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HETEROCONTROL OF FLUORIDATION OF PUBLIC WATER SUPPLY PUBLIC IN UBERLÂNDIA, STATE OF MINAS GERAIS, BRAZIL

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ABSRACT: This study aimed to analyze the fluoride levels in the public water supply in Uberlândia, State of Minas Gerais, and, in addition, to compare the values with data from the operational control and from a reference laboratory. A total of 126 samples were collected over 6 months. Samples were analyzed using the electrometric technique, initially at the Federal University of Uberlândia and later at the reference laboratory. With the *Generalized Estimating Equations*, data were compared to each other and to the operational control data. A statistical difference was detected between the laboratories, between the moments evaluated and in the interaction between the laboratory and the time of sample collection. Even with variability in the results, it can be concluded that fluoride is present in the water supply in the municipality of Uberlândia, at levels within the range recommended by the Collaborating Center of the Ministry of Health in Oral Health Surveillance regarding the concentration of fluorides, and the population has been served with safe water.

KEY WORDS: Fluoridation; Oral health; Public health.

HETEROCONTROLE DA FLUORETAÇÃO DA ÁGUA DE ABASTECIMENTO PÚBLICO EM UBERLÂNDIA, MINAS GERAIS, BRASIL

RESUMO: Este estudo teve como objetivo analisar os teores de flúor na água de abastecimento público de Uberlândia-MG e, adicionalmente, comparar os valores encontrados com os dados do controle operacional e de um laboratório de referência. Foram coletadas um total de 126 amostras por um período de 6 meses. As amostras foram analisadas pela técnica eletrométrica, inicialmente na Universidade Federal de Uberlândia e depois pelo laboratório de referência. Através do teste *Generalized Estimating Equations* os dados foram comparados entre si e com os dados de controle operacional. Observou-se diferença estatística entre os laboratórios, entre os momentos avaliados e na interação entre laboratório e tempo. Mesmo com variabilidade entre os resultados pode-se concluir que o flúor está presente na água de abastecimento do município de Uberlândia com teores dentro dos padrões recomendados pelo Centro Colaborador do Ministério da Saúde em Vigilância da Saúde Bucal quanto a concentração de fluoretos e a população tem sido assistida de forma segura.

PALAVRAS-CHAVE: Fluoretação; Saúde bucal; Saúde pública.

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INTRODUCTION

The World Health Organization (WHO)[1] cites dental caries as the most prevalent non-communicable disease globally, present on all continents, with a higher incidence in individuals living in countries in the southern hemisphere and for populations with low socioeconomic status in countries with developed capitalism. Although epidemiological studies have registered a decrease in prevalence worldwide since the mid-twentieth century, this disease remains a serious public health problem[2,3].

In Brazil, dental caries is the most prevalent oral disease, affecting individuals of all age groups and socioeconomic levels unevenly. It affects 60% to 90% of the school-age population, growing proportionally in adulthood, when it becomes an important cause of pain, tooth loss and absenteeism at work[4].

Because it is such a wide-ranging disease, and causes sequelae that interfere with the quality of life of individuals, in addition to the high costs for treatment, several strategies to control and mitigate this problem have been adopted worldwide[4].

The main measure of prevention of dental caries that has a wide population reach and that is used in population strategies of Public Health involves the use of fluorides. The World Health Organization and the Ministry of Health in Brazil indicate the use of fluorides in toothpaste and public water supply as a priority[5].

In places where social inequality is intense, water fluoridation is often the only method for preventing dental caries for a large portion of the population who do not have access to other preventive methods, such as topical fluoride applications, mouthwash with fluoride solution and fluoridated toothpaste[6].

Regarding the use of fluoride as specific protection against oral diseases, it is characterized by the concomitance of protection and risk, that is, it is a factor of protection against dental caries (if its concentration is within the recommended range), as well as it is a risk factor for dental fluorosis (if the concentration is above the recommended). So, if fluoride levels in the water are insufficient, or if the addition of fluoride is interrupted, the benefit of caries prevention will be ineffective[7,8].

To ensure the preventive efficacy of fluoridation, avoiding fluorosis, it is essential to have operational control at water treatment plants, carried out by those responsible for the process of water fluoridation and its monitoring, which in terms of Health Surveillance, is known as heterocontrol[9,10]. Heterocontrol is the principle that if any good or service implies risk or represents a protective factor for public health, then, in addition to the producer control over the production, distribution and consumption process, there must be control by the institutions of the state[8]. It is carried out through the direct evaluation of water samples collected in the distribution network and aims to ensure the quality of the process, the validity of information and the reliability to achieve oral health goals[11,12].

Given the importance of the fluoridation strategy for the oral health of the population and the importance of monitoring the appropriate concentrations of fluoride in public water supply, it is justified the concern of research such as this in the area of surveillance for a more comprehensive assessment.

In Uberlândia, State of Minas Gerais, there is no regular heterocontrol, only the operational control that publishes the data on the website of the sanitation company. In addition, reliable information is not available to assess the extent of coverage of this measure in the city. In this sense, this study can bring benefits while stimulating and inducing discussions about coverage and surveillance of public water supply fluoridation, in addition to alerting the need for the academic community to dedicate to the production of knowledge about water quality, considering that fluoridated water is first of all treated water.

In view of the above, the objective of the present study was to analyze the fluoride levels in public water supply in the municipality of Uberlândia, State of Minas Gerais and, additionally, to compare the values found in this municipality, with data from the operational control and from a reference laboratory.

METHODS

This is a health surveillance study, with a quantitative and descriptive approach. It was held in Uberlândia, State of Minas Gerais, southeastern Brazil. The municipality of Uberlândia, according to the Brazilian Institute of Geography and Statistics (IBGE)[13], had a

population estimate of 669,672 inhabitants, and is the second largest city in the state. According to the report of the Instituto Trata Brasil (2016)[14], Uberlândia holds the third best sanitation service in Brazil, considered as a reference. The municipality has 100% water coverage and 99% sewage collection coverage, of the sewage collected 100% is treated[14].

In 1967, the Municipal Department of Water and Sewage (DMAE) was created, completing the construction of the first Water Treatment Plant (ETA). Currently, Uberlândia has two ETA (ETA Sucupira and ETA Bom Jardim). Each ETA covers an area of the territory of the municipality of Uberlândia. The northern and eastern sector is supplied by ETA Bom Jardim; and the central, south and west sector is supplied by ETA Sucupira (Figure 1).

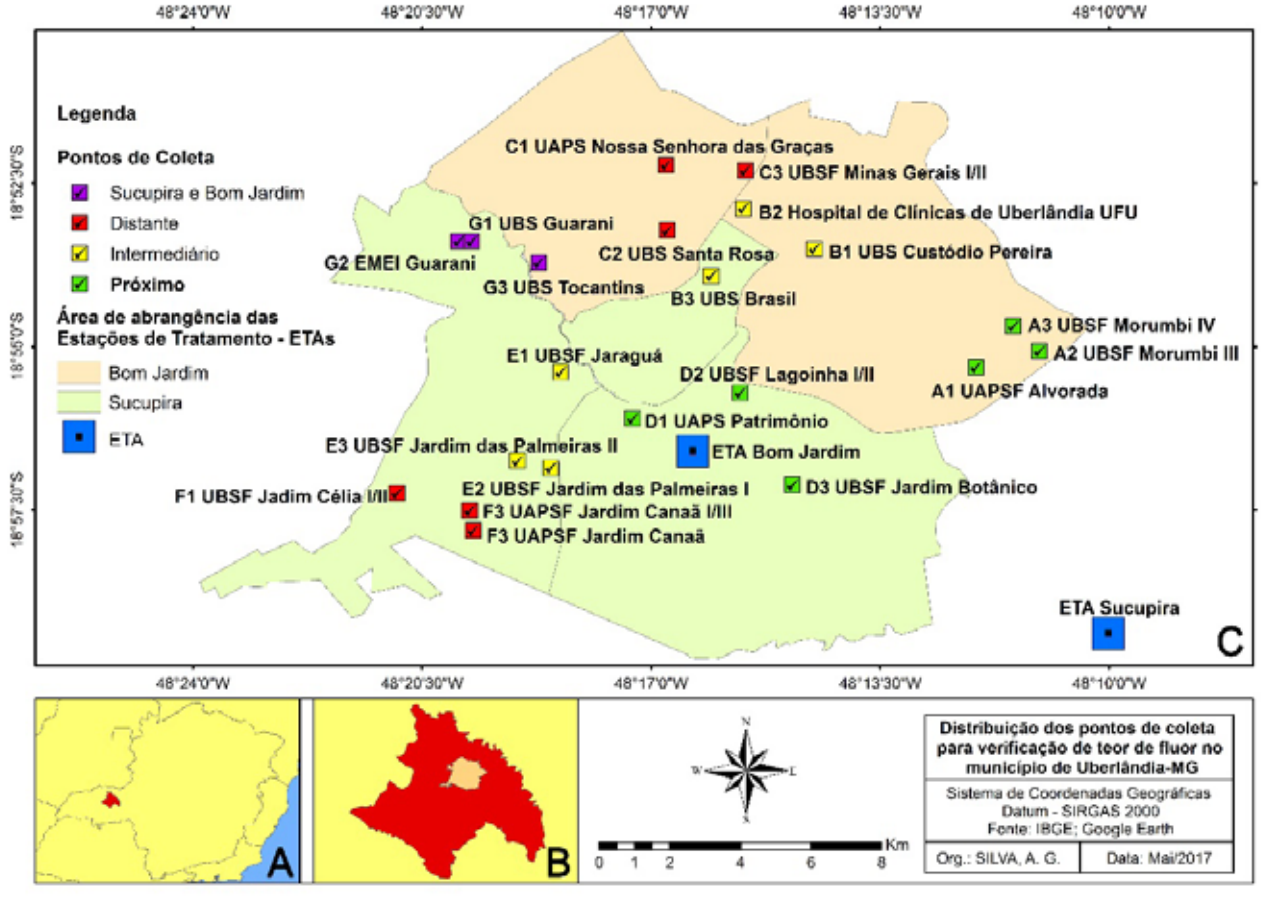

Figure 1. A – Location of the municipality of Uberlândia, State of Minas Gerais. B - Delimitation of the urban perimeter in the territorial area of the municipality. C - Distribution of sampling sites points in the urban perimeter of Uberlândia.

The methodology used to collect and analyze the samples followed a standard protocol for studies of this typee[15,16]. The definition of the sampling sites analyzed the representativeness and the spatial coverage of each ETA, for that it is necessary to know the water distribution network in the municipality, locate the number of treatment plants, the existence of collective alternative solutions and the scope of these systems[17].

For this study, three main sites were defined, namely, a close, an intermediate and a distant from the ETA. For each of these three main sites, two more sites were established, as shown in figure 2. Thus, there were a total of nine sites for each ETA (18 sites, considering the 2 ETA) and three additional sampling sites for the region supplied by both ETA (total of 21 sampling sites per month). Considering the 6 sampling months, we collected 126 samples (Figure 2). The priority places for such collections were health units and public schools[18].

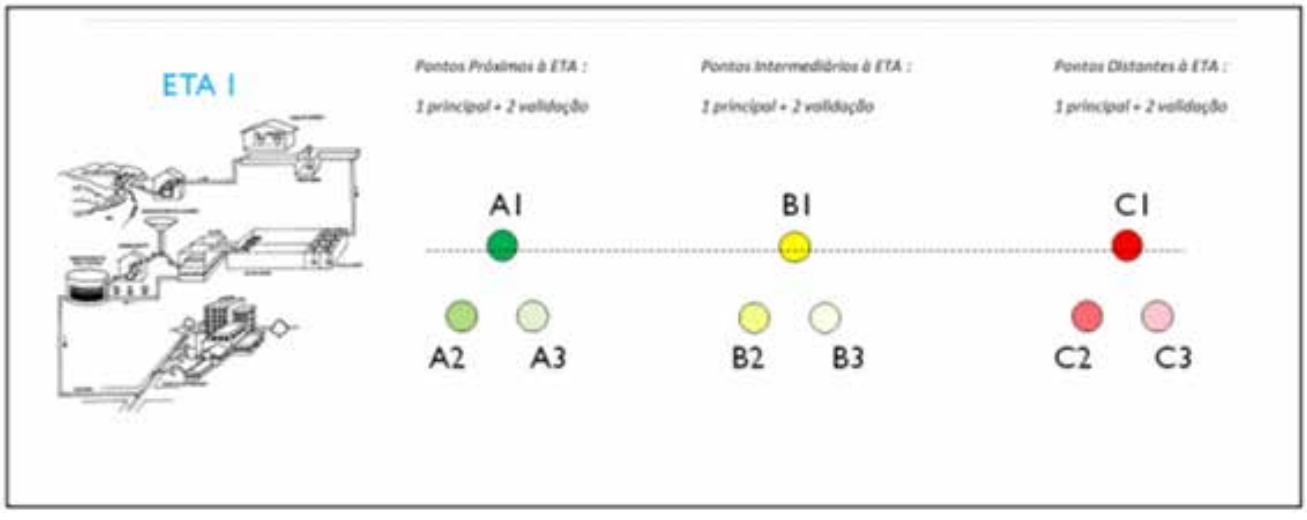

Figure 2. Summary scheme of the sampling method for analysis of fluoride in the city of Uberlândia, State of Minas Gerais.

Water samples were taken in 20 mL plastic containers with pressure cap, previously identified with a permanent marker, once a month for six months. The days of each collection, known only to the team responsible for the research, were made by draw, disregarding the days of holidays, Saturdays and Sundays.

The analyses of the collected water samples were performed in the laboratory of the Technical Course in Environmental Control and Environment of the Technical School of Health (ESTES) of the Federal University of Uberlândia (UFU), using the electrometric technique[19].

The device used for the evaluation was the specific electrode for fluoride ion coupled to the potentiometer previously calibrated with standards from 0.125 to 1.00 mg F/L. The materials used were Tisab II pH 5.0, Standards 0.125 - 0.250 - 0.500 -1.00 mg F/L, distilled and deionized water.

For this evaluation, we adopted the parameters of the Collaborating Center of the Ministry of Health in Oral Health Surveillance (CECOL)[20] of the University of São Paulo (USP), which proposed a criterion for the classification of water according to fluoride content, according to the variation of temperature of the region, relating the dimensions with the greatest benefit and the lowest risk.

The concentration of acceptable fluoride identified in the samples and given by milligrams of fluorine per liter was set from the averages of the maximum annual temperatures of the years evaluated (2015/1016). The average maximum temperature for the municipality of Uberlândia, in the last 30 years, was 29.0 °C [21], and the limits in which maximum benefit and minimum risk are obtained are from 0.55 to 0.84 mg F/L, respectively[20].

Samples were analyzed by three laboratories (DMAE-operational control, UFU and UNICAMP), in the same period, in the same water treatment plants and using the same technique for analysis (electrometric), and UFU and UNICAMP used the same samples.

Additionally, the same water parameters of the Oral Biochemistry Laboratory of the Faculty of Dentistry of Piracicaba/UNICAMP were evaluated. The researchers involved were trained to analyze fluoride following the same criteria adopted in ESTES and DMAE-operational control.

As a way to check the results, the Uberlândia samples were sent to the UNICAMP laboratory, which carried out a new analysis of the parameters, validating the results obtained in Uberlândia.

STATISTICAL ANALYSIS

The Generalized Estimating Equations (GHG)[22], with unstructured correlation and maximum likelihood estimation, was applied to compare the differences in fluoride content in water between the evaluated laboratories (UFU, DMAE and UNICAMP), over time and the interaction (Laboratory x Time). The same test was used to check for differences in the fluoride content in water in the treatment plants (ETA) that were evaluated, over time and the interaction (ETA x Time). Data were presented as estimated mean and Wald confidence interval (95% CI), provided by the test. Statistical tests with p

<0.05 were accepted as significant. For data analysis, IBM SPSS software version 20.0 was used.

RESULTS

Table 1 lists the comparison data of the analyses in the different laboratories. There was a statistical difference between the laboratories (p <0.001), between the moments evaluated (p <0.001) and in the interaction between laboratory and time (p <0.001). Only for November 2015, the laboratories did not present different mean values. The mean fluoride content in water is lower when evaluated by the UFU laboratory. Although the analyses of this laboratory have presented the lowest mean values, only in April 2016 the mean was below the minimum limit.

Table 1. Comparison of the concentration of fluoride in mg F/L obtained by the UFU, DMAE and UNICAMP laboratories between November 2015 and April 2016 in the city of Uberlândia, State of Minas Gerais

Time	UFU	DMAE	UNICAMP	Laboratory		Laboratory*Time	
				Df	p-value	Df	p- value
Nov 2015	0.62 [0.54-0.71]^{a}	0.57 [0.44-0.76]^{a}	0.75 [0.69-0.81]^{a}				
Dec 2015	0.60 [0.58-0.61]^{a}	0.77 [0.70-0.85]^{b}	0.68 [0.67-0.68]^{b}				
Jan 2016	0.55 [0.54-0.55]^{a}	0.80 [0.76-0.83]^{b}	0.69 [0.67-0.71]^{c}	2	**<0.001**	10	**<0.001**
Feb 2016	0.59 [0.58-0.60]^{a}	0.86 [0.83-0.89]^{b}	0.73 [0.72-0.74]^{c}				
Mar 2016	0.56 [0.53-0.59]^{a}	0.87 [0.83-0.90]^{b}	0.72 [0.70-0.74]^{c}				
Apr 2016	0.52 [0.49-0.55]^{a}	0.73 [0.59-0.90]^{a,b}	0.65 [0.61-0.69]^{b}				

The values in bold are significantly different.

Mean values of fluoride concentration in water, over time, determined by the laboratories (UFU, DMAE and UNICAMP) are illustrated in Figure 3.

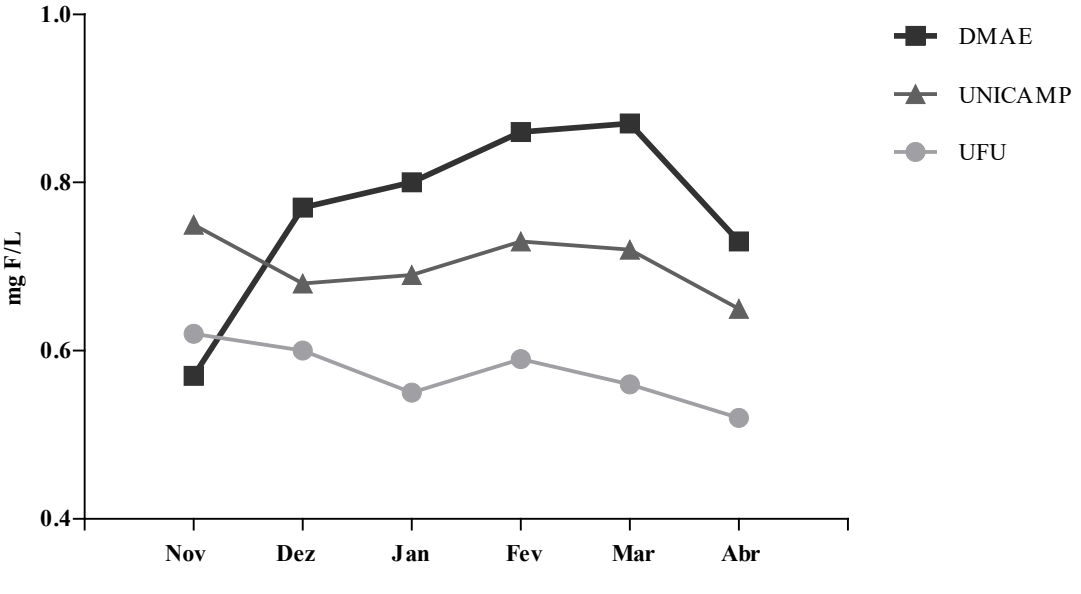

Figure 3. Fluoride levels in mg F/L determined by the laboratories UFU, DMAE and UNICAMP between November 2015 and April 2016 in the city of Uberlândia, State of Minas Gerais.

Table 2 presents the same analysis, but now comparing fluoride concentrations in the months evaluated within the same laboratory. Variation in the fluoride levels was observed throughout the sampling months and between the laboratories that evaluated the samples. Although differences were detected in these concentrations over time, the values found meet the recommendation, as explained.

Table 2. Comparison of the concentration of fluoride in mg F/L between November 2015 and April 2016, in each laboratory evaluated, in the city of Uberlândia, State of Minas Gerais

Laboratory	Nov	Dec 2015	Jan 2016	Feb	Mar	Apr	Time		Laboratory*Time	
							Df	p-value	Df	p-value
UFU	0.62 [0.54-0.71] [a.b]	0.60 [0.58-0.61] [a]	0.55 [0.54-0.55] [b]	0.59 [0.58-0.60] [a]	0.56 [0.53-0.59] [a.b]	0.52 [0.49-0.55] [b]	5	**<0.001**	10	**<0.001**
DMAE	0.57 [0.44-0.76] [a]	0.77 [0.70-0.85] [a.b]	0.80 [0.76-0.83] [a.b]	0.86 [0.83-0.89] [b]	0.87 [0.83-0.90] [b]	0.73 [0.59-0.90] [a.b]				
UNICAMP	0.75 [0.69-0.81] [a.b.c]	0.68 [0.67-0.68] [a.c]	0.69 [0.67-0.71] [a.b.c]	0.73 [0.72-0.74] [b]	0.72 [0.70-0.74] [b.c]	0.65 [0.61-0.69] [c]				

The values in bold are significantly different.

The concentrations of fluoride ions collected in the different water treatment plants (Sucupira and Bom Jardim) were analyzed in the same period, and there was also a statistical difference between the ETA ($p < 0.001$), between the evaluated moments ($p < 0.001$) and interaction ($p < 0.001$) (Table 3). When comparing the fluoride content in water between each ETA month by month, a difference was found only in November 2015 between the ETA.

Table 3. Comparison of the concentration of fluoride in mg F/L determined for the treatment plants (ETA), between November 2015 and April 2016, in the municipality of Uberlândia, State of Minas Gerais

Time	Sucupira	Bom Jardim	ETA		ETA*Time	
			Df	p-value	Df	p-value
Nov	0.68 [0.65-0.71] [a]	0.55 [0.54-0.57] [b]	1	**<0.001**	5	**<0.001**
Dec 2015	0.61 [0.59-0.63] [a]	0.59 [0.55-0.62] [a]				
Jan 2016	0.54 [0.49-0.59] [a]	0.55 [0.50-0.61] [a]				
Feb	0.60 [0.58-0.61] [a]	0.59 [0.57-0.60] [a]				
Mar	0.58 [0.55-0.61] [a]	0.54 [0.52-0.55] [a]				
Apr	0.55 [0.48-0.62] [a]	0.50 [0.49-0.51] [a]				

The values in bold are significantly different.

In the Sucupira ETA, the highest value was observed in November 2015 (0.68 [0.65-0.71] mg F/L). In the Bom Jardim ETA, the lowest value was found in April 2016 (0.50 [0.49-0.51] mg F/L). There was a large variation in the fluoride levels over the sampling months and between the ETA of origin of the samples. None of the analyses showed a peak that would alert the chronic exposure to fluoride levels above that recommended by the Public Health agencies, exposing the target population to a possible development of fluorosis.

DISCUSSION

Based on the limits adopted, of the total of 126 water samples collected in the time interval between the November 2015 and April 2016, even though there were statistically significant differences between the laboratories (DMAE, UFU and UNICAMP); 100% samples were within the recommended range of greatest benefit for preventing caries and less risk of developing dental fluorosis.

The difference detected in the values of the different laboratories can be explained by some external factors, since all the analyses were performed by the same technique (electrometric). According to the American Public Health Association (2005)[23], the electrometric technique may affect the results due to the presence of chemical substances in the analyzed water (chloride (Cl^-), and/or hexametaphosphate ($[NaPO_2]^6$) and/or phosphate (PO_4^{3-}), which may justify the differences found between the operational control and the other two laboratories, but not between the laboratories, since they used the same samples. Therefore, this difference can be possibly related to the difference in equipment and/or the sensitivity or specificity of the operator.

Statistically significant differences between heterocontrol and operational control were also found in studies by Piorunneck (2017),[24] Olivati et al. (2011)[25] and Marmolejo and Coutinho (2010)[26].

Given the mandatory fluoridation of water in Brazil, through law 6050/1974[27], several studies have been conducted with the aim of quantifying and/or analyzing fluoride levels. However, the comparison with the results of other studies should be careful due to the lack of standardization in the protocols adopted in different studies. Variations in the number of samplings, fluoride measurements and the way in which these data were collected (cross-sectional or longitudinal studies) can influence the results presented. In addition, few studies describe the population covered by the investigated source of supply and do not follow a standard in the analysis technique in the classification or in the measurement units[28].

Saldanha et al. (2014)[29] verified fluoride concentrations in public water supply in the cities of Fortaleza, Sobral, Viçosa and Rafael Arruda. This study analyzed 156 samples by the electrometric technique, which showed that 66.4% samples were below the concentration considered ideal. Although it is a cross-sectional study, it demonstrated that as important as adding fluoride is to perform heterocontrol, ensuring effective action, without occurrence of cases of fluorosis.

A 10-year study carried out in the municipality of Lages, State of Santa Catarina, collected samples monthly that were analyzed using the electrometric technique. According to the CECOL criteria, as well as that used in our study, 45% samples were characterized by moderate to very high risk of developing fluorosis (fluoride levels between 0.95 and 1.45 mg. L^{-1})[30].

A more comprehensive survey evaluated fluoride levels in the water supply of 40 cities in the State of São Paulo, over a period of 13 years. Of the 34,993 samples analyzed by the electrometric technique, 52.47% contained fluoride levels within the recommended range[31].

Since fluoride present in water is a protective factor or risk to dentition, depending on its concentration, the availability of valid and reliable information on the population exposure to this substance is important not only for the management of public policy, but also to ensure safety and quality standards, in addition to producing scientific evidence on the effectiveness of the method.

The limitation of our study is the observation time, and we suggest a longer time of longitudinal monitoring for future studies.

CONCLUSION

The results of this study allowed to conclude that fluoride is present in the water supply in the city of Uberlândia, with monthly variations between the sampling sites and at the same site over the analyzed period, but with levels within the range recommended by CECOL/ Ministério of Health, regarding the concentration of fluorides and the population has been served with safe water, with maximum benefit in preventing caries and low risk for developing fluorosis.

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