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https://doi.org/10.22239/2317-269x.01169

# Public water supply fluoridation: 10 years of monitoring in 38 municipalities of Centro-Oeste Paulista, São Paulo, Brazil

## Fluoretação das águas de abastecimento público: 10 anos de monitoramento em 38 municípios do Centro-Oeste Paulista, São Paulo, Brasil

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## ABSTRACT

**Introduction:** In the State of São Paulo, the concentration of fluoride in the public water supply should be maintained in the range of 0.6 to 0.8 mg/L, in order to prevent caries and avoid the risk of fluorosis. **Objective:** To evaluate the concentration of fluoride in public water supply in the municipalities covered by the Bauru Sanitary Surveillance Group. **Method:** Data were extracted from the routine of the Adolfo Lutz Institute - Bauru, from 38 municipalities monitored by the Proágua Program, in the period 2007-2016. Laboratory analyses were performed using the potentiometric method with ion-selective electrode and the interpretation of the results was based on Resolution SS-250/95 and the classification proposed by the Collaborating Center of the Ministry of Health in Oral Health Surveillance (CECOL) **Results:** Of the 8,887 samples analyzed, 31.1% had inadequate levels of fluoride ions, with 22.7% being below and 8.4% above the limit established by the legislation. According to the CECOL proposal, 59.4% of the samples showed maximum benefit for caries prevention and 0.6% revealed a very high risk for the production of dental fluorosis. **Conclusions:** These data point out the need to improve the operational control of the fluoridation process and emphasize the importance of water quality surveillance.

**KEYWORDS:** Water; Fluoride; Fluoridation; Public Supply; Sanitary Surveillance

## RESUMO

**Introdução:** No estado de São Paulo, a concentração de flúor na água de abastecimento público deve ser mantida na faixa de 0,6 a 0,8 mg/L, a fim de prevenir a cárie e evitar o risco de fluorose. **Objetivo:** Avaliar a concentração de fluoretos na água de abastecimento público dos municípios de abrangência do Grupo de Vigilância Sanitária de Bauru. **Método:** Os dados foram extraídos da rotina do Instituto Adolfo Lutz - Bauru e oriundos de 38 municípios monitorados pelo Programa de Vigilância da Qualidade da Água para Consumo Humano (Proágua), no período de 2007-2016. As análises laboratoriais foram realizadas utilizando-se o método potenciométrico com eletrodo íon-seletivo e a interpretação dos resultados baseou-se na Resolução SS nº 250/95 e na classificação proposta pelo Centro Colaborador do Ministério da Saúde em Vigilância da Saúde Bucal (CECOL). **Resultados:** Das 8.887 amostras analisadas, 31,1% apresentaram teores inadequados de íons fluoretos, sendo que 22,7% estavam abaixo e 8,4% acima do limite estabelecido pela legislação. De acordo com a proposta do CECOL, 59,4% das amostras exibiram benefício máximo para prevenção de cárie e 0,6% revelaram risco muito alto para produção de fluorose dentária. **Conclusões:** Tais dados apontam a necessidade de aprimorar o controle operacional do processo de fluoretação e enfatiza a importância da vigilância da qualidade da água.

**PALAVRAS-CHAVE:** Água; Flúor; Fluoretação; Abastecimento Público; Vigilância Sanitária

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Received: Jul 04, 2018
Approved: Oct 17, 2018

## INTRODUCTION

Fluorides, the ionic form of the fluorine element, are primarily responsible for the decline of dental caries. Their use as a preventive and therapeutic tool began in 1945/1946, with the fluoridation of public water supply in the United States and in Canada. The efficacy of the method was confirmed by studies that demonstrated a decrease of about 50% in the caries index of the studied population. Fluoridation was recommended by both the World Health Organization (WHO) and other healthcare institutions and proved to be so effective that it was considered by the US Centers for Disease Control and Prevention (CDC) as one of the top 10 achievements of Public Health in the twentieth century[1,2].

In Brazil, fluoridation was enforced in the 1970s after the approval of Federal Law n. 6.050, of May 24, 1974, which determined its mandatory use in public water supply systems in places with water treatment plants[2]. The monitoring of this process was instituted in the Program for Monitoring the Quality of Water for Human Consumption (Proágua) at the initiative of the public power and focused on the potability of the water offered to the population. Thus, in 2012, Brazil already had the world's second largest fluoridation system for public water supply[3].

Therefore, one of the relevant aspects related to water for human consumption concerns oral health, for which the addition of fluoride ions to water is a traditional and recognized effective measure. Basically, the fluoridation process consists of the controlled addition of a fluorine compound to the water distributed to the population, in order to raise its concentration to a certain value, established as effective and beneficial. It is considered as one of the broadest measures of health promotion in the dental area and the main one in terms of the use of fluoride on a population scale, since it is a safe and cost-effective process with great social reach[1,3,4].

However, it is worth emphasizing that the action of these ions is dose-dependent. At low concentrations, they play no relevant role and, in excess, they may favor the development of dental fluorosis[5,6].

Dental fluorosis is a tooth enamel mineralization defect, with severity associated directly with the amount of fluoride ingested during the tooth germ formation process, which consists of symmetrical changes ranging from transverse white diffuse lines crossing the teeth to various types of teeth erosion[7].

Brazil has one of the largest populations of fluoridated dentifrice consumers, and a large part of the population is exposed to multiple formulations of fluoride products like mineral water, teas, medicines, toothpastes, nutritional supplements and others[3]. Consequently, exposure of the population to multiple sources of fluoride ions emphasizes concern about excessive fluoride consumption[1].

The concentration limits of fluoride ions in public water supply are regulated by specific legislation and calculated according to the average maximum daily temperatures, i.e., they depend on the climatic conditions of each locality, which interfere in the increase or decrease of the water consumption by the population. In colder places, water intake is lower and hence fluorine levels have to be higher compared to warmer regions[8]. Thus, each Brazilian state can establish its ideal range for fluoride ions according to the criteria established in Ordinance n. 635/Bsb, of December 26, 1975[9]. In the absence of state legislation, the Ministry of Health (MS) Consolidation Ordinance n. 5, of September 28, 2017, should prevail, with a maximum permitted value for fluoride ions of 1.5 mg/L[10].

In the state of São Paulo, Resolution n. 250, of August 15, 1995, from the State Health Department (SES), establishes that the ideal fluoride ions content is 0.7 mg/L. The range of 0.6 to 0.8 mg/L is considered within the potability standard[11]. Values above this concentration are only accepted when proven by the Public Water Supply Service that the average maximum daily air temperature of the municipality it supplies is below 14.7°C for a minimum period of one year.

According to the Collaborating Center of the Ministry of Health in Oral Health Surveillance (CECOL), the interpretation of the analytical results in relation to the quantification of fluoride ions in water should not be simplified as merely "adequate" or "inadequate". Measurements of fluoride levels vary on a continuous scale of values and the inclusion of these values on a scale with only two categories reduces the options for interpretation and understanding the characteristics of the samples. Thus, it is recommended that the assessment of the fluoride content in the public water supply be made considering both the dimensions related to the benefit and the risk, seeking to assess, in each analysis, the intensity of both the preventive benefit of dental caries and the risk inherent in the exposure to fluoride ions[12].

Certainly, in order for the standards established by the legislation to be maintained and the benefits achieved, the process requires constant monitoring and evaluation, with an ongoing focus on the quality of public supply systems. In fact, this need for control mechanisms has led to the emergence of the concept of heterocontrol, which consists of periodic analyses of the water fluoridation process by an institution (public or private) other than the company responsible for the water treatment and distribution[13].

Considering the public health relevance of the effective control of the process of fluoridation of water intended for human consumption, the present study had the general objective of evaluating the fluoride concentration in the public water supply of all the municipalities covered by the Health Surveillance Group Bauru (GVS XV), Brazil, from 2007 to 2016.

## METHOD

Descriptive research in which the results of fluoride ions found in the public water supply samples from Proágua, which compose the heterocontrol of this parameter in the study region, were computed and interpreted.

The data were extracted from the laboratory routine of the Center of Chemical and Bromatological Sciences of the Adolfo Lutz Institute - Bauru, from the 38 municipalities within the Bauru Health Surveillance Group (GVS XV), from January 2007 to December 2016.

In the study period, the water samples were collected monthly along the distribution network, always at strategic points, external to the households and predetermined by the professionals of the Municipal Health Surveillance body (VISA), according to the criteria established in the National Plan of Sampling Guidelines of the Environmental Health Surveillance related to the quality of water for human consumption[14].

For the laboratory analysis, we used the potentiometric method with ion-selective electrode of the Orion brand, model 9609, coupled to the potentiometer of the Mettler-Toledo brand, Model 355. The concentration of fluoride found in the water samples was determined using 25 mL of the sample to which the following amounts were added: 2.5 mL of TISSAB 3 buffer, composed basically of 1,2-cyclohexylenedinitrilotetracético acid (CDTA), sodium citrate dihydrate and chloride of sodium and water in specific amounts[15]. The electrode was previously calibrated with standard solutions containing 0.3; 0.6; 0.8; 1.0 and 1.5 mg/L of fluoride ion. The reproducibility of the results was verified by re-reading both the patterns and the samples during the execution of the analytical routine.

Initially, the results were interpreted as satisfactory and unsatisfactory, considering the range established by Resolution SS n. 250/1995[11]. Moreover, in order to evaluate the possible benefits for the prevention of caries and the possible risks for the production of dental fluorosis, the results were evaluated through the classification proposed by CECOL[12].

According to CECOL[12], the consensus to guide the classification of water, taking into account both the benefit and the risk, for locations where the average maximum temperatures are between 26.3°C and 32°C, 5°C is shown in the Table.

The simple analyses of the data were done in Microsoft Office Excel 2010® and the statistical analyses were done in Statistica - version 10 (StatSoft), considering a significant difference when $p < 0.05$.

## RESULTS AND DISCUSSION

From 2007 to 2016, 8,887 samples of public water supply were analyzed at the Adolfo Lutz Institute - Bauru. In general, the values of fluoride ions observed in these samples are shown in Table 1.

**Chart.** Water classification for localities where the maximum temperature averages are between 26.3°C and 32.5°C, according to CECOL[12].

| Fluoride content in the water (in ppm or mg F-/L) | Benefit (preventing caries) | Risk (producing dental fluorosis) |
|---|---|---|
| 0.00 to 0.44 | Insignificant | Insignificant |
| 0.45 to 0.54 | Minimum | Low |
| 0.22 to 0.84 | Maximum | Low |
| 0.85 to 1.14 | Maximum | Moderate |
| 1.15 to 1.44 | Questionable | High |
| 1,45 or more | Harmful | Very high |

ppm: parts per million

**Table 1.** Annual classification of water samples for fluoride ions from the 38 municipalities covered by the Bauru Health Surveillance Group (GVS-XV), according to the current legislation.

| Year | N | Reference values of fluoride according to SS Resolution n. 250/1995[11] | | |
|---|---|---|---|---|
| | | Below the minimum limit | Satisfactory | Above the maximum limit |
| | | (≤ 0.6 mg/L $F^-$) | (0.6 to 0.8 mg/L $F^-$) | (≥ 0.8 mg/L $F^-$) |
| 2007 | 1,005 | 28.1% ↑ | 66.5% | 5.5% ↓ |
| 2008 | 1,148 | 26.3% ↑ | 67.9% | 5.8% ↓ |
| 2009 | 945 | 27.4% ↑ | 66.7% | 5.9% ↓ |
| 2010 | 733 | 22.7% | 65.5% ↓ | 11.9% ↑ |
| 2011 | 745 | 22.7% | 69.1% | 8.2% |
| 2012 | 379 | 30.3% ↑ | 59.1% ↓ | 10.6% |
| 2013 | 745 | 24.8% | 63.9% ↓ | 11.3% ↑ |
| 2014 | 948 | 18.8% ↓ | 73.3% ↑ | 7.9% |
| 2015 | 1,059 | 14.6% ↓ | 75.7% ↑ | 9.6% |
| 2016 | 1,180 | 17.2% ↓ | 72.4% ↑ | 10.4% ↑ |
| Total | 8,887 | 22.7% | 68.9% | 8.4% |

Chi-square: $p < 0.001$.
Because of the large number of categories, the residue analysis was carried out, whereby the arrows (↑ or ↓) indicate significantly higher or lower percentages, respectively, than the expected frequencies in each year we investigated.

Considering Resolution SS n. 250/1995[11], during the study period we found that 68.9% of the samples presented satisfactory values, within the range established by the legislation of the state of São Paulo (0.6 to 0.8 mg/L $F^-$).

According to the statistical analysis, in the first years investigated (2007, 2008 and 2009) the number of samples with fluoride ions below the minimum limit was higher than the historical average, while the percentage of samples above the maximum limit was lower. In 2010, 2012 and 2013, the percentage of samples with satisfactory levels was below expectations, with deviations above the maximum limit in 2010 and 2013 and below the minimum threshold in 2012. However, it is worth noting that in 2014, 2015 and 2016, there was a significant improvement in water fluoridation parameters, which can be demonstrated by the significant increase in the percentage of samples with satisfactory levels of fluoride ions. Furthermore, this improvement over time was reinforced by the reduction in the percentage of samples below the minimum limit (0.6 mg/L $F^-$) in the last three years we analyzed (Table 1).

A similar result has already been described by Catani et al.[16], who, following the water fluoridation heterocontrol program of several municipalities in the states of São Paulo, Minas Gerais and Ceará, from 1996 to 2006, observed that 63.8% of the analyzed samples presented ideal concentrations of ions fluorides, 19.7% had concentrations below the minimum value and 16.5% showed concentrations above the maximum value established by the legislation.

Divergently, when analyzing 480 samples of heterocontrol of the fluoridation of public water supply in São Luís, Maranhão, Paredes[17] verified that the majority of the samples (62.9%) presented inadequate values, according to the federal ordinance (n. 635/Bsb/1975) prevalent in the state. Similarly, evaluating the concentration of fluoride in the water of the municipalities of the state of Ceará, Saldanha et al.[18] reported that in 100%, 81.5%, 66.4% and 55.5% of the samples, values were below the concentration considered ideal in the state, in Viçosa, Sobral, Fortaleza and Rafael Arruda, respectively. These results reinforce the challenges of fluoridation systems, especially in ensuring the minimum levels of fluoride in water.

Table 2 shows the values of fluoride ions observed in each municipality during the study period, in accordance with the limits established by current legislation, in order to evaluate the fluoridation of the water in each GVS-XV municipality.

Of the 38 municipalities investigated, the majority (68.4%) presented water samples with concentrations of fluoride ions within the recommended parameters, however, 12 (31.6%) municipalities had satisfactory percentages significantly lower than the expected frequencies. Of these, 11 municipalities have public water supply systems managed by autonomous services and one municipality has its service managed by the São Paulo State Sewage Company (Sabesp), which emphasizes the greater difficulty faced by the municipalities where management is the responsibility of their own autonomous service. Often, systems operated by Sabesp demonstrate better operational control, since they have greater financial support, infrastructure and technical training[19].

Additionally, in order to evaluate the benefit for caries prevention and the risk for fluorosis production, we drew a comparison of the fluoride ion results obtained in the present study with the criteria adopted by the CECOL, University of São Paulo (USP)[12]. The data of these evaluations are arranged in Tables 3 and 4, respectively.

In the years 2007, 2008, 2010 and 2012, a significant percentage of the samples presented insignificant benefit for caries prevention. In the years 2014 to 2016, in turn, these indices decreased and simultaneously we found a significant percentage of samples capable of generating maximum benefit. Regarding the risk of fluorosis, even though the percentage of samples with fluoride ion dosages below the lower limit has decreased in the last years evaluated, a significantly higher percentage of samples still indicates a low risk for the production of dental fluorosis.

Considerably, the ideal range of fluoride ions concentration in the water is quite narrow (0.6 to 0.8 mg/L), which makes it difficult to establish the correct fluoride dosage to be added, since it depends on the flow rate, on the water pressure in the system, and on possible problems presented in the operation of the dosing devices, among others. However, considering that the permanent interruption of the addition of fluoride to the public supply water would cease the benefits of caries prevention, the addition of insufficient amounts renders the measure useless, the addition of excessive quantities may cause fluorosis and that both (caries and fluorosis) are undesirable consequences, these situations should be carefully avoided[19].

Tables 5 and 6 show the values of fluoride ions found in each municipality of GVS-XV in the study period, taking into account the benefit for caries prevention and the risk of fluorosis, respectively, according to with CECOL[12].

Overall, our data indicated significantly higher percentages of samples with negligible benefit for caries prevention in eight (21.1%) of the 38 municipalities we evaluated. Regarding fluorosis, five (13.6%) municipalities presented significantly higher percentages than those expected for samples with very high risk of dental fluorosis.

Kuhnen et al.[20], when evaluating the water fluoridation heterocontrol in Santa Catarina between 2004 and 2013, found a higher percentage of samples with a high risk of fluorosis. The aforementioned study found that approximately 45% of the analyzed samples had inadequate fluoride contents (above 0.95 mg/L).

As previously reported, the difficulties faced in maintaining ideal concentrations of fluoride can involve several factors, like (1) the narrow range of adequacy of the levels established by the legislation, which may be the main difficulty; (2) the dosing pump and the fluorine compound that are used, which may cause interruptions in the treatment process; (3) the conditions of the

**Table 2.** Classification of water samples for fluoride ions for each of municipality covered by the Bauru Health Surveillance Group (GVS-XV), according to the current legislation, from 2007 to 2016.

| Municipality | Utility manager company | N | Reference values of fluoride according to SS Resolution n. 250/1995[11] | | |
|---|---|---|---|---|---|
| | | | Below the minimum limit | Satisfactory | Above the maximum limit |
| | | | (≤ 0.6 mg/L $F^-$) | (0.6 to 0.8 mg/L $F^-$) | (≥ 0.8 mg/L $F^-$) |
| M1 | Sabesp | 270 | 5.9% ↓ | 92.6% ↑ | 1.5% ↓ |
| M2 | Sabesp | 146 | 8.9% ↓ | 86.3% ↑ | 4.8% |
| M3 | Autonomous service | 883 | 2.9% ↓ | 94.8% ↑ | 2.3% ↓ |
| M4 | Autonomous service | 304 | 43.1% ↑ | 51.3% ↓ | 5.6% |
| M5 | Autonomous service | 378 | 10.9% ↓ | 74.9% ↑ | 14.3% ↑ |
| M6 | Sabesp | 216 | 0.9% ↓ | 92.6% ↑ | 6.5% |
| M7 | Sabesp | 132 | 9.1% ↓ | 88.6% ↑ | 2.3% ↓ |
| M8 | Autonomous service | 106 | 11.3% ↓ | 82.1% ↑ | 6.6% |
| M9 | Autonomous service | 218 | 8.3% ↓ | 77.1% ↑ | 14.7% ↑ |
| M10 | Autonomous service | 121 | 32.2% ↑ | 45.5% ↓ | 22.3% ↑ |
| M11 | Autonomous service | 331 | 58.9% ↑ | 29.9% ↓ | 11.2% |
| M12 | Autonomous service | 266 | 69.9% ↑ | 18.1% ↓ | 12.0% ↑ |
| M13 | Sabesp | 187 | 7.5% ↓ | 78.6% ↑ | 13.9% ↑ |
| M14 | Autonomous service | 260 | 13.9% ↓ | 73.1% | 13.1% ↑ |
| M15 | Autonomous service | 266 | 1.9% ↓ | 95.9% ↑ | 2.3% ↓ |
| M16 | Autonomous service | 145 | 12.4% ↓ | 75.9% | 11.7% |
| M17 | Autonomous service | 259 | 69.9% ↑ | 20.5% ↓ | 9.7% |
| M18 | Autonomous service | 254 | 82.3% ↑ | 10.2% ↓ | 7.5% |
| M19 | Autonomous service | 110 | 16.4% | 80.9% ↑ | 2.7% ↓ |
| M20 | Autonomous service | 706 | 31.2% ↑ | 62.0% ↓ | 6.8% |
| M21 | Autonomous service | 491 | 11.2% ↓ | 71.3% | 17.5% ↑ |
| M22 | Sabesp | 350 | 1.7% ↓ | 81.1% ↑ | 17.1% ↑ |
| M23 | Sabesp | 132 | 5.3% ↓ | 88.6% ↑ | 6.1% |
| M24 | Autonomous service | 229 | 9.6% ↓ | 84.7% ↑ | 5.7% |
| M25 | Autonomous service | 218 | 26.2% | 57.3% ↓ | 16.5% ↑ |
| M26 | Sabesp | 350 | 6.3% ↓ | 93.1% ↑ | 0.6% ↓ |
| M27 | Sabesp | 219 | 28.3% ↑ | 65.8% | 5.9% |
| M28 | Autonomous service | 150 | 93.3% ↑ | 5.3% ↓ | 1.3% ↓ |
| M29 | Autonomous service | 336 | 18.2% ↓ | 64.0% ↓ | 17.9% ↑ |
| M30 | Sabesp | 124 | 1.6% ↓ | 98.4% ↑ | 0.0% ↓ |
| M31 | Autonomous service | 141 | 46.8% ↑ | 43.3% ↓ | 9.9% |
| M32 | Autonomous service | 134 | 10.5% ↓ | 87.3% ↑ | 2.2% ↓ |
| M33 | Sabesp | 126 | 62.7% ↑ | 31.8% ↓ | 5.6% |
| M34 | Sabesp | 114 | 0.9% ↓ | 96.5% ↑ | 2.6% ↓ |
| M35 | Sabesp | 60 | 10.0% ↓ | 88.3% ↑ | 1.7% |
| M36 | Sabesp | 81 | 18.5% | 74.1% | 7.4% |
| M37 | Sabesp | 43 | 9.3% ↓ | 86.1% ↑ | 4.7% |
| M38 | Sabesp | 31 | 9.7% | 83.9% | 6.5% |
| Total | | 8,887 | 22.7% | 68.9% | 8.4% |

Chi-square: $p < 0.001$.
Sabesp: São Paulo State Sewage Company.
Because of the large number of categories, the residue analysis was carried out, whereby the arrows (↑ or ↓) indicate significantly higher or lower percentages, respectively, than the expected frequencies in each year we investigated as to the reference values for fluoride levels according to the legislation in force.

**Table 3.** Annual classification of water samples for fluoride ions results according to their ability to prevent caries, according to criteria of the Collaborating Center of the Ministry of Health in Oral Health Surveillance (CECOL)[12].

| Year | N | Benefit for caries prevention | | | | | |
|---|---|---|---|---|---|---|---|
| | | Insignificant | Minimum | Moderate | Maximum | Questionable | Harmful |
| 2007 | 1,005 | 19.5% ↑ | 8.6% ↑ | 21.7% ↑ | 49.6% ↓ | 0.3% | 0.4% |
| 2008 | 1,148 | 18.8% ↑ | 7.5% | 22.3% ↑ | 50.2% ↓ | 0.6% | 0.6% |
| 2009 | 945 | 18.2% | 8.4% ↑ | 23.8% ↑ | 48.3% ↓ | 0.5% | 0.9% |
| 2010 | 733 | 19.0% ↑ | 3.1% ↓ | 11.6% ↓ | 65.5% ↑ | 0.4% | 0.4% |
| 2011 | 745 | 18.3% | 4.2% ↓ | 9.3% ↓ | 67.8% ↑ | 0.3% | 0.3% |
| 2012 | 379 | 24.3% ↑ | 6.1% | 16.1% | 52.0% ↓ | 0.5% | 1.1% |
| 2013 | 745 | 17.9% | 6.4% | 14.2% ↓ | 60.7% | 0.4% | 0.4% |
| 2014 | 948 | 11.3% ↓ | 7.1% | 17.9% | 62.8% ↑ | 0.7% | 0.2% |
| 2015 | 1,059 | 9.6% ↓ | 4.7% ↓ | 15.1% | 69.3% ↑ | 0.7% | 0.6% |
| 2016 | 1,180 | 11.7% ↓ | 5.2% | 14.8% ↓ | 66.9% ↑ | 0.3% | 1.1% |
| Total | 8,887 | 16.1% | 6.2% | 17.2% | 59.4% | 0.5% | 0.6% |

Chi-square: $p < 0.001$.
Because of the large number of categories, the residue analysis was carried out, whereby the arrows (↑ or ↓) indicate significantly higher or lower percentages, respectively, than the expected frequencies in each year we investigated.

**Table 4.** Annual classification of water samples for fluoride ions results according to the risk of producing dental fluorosis, according to criteria of the Collaborating Center of the Ministry of Health in Oral Health Surveillance (CECOL)[12].

| Year | N | Risk of producing dental fluorosis | | | | |
|---|---|---|---|---|---|---|
| | | Insignificant | Low | Moderate | High | Very high |
| 2007 | 1,005 | 19.5% ↑ | 77.0% ↓ | 2.8% | 0.3% | 0.4% |
| 2008 | 1,148 | 18.8% ↑ | 77.6% | 2.4% | 0.6% | 0.6% |
| 2009 | 945 | 18.2% | 78.9% | 1.5% ↓ | 0.5% | 0.9% |
| 2010 | 733 | 19.0% ↑ | 73.9% ↓ | 6.3% ↑ | 0.4% | 0.4% |
| 2011 | 745 | 18.3% | 78.1% | 3.1% | 0.3% | 0.3% |
| 2012 | 379 | 24.3% ↑ | 71.0% ↓ | 3.2% | 0.5% | 1.1% |
| 2013 | 745 | 17.9% | 78.5% | 2.8% | 0.4% | 0.4% |
| 2014 | 948 | 11.3% ↓ | 84.9% ↑ | 2.9% | 0.7% | 0.2% |
| 2015 | 1,059 | 9.6% ↓ | 84.6% ↑ | 4.5% ↑ | 0.7% | 0.6% |
| 2016 | 1,180 | 11.7% ↓ | 83.6% ↑ | 3.2% | 0.3% | 1.1% |
| Total | 8,887 | 16.1% | 79.6% | 3.2% | 0.5% | 0.6% |

Chi-square: $p < 0.001$.
Because of the large number of categories, the residue analysis was carried out, whereby the arrows (↑ or ↓) indicate significantly higher or lower percentages, respectively, than the expected frequencies in each year we investigated.

treatment plant; (4) the points established for collection; (5) the training and education of responsible workers, among others[21].

In order to ensure operational control of the water treatment system in relation to fluoridation, municipalities need, in addition to financial resources and investments in adequate and calibrated equipment, structural improvements and technical supervision, hiring and training of skilled workers and maintenance of the necessary infrastructure[22].

In order to avoid the occurrence of undesirable water quality episodes or inadequate procedures in the fluoridation process, systematic inspections are necessary, at appropriate frequency and at vulnerable points in the system, to prevent, avoid or correct possible deviations from the ideal concentration of fluorine in the public supply network[23,24].

Thus, the role of health surveillance authorities in monitoring and inspecting the fluoridation of public water supply is clear, as well as the need to enable the implementation, structuring and training of the work teams in the municipalities so that activities and actions can be effective and free of political interference. Furthermore, in order to evaluate the efficacy/efficiency and the risk/benefit analysis of the public fluoridation policy, further epidemiological studies on the incidence/prevalence of caries and fluorosis in Brazilian municipalities and its relationship with the indices of fluorine in the public water supply are essential.

**Table 5.** Classification of water samples for fluoride ions results for each municipality within the Bauru Health Surveillance Group (GVS-XV), according to their ability to prevent caries, according to criteria of the Collaborating Center of the Ministry of Health in Oral Health Surveillance (CECOL)[12].

| Municipality | N | Benefit of caries prevention | | | | | |
|---|---|---|---|---|---|---|---|
| | | Insignificant | Minimum | Moderate | Maximum | Questionable | Harmful |
| M1 | 270 | 4.1% ↓ | 1.9% ↓ | 20.7% | 73.3% ↑ | 0.0% | 0.0% |
| M2 | 146 | 2.1% ↓ | 6.9% | 20.6% | 70.6% ↑ | 0.0% | 0.0% |
| M3 | 883 | 1.5% ↓ | 1.4% ↓ | 24.8% ↑ | 72.0% ↑ | 0.2% | 0.1% |
| M4 | 304 | 30.9% ↑ | 11.5% ↑ | 21.1% | 35.9% ↓ | 0.3% | 0.3% |
| M5 | 378 | 5.6% ↓ | 4.5% | 12.7% ↓ | 76.2% ↑ | 0.5% | 0.5% |
| M6 | 216 | 0.5% ↓ | 0.5% ↓ | 19.0% | 78.7% ↑ | 0.5% | 0.9% |
| M7 | 132 | 6.1% ↓ | 3.0% | 22.0% | 67.4% | 1.5% | 0.0% |
| M8 | 106 | 2.8% ↓ | 5.7% | 27.4% ↑ | 63.2% | 0.9% | 0.0% |
| M9 | 218 | 1.8% ↓ | 6.0% | 18.4% | 72.5% ↑ | 0.9% | 0.5% |
| M10 | 121 | 19.8% | 12.4% ↑ | 9.1% ↓ | 56.2% | 0.8% | 1.7% |
| M11 | 331 | 47.4% ↑ | 10.6% ↑ | 11.2% ↓ | 28.4% ↓ | 0.9% | 1.5% ↑ |
| M12 | 266 | 67.3% ↑ | 2.6% ↓ | 3.8% ↓ | 23.3% ↓ | 0.8% | 2.3% ↑ |
| M13 | 187 | 0.5% ↓ | 6.4% | 14.4% | 78.1% ↑ | 0.5% | 0.0% |
| M14 | 260 | 4.6% ↓ | 8.9% | 14.2% | 71.2% ↑ | 1.2% | 0.0% |
| M15 | 266 | 0.4% ↓ | 1.5% ↓ | 13.9% | 84.2% ↑ | 0.0% | 0.0% |
| M16 | 145 | 5.5% ↓ | 6.2% | 13.1% | 73.1% ↑ | 0.7% | 1.4% |
| M17 | 259 | 59.9% ↑ | 9.7% ↑ | 5.4% ↓ | 22.8% ↓ | 0.4% | 1.9% ↑ |
| M18 | 254 | 76.8% ↑ | 5.5% | 4.3% ↓ | 11.4% ↓ | 0.8% | 1.2% |
| M19 | 110 | 9.1% ↓ | 7.3% | 27.3% ↑ | 56.4% | 0.0% | 0.0% |
| M20 | 706 | 16.6% | 14.2% ↑ | 24.1% ↑ | 44.1% ↓ | 0.9% | 0.3% |
| M21 | 491 | 6.3% ↓ | 4.9% | 15.9% | 72.7% ↑ | 0.0% | 0.2% |
| M22 | 350 | 1.1% ↓ | 0.6% ↓ | 5.4% ↓ | 92.3% ↑ | 0.3% | 0.3% |
| M23 | 132 | 3.8% ↓ | 1.5% ↓ | 24.2% ↑ | 68.9% ↑ | 0.0% | 1.5% |
| M24 | 229 | 4.4% ↓ | 5.2% | 19.2% | 71.2% ↑ | 0.0% | 0.0% |
| M25 | 218 | 14.2% | 11.5% ↑ | 13.3% | 55.5% | 2.8% ↑ | 2.8% ↑ |
| M26 | 350 | 2.3% ↓ | 4.0% | 2.08% ↑ | 65.7% ↑ | 0.0% | 0.0% |
| M27 | 219 | 14.6% | 12.8% ↑ | 25.6% ↑ | 47% ↓ | 0.0% | 0.0% |
| M28 | 150 | 89.3% ↑ | 4.0% | 3.3% ↓ | 2.7% ↓ | 0.0% | 0.7% |
| M29 | 336 | 6.0% ↓ | 11.3% | 19.1% | 61.6% | 0.9% | 1.2% |
| M30 | 124 | 1.6% ↓ | 0.0% ↓ | 16.1% | 82.3% ↑ | 0.0% | 0.0% |
| M31 | 141 | 36.2% ↑ | 9.9% | 19.9% | 32.6% ↓ | 0.7% | 0.7% |
| M32 | 134 | 4.5% ↓ | 5.2% | 24.6% ↑ | 65.7% | 0.0% | 0.0% |
| M33 | 126 | 58.7% ↑ | 4.0% | 7.9% ↓ | 25.4% ↓ | 0.8% | 3.2% ↑ |
| M34 | 114 | 0.9% ↓ | 0.0% ↓ | 0.9% ↓ | 98.3% ↑ | 0.0% | 0.0% |
| M35 | 60 | 1.7% ↓ | 6.7% | 25.0% | 66.7% | 0.0% | 0.0% |
| M36 | 81 | 3.7% ↓ | 14.8% ↑ | 25.9% ↑ | 55.6% | 0.0% | 0.0% |
| M37 | 43 | 0.0% ↓ | 9.3% | 18.6% | 72.1% | 0.0% | 0.0% |
| M38 | 31 | 3.2% | 6.5% | 16.1% | 74.2% | 0.0% | 0.0% |
| Total | 8,887 | 16.1% | 6.2% | 17.2% | 59.4% | 0.5% | 0.6% |

Chi-square: $p < 0.001$.
Because of the large number of categories, the residue analysis was carried out, whereby the arrows (↑ or ↓) indicate significantly higher or lower percentages, respectively, than the expected frequencies in each year we investigated as to the values of fluoride capable of generating the caries prevention benefit.

**Table 6.** Classification of water samples for the fluoride ions results for each municipality within the Bauru Sanitary Surveillance Group (GVS-XV), according to the risk of generating dental fluorosis, according to criteria of the Collaborating Center of the Ministry of Health in Oral Health Surveillance (CECOL)[12].

| Municipality | N | Risk of production of dental fluorosis | | | | |
|---|---|---|---|---|---|---|
| | | Insignificant | Low | Moderate | High | Very high |
| M1 | 270 | 4.1% ↓ | 95.6% ↑ | 0.4% ↓ | 0.0% | 0.0% |
| M2 | 146 | 2.1% ↓ | 97.3% ↑ | 0.7% | 0.0% | 0.0% |
| M3 | 883 | 1.5% ↓ | 97.4% ↑ | 0.8% ↓ | 0.2% | 0.1% |
| M4 | 304 | 30.9% ↑ | 65.1% ↓ | 3.3% | 0.3% | 0.3% |
| M5 | 378 | 5.6% ↓ | 86.5% ↑ | 6.9% ↑ | 0.5% | 0.5% |
| M6 | 216 | 0.5% ↓ | 96.8% ↑ | 1.4% | 0.5% | 0.9% |
| M7 | 132 | 6.1% ↓ | 91.7% ↑ | 0.8% | 1.5% | 0.0% |
| M8 | 106 | 2.8% ↓ | 92.5% ↑ | 3.8% | 0.9% | 0.0% |
| M9 | 218 | 1.8% ↓ | 90.8% ↑ | 6% ↑ | 0.9% | 0.5% |
| M10 | 121 | 19.8% | 67.8% ↓ | 9.9% ↑ | 0.8% | 1.7% |
| M11 | 331 | 47.4% ↑ | 45.3% ↓ | 4.8% | 0.9% | 1.5% ↑ |
| M12 | 266 | 67.3% ↑ | 26.3% ↓ | 3.4% | 0.8% | 2.3% ↑ |
| M13 | 187 | 0.5% ↓ | 90.9% ↑ | 8.0% ↑ | 0.5% | 0.0% |
| M14 | 260 | 4.6% ↓ | 89.6% ↑ | 4.6% | 1.2% | 0.0% |
| M15 | 266 | 0.4% ↓ | 98.9% ↑ | 0.8% ↓ | 0.0% | 0.0% |
| M16 | 145 | 5.5% ↓ | 86.2% ↑ | 6.2% ↑ | 0.7% | 1.4% |
| M17 | 259 | 59.9% ↑ | 33.6% ↓ | 4.3% | 0.4% | 1.9% ↑ |
| M18 | 254 | 76.8% ↑ | 17.3% ↓ | 3.9% | 0.8% | 1.2% |
| M19 | 110 | 9.1% ↓ | 90.9% ↑ | 0.0% | 0.0% | 0.0% |
| M20 | 706 | 16.6% | 79.0% | 3.3% | 0.9% | 0.3% |
| M21 | 491 | 6.3% ↓ | 88% ↑ | 5.5% ↑ | 0.0% | 0.2% |
| M22 | 350 | 1.1% ↓ | 97.1% ↑ | 1.1% ↓ | 0.3% | 0.3% |
| M23 | 132 | 3.8% ↓ | 94.7% ↑ | 0.0% ↓ | 0.0% | 1.5% |
| M24 | 229 | 4.4% ↓ | 95.2% ↑ | 0.4% ↓ | 0.0% | 0.0% |
| M25 | 218 | 14.2% | 74.3% ↓ | 6% ↑ | 2.8% ↑ | 2.8% ↑ |
| M26 | 350 | 2.3% ↓ | 97.4% | 0.3% ↓ | 0.0% | 0.0% |
| M27 | 219 | 14.6% | 81.3% | 4.1% | 0.0% | 0.0% |
| M28 | 150 | 89.3% ↑ | 9.3% ↓ | 0.7% | 0.0% | 0.7% |
| M29 | 336 | 6.0% ↓ | 83.6% | 8.3% ↑ | 0.9% | 1.2% |
| M30 | 124 | 1.6% ↓ | 98.4% ↑ | 0.0% ↓ | 0.0% | 0.0% |
| M31 | 141 | 36.2% ↑ | 58.2% ↓ | 4.3% | 0.7% | 0.7% |
| M32 | 134 | 4.5% ↓ | 94.8% ↑ | 0.8% | 0.0% | 0.0% |
| M33 | 126 | 58.7% ↑ | 37.3% ↓ | 0.0% ↓ | 0.8% | 3.2% ↑ |
| M34 | 114 | 0.9% ↓ | 98.3% ↑ | 0.9% | 0.0% | 0.0% |
| M35 | 60 | 1.7% ↓ | 96.7% ↑ | 1.7% | 0.0% | 0.0% |
| M36 | 81 | 3.7% ↓ | 91.4% ↑ | 4.9% | 0.0% | 0.0% |
| M37 | 43 | 0.0% ↓ | 100.0% ↑ | 0.0% | 0.0% | 0.0% |
| M38 | 31 | 3.2% | 90.3% | 6.5% | 0.0% | 0.0% |
| Total | 8,887 | 16.1% | 79.6% | 3.2% | 0.5% | 0.6% |

Chi-square: $p < 0.001$.
Because of the large number of categories, the residue analysis was carried out, whereby the arrows (↑ or ↓) indicate significantly higher or lower percentages, respectively, than the expected frequencies in each year we investigated as to the levels of fluoride that pose risks to the production of dental fluorosis.

## CONCLUSIONS

Our data indicate that, in the period from 2007 to 2016, there was increasing improvement in the fluoridation process of the municipalities covered by GVS-XV. However, the percentages of samples outside the appropriate limits, especially below the minimum threshold established by legislation, demonstrate the need to improve the operational control of supply systems and the monitoring and surveillance of the water supplied to the population.

The monitoring of the fluoridation of public water supply, the identification of problems and the adoption of effective corrective measures for the adequacy of the fluoridation process in municipalities where there are oscillations of fluorine levels are essential to protect the health of individuals.

It is also important to carry out epidemiological studies of water fluoridation-related diseases in order to allow an adequate critical analysis of the risk/benefit of this treatment for the oral health of the population.

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## Conflict of Interest

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