Pesquisa Brasileira em Odontopediatria e Clínica Integrada 2022; 22:e210153
https://doi.org/10.1590/pboci.2022.031
ISSN 1519-0501 / eISSN 1983-4632

ORIGINAL ARTICLE

Fluoride Concentration in Public Water Supply in a City in the Amazon Region

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Academic Editor: Alessandro Leite Cavalcanti

Received: 05 August 2021 / **Review:** 23 September 2021 / **Accepted:** 23 October 2021

How to cite: Bandeira RHL, Rebelo MAB, Freitas YNL, Quadros LN, Gomes AC, Gomes AC, et al. Fluoride concentration in public water supply in a city in the Amazon region. Pesqui Bras Odontopediatria Clín Integr. 2022; 22:e210153. https://doi.org/10.1590/pboci.2022.031

ABSTRACT

Objective: To analyze the fluoride concentration in the public water supply in Manaus, Brazil. **Material and Methods:** Water samples were collected in 50 mL polyethylene bottles, identified, and labeled. The collection was performed from September 2016 to August 2018. For the selection of collection points, all neighborhoods of the city of Manaus, divided into four health districts (North, South, East, and West), were mapped. From each district, 30 samples were collected, totaling 120 monthly samples. Water samples were analyzed using an ion analyzer, ORION 720-A, and a specific electrode, ORION 96-09. The ion analyzer and electrode were calibrated in standard solutions. The levels were classified in intervals based on technical consensus to guide the health surveillance agencies. **Results:** Of the 2,874 water samples, 50.3% were within the recommended range, and 49.7% were inadequate, with 31.6% considered above the parameters and 18.1% below. Among the districts, the North had the highest percentages of unsatisfactory samples, resulting in limited action to prevent tooth decay. During the 24 months of analysis, there were large oscillations in the values in all four districts of Manaus. **Conclusion:** Results reinforce the importance of heterocontrol for the city to guarantee the effectiveness of this public health measure.

Keywords: Fluoridation; Fluorides; Oral Health; Public Health; Dental Caries.

Introduction

Although the Amazon boasts a great environmental heritage and abundance of water resources, it is in the northern region of Brazil, contained in this remarkable biome, that the worst rates of access to sanitation services and respective public health indicators are verified [1]. Even though it has the largest concentration of freshwater in the world, the region's population suffers from water shortages and diseases related to a lack of sewage collection and treatment [2]. In this geographical and social context is the urban area of Manaus, capital of the state of Amazonas.

Within this water-health dyad, recognized by mankind as life-threatening or protective, is fluoride halogen. All water has some amount of fluoride. However, to ensure its benefit to oral health, fluoride levels must be within scientifically recommended ranges [3]. The practice of supply water fluoridation as a public health measure for controlling the development of dental caries is supported by numerous national and international health institutions, including the World Health Organization (WHO) [4]. In more than 50 years of research attesting to its efficacy and safety [5], it is the best method to provide population-based fluoride. This potential measure explains the lower magnitude of dental caries experience among exposed individuals [6].

In Brazil, the fluoridation of water supplies was initiated in 1953 [7] and consisted of the controlled addition of fluoride to public water supply treatment facilities, with the purpose of raising its concentration to a certain value established as effective in the prevention of dental caries [3]. As such, it is required in Brazilian municipalities that have a water treatment plant, provided for by Federal Law No. 6,050 of May 24, 1974 [8]. In the late 1980s, fluoride monitoring programs in public water supply were created. This parameter has been incorporated into monitoring and surveillance actions in conjunction with other parameters such as turbidity, chlorine residual, colorimetry, pesticides and mercury [9].

To ensure safe results, fluoride levels should be within scientifically recommended range, stably and steadily, without interruption [10-12]. Thus, it is indispensable to periodically execute heterocontrol of supply water fluoridation to the population, understood as a principle for producer control over the production and consumption process, as well as for control by state institutions [4]. Or in other words, heterocontrol is called the implementation of control and surveillance systems developed by a different agency from the one that performs the execution of the measure to maintain the quality standard and protect the population's health [4]. For example, in Manaus, the population was contemplated with the fluoridation of the public water supply late, only in 2015, being performed by a private institution responsible for the city's water supply.

Therefore, this study aimed to analyze the fluoride concentration and its variations in public water supply in the municipality of Manaus, Amazonas, Brazil, for 24 months.

Material and Methods

Study Area Characteristics

This is a cross-sectional observational study carried out in Manaus. It is located in northern Brazil, in state of Amazonas, which currently has around 2,182,763 inhabitants [13]. According to the latest census data conducted in 2010, most of the population lives in urban area (99.49%). The city has 458,300 households, of which 89.65% have piped water, demonstrating that a significant portion of the city's urban perimeter receives this benefit. Of the 1,792,881 inhabitants of the urban zone, 67.88% are between 15-64 years old and 28.24% are 0-15 years old [14]. Corresponding to data from the last national oral health survey [15], Manaus

presented a mean decayed, missing, and filled teeth (DMFT) index of 2.88 for 5 years old, 2.34 for 12 years, and 4.85 in the 15-19 age group.

Manaus is the only city in the state to have water treatment plants and water fluoridation. The current company responsible for water distribution in Manaus is the Águas de Manaus concessionaire (Aegea Group), which has been operating in the city since 2018. Manaus has four Water Treatment Plants (WTP): two WTP located in the Ponta do Ismael Complex (PIC), Mauazinho WTP and Ponta das Lages WTP. The water distribution network in the city is unique and a significant portion of the population is supplied by it. However, the supply network also has independent systems, represented by the concessionaire's own deep wells and community wells in some neighborhoods. Officially, only the WTPs located in PIC receive fluoridation. Although legislation regulating the fluoridation of water supplies public in the country is not recent, water fluoridation in the city began only in 2015 [16].

Selection and Collection of Samples

Water samples were collected in 50 mL polyethylene bottles, identified and labeled (collector, collection points, collection location, and date) and previously rinsed with deionized water. The collection was performed monthly by technicians of the Water, Soil and Air Surveillance from Municipal Health Department, for over twenty-four months, from September 2016 to August 2018.

To select sample collection points, all neighborhoods from Manaus were initially mapped according to the territorial division on January 14, 2010, totaling 63. Then, the neighborhoods were divided into four health districts (North, South, East and West). Subsequently, the distribution of neighborhoods was considered according to the Manaus water supply distribution system. Therefore, the collection points were the same as those used by the Drinking Water Quality Surveillance Program from Unified Health System (SUS), following the criteria of the Drinking Water Quality Surveillance Sampling National Plan [9]. From each health district, 30 water samples were collected, 120 samples per month, totaling 2,874 samples in 24 months.

Fluoride Determination and Classification of the Results

The analysis was performed by the Laboratory of Research, Faculty of Dentistry of UFAM, using an ion-specific electrode Orion 96-09 (Thermo Scientific Inc., Waltham, MA, USA) coupled to an Orion 720-A ion analyzer (Thermo Scientific Inc., Waltham, MA, USA). Duplicate samples were buffered with the same volume of TISAB II (1.0 M acetate buffer pH 5.0, 1.0 M NaCl and 0.4% CDTA), prepared in the laboratory. The ion analyzer and the ion-specific electrode were calibrated with standard solutions ranging from 0.2 to 2.00 mg F/mL, containing 50% of TISAB II. The direct reading method was used and the accuracy of the analysis was determined with the ORION standard (940907). The readings were obtained in mV and by linear regression; the results were expressed in ppm F/mL water [17].

The samples were classified in intervals, based on technical consensus to guide health surveillance agencies, considering the balance between anticaries benefit and risk of the fluorosis for locations where mean maximum temperatures are between 26.3 °C and 32.5 °C, with the optimal range of fluoride for the Manaus city ranging from 0.55 to 0.84 ppm/F [10].

Statistical Analysis

Data were analyzed using descriptive statistics, including the distribution of variables by median, mean, standard deviation, and proportion and presented by health districts. The analyses were performed using SPSS software version 20.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

During the twenty-four months of the study, 2,880 samples were collected, of which six were discarded because they contained insufficient material for analysis, resulting in a total of 2,874 samples. As shown in Table 1, the annual mean (standard deviation) and median (minimum-maximum values) concentrations of fluoride found were, according to the *Centro Colaborador do Ministério da Saúde em Vigilância da Saúde Bucal* (CECOL/USP) technical consensus, in the range of 0.55 to 0.84 mg F/L in all four districts (North/East/South/West). However, the benefit of the caries preventive effect was considered maximum and the risk for producing dental fluorosis was low in the East, South, and West districts, as shown in Figure 1.

Table 1. Fluoride concentration analysis results during the 24-month study period.

District	Samples	Median (Min - Max)	Mean (SD)
East	720	0.78 (0.24 – 0.94)	0.72 (0.18)
North	718	0.61 (0.35 – 0.92)	0.60 (0.12)
South	719	0.78 (0.64 – 1.30)	0.81 (0.13)
West	717	0.78 (0.56 – 0.98)	0.80 (0.12)
Total	2874	0.75 (0.24 – 1.30)	0.73 (0.41)

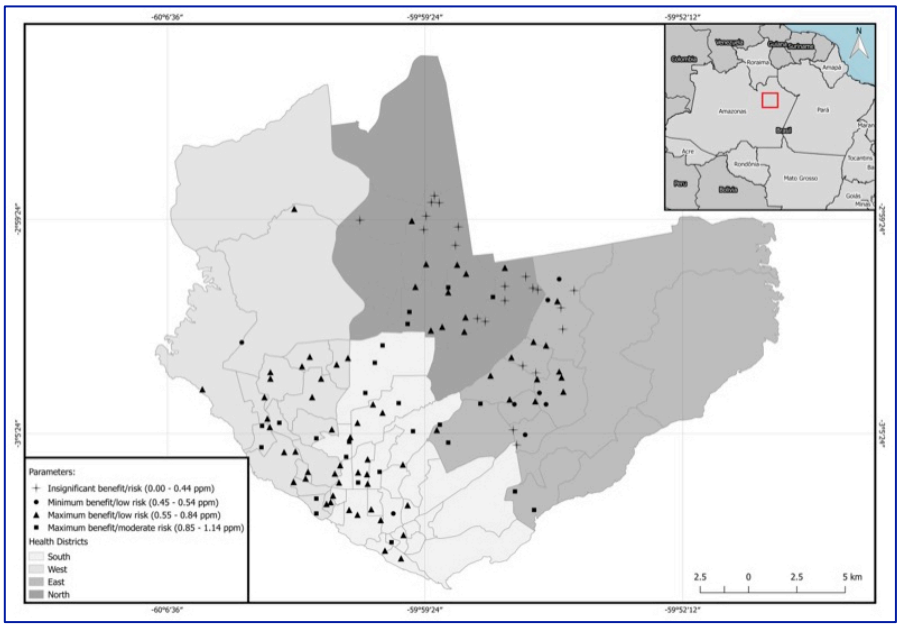

Figure 1. Manaus city map according to health districts and parameters related to balance between anticaries benefit and risk of fluorosis expected.

Table 2 shows the absolute and relative frequencies of the samples analyzed during the study period according to the four districts classified to conform to the fluoride levels in below, in the optimal range and above the recommended values. Almost half (49.7%) of all samples were not appropriate according to the optimal levels established by CECOL/USP.

Figure 2 shows that from September 2016 to May 2017, the F concentration in the four districts of the Manaus city studied showed large oscillations between the values considered by CECOL/USP (values below or above). However, for the following months, when compared to the first year, it is possible to observe that the oscillations between the four districts decreased slightly. And overall, fluoride levels have increased significantly in all districts.

Table 2. Classification (%) of all water samples based on CECOL/USP parameters.

District	Bellow (0.00 to 0.54)	Optimal range (0.55 to 0.84)	Above (> 0.84)
East	263 (36.6)	278 (38.7)	177(24.7)
North	172 (23.8)	310 (43.1)	238 (33.1)
South	37 (5.2)	425 (59.1)	257 (35.7)
West	48 (6.7)	432 (60.2)	237 (33.1)
Total	520 (18.1)	1445 (50.3)	909 (31.6)

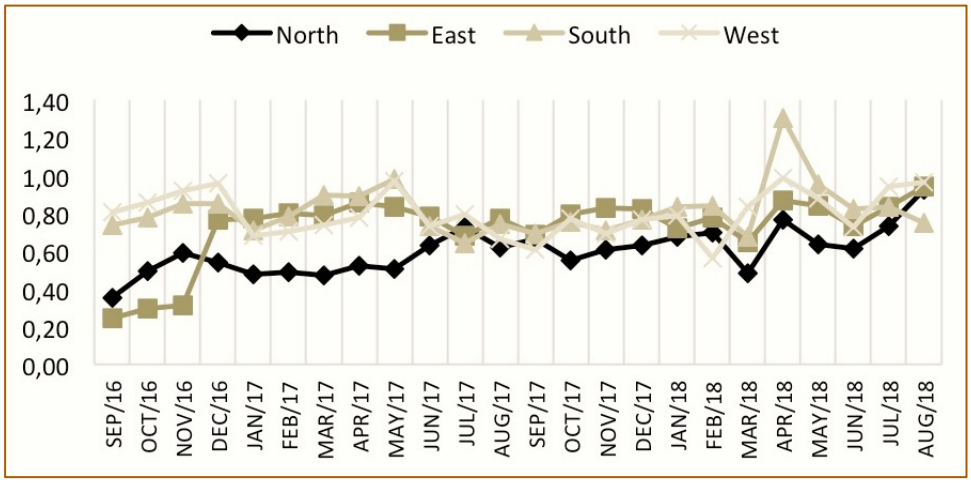

Figure 2. Fluoride concentration according to health district during the 24-month study period.

Discussion

The provisions of Ordinance MS-635/1974 [18] on the adequacy of fluoride contents in waters in the national territory were established 60 years ago when the understanding of how fluoride controls caries and leads to fluorosis differed from the currently accepted understanding. Considering the benefit of fluoride use in controlling the development of dental caries and the risk of dental fluorosis, the exposure to a low or high fluoride concentration should be considered [19]. In view of this, CECOL/USP [10] has reached a consensus to guide water fluoridation classification by health surveillance agencies while taking into account both the benefit of preventing caries and the risk of producing dental fluorosis.

The present study's findings reveal large fluctuations in fluoride concentration in public water supply in the city of Manaus/AM, showing that the practice of heterocontrol is indispensable for the municipality. Furthermore, several studies [20-24] show that oscillations impair the preventive action of fluoride concerning dental caries. These studies also reinforce that the fluoridation of water supplies reaches its maximum efficiency if the fluoride concentration is within the so-called "optimal level" and uninterrupted for long periods.

Other longitudinal heterocontrol studies also demonstrated these variations, as in the results of Scalize et al. [22] in 225 cities of Goiás, Moimaz et al. [25] in 40 cities of São Paulo and Brito et al. [26] in Passo Fundo city. Specifically, in the studies by Kuhnen et al. [27] and Lacerda et al. [12], a large proportion of the samples (41.4% and 46.5%, respectively) presented inadequate fluoride levels, as in this study. In the present study, the collection points were established according to the city's health districts, making it possible to identify the districts and neighborhoods that are receiving the benefit and those at risk for dental fluorosis. The oscillations are evident and frequent characteristics during the 24 months of the study, as shown in Figure1. A clear polarization is observed, especially in the first months, between the districts, with the South

and West health districts presenting fluoride levels within the range established, conflicting with the East and North districts that presented values below the established parameter. Among these, the district with the lowest fluoride content was North, with 36.6% of the samples lower than recommended. In contrast, this district represents the most populous region in the entire city, characterized by disorderly population growth and serious socio-environmental problems.

One possible explanation for this is the fact that the North and East districts were the last to receive the fluoridation benefit, with coverage of 53.3% and 83.3%, respectively, in February 2017 [16]. It is evident the improvement in fluoride levels in samples from the East district, which moved from a non-fluoridated region, with insignificant values (0.01-0.02 ppm F) in December 2015 to 83.3% coverage in February 2017, while the North district, during the same period, increased only 13.3%, suggesting possible structural problems in the water distribution network in this region.

The South and West districts presented more points with concentrations above the recommended parameters, especially in May and June 2018 in the Southern district, with fluoride contents of 1.30 and 0.95 ppm, respectively. Such data are worrying because, in the long run, they may lead to unfavorable consequences for oral health, such as the higher risk for producing dental fluorosis and should trigger actions that alert the operator to promote system adjustments, as recommended by the technical consensus [10].

It should be noted that fluoridation of water supplies in Manaus is still recent compared to other Brazilian capitals such as Curitiba, the country's first state capital to fluoridate its waters in 1958 [28] and other major capitals such as Belo Horizonte, which started in 1975 [29] and São Paulo in 1985 [30]. Furthermore, in the northern region of the country, the first capital to receive this benefit was Palmas in 1993 [31], which contributes to the fact that so far only three capitals of this region receive fluoridation of water supplies, assigning the lowest percentage (25.3%) of the country's population covered by this measure [16].

The study by Roncalli et al. [32] signaled the large interregional differences related to low fluoridation provision and its surveillance when comparing the North and Northeast regions with the South and Southeast. The authors confirmed this discrepancy by observing in the Southern region the effectiveness of implementation measures from Water Fluoridation Surveillance Systems since 2008, while in the Northern region, in 70% of municipalities, the collection from this study was the first initiative to monitor fluoridation, that is, in addition to the low rate of fluoridation, surveillance also appears poorly implanted in this region.

Considering that the obligation of water fluoridation has been foreseen for over 40 years in the country and is characterized as an important intersectoral health policy, as advocated by the National Oral Health Policy (PNSB) [33] and more recently by the National Health Surveillance Policy (PNVS) [34], greater attention is needed from the authorities regarding the practice of heterocontrol. In addition, there is the specificity of the city itself, which has a high mean temperature, resulting in greater water consumption by the population and reiterating the need for more rigorous control of fluoride levels [20].

Some limitations of the present study need to be considered. The city of Manaus has a complex public supply network, making it difficult to clearly understand the water distribution network, which limited the possible explanations for the fluctuations found. Population growth makes it difficult to perform a service that is historically deficient. The pursuit for more space and housing led the population to live in areas of precarious urbanization, expanding horizontally, spreading the city into the middle of the forest and making it difficult to access the services provided by the state [2]. In addition, there is a discrepancy in information related to the water supply system from the municipality's regulatory bodies, the national sanitation system, and the concessionaire responsible for the service itself.

On the other hand, there are no published papers with the respective theme in the present city, which is the first study that performs this analysis in Manaus, Brazil. However, it is noteworthy that the Vigifluor project and the publication of the book entitled "Coverage and surveillance of water fluoridation in Brazil: municipalities with more than 50,000 inhabitants" were important milestones in bringing the theme of fluoridation of water supplies into evidence.

Conclusion

In twenty-four months of surveillance of public water supply in the city of Manaus, it was possible to identify significant fluctuation in fluoride levels in the samples analyzed, with special attention to the North district, which presented the worst results among the others, highlighting the importance of external control of fluoridation of water supplies to the municipality. Thus, greater attention is required from state surveillance agencies, municipal public administration, and social control to ensure effective fluoridation of public water supply, an important public health policy for dental caries control.

Authors' Contributions

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All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

Financial Support

None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

Acknowledgements

Thanks to Prof. Dr. Jaime A. Cury, FOP-UNICAMP, for providing spreadsheets for calculating fluoride concentrations and advising.

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