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Quality of treated water: evaluation of fluoride levels in 10 years of heterocontrol in a city of the State of Santa Catarina

Qualidade da água tratada: avaliação dos teores de flúor em 10 anos de heterocontrole no município de Lages, Santa Catarina, Brasil

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ABSTRACT

The public water supply fluoridation is the addition of fluorine in the water treatment plants, as a way of preventing tooth decay. This study evaluated the situation of fluoridation of public water supply in the city of Lages, of the State of Santa Catarina, systematizing data from 10 years of external control (2004-2013). Monthly, every other day, 67 water samples from 11 points of supply were collected, totaling 737 samples. To determine the fluoride concentration in the water samples, an electrometric method was used. After analysis, the samples were classified according to the criteria of Ordinance nº 635/Bsd of 26/12/1975 (adequate or inadequate) and the criteria proposed by the Ministry of Health Collaborating Centre for Surveillance of Oral Health (CECOL) of the University of São Paulo (benefits and health risks of the population). Of the samples analyzed, 58.6% had adequate levels of fluoride and 51.1% had maximum benefit and low risk, according to each criterion. Of the inadequate samples of fluoride concentration, 34.7% stood at levels above 1.0 mg L^{-1} and 6.7% at low levels of fluoride in water (<0.7 mg L^{-1}). For CECOL criteria, 45% of the samples were characterized by moderate to very high risk of developing fluorosis (fluoride content between 0.95 and ≥ 1.45 mg. L^{-1}). It is recommended to adopt effective measures to ensure that the population ingests treated water quality, including appropriate levels of fluoride in the water and the maintenance of health surveillance by the Public Health authorities.

KEYWORDS: Fluoridation; Water Treatment; Water Quality Control; Water Analysis; Water Supply; Water Monitoring; Sanitary Surveillance

RESUMO

Fluoretação da água de abastecimento público é a adição de compostos de flúor nas estações de tratamento da água como uma das formas de prevenção da cárie dentária. Este estudo avaliou a situação da fluoretação das águas de abastecimento no município de Lages, Santa Catarina, sistematizando dados de 10 anos de heterocontrole (2004-2013). Mensalmente, em dias alternados, foram coletadas 67 amostras de água de 11 pontos de abastecimento, totalizando 737 amostras. Para a determinação da concentração de flúor nas amostras de água utilizou-se o método eletrométrico. Após análise, as amostras foram classificadas, segundo os critérios da Portaria nº 635/Bsd, de 26/12/1975 (adequadas ou inadequadas), e os critérios propostos pelo Centro Colaborador do Ministério da Saúde em Vigilância da Saúde Bucal (Cecol) da Universidade de São Paulo (benefícios e riscos à saúde da população). Das amostras analisadas, 58,6% apresentaram teores adequados de flúor e 51,1% máximo benefício e baixo risco apresentaram, de acordo com cada critério. Nas amostras inadequadas de concentração de flúor, 34,7% situou-se nos teores acima de 1,0 mg.L^{-1} e 6,7%, baixos teores de flúor na água (< 0,7 mg.L^{-1}). Pelos critérios do Cecol, 45,0% das amostras caracterizaram-se por risco moderado a muito alto de desenvolvimento de fluorose (teores de flúor entre 0,95 e ≥ 1,45 mg.L^{-1}). Recomenda-se a adoção de medidas efetivas para garantir à população o consumo de água tratada com qualidade, o que inclui teores adequados de flúor na água e manutenção de ações de vigilância sanitária por parte das autoridades de Saúde Pública.

PALAVRAS-CHAVE: Fluoretação da Água; Tratamento da Água; Controle da Qualidade da Água; Análise da Água; Abastecimento de Água; Monitoramento da Água; Vigilância Sanitária

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INTRODUCTION

The fluoridation of the public water supply is considered as the addition of fluorine compounds, in solid form or aqueous solution, in water treatment plants or collection wells, which act to prevent dental caries[1].

To produce the expected preventive effects on dental caries with effectiveness and safety, an optimal concentration of fluoride in the water is required – in Brazil, this value varies between 0.7 and 1.0 parts per million (ppm) – as well as the continuity of long-term measurement[2]. Otherwise, if fluoride is continuously ingested at concentrations higher than recommended during the period of tooth formation, dental fluorosis may occur, characterized by malformations of tooth enamel, with changes in color or shape in the most severe cases[1,3].

Ordinance No. 2,914, dated December 12, 2011, which deals with the procedures for controlling and monitoring the quality of water for human consumption and its standard of potability[2], affixed the value of 1.5 mg L^{-1} of fluorine as the potability standard for chemicals posing a health risk. This fluoride level is certainly harmful to children under the age of eight years old who are continually exposed, and is not recommended in Brazil by the National Oral Health Coordination nor by any public health entity[3].

Although it has been the subject of research since the first decades of the twentieth century, fluoridation of the public water supply is a current issue, as there are often questions about the efficiency and effectiveness of the measure and the costs involved. We must also add that, despite all the advantages that fluoridation can provide, its implementation has undergone marked regional inequalities[4] and many Brazilian cities need improvements in the operational control of water supply systems to ensure the effectiveness of the public policy that seeks to prevent dental caries[5].

With the fluoridation of water as a proven health promotion measure of high efficiency, low cost and great social benefit, the external controls allow the monitoring of fluoridation of the water supply through surveillance systems, constituting a fundamental action for the maintenance of a good program of fluoridation and dental caries control[6].

Concerned about this subject, the Universidade do Planalto Catarinense began a study in October 2004 to monitor the levels of fluoride present in the public water supply of the city of Lages, Santa Catarina, Brazil, on a monthly basis.

The city of Lages is located 225 km from the state capital, Florianópolis. It has 158,961 inhabitants[7] and is considered a regional reference center for health, education, and trade services. Fluoridation began in 1982 and, since 2003, the Municipal Agency of Water and Sanitation has been responsible for the fluoridation process carried out in the city's only water treatment station. The water supplying the city is taken from the Caveira River and the water supply network has three reservoirs with capacities of 1,500 m^3 to 4,500 m^3 and about 20 smaller reservoirs spread throughout the city's territory. With a mean maximum daily temperature of 22.4ºC, the ideal is a fluorine concentration between 0.7 and 1.0 mg L^{-1}. The salt used is fluosilicic acid, which is added by a fluoride metering pump (CM SIC – Tecnobio). The concentration is controlled by a technician every hour and a half (which may vary according to the flow) through laboratory analysis performed by the spectrophotometer (colorimetric) method.

This study aimed to evaluate the state of fluoridation of the public water supply in Lages, systematizing data from 10 years of external control (2004-2013).

METHOD

As Lages has only one water treatment station, and considering the number of inhabitants supplied by treated water in the city, 10 water collection points were established[8]. These points were divided geographically to cover all regions of the city and were in public places, with collection directly from taps or trestles connected to the water supply network. As of August 2011, another collection point was included in the water treatment station, with water collected from an external faucet.

Following the same protocol every year, the water samples were collected in two 10 ml plastic bottles, from each collection point. Before collection, the flasks were rinsed three times with the same water as was being collected and then labeled[8]. A list of the complete addresses of collection points, day, time, and the responsible agent was organized. The water collections were performed monthly, all on the same day, alternating the collection dates each month.

After the samples were collected, they were sent to the Fluoride Sanitary Surveillance Laboratory of the Universidade do Vale do Itajaí, Santa Catarina, from 2004 to July 2011 and, afterwards, to the biochemistry laboratory in the Faculty of Dentistry of the Universidade Estadual de Campinas of Piracicaba, São Paulo.

To determine fluoride dosage in water, the electrometric[9] method was used, which is based on the direct measurement of the free fluoride ions. A fluoride ion-specific electrode (*Orion model* 96-09, *Orion Research*, Cambridge, MA, USA) coupled to an ion analyzer (Orion EA-740) was used for this dosage and 1.0 mL of the sample was added to 1.0 mL of TISAB II. The calibration curve was performed in triplicate from known F concentration patterns of 0.125 to 1.0 µgF/mL, which was prepared in the same way as the samples. The fluorine concentration was calculated by linear regression of the calibration curve and expressed in µgF/mL[5].

The fluorine levels of the collected water samples were classified according to two reference criteria:

Ordinance#635[10] (Brazil, 1976): 0.8 mgF/L (mg L^{-1}) is the optimal concentration, with 0.7 and 1.0 mgF/L (mg L^{-1}), respectively, considered as minimum and maximum values for cities with a mean of maximum daily temperatures between 21.5ºC and 26.3ºC.

Criteria proposed by the Collaborating Center of the Ministry of Health in Oral Health Surveillance (CECOL) of the Universidade

de São Paulo[11] classifies the fluoride levels of public water supply according to benefits and risks to the population, and the fluoride level between 0.65 mg L^{-1} to 0.94 mg L^{-1} provides the maximum population benefit and lowest risk of dental fluorosis (Box).

RESULTS

In the study period, the fluoride levels in the water ranged from 0.22 to 1.91 mg L^{-1}. The mean values found per year of follow-up showed frequent oscillations, reaching the highest values in 2006. These fluctuations of mean fluoride values occurred for values above 0.7 mg L^{-1} (until 2007), showing a greater tendency for excess fluoride (Figures 1 and 2).

The analysis of the fluorine levels, according to criterion I of Ordinance #635[10], showed that 58.6% of the water samples had adequate fluorine contents, that is, between 0.7 and 1.0 mg L^{-1}. However, 34.7% had high fluoride levels and 6.7% had low fluoride levels in the water (Table).

Using the CECOL[11] classification, it was observed that 51.2% of the analyzed water samples were within the appropriate parameters of fluorine levels (between 0.65 and 0.94 mg L^{-1}), causing maximum prevention benefits against caries and a low risk of dental fluorosis. We must highlight that 32.4% of the samples showed fluoride levels between 0.95 and 1.24 mg L^{-1} (maximum benefit for caries prevention, but with a moderate risk of fluorosis), 8.7% with fluorine levels between 1.25 and 1.44 mg L^{-1} (questionable benefit and high risk for fluorosis) and 3.9% with fluorine content equal to or greater than 1.45 mg L^{-1} (causing harm and high risk of fluorosis) (Figure 3).

The mean values and percentages obtained from adequate and inadequate samples were calculated for each criterion evaluated.

The characteristics of the distributions of the values with highlights for the respective medians and quartiles are shown in Figure 2, which contains the *box plots* for each of the years considered in the study.

DISCUSSION

The results of this external control allowed us to confirm that fluoride is present in the water for human consumption in the city of Lages, showing monthly variations in the content of fluoride identified between the points of water collection, and at the same points, throughout the analyzed period.

The proven preventive efficacy of water fluoridation depends on the adequacy of fluoride levels and the long-term continuity of the process, and a temporary or permanent interruption makes the measure ineffective[1]. Thus, it is essential to control the content of fluorine added to the water supply, either in operational terms in water treatment plants or in terms of health surveillance. In the first case, there should be routine operational control procedures. In surveillance, external control is imperative and must be understood as the principle according to which,

Box. Criteria proposed by the Collaborating Center of the Ministry of Health in Oral Health Surveillance of the Universidade de São Paulo[11].

Fluorine level in water (in mg L^{-1} or mg F/L)	Benefit (prevents caries)	Risk (produces dental fluorosis)
0.00 to 0.44	Insignificant	Insignificant
0.45 to 0.54	Minimum	Low
0.55 to 0.64	Moderate	Low
0.65 to 0.94	Maximum	Low
0.95 to 1.24	Maximum	Moderate
1.25 to 1.44	Questionable	High
1.45 or higher	Harmful	Very high

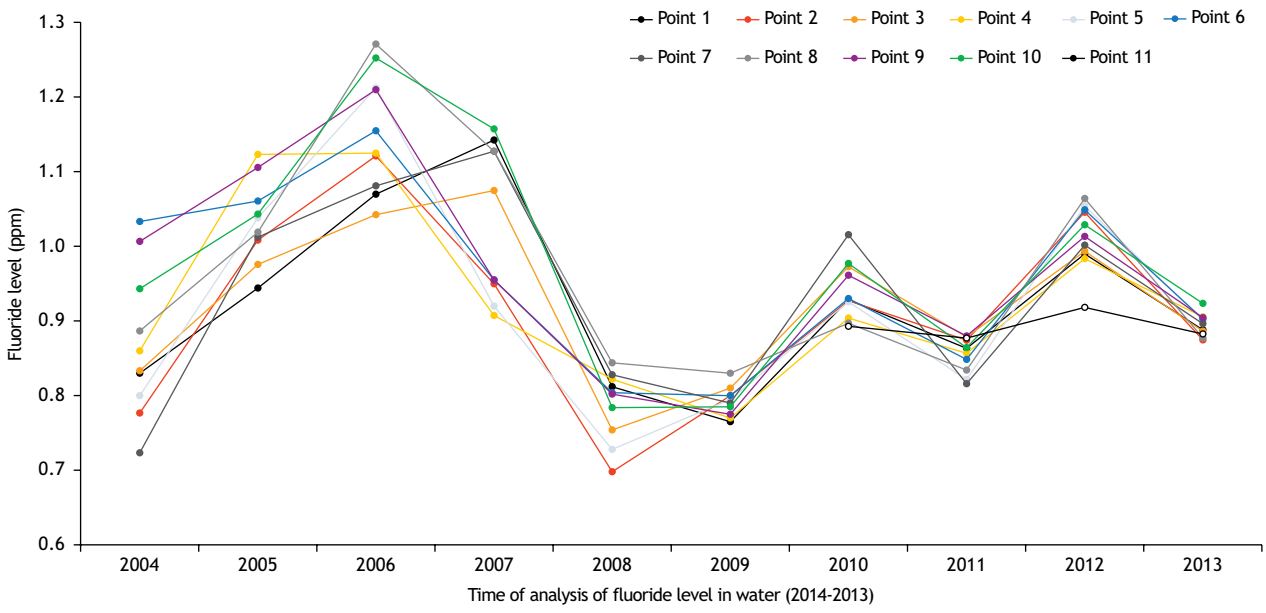

Figure 1. Mean levels of fluorine (mg L^{-1}) found in water samples collected per year of follow-up. Lages, Santa Catarina, 2004-2013.

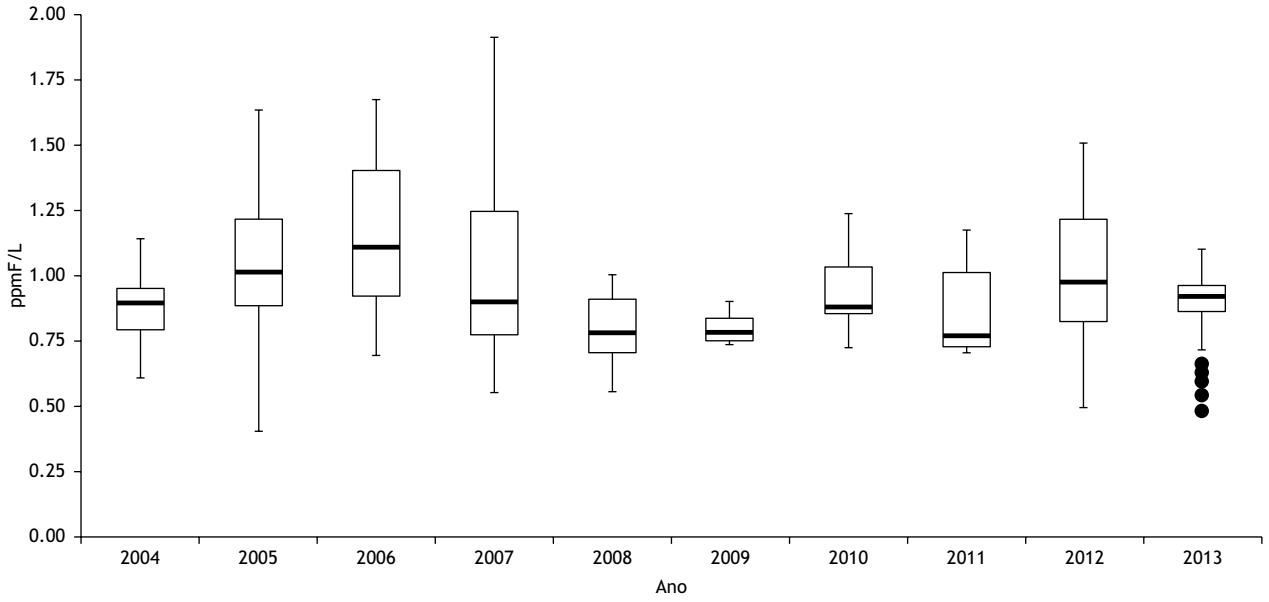

Figure 2. Characteristics of fluoride levels distribution according to the year, in water samples collected in Lages, Santa Catarina, 2004-2013.

Table. Fluorine level in the water samples according to the year and the number of collection months. Lages, Santa Catarina, 2004-2013.

Year	Collection months (n)	Fluorine level in the water samples (mg L^{-1}) [n (%)]			Total [n (%)]
		< 0.7	0.7 to 1.0	> 1.0	n (%)
2004	3	4 (13.3)	22 (73.4)	4 (13.3)	30 (100)
2005	12	8 (6.7)	51 (42.5)	61 (50.8)	120 (100)
2006	8	1 (1.3)	25 (31.3)	54 (67.5)	80 (100)
2007	4	4 (10)	20 (50)	16 (40)	40 (100)
2008	5	10 (20)	40 (80)	0 (0)	50 (100)
2009	2	0 (0)	20 (100)	0 (0)	20 (100)
2010	7	0 (0)	52 (69.3)	23 (30.7)	75 (100)
2011	7	1 (1.4)	52 (71.2)	20 (27.4)	73 (100)
2012	12	8 (6.3)	60 (46.9)	60 (46.9)	128 (100)
2013	11	13 (10.7)	90 (74.4)	18 (14.9)	121 (100)
Total	71	49 (6.7)	432 (58.6)	256 (34.7)	737 (100)

if any service implies risk or represents a protection factor for public health, then state institutions must also be responsible for control, alongside the responsible agency's control over the production, distribution, and consumption process[6].

Differences were observed among the criteria adopted in the analysis of fluoride level in the city. In analysis according to criterion I, a significant number of inadequate samples was highlighted, with 34.7% of the samples with fluorine level above 1.0 mg L^{-1}. If the analysis perspective considers the benefits and risks of fluoride levels in the public water supply to the population - criterion II - the percentage of water samples with moderate-to-very-high risk of developing fluorosis reached approximately 45%.

The technical consensus document on the classification of public water supply according to the fluorine level[11] made it possible to overcome the limitation of classification by values on a scale with only two categories - adequate and inadequate - improving the options for interpretation and the attribution of meaning to the characteristics of the samples when assessing, simultaneously, the preventive benefit against caries and the inherent risk of exposure to fluoride[12].

It is necessary to understand that the finding of inadequate levels of fluoride in the public water supply has ethical implications. Water with insufficient fluoride does not protect against caries and the population should be informed about this. On the other hand, the consumption of water with too much fluoride causes the population below the age of eight years old to be prone to developing dental fluorosis[3]. In this study, 19 (2.6%) samples had a fluoride concentration above 1.5 mg L^{-1}, which may represent a risk for dental fluorosis, although in very mild degrees.

External control studies of water fluoridation in Brazil have also identified, with important variations, inadequate values of fluorine levels, both below the recommended level and above the maximum value allowed[5,13-16].

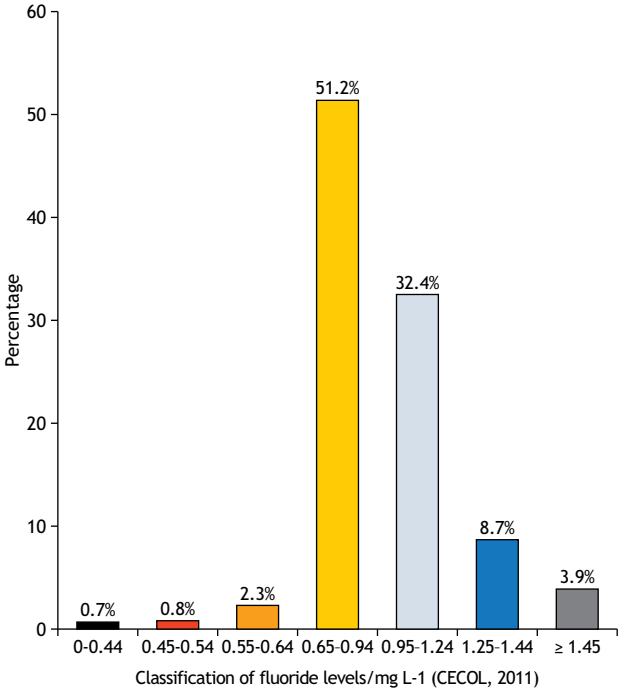

Figure 3. Mean levels of fluorine (mg L^{-1}) found in water samples collected per year of follow-up. Lages, Santa Catarina, 2004-2013.

A review that analyzed the potability of water for human consumption with respect to the fluoride level in Brazil, considering the balance between benefits and health risks, showed that temperatures in Brazilian capitals indicate that fluoride should range from 0.6 to 0.9 mg L^{-1} to prevent dental caries and that concentrations above 0.9 mg L^{-1} represent a risk to dentition in children under eight years of age[17]. Concentrations of 1.5 mg L^{-1} are tolerable when natural and if there is no acceptable cost-benefit technology for adequacy or removal of the excess.

Compared with the previous study conducted in Lages between 2004 and 2005, after 12 months of external control[18], an improvement in the adequacy of the fluorine content in the water supply was observed. Over 50% of the samples showed adequate levels of fluoride for the two analysis criteria used. However, the percentage of inadequate fluoride levels identified in the Lages water supply confirms the importance of conducting external control studies of fluoridation, with longitudinal analyses that indicate the need for effective interventions by the company responsible for water treatment in the city[5,14].

The results presented here reinforce the importance of longitudinal monitoring for external control. Studies with this characteristic help to maintain optimal fluoride levels in the public water supply and present a better standard of maintenance for adequate fluoride levels[5,15-18]. In Chapecó, Santa Catarina, for example, after 10 years of analysis, an improvement in the adequacy of the fluoride concentration was observed, showing up to 63% of adequate samples[14].

The interruptions of the monthly collections of water samples in specific months of the research are identified as a limitation of this study. Such interruptions are justified by the project financing periods, which were defined by the beginning and end of the university's research notices. Despite the interruptions in the analyses, there is no doubt about the exposure of the population of Lages to the preventive benefit of fluoridation of water during most of the time the study was performed.

CONCLUSIONS

The analysis of the fluoride contents of 737 water samples in 71 months of research in Lages, Santa Catarina, identified 58.6% of the samples as having adequate fluoride content and 51.1% with maximum benefit and low risk according to the criteria of analysis. In the samples considered inadequate, 34.7% showed fluorine level above 1.0 mg L^{-1}. According to the CECOL criterion, the percentage of water samples with moderate-to-very-high risk of developing fluorosis reached approximately 45%. It should be noted, however, that the data indicate that the population of the city has consistently benefited, without interruption, from the fluoride present in the public water supply. In terms of the benefit/risk balance that must be sought when implementing fluoridation, it can be said that it has been successful.

For the city of Lages, we recommend the adoption of effective measures to guarantee the population the consumption of good quality treated water, which includes adequate levels of fluoride in the water and maintenance of health surveillance actions for this measure by the Public Health authorities, seeking to maintain said benefit/risk balance.

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Conflict of Interest

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