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Access to fluoridated water: an overview since its implantation in a city of Rio de Janeiro State, Brazil

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• Conflicts of interest: none declared.

Abstract

Objective: to evaluate the fluoridation scenario in a city of the State of Rio de Janeiro, since its implantation to the present day. **Material and Methods**: water samples were collected from 2011 to 2017, in 21 locations of the city, analyzed by the electrometric method and classified based on the recommended national fluoride concentrations. **Results:** from a total of 2,297 samples collected, only 688 (29.95%) were within the recommended range (0.65-0.94 ppmF), with concentrations ranging from 0.00 to 1.92 ppmF and with an average concentration of 0.41 ppmF. During the period of evaluation, it was observed that the locations that were closest to the central region of the city were constantly fluoridated, and most of the samples were in accordance with the parameters recommended by CECOL-USP. On the other hand, in the peripheral neighborhoods, the samples were considered underfluoridated, which might result in inefficacy in the prevention of caries disease. **Conclusion**: the city showed a clear deficiency in maintaining of fluoride levels at adequate concentrations, which reinforces the relevance of controlling of this measure as part of a continuous surveillance action in oral health care.

Keywords: Fluoridation; Water treatment; Public water supply.

Introduction

Dental caries is a chronic and multifactorial disease that affects a large part of the population of developing countries, such as Brazil. Fluoride has the ability to reduce the incidence of caries and delay or reverse the progression of incipient lesions.[1]

Fluoridation of public water supply was recognized in the 20th century, and the application of this measure has demonstrated good results in decreasing caries prevalence and incidence.[2] According to the Centers for Disease Report Control and Prevention,[3] fluoridation of public water supply is the safest, most effective and economical way to prevent caries, and it is also recommended by the American Dental Association (ADA), the International Association for Dental Research (IADR), and the World Health Organization (WHO).[4]

Since May 24, 1974, by force of Law No. 6050, fluoridation of public water supply in Brazil is mandatory in locations with a Water Treatment Station (WTS).[5] Resolutions no. 635 and no. 2914, issued by the Ministry of Health in 1975 and 2011, respectively, set forth the regulations and standards for fluoridation and fluoride concentration - in parts per million (ppm) or milligrams per liter (mg/L), recommended for each location, and established the maximum amount of fluoride allowed in drinking water equal to 1.5 mg/L.[6,7]

Despite the recognition of fluoridated water as an effective, economical and comprehensive measure for dental caries prevention in places with a high prevalence of this disease,[8] it is known that there are still cities in in Brazil that do not add fluoride to public water supply in spite of legal obligation. The preventive efficacy of fluoride in drinking water depends on having an adequate fluoride concentration in the water consumed by the population and a continuity in the fluoridation process, making it essential to have control in terms of both operational procedures in the WTSs and sanitary surveillance as a basic right of citizenship in all cities[5]. In some cases, there is budget limitation, but the costs of water fluoridations are much smaller than those related to the measures necessary to treat caries disease and its consequences.[8]

Considering the lack of a structured oral health surveillance policy in many Brazilian cities,[9] as the city described in this study, reinforced by the proposal instituted by the National Oral Health Policy in 2004, the contribution of the universities is relevant in some surveillance actions, such as the control of fluoride levels in public water supply.[10] In this way, the purpose of the present study was to depict the scenario of public water supply fluoridation in the city of Nova Friburgo, Rio de Janeiro State, during a 84- month evaluation period (2011-2017), observing whether there were changes regarding the expansion and adequacy of fluoridation after its implementation, in the year 2010.

Material and Methods

Characterization of the City and the Water Distribution Network

Nova Friburgo is a city located in the mountainous region of Rio de Janeiro State, which has 185,102 inhabitants, 22,710 living in rural areas and 159,372 living in urban areas. It has

8 districts, namely Nova Friburgo (1st District), Riograndina (2nd District), Campo do Coelho (3rd District), Amparo (4th Distrito), Lumiar (5th District), Conselheiro Paulino (6th District), São Pedro da Serra (7th District) and Mury (8th District).

According to information obtained from the Municipal Water Treatment Company, Nova Friburgo has 15 WTSs. Cascatinha, Caledônia, Curuzu, Debossan, Rio Grande de Cima and Riograndina WTSs are responsible for the treatment of water distributed to the most central districts (1st, 2nd, 6th and 8th), while the Amparo, Bela Vista, Santa Cruz, Boa Esperança, Santa Margarida, Bocaina, Tapera, Santana and Janson WTSs are responsible for the treatment of water distributed to the most peripheral districts and rural areas (3rd, 4th, 5th and 7th).

Sampling Collection

To facilitate access to the locations and avoid sample losses, it was defined that the collection sites would be public organs, Basic Health Units, State and Municipal Schools.

Initially, 26 collection sites were selected for the study, in order to include all regions of the city. However, most of the collection sites were excluded because the real origin of the water could not be confirmed, whether it came from WTSs or alternative sources. Fifteen, collection points were excluded and 11 remained throughout the evaluation period (2011-2017). In September 2013, 10 new collection sites from WTSs and close to the old sites were included in order to establish a minimum coverage of 1 site per WTS,[11] totalizing 21 collection sites.

Public drinking water samples were collected in duplicate at various regions of the city, monthly, in a random and uniform manner. The person responsible for the collection was instructed to discard 30 seconds of the tap water, do three washes with running water and then fill a sterile polyethylene container with 100 mL of water. All containers were kept at room temperature during transportation, labeled with the location and date of collection, and sent to the clinical research laboratory of Nova Friburgo Health Institute, Fluminense Federal University, for storage at 20°C and subsequent analysis.

Laboratory Analysis

The electrometric method was used to measure fluoride concentration in the water using a digital potentiometer with fluoride ion-specific electrode. Fluoride concentration in the water samples was determined using the sensitive ion electrode coupled to a high-resolution digital bench potentiometer. All analyzes were performed in duplicate in order to test the reproducibility of the readings.[12]

The city of Nova Friburgo has an average annual maximum temperature of around 24.3°C. According to the Collaborative Center of Brazilian Health Ministry for Oral Health Surveillance (CECOL/USP), locations with maximum annual temperatures below 26.3°C should have their water fluoride concentration ranging from 0.65 ppmF to 0.94 ppmF, which was the range used as a parameter for this study.[11]

The collected data were tabulated in the Microsoft Excel 2011 program and presented as descriptive statistics.

The project was approved by the Research Ethics Committee under number CMM/HUAP 272/10 (CAAE 0217.0.258.000-10).

Results

Fluoridation of public water supply in the city of Nova Friburgo, RJ, began in 2010, with the fluoridation of the two largest WTS, representing 70.58% of population coverage. During the course of this study, three other WTS started fluoridation, thus increasing to 77.15% the number of residents with access to fluoridated water.

It was possible to observe a great variation in the fluoride concentration of the water samples. Form a total of 2,297 samples, only 688 (29.95%) were within the recommended range (0.65-0.94 ppmF), while 1,381 (60.12%) samples were underfluoridated and 228 (9.93%) were overfluoridated (Table 1). Concentrations varied from 0.00 ppmF to 1.92 ppmF (Table 2).

Table 1. Classification of water samples collected from January 2011 to December 2017. Nova Friburgo, RJ, 2018

Year	Total of samples n(%)	Underfluoridated <0.65 ppmF n(%)	Adequate 0.65-0.94 ppmF n(%)	Overfluoridated >0.94 ppmF n(%)
2011	262 (100.00)	201 (76.72)	56 (21.37)	5 (1.91)
2012	264 (100.00)	154 (58.33)	95 (35.99)	15 (5.68)
2013	336 (100.00)	202 (60.12)	82 (24.40)	52 (15.48)
2014	502 (100.00)	315 (62.75)	162 (32.27)	25 (4.98)
2015	500 (100.00)	247 (49.40)	166 (33.20)	87 (17.40)
2016	246 (100.00)	153 (62.20)	71 (28.86)	22 (8.94)
2017	187 (100.00)	109 (58.29)	56 (29.95)	22 (11.76)
Total	2297 (100.00)	1381 (60.12)	688 (29.95)	228 (9.93)

Table 2. Variation of fluoride concentration in water samples collected from January 2011 to December 2017. Nova Friburgo, RJ, 2018

Year	Minimum	Maximum	Average	Standard deviation
2011	0.01	1.03	0.27	0.32
2012	0.00	1.48	0.41	0.39
2013	0.02	1.92	0.44	0.46
2014	0.00	1.92	0.42	0.38
2015	0.01	1.60	0.51	0.44
2016	0.00	1.39	0.40	0.40
2017	0.00	1.64	0.43	0.43
Total	0.00	1.92	0.41	0.04

When analyzing the average concentration of the samples obtained in each WTS monthly, it was observed that the WTSs Amparo, Boa Esperança, Bocaina, Cascatinha, Curuzu, Santa Cruz, Santa Margarida, Santana/Jason and Tapera, which do not undergo water fluoridation, did not present fluoride concentration within the recommended range. However, the water samples from the WTSs Bela Vista, Caledônia, Debossan, Rio Grande de Cima and Riograndina were fluoridated, although fluoride concentration varied over the months and years (Figure 1).

In general, it was possible to notice that the WTSs with the largest number of fluoridated samples are those that supply the 1st, 6th and 8th districts of the city (Nova Friburgo, Conselheiro Paulino and Mury, respectively) (Table 3).

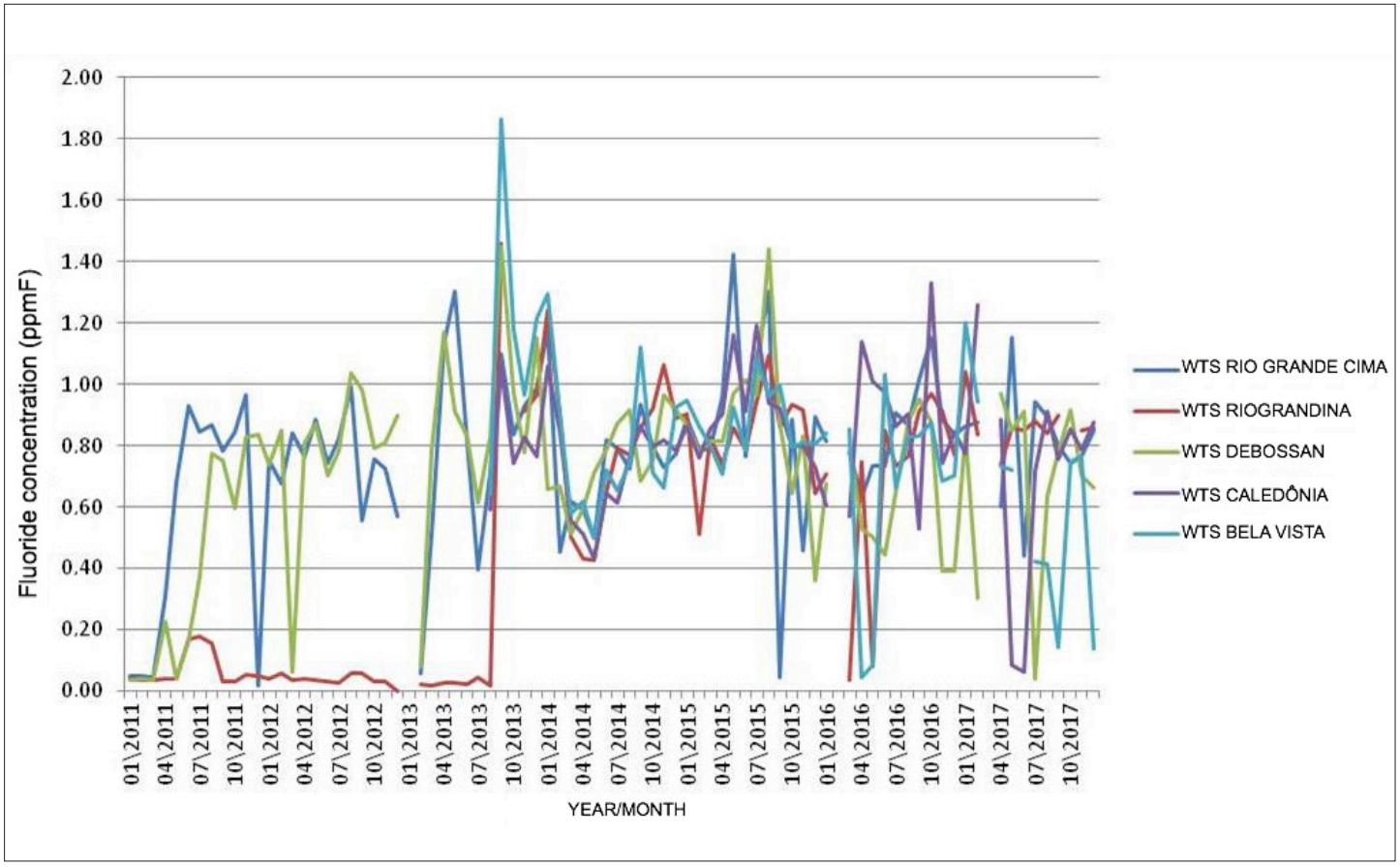

Figure 1. Mean fluoride concentration (ppmF) in water samples from Water Treatment Stations (WTSs) fluoridated during the 84 months of evaluation. Nova Friburgo, RJ, Brazil, 2018

Table 3. Classification of water samples by WTS. Nova Friburgo, RJ, 2018

WTS (District)	Total of samples n(%)	Underfluoridated (<0.65 ppmF) n(%)	Adequate (0.65-0.94 ppmF) n(%)	Overfluoridated (>0.94 ppmF) n(%)
Bela Vista (1º)	79 (100.00)	15 (18.99)	41 (51.90)	23 (29.11)
Cascatinha (1º)	79 (100.00)	74 (93.67)	04 (5.06)	01 (1.27)
Curuzu (1º)	220 (100.00)	200 (90.91)	14 (6.36)	6 (2.73)
Caledonia (1º)	138 (100.00)	39 (28.26)	74 (53.62)	25 (18.12)
Riograndina (2º)	137 (100.00)	76 (55.47)	50 (36.50)	11 (8.03)
Santa Cruz (3º)	137 (100.00)	137 (100.00)	0 (0.00)	0 (0.00)
Santana/ Janson (3º)	157 (100.00)	153 (97.45)	04 (2.55)	0 (0.00)
Amparo (4º)	139 (100.00)	139 (100.00)	0 (0.00)	0 (0.00)
Boa Esperança (5º)	73 (100.00)	63 (86.30)	4 (5.48)	6 (8.22)
Santa Margarida (5º)	140 (100.00)	124 (88.57)	1 (0.71)	15 (10.72)
Rio Grande de Cima (1º/6º)	400 (100.00)	84 (21.00)	249 (62.25)	67 (16.75)
Bocaina (7º)	78 (100.00)	78 (100.00)	0 (0.00)	0 (0.00)
Tapera (7º)	79 (100.00)	79 (100.00)	0 (0.00)	0 (0.00)
Debossan (8º)	395 (100.00)	92 (23.29)	223 (56.46)	80 (20.25)

Discussion

The fluoridation of public water supply is a recognized and recommended measure, both nationally and internationally, contributing to the improvement of people's quality of life.[12,13] In 2000, a systematic review on fluoridated water proved that regions with fluoridated water presented an average difference of 14.6% in the proportion of caries-free children and an average difference in DMFT/ceo-d (number of decayed, lost and restored permanent teeth/ number of decayed, lost and restored deciduous teeth) of 2.23, when compared with regions without fluoridated water.[13] Brazilian studies also carried out in cities with and without fluoridated water demonstrated the preventive effect of this measure, with significant reductions in caries incidence in deciduous and permanent teeth. The decrease in caries incidence in the capitals of the Brazilian states with fluoridated water has also been demonstrated, confirming the importance of this measure, its continuity and expansion as part of public policy in the pursuit of equity in oral health.[4,14]

This measure for human consumption would, theoretically, guarantee social equality because of its population reach.[15] However, although it has been approved by law since 1974, there is still an inequality in the distribution of fluoridated water in Brazil, as far as geographic location is concerned. This fact was verified by Peres *et al.*,[16] who conducted a study on water fluoridation inequality and stated that this measure focuses on the richest and most developed areas, covering about 62% of the population in the South and Southeast regions of Brazil, while in the North and Northeast regions it cover only approximately 13% of the population, considered, resulting in an unfair distribution in face of the need of the population. Cesa *et al.*[17] came to a result similar to Peres *et al.*,[16] stating that about 80% of the water samples at Porto Alegre, RS, presented adequate fluoride concentration, whereas in Aracaju, SE, only 28% of the samples presented adequate fluoride concentration. In

Nova Friburgo, RJ, the results show that the districts closest to the central region, Nova Friburgo (1st district), Conselheiro Paulino (6th district), Mury (8th district) and, more recently, Riograndina (2nd district), while the more distant districts, in rural areas for example, are still not benefited with this measure, since the fluoride concentration in most of these samples were below the level recommended by CECOL-USP.[11] This result shows that water fluoridation in these districts is not yet being done properly raising doubt on whether water fluoridation could be contributing to increase the inequity in oral health.

The preventive efficacy of fluoridation depends on a safe and adequate concentration of fluoride.[11] The results of this study showed, however, that WTSs with fluoridated water supply showed variations of this ion in over the months and years, providing both underfluoridated and overfluoridated samples. According to the CECOL-USP11, these variations in fluoride concentration are considered tolerable in some situations, for example, when concentrations with insignificant benefit (0.00 to 0.44 ppmF) or very high health risk (>1.45 ppmF) occur only one day a year. This study was able to demonstrate that the water samples collected in the WTS Rio Grande de Cima presented variations in the non-tolerable fluoride concentration in the years 2011, 2013 to 2017, since concentrations with insignificant benefit or very high health risk occurred more than once a year. The same situation occurred in WTS Riograndina in 2011 to 2017; WTS Debossan in 2011, 2014 to 2017; WTS Bela Vista in 2015 to 2017; and WTS Caledônia in 2014 to 2017, which shows that the fluoridation of the points supplied by these WTSs was not effective.

Overfluoridation (about 10% of samples) could be justified by the fact that the Ministry of Health's Ordinance No. 2914/2011[7] recommends that the concentration of fluoride added to the public water supply does not exceed 1.5 mg/L (or 1.5 ppmF). However, the same Ordinance recommends complying with Ordinance No. 635/1975,[6] which states that the ideal fluoride concentration should be calculated according to the average maximum annual temperatures of each region, as recommended by CECOL-USP.[11] Thus, it seems reasonable to assume that water fluoridation requires a periodic assessment by the sanitary surveillance agency, as the outcomes of this work demonstrate.

The present study found that only about 30% of the collected water samples presented fluoride concentration within the range considered ideal for the city of Nova Friburgo. A similar result was obtained by Carmo *et al.*,[18] in São Luis Island (MA, Brazil), who reported 46.43% of the samples presented adequate fluoride concentration, and the most peripheral regions were the most affected by underfluoridation. Very different results, however, were reported by Ramires *et al.*,[12] in Region 15 (Bauru-SP) Health Surveillance Group, who obtained 85% of the water samples with optimal concentration and compared this result with the percentage obtained in studies conducted prior to the implantation of the external control and found a significant improvement in the fluoridation conditions. This improvement was also observed in the city of Nova Friburgo, since, after the implantation of the external control, the fluoridation process was initiated in other three WTSs. However, despite the expansion of fluoridation coverage, during the 7-year period of research, the inadequate fluoride levels in water was observed, confirming the importance of having a external control.

Given the importance of fluoridation of water to control dental caries, it is essential to ensure that this measure reaches the population adequately, in an ideal concentration to obtain the maximum benefit and minimum risk.[16] An efficient form to ensure it is maintaining surveillance through an external control.

Despite the limitations of this study, such as the loss of some samples due to the impossibility of collection in few months, the data obtained from the external control suggest that there is an inequality between the distribution of fluoridation in public water supply in Nova Friburgo, underscoring the importance and benefits of continuing the research and intensifying the surveillance. In this sense, the partnership established between the University and the Health Secretariat/Environmental Health Surveillance Department establishes a clear contribution to the strengthening of health information for the city, in view of guaranteeing this measure of protection to the entire population.

Conclusion

It may be concluded that, despite the expansion of fluoridation since its implantation, the city has a clear deficiency regarding the continuous maintenance of fluoride concentration at appropriate levels, which undermines the efficacy of the measure. In addition, there is a clear presence of inequalities in the access to fluoridation between the central and peripheral regions of the city. These findings reinforce the relevance of the maintaining a periodic external control in the city as part of a surveillance action to guarantee to the population the right to fluoridated water in an equal, effective and safe manner.

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Mini Curriculum and Author's Contribution

1. Ana Paula Ferreira Marques – DDS and MSc student. Contribution: conception and design of the study, analysis and interpretation of the data and writing of the manuscript.
2. Ariane Ferraz – DDS and MSc student. Contribution: analysis and interpretation of the data and writing of the manuscript.
3. Lund Lima Godinho Netto – Graduate dentist. Contribution: data collection and analysis.
4. Rafael Gomes Ditterich – DDS and MSc. Contribution: conception and design of the study.
5. Flávia Maia Silveira – DDS and PhD. Contribution: data collection and critical review of the manuscript.
6. Ângela Scarparo – DDS and PhD. Contribution: critical review of the manuscript.
7. Maria Isabel Bastos Valente – DDS and PhD. Contribution: data analysis and critical review of the manuscript.
8. Roberta Barcelos Pereira de Souza – DDS and PhD. Contribution: conception and design of the study, analysis and interpretation of the data.
9. Andréa Videira Assaf – DDS and PhD. Contribution: conception and design of the study and critical and final review of the manuscript.

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