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Public water supply fluoridation: an analysis from the equity principle

A fluoretação das águas de abastecimento público: uma análise a partir do princípio da equidade

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ABSTRACT

Introduction: Public water supply fluoridation represents an important public health measure for preventing dental caries, and should be monitored for the fluoride content in an ideal dose, as well as in relation to its population reach with a view to reducing inequalities and providing benefits in oral health. **Objective:** The study evaluated the equity in the distribution of fluoridated water in the city of Manaus, AM, through the relationship between fluoride levels in the water supply of the neighborhoods that compose the city's health districts and contextual indicators of municipal development. **Method:** Cross-sectional ecological study that was performed from 2016 to 2018. Water samples were collected monthly from each health district, whose fluoride concentrations were determined using a specific electrode. Municipal Human Development Index (MHDI), infant mortality, number of children out of school and life expectancy represented the municipality's contextual indicators, obtained from the Human Development Atlas in Brazil. Data were submitted to a descriptive analysis, bivariate statistics and spatial analysis. **Results:** A large variation in fluoride levels was found in the analyzed samples, of which 50.02% showed inadequate fluoride concentrations and the highest concentrations predominated in the samples collected in the second half of the year. The spatial distribution indicated that the neighborhoods with the best MHDI values, infant mortality, number of children out of school and life expectancy had a better concentration of fluoride in the water supply. **Conclusions:** The lack of equity in the distribution of fluoridated water is evident, suggesting that access to fluoridated water reflects the social inequalities present in the city itself.

KEYWORDS: Health Equity; Public Health; Fluoridation; Oral Health

RESUMO

Introdução: A fluoretação das águas de abastecimento público representa uma importante medida de saúde pública para prevenção da cárie dentária, devendo ser monitorada quanto ao teor de fluoreto em dose ideal, bem como em relação ao seu alcance populacional na perspectiva de reduzir as desigualdades e proporcionar benefícios em saúde bucal. **Objetivo:** O estudo avaliou a equidade na distribuição de água fluoretada na cidade de Manaus/AM, por meio da relação entre indicadores contextuais de desenvolvimento municipal e os teores de fluoreto na água de abastecimento dos bairros que compõem os distritos sanitários da cidade. **Método:** Realizou-se estudo ecológico transversal no período de 2016 a 2018. Amostras de água foram coletadas mensalmente de cada distrito sanitário, cujas concentrações de fluoreto foram determinadas utilizando-se um eletrodo específico. Índice de Desenvolvimento Humano Municipal (IDHM), mortalidade Infantil, número de crianças fora da escola e expectativa de vida representaram os indicadores contextuais do município, obtidos a partir do Atlas do Desenvolvimento Humano no Brasil. Os dados foram submetidos a uma análise descritiva, estatística bivariada e análise espacial. **Resultados:** Observou-se grande variação nos teores de fluoreto das amostras, das quais 50,02% apresentaram concentrações de fluoreto inadequadas e as maiores concentrações predominaram nas amostras coletadas no segundo semestre do ano. A distribuição espacial indicou que os bairros com melhores valores de IDHM, mortalidade infantil, número de crianças fora da escola e expectativa de vida apresentaram melhor concentração de fluoreto na água de abastecimento. **Conclusões:** Evidenciou-se a ausência de equidade na distribuição de água fluoretada, sugerindo que o acesso à água fluoretada reflete as desigualdades sociais presentes na própria cidade.

PALAVRAS-CHAVE: Equidade em Saúde; Saúde Pública; Fluoretação; Saúde Bucal

INTRODUCTION

Water is an indispensable public good and its importance for public health is widely recognized by humanity. About a century ago, scientific knowledge linked fluorides in water to the prevention of dental caries, provided that the fluoride content is at suitable levels.[1,2] This technology can significantly reduce the occurrence of dental caries in the population,[3,4] despite unfavorable social and economic factors, precisely because it covers the entire population without distinctions between social classes,[5] in addition to being very cost-effective.[6]

Water fluoridation has been introduced in more than 30 countries, and today about 380 million people receive artificially fluoridated water[7] worldwide. In Brazil, Federal Law n. 6.050, of May 24, 1974,[8] made the adoption of this preventive technology mandatory in all municipalities with a Water Treatment Plant. Ordinance n. 635, of December 26, 1975,[9] set the standards for the implementation of this measure, with the recommended limits of fluoride concentration as a ratio of the local maximum average daily temperature. In 2011, the Collaborating Center of the Ministry of Health in Oral Health Surveillance (Cecol) signed a technical consensus to guide the classification of water by health surveillance bodies, considering simultaneously the maximum benefit of preventing caries and the minimal risk of causing dental fluorosis.[10]

In Brazil, about 96.5 million individuals residing in municipalities with 50,000 inhabitants or more have access to the benefit of fluoridation of public-supply water, which accounts for 68.3% of this population.[2] With that, Brazil is the country with the second largest coverage of fluoridated water in the world.[7] However, severe inequalities hinder the enforcement of the Federal Law[8] and the implementation of the measure in Brazil's macro-regions, states, and municipalities. The South Region stands out, with 88.7% coverage, and the worst situation is found in the North, with 25.3%.[2] In addition, there is a clear difference between the population coverage rate of fluoridated municipalities that have water control surveillance actions in the South (80.5%) and Southeast (66.4%) regions and in the Northeast (14.8%) and North (0.0%).[11] This finding is a major problem if we consider the importance of adding fluoride to public-supply water as a measure to reduce disparities in dental caries between different social and economic strata.[5]

More than inequalities, unnecessary and avoidable differences that are considered both unjust and undesirable are called health inequities.[12] Although the term equity is of relatively recent use in the Brazilian health context, it was formulated with the purpose of incorporating the parameter of justice to the equal distribution[13] and is one of the doctrinal principles of Brazil's Unified Health System (SUS). Although there is no consensus in the literature as to the best methodology for quantifying health equity, experts on the subject recognize that it almost always involves comparing health indicators or health-related factors in one or more groups of people,[14] analyzing, for example: the infant mortality rate[15] and the Human Development Index (HDI).[16]

Thus, the objective of the present study was to evaluate the equity in the distribution of fluoridated water in the Brazilian city of Manaus, state of Amazonas, through the comparison of social and economic indicators with the fluoride content in the water of each local health district.

METHOD

A cross-sectional ecological study was carried out using the health districts (North, South, East, and West) of the city of Manaus and their respective neighborhoods. Data collection started by taking water samples in 50 ml polyethylene bottles that were identified, labeled (collector, collection points, collection location, and date), and previously rinsed with deionized water. The collection was done monthly by the technicians of the Water, Soil, and Air Surveillance (Environmental Surveillance) of the Municipal Health Department (SEMSA) of Manaus, over 24 months, from September 2016 to August 2018. Manaus had a late start in the fluoridation of its public-supply water. It started partially in 2015, covering the neighborhoods located in the South and West districts. After 2016, it was extended to the other neighborhoods.

To select the sample collection points, initially all the neighborhoods in the city of Manaus were mapped, totaling 63 neighborhoods, divided into four health districts (North, South, East, and West) (Figure 1). Subsequently, the distribution of the neighborhoods was considered, according to the water supply system. The collection points were the same used by the local SUS Quality Monitoring Program of Water for Human Consumption in its routine to assess the potability standard. Thirty samples were collected from each district to meet the number indicated in the Brazilian guidelines for the aforementioned program, totaling 120 per month.[17]

The water samples were analyzed in duplicate, using an ion analyzer, ORION 720 A, and a specific electrode, ORION 96-09. The ion analyzer and electrode were previously calibrated with standard triplicate solutions, containing 0.2 to 2.0 µg F/mL, prepared in total ionic strength adjustor buffer (TISAB II), consisting of 1 M solution buffer, at pH 5.0, 1 M sodium chloride (NaCl) and 0.4% 1,2-cyclohexylenedinitrilotetraacetic acid (CDTA). It was used the direct reading method after placing 1 mL of the water sample and 1 mL of TISAB II, and the precision of the analyses was determined according to the ORION standard (940907). The readings were obtained in mV, and through linear regression the results were expressed in ppm of fluorine/mL of water.[18] All water samples were analyzed at the Research Lab of the School of Dentistry of the Federal University of Amazonas (UFAM).

The fluoride content was classified in ranges (above, optimal level or below the recommended range), based on the technical consensus of Cecol/University of São Paulo (USP)[10] to guide health surveillance bodies, considering the benefit of preventing dental caries and the risk of fluorosis for locations where average maximum temperatures are between 26.3° C and 32.5° C. Therefore, it was considered that the optimal level of fluoride content for the city of Manaus ranges from 0.55 to 0.84 ppm/F.[10]

As contextual indicators of municipal development, it was used demographic, human development, and vulnerability indicators obtained from the Human Development Atlas of Brazil produced by the United Nations Development Program,[20] with data retrieved from the 2010 Demographic Census on the neighborhoods that make up each health district, in order to explore possible relationships with the fluoride content in the collected samples. The indicators were divided as follows:

Demographics

Life expectancy at birth: average number of years of life expected for a newborn considering the current mortality pattern of the population living in a given geographic space in the year in question.[21]

Infant mortality: number of children who should not survive their first year of life in every 1,000 children born alive.

Human Development

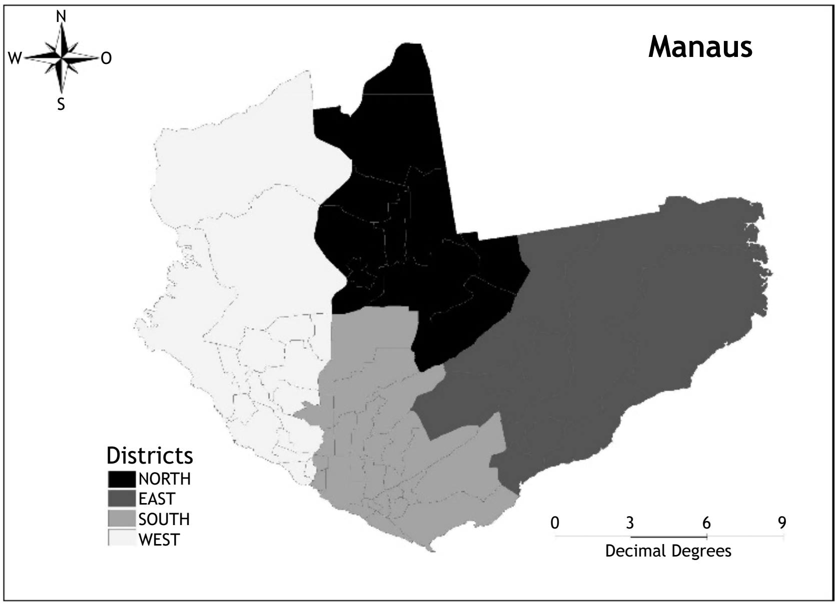
MHDI: geometric mean of the indices of income, education, and longevity, with equal weights.

Vulnerability

Percentage of children aged 0 to 5 out of school: ratio between the number of children aged 0 to 5 who are not attending school and the total number of children in this age group, multiplied by 100.

Percentage of children aged 6 to 14 out of school: ratio between the number of children aged 6 to 14 who are not attending school and the total number of children in this age group, multiplied by 100.

The data were initially submitted to a descriptive analysis, using means, standard deviation, and absolute and relative frequencies. In order to verify the seasonal interference regarding the change in fluoride content in the water distributed to the population, the results were analyzed considering the two halves of the year. Bivariate statistics using Student's t test and ANOVA One Way enabled us to observe differences in fluoride concentrations between the four health districts. The analyses were performed using SPSS version 20.0 for Windows (SPSS Inc., Chicago, IL, United States).



Source: Prepared by the authors based on data from the Manaus Municipal Health Department.[19]

Figure 1. Map of the city of Manaus (urban area) divided by health districts.

A spatial analysis was also performed in the data set and presented on choropleth maps by quartiles to reveal the situation of each variable by neighborhood. For the production of thematic maps, we used the cartographic base found on the website of the Brazilian Institute of Geography and Statistics (https://ibge.gov.br/) and the Terraview 4.2.2 software (INPE, 2011, Tecgraf PUC-Rio/FUNCAT, Brazil). The georeferencing of water collection points for fluoride analysis was performed based on geocoding using the geographic information system (GIS). The analyses were performed using Excel and Quantum GIS version 2.18.2 Las Palmas (QGIS Development Team, 2015).

RESULTS

A total of 2,874 samples were analyzed from August 2016 to September 2018. In general, we found a significant variation in the fluoride levels of the analyzed samples, of which 50.02% had inadequate fluoride concentrations (18.16% below and 31.86% above the recommended) and 49.98% were within the appropriate range according to the technical consensus of Cecol/USP. As shown in Table 1, the lowest rate of optimal fluoride level was found in the East health district, whereas the highest rate of fluoride concentration below the recommended level was found in the North health district. The best fluoride concentrations in the first half year were concentrated in the South and West districts, whereas in the second half, in addition to these, the East district also achieved better results.

Bivariate statistics have shown that higher fluoride contents were found in the samples collected in the second half, with a statistically significant difference. The analysis of variance of the fluoride content between the districts has shown a significant difference between all the health districts, except between the South and the West in the first half years of the period, when they achieved the best fluoride concentrations. These differences remained in the second halves and there was no significant difference between East and West (Table 2).

The values of social and economic indicators varied both between health districts and between the neighborhoods within a district. The indicators of infant mortality and percentage of children out of school ranged from 7.00% to 28.10% and from 43.46% to 78.62%, respectively. Similarly, for life expectancy at birth and MHDI, the values ranged from 69.12 to 81.54 and from 0.574 to 0.930, which shows a substantial difference between all investigated indicators. In our results, the spatial distribution of the mean fluoride levels indicated that the neighborhoods with the best MHDI and life expectancy scores and the lowest scores for infant mortality and children out of school also had the best fluoride levels in the public-supply water. In the North health district, the neighborhoods with the lowest MHDI and life expectancy and the highest rates of infant mortality and children out of school had the worst fluoride levels. Therefore, these neighborhoods do not fully benefit from fluoride in the prevention of dental caries. In contrast to this, in most neighborhoods of the East district that also had inadequate demographic, development, and vulnerability indicators, fluoride levels were within the recommended values, in accordance with the principles of equity (Figure 2).

DISCUSSION

The overall analysis of public-supply water fluoridation in Manaus has shown that the local population is not yet fully covered by this benefit, since not all neighborhoods are within the appropriate range to achieve the maximum benefit of preventing dental caries and the minimum risk of fluorosis. Of the four health districts evaluated, the most affected in terms of the quality of this benefit is the North. This district is an area of recent urban expansion and ongoing population mobility. It is currently the most populous administrative area of the city, with more than half a million inhabitants, of whom over 30.00% are in the age group of 0 to 14 years old.[19]

Table 1. Average fluoride content in the samples, by health district. Manaus/AM (2016-2018) according to Cecol/USP classification, 2011[10].

	Fluoride content	Health districts n (%)				Total
		North	South	East	West	
1st half	Below	142 (45.70)	18 (5.80)	123 (39.50)	28 (9.00)	311 (100.00)
1st half	Optimal level*	137 (18.80)	244 (33.50)	112 (15.40)	236 (32.40)	729 (100.00)
1st half	Above	81 (20.90)	94 (24.20)	117 (30.20)	96 (24.70)	388 (100.00)
	Fluorine content	Health districts n (%)				Total
		North	South	East	West	
2nd half	Below	121 (58.70)	19 (9.20)	46 (22.30)	20 (9.70)	206 (100.00)
2nd half	Optimal level*	141 (20.30)	170 (24.50)	187 (26.90)	196 (28.20)	694 (100.00)
2nd half	Above	98 (18,90)	162 (31.20)	115 (22.20)	144 (27.70)	519 (100.00)

Source: Prepared by the authors, 2020.
* Optimal level: 0.55-0.84 ppm/F.

Table 2. Values of means, standard deviation, difference between means and confidence interval of fluoride content levels per half year and health district. Manaus/AM (2016-2018).

North health district				
	Mean (SD)	**Difference from the mean**	**CI 95%**	***p****
1st Half	0.56 (0.36)	- 0.07	(-0.12 - -0.02)	0.008
2nd Half	0.63 (0.36)			
East health district				
	Mean (SD)	**Difference from the mean**	**CI 95%**	***p****
1st Half	0.65 (0.37)	- 0.15	(-0.19 - -0.10)	0.000
2nd Half	0.80 (0.25)			
South health district				
	Mean (SD)	**Difference from the mean**	**CI 95%**	***p****
1st Half	0.77 (0.17)	- 0.08	(-0.11 - 0.05)	0.000
2nd Half	0.85 (0.24)			
West health district				
	Mean (SD)	**Difference from the mean**	**CI 95%**	***p****
1st Half	0.76 (0.19)	- 0.08	(-0.11 - -0.04)	0.000
2nd Half	0.83 (0.24)			
Health districts				
	North	**East**	**South**	**West**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
1st Half	0.56 (0.36)^{A}	0.65 (0.37)^{B}	0.77 (0.17)^{C,D}	0.76 (0.19)^{D**}
2nd Half	0.63 (0.36)^{A}	0.79 (0.25)^{B,D}	0.80 (0.24)^{C,D}	0.83 (0.24)^{D**}

Source: Prepared by the authors, 2020.
* *p*: Student's t test for independent samples.
** Equal letters denote no significant difference for a 5% significance level, according to the ANOVA One Way test with Tukey Post Hoc test.

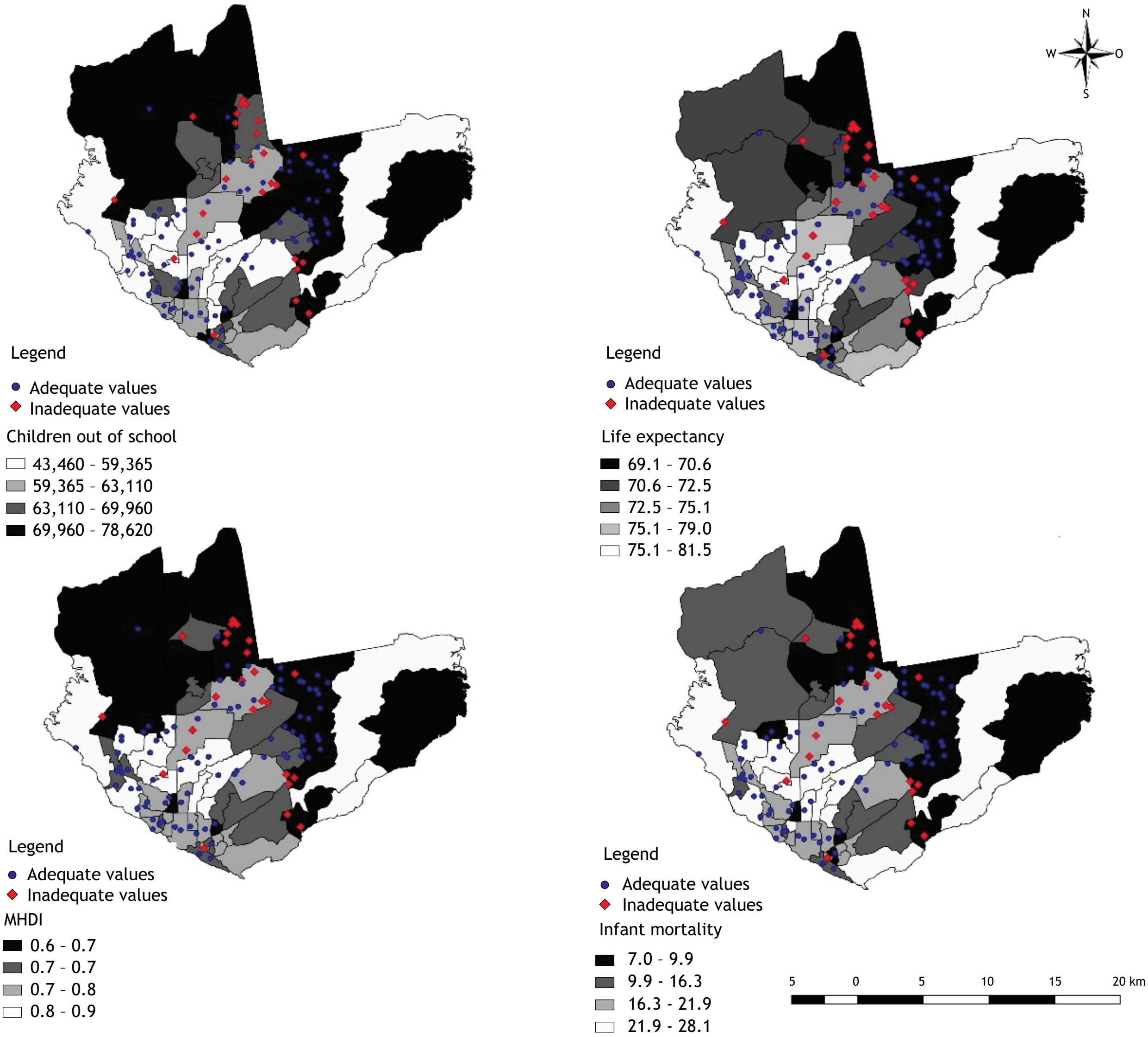
It was also noted that neighborhoods located in health districts with better contextual indicators and, therefore, with better social and economic conditions, have more suitable concentrations of fluoride. Similar results have been found in both national[22] and regional[23] studies. A study by Gabardo et al.[22] has shown that the municipalities located in the Brazilian regions with the worst social and economic indicators are also those with the greatest failure of this benefit. Belotti et al.,[23] in a study carried out in the metropolitan area of Vitória, state of Espírito Santo, have shown a strong positive correlation between MHDI and the quality of fluoridation, while infant mortality had a strong negative correlation, reinforcing the inequalities in the compliance with this measure.

This finding leads us to the assumptions of the reverse care law, that is, the availability of good healthcare tends to vary inversely with the needs of the population.[24] Even though it was written over 40 years ago, the inverse equity hypothesis is still valid. It reflects the social determination of diseases and the disparities in access and use of healthcare services, observed in Brazilian[25] and international[26] studies.

Unlike in high-income countries, the supply of healthcare is more socially unequal in low and middle-income countries.[27] Similarly to other Brazilian cities, Manaus has low healthcare coverage, with an estimated population coverage of 43.95% for Primary Care (AB) and 27.16% for the Family Health Strategy (ESF). The latter is even lower in the North health district (24.00%).[19] Regarding primary oral healthcare, population coverage is at 28.64% according to the Municipal Health Plan 2018-2021.[19] Therefore, the poor are also at greater risk of disease and have less access to oral healthcare, as shown by Petersen and Kwan.[27]

However, we must say that, among the studied districts, a significant part of the neighborhoods of the East district has good coverage in terms of fluoridation, despite the poor demographic, human development, and vulnerability indicators found in that area. This situation means the area has better equity, because although fluoridation offers benefit to all social groups, its effects are greater among the most vulnerable populations.[27]

Data from several studies collectively suggest that social and economic status and water fluoridation levels are determinants of dental caries.[28,29] In this way, health policies and programs, health promotion, protection, assistance, and surveillance initiatives could improve the population's health and living conditions. Locally, public health stakeholders can strive to implement water fluoridation wherever necessary and maintain or improve it where it already exists.[5] According to Venturini et al.,[30] a common aspect in many studies on the fluoridation of public-supply water is the discontinuity of the measures, with concentration values that are eventually not in accordance with the legislation and below what is indicated for the prevention of caries. Furthermore, the identification of



Source: Prepared by the authors, 2020.

Figure 2. Map of collection points and classification sites according to fluoride levels and contextual characteristics of the city of Manaus/AM (out-of-school children, life expectancy, Municipal Human Development Index and infant mortality). Adequate values correspond to fluoride contents between 0.55 to 0.84 ppm. Inappropriate values correspond to those below or above those values.

factors that are possibly associated with the results on fluoride concentration is insufficient.

The factors that may be related to oscillations in fluoride concentration in public-supply water indicated in the literature are related to: geographical area; water companies; weather conditions; equipment malfunctioning; and the type of test used to monitor the results.[30] Data from the present study suggest the influence of seasonality on the fluoride concentration of public-supply water, showing that the highest concentrations of fluoride were found in the hottest season (second half of the year). Only two studies have shown results on the influence of seasonality on the fluoride concentration.[31,32] However, they limited their observations to descriptive analyses and did not confirm the differences with the appropriate statistical tests.

Some limitations of the present study must be considered. We could not have stricter control of the sampling processes and procedures because these steps were performed by the Municipal Environmental Surveillance body itself. In addition, the municipality's contextual indicators were obtained from a secondary source,[20] which limits data quality assurance. It should also be noted that the cross-sectional analysis enabled us to identify some associations, but it does not enable the establishment of any causality.

CONCLUSIONS

Based on the analyzed data, we can infer that equity was not the guiding principle for the implementation of the public-supply water fluoridation policy in the city of Manaus. The fluoridation of public-supply water is a recommended public health policy. Since it is related to the health of the population, this policy should be controlled and monitored by external bodies, in a process called heterocontrol. Further studies are needed to overcome the limitations identified here and encourage a more active surveillance process over the city's fluoridation system.

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Authors' Contribution

Rebelo MAB, Freitas YNL, RHL Bandeira, Quadros LN, Gomes AC, Gomes AC, Rebelo Vieira JM - Conception, planning (study design), acquisition, analysis, data interpretation, and writing of the manuscript. Barbosa IR - Data interpretation and writing of the manuscript. All authors approved the final draft of the manuscript.

Conflict of Interest

Authors have no potential conflict of interest to declare, related to this study's political or financial peers and institutions.