

Among the limitations of the study, no water quality surveillance sampling checks were carried out taking into account the population ranges estimated for the minimum number of samples of free residual chlorine parameters, turbidity, total coliforms and *E. coli*, as recommended by the National Guideline for the Sampling Plan for the Surveillance of Water Quality for Human Consumption[34]. Another limitation was the fact that there was no information on the pairing of samples in the database provided by SISAGUA, in terms of the number of parameters assessed in the same sample. Analyzing multiple parameters per sample would have allowed for more detailed approaches, such as principal component analysis, to determine physical-chemical[35] and microbiological profiles to discriminate between water supplies.

CONCLUSIONS

Analysis of SISAGUA data shows that the micro-regions located in the interior of Amazonas have a lower proportion of municipalities with registered data for monitoring basic water quality parameters. The water samples obtained in the Manaus micro-region have a low free residual chlorine content, a higher fluoride content and higher apparent color and turbidity values, compared to the samples collected in the inland micro-regions.

Of concern is the high percentage of samples collected in the Manaus micro-region classified outside the pH range recommended by current regulations, as well as the high proportion of samples obtained in the inland micro-regions with inadequate fluoride concentrations, including the worsening trend in the apparent color parameter of the water distributed in these locations. These findings make up a set of data that signal the need for improvements in the control of chemical and physical parameters that adequately guide water collection, treatment and distribution processes.

However, there are noticeable trends towards improvements in the quality parameters for apparent color in the water samples obtained in the Manaus micro-region, and for the parameters of free residual chlorine, total *coliforms* and *E. coli in the* samples collected in the micro-regions of the interior of Amazonas.

The analysis of the water quality parameters in the Amazonas Sisagua highlights the need for improvements in the management, surveillance and monitoring of the results of the samples included in the Sisagua, in terms of looking closely at the analysis and inspection of water quality in the state of Amazonas, also taking into account the sociodemographic specificities and limitations of the region's infrastructure, human resources and geographical obstacles, the results of which showed that there are important distinctions between the micro-regions analyzed.

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Authors' Contribution

Lopes AF, Mendes AP, Yamaguchi KKL - Conception, planning (study design), analysis, data interpretation and writing of the work. Santana ABC - Conception, planning (study design), acquisition, analysis, data interpretation and writing of the work. All the authors have approved the final version of the work.

Conflict of Interest

The authors inform that there is no potential conflict of interest with peers and institutions, political or financial, in this study.