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Original Research Article

Retrospective analysis of the fluoride level in the public water supply and its correlation with dental fluorosis at two cities of South Santa Catarina

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Abstract

Introduction and Objective: To analyze retrospectively the fluoride level in the public water supply of two cities of the south Santa Catarina and to verify whether 12-year-old schoolers, who had used public water supply had dental fluorosis. **Material and methods:** 97 schoolers of the cities of Cocal do Sul and Morro da Fumaça were evaluated. Dental fluorosis was determined through Dean index. The annual averages of the fluoride concentrations in waters between the years of 2004 and 2015 were verified by reports supplied by the responsible company. **Results:** The averages of the fluoride concentrations in the water supply in the cities of Cocal do Sul and Morro da Fumaça, during the analyzed period, were 0.86 and 0.85 ppm of fluoride, respectively, without statistically significant difference. The smaller concentration was found in 2006, in the city of Morro da Fumaça, with 0.64 ppm of F; the greatest concentration occurred in Cocal do Sul, in 2007, with 1.1 ppm of F. The prevalence of dental fluorosis in Cocal do Sul was 24.5% and in Morro da Fumaça was 14.6%, without statistically significant differences. All 12-year-old schoolers who had dental fluorosis were classified as light according to Dean index. **Conclusion:** Most of the 12-year-old schoolers did not show any fluorosis degree. The cases of dental fluorosis were classified as little severity and with low esthetic impairment. It can be concluded that the fluoride levels in water supply were within the adequate and safe limits with low risk of dental fluorosis.

Introduction

The most prevalent infectious disease of the mouth is caries. In Brazil, caries is considered one of the main public health burden, reaching all the age ranges and socioeconomic levels [22].

The discovery of fluoride as prevention agent for dental caries, accounts for the reduction of the caries prevalence and severity worldwide. The controlled addition of fluoride to the public water supply is one of the most important benefits to public health, and thus, considered the most effective collective method for caries prevention [1, 2, 5, 14, 28].

The preventive properties of fluoride appeared because of investigations on its toxic effect on the developing dental enamel, so-called of dental fluorosis. By observing dental fluorosis, a series of studies resulted in the discover of the water fluoridation as measurement of control of the dental caries [21, 34]. The fluorides are chemical compounds formed by the combination with other elements found in the nature. Many foods contain fluoride; however, what we ingest does not pass the average of 0.3 mg per day [6, 7].

In the process of hydroxyapatite demineralization, with oral pH between 5.5 and 4.5, the calcium phosphate, and hydroxyls are released in the oral environment. If fluoride is present in oral environment, fluoride decreases the enamel solubility, because the release ions reacts with it, forming the fluorapatite or fluorinated hydroxyapatite, which saturates in this pH and deposits in dental enamel [26].

The World Health Organization (WHO), in 1958, recognized the importance of fluoridation and established a Committee of experts in water fluoridation, whose first report gave a favorable opinion on the initiative, indicating water fluoridation as a public health measure [8].

The Ordinance No. 421, from May 13, 2016, considering the recommended limits for the concentration of fluoride in the function of the average daily maximum temperatures in the State of Santa Catarina, established that the level of concentration of the fluoride in human drinking water is 0.8 mg/L, with a minimum of 0.7 mg/L and a maximum of 1.0 mg/L [32].

The fluoridation of the public water supply was recognized as a responsible measure for the decline of the dental caries. However, together with the decrease of dental caries, there are risks of increasing the prevalence of dental fluorosis [15].

Fluorosis is an alteration due to the ingestion of fluoride excess during tooth formation. It is characterized by the color alteration of the enamel from whitish color or small white spots or lines. In the most serious cases, dental fluorosis acquires a brownish or brown color, and loss of tooth structure [15, 31, 38].

In 1989, according to Capella *et al.* [9], the prevalence of dental fluorosis in children between 3 and 10 years of age in Cocal do Sul was 62.38%. At that time, the water supply had fluoride levels ranging from 1.2 to 5.6 ppm. In that study, the Dean index was used for the evaluation.

Moura *et al.* [24] evaluated the dental prevalence of fluorosis, in the years of 2005 to 2006, in 12-year-old children of Teresina (PI). They found a prevalence of 61.5% of fluorosis in the examined cases.

In 2011, Carvalho *et al.* [12] analyzed for three months the level of water fluoridation of three cities in the Espírito Santo and its influence on dental fluorosis. São João presented the average of 0.12 ppm of F, considered without fluoridation. São Roque showed a mean of 0.81 ppm and Serra de Cima a mean of 2.54 ppm of F. In Serra de Cima, 100% of the analyzed children had presented some degree of fluorosis. In the city without fluoridation, the prevalence of fluorosis was of 16% and in the city of São Roque the prevalence was of 94%.

Considering the aforementioned information, this study aimed to analyze retrospectively the fluoride level in the public water supply of two cities located in the south Santa Catarina and to verify whether 12-year-old schoolers who had used public water supply in the studied period showed dental fluorosis.

Material and methods

This was a study predominantly quantitative and divided into two different phases. Each study phase had a specific design. In the first stage, the assessment of the index of dental fluorosis, was an observational and transversal study. In the second stage of analysis of the fluoride concentrations in public water supply, the study was retrospective. In both stages, the descriptive analysis of the data was performed.

This study was submitted and approved by the Institutional Review Board regarding ethical aspects (protocol #1.305.634). After that, we selected 12-year-old students regularly enrolled in the public schools of the cities of Cocal do Sul and Morro da Fumaça, both located in the south of the state of Santa Catarina.

The choice of these cities was intentional because they belonged to the same region, had a similar population number (Morro da Fumaça – 17,373 inhabitants and Cocal do Sul, 16,301 [19]), and had the water supplied by different companies, which enable their comparison. The city of Cocal do Sul receives water treated by the Municipal Autonomous Service of Water and Sewer (Samae) and Morro da

Fumaça by the Santa Catarina Company of Waters and Sanitation [18].

The sample was based on the census of 12-year-old children aged 12 in the study cities, totaling 200 children. The inclusion criteria comprised the sign of the Free and Clarified Consent Form by the parents or responsible guardians, 12-year-old students enrolled in a municipal or state public school, living in the city since the birth, to have the house supplied by the same water source selected for the study. The exclusion criteria were: 12-year-old students who had lived in other cities, who used fixed orthodontic appliances, and those whose parents/guardians did not sign the Free and Clarified Consent Form.

According to the Resolution no. 466/2012 of the Brazilian Health Council the Free and Clarified Consent Form and a questionnaire were sent to the 200 selected participants of the public schools of the two cities. The questionnaire contained the socioeconomic questionnaire to obtain the familial income and the period living in the address.

The data collection was carried out in the school environment, from March to July of 2016, by a dentist of the program of Multiprofessional Residence in Basic Care and an undergraduate in Dentistry.

The clinical examinations were performed with use of individual protection equipment, wooden spatula, and natural light, by single calibrated examiner in lux. The clinical examination of all mouth was carried out to verify if the student had dental fluorosis. If the presence of dental fluorosis was confirmed, the two most affected teeth were classified according the code of the least affected teeth, following the WHO guidelines [38], and the index of Dean, which classifies dental fluorosis in normal, questionable, very mild, mild, moderate, and severe.

The second stage of the study was to verify the annual average of the fluoride concentration in public water supply, in the period from 2004 to 2015, based on the reports of the waters supplied by each company. The data of the System of Information of Monitoring the Quality of the Water for Human Consumption (Sisagua) did not have the data of every year enclosed in the research.

The data obtained were transcribed in spreadsheets of Microsoft Excel software, then were exported to Statistical Package for the Social Sciences software (SPSS – IBM) version 20.0. Then, the descriptive analyses of the quantitative variables regarding to the questions of the questionnaires. To compare the quantitative data between the groups, independent or paired t test were used. To analyze the nominal data, we applied the cross-reference analysis through Pearson chi-square test and reason of probability. The level of significance for all the statistical tests was $p < 0.05$.

Results

The sample of this present study was composed by 97 students who had agreed in participating in the research, subdivided into two groups, according to the residence cities. Of these students, 50.5% ($n=49$) lived in the city of Cocal do Sul and 49.5% ($n=48$) in the city of Morro da Fumaça.

The students from Cocal do Sul, 49.0% ($n=24$) were females and 51.0% ($n=25$) were males. In the group of the students of Morro da Fumaça, 62.5% ($n=30$) were females and 37.5% ($n=18$) were males. No statistically significance occurred between the studied groups ($P=0.180$; $p>0.05$).

In relation to the time period living in the city, in the group of Cocal do Sul, the average in years was of 20.6939 ± 12.17614 and in Morro da Fumaça was of 20.7917 ± 13.35116 . No statistically significance occurred between the studied groups ($P=0.970$; $p>0.05$).

Considering the clinical examination and the classification according to the index of Dean, we observed that in the city of Cocal do Sul 75.5% ($n=37$) of the students were classified as considered normal, 20.4% ($n=10$) as very mild, and 4.1% ($n=2$) mild. In the city of Morro da Fumaça, 85.4% ($n=41$) of the students were classified as normal and 14.6% ($n=7$) as very mild. No examined student was classified as questionable, moderate, or severe fluorosis, according to the index of Dean. No statistically significance occurred between the studied groups ($P=0.174$; $p>0.05$).

Table I - Dean Index

Groups		Dean Index				p
		Normal	Very mild	mild	Total	
Cocal do Sul	n	37	10	2	49	p=0.174 p>0.05
	%	75.5%	20.4%	4.1%	100%	
Morro da Fumaça	n	41	7	0	48	
	%	85.4%	14.6%	0%	100%	
Total	n	78	17	2	97	
	%	80.4%	17.5%	2.1%	100%	

Used statistical method: chi-square test reason of probability

Concerning to the socioeconomic conditions, we observed in table II a variation in the familial income. In the city of Cocal do Sul, 2.0% (n=1) of the participants had familial income smaller than the minimum wage; 8.2% (n=4) live with a minimum wage; 42.9% (n=21) with two minimum wages; 24.5% (n=12) with three minimum wages; 14.3% (n=7) with four minimum wages, and 8.2% (n=4) live with five or more minimum wages. In the city of Morro da Fumaça, it was observed that 31.1% (n=14) receive one minimum wage; 44.4% (n=20) two minimum wages; 20.0% (n=9) three

minimum wages, and 2.2% (n=1) live with five or more minimum wages. The comparison of the cities showed that the familial income had statistically significant differences ($p=0.012$; $p<0.05$). The analysis of adjusted residuals (ar) demonstrated that the income of one minimum wage occurred in most of the families whose students who lived in Morro da Fumaça (ar=2.8); the income of four minimum wages occurred in the families of the students who lived in the city of Cocal do Sul (ar=2.6) (table II).

Table II - Familial income

Groups		Familial income						p
		Less than 1 minimum wage	1 minimum wage	2 minimum wages	3 minimum wages	4 minimum wages	5 or more minimum wages	
Cocal do Sul	n	1	4	21	12	7	4	49
	%	2.0%	8.2%	42.9%	24.5%	14.3%	8.2%	100%
	ar	-0,1	-2,8	-0,2	0,5	2,6	1,3	-
Morro da Fumaça	n	1	14	20	9	0	1	45
	%	2.2%	31.1%	44.4%	20.0%	0%	2.2%	100%
	ar	0,1	2,8	0,2	-0,5	-2,6	-1,3	-
Total	n	2	18	41	21	7	5	94
	%	2.1%	19.1%	43.6%	22.3%	7.4%	5.3%	100%

Used statistical method: chi-square test reason of probability

Concerning to the topical fluoride application (TFA) at dental office, it can be observed that in the city of Cocal do Sul 59.2% (n=29) of the participants did it and 40.8% (n=20) never did. In the city of Morro da Fumaça, 56.3% (n=27) performed TFA in the office, while 43.8% (n=21) never did, without statistically significant difference in the association between groups ($p=0.770$; $p>0.05$).

In relation to fluoride mouthwash, 87.8% (n=43) of the students from the city of Cocal do Sul performed it at some stage of life and 12.2% (n=6) did not. In the city of Morro da Fumaça, 64.6% (n=31) underwent fluoride mouthwash against 35.4% (n=17) who did not. The group comparison regarding fluoride mouthwash showed statistically significant difference ($p=0.007$, $p<0.05$). The analysis of adjusted residuals (ar) showed that students living in the city of Cocal do Sul (ar=2.7) underwent more fluoride mouthwash compared to residents of Morro da Fumaça (ar=-2.7).

When asked about the place where the fluoride mouthwash took place, 12.2% (n=6) of the students from Cocal do Sul answered that

they did not perform anywhere; 16.3% (n=8) underwent mouthwash at home; 40.8% (n=20) did only performed mouthwash at school; 14.3% (n=7) in the dentist, and 16.3% (n=8) answered all three options. The students from Morro da Fumaça, 35.3% (n=17) did not have any mouthwash; 27% (n=13) used only at home; 10.4% (n=5) only at school; 14.6% (n=7) only in the dentist, and 12.5% (n=6) in the three options. The intergroup comparison of the place where fluoride application occurred exhibited statistically significant difference ($p=0.003$, $p<0.05$). The analysis of adjusted residuals (ar) disclosed that the students of Cocal do Sul underwent mouth washing in the school (ar=3.4) and the students of Morro da Fumaça at no place (ar=2.7).

In relation to the beginning of toothbrushing, the students living in the city of Cocal do Sul, on average, initiated the toothbrushing at 1.4694 ± 1.48748 years, while those living in Morro da Fumaça initiated on average of 2.4792 ± 1.62415 . The intergroup comparison of the average age for the beginning of toothbrushing exhibited statistical significant difference. Participants from the city of Cocal do

Sul had the lowest mean age for the beginning of toothbrushing ($p=0.002$, $p<0.05$).

For students who had a daily habit of using fluoride dentifrice, 87.8% ($n=43$) of Cocal do Sul used, while 12.2% ($n=6$) did not use. In the city of Morro da Fumaça, 87.5% ($n=42$) did not use fluoride dentifrice and 12.5% ($n=6$) did not use it. There was no statistically significant difference between groups ($p=0.970$; $p>0.05$) for the relation of the daily intake of fluoridated dentifrice.

The analysis of the fluoridated dentifrice swallowing, 44.9% ($n=22$) of Cocal do Sul students swallowed the dentifrice and 55.1% ($n=27$) did

not. In the city of Morro da Fumaça, 52.1% ($n=25$) swallowed fluoride dentifrice and 47.9% ($n=23$) did not have this habit. The intergroup comparison of the dentifrice swallowing showed no statistically significant difference ($p=0.479$; $p>0.05$).

Concerning to the fluoride concentration in the public water supply, it was observed that in the period from 2004 to 2015, the average concentration of fluoride in the city of Cocal do Sul was 0.8618 ± 0.13497 and in the city of Morro da Fumaça 0.8545 ± 0.09832 (figure 1). The annual fluoride in water means showed no statistically significant difference between the groups ($p=0.899$; $p>0.05$).

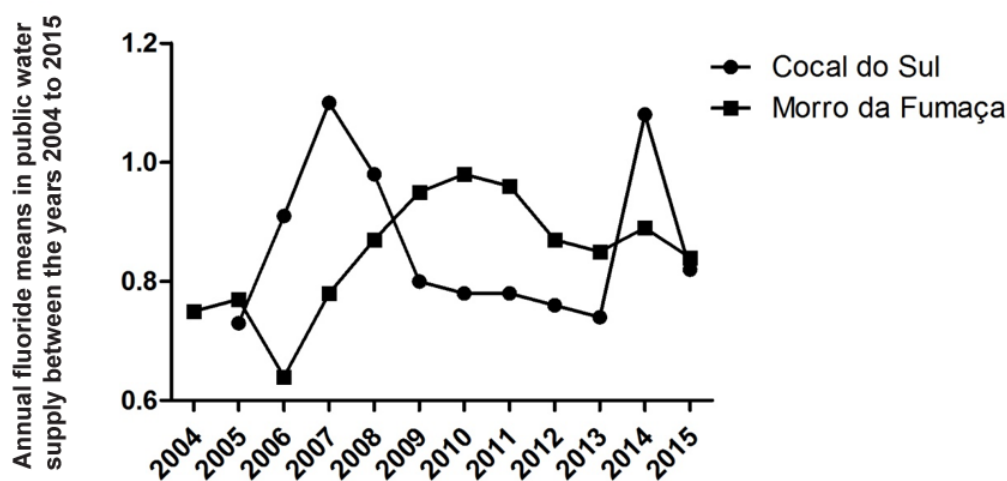


Figure 1 - Annual fluoride means in public water supply between the years 2004 to 2015

Discussion

This study aimed to analyze the fluoride concentration in the public water supply of two cities in southern Santa Catarina, from 2004 to 2015, to compare the average annual concentration of fluoride in the public water supply in that period and to verify whether 12-year-old students, who used water from public supply in the same period, had dental fluorosis.

According to the data collected in our study, the average annual fluoride concentration in the water supply in the cities of Cocal do Sul and Morro da Fumaça between 2004 and 2015 were respectively 0.86 and 0.85 ppm of fluoride. The lowest concentration found was in 2006, in the city of Morro da Fumaça, with 0.64 ppm of fluoride, and the highest was in Cocal do Sul, in 2007, with 1.1 ppm of fluoride.

In Cocal do Sul, 10% of the participants had a family income less than or equal to a minimum wage. In Morro da Fumaça, 33.3% reported having the same income. Therefore, Morro da Fumaça presents a larger number of students in the family income considered vulnerable. In total, 20 students in both cities were in that family income range; of these, three had some level of fluorosis, representing 15% of the students in that income range. Of the remaining 74, whose family income was two minimum wages or more, 16 students had some level of fluorosis (21.62%). By the approximate numbers, it was assumed that family income did not play such an important role in dental fluorosis.

The prevalence of dental fluorosis in Cocal do Sul was 24.5%, and in Morro da Fumaça, 14.6%. Among the students analyzed, no student, in the two cities, had questionable, moderate, or severe fluorosis, according to the Dean index. In Cocal do

Sul, only 4.1% had mild fluorosis, while in Morro da Fumaça, no student had fluorosis classified at the same level. The very light fluorosis in Cocal do Sul occurred in 20.4% of the participants analyzed and in Morro da Fumaça, 17.5%.

According to a systematic review of Reddy *et al.* [18], the estimate of dental fluorosis in a population that uses fluoridated water with a fluoride content between 0.7 and 1.2 ppm is 29.8% among the studies analyzed. In our study, the prevalence in the studied cities was lower than this estimate [18].

Carvalho *et al.* [12] published a study in which a locality with natural fluoridation presented 2.54 ppm of fluoride. At this site, the prevalence of fluorosis was 100%, and when compared to the neighboring locality, which had a fluoride index of 0.81 ppm, the severity of fluorosis was higher according to the Dean index, which justifies the concern to maintain the fluoride levels within the indicated ranges. Notwithstanding, the correct fluoride content in the water supply alone does not prevent dental fluorosis. The use of dentifrices of pleasant color and taste by students may result in a daily intake above the recommended dose [36], as well as the association between accidental ingestion of dentifrices and fluorosis, especially in localities supplied with fluoridated water. In the study by Carvalho *et al.* [12] the locality with 0.81 ppm F had 94% prevalence of dental fluorosis.

Capella *et al.* [9] conducted a study in which the prevalence of fluorosis in the children of Cocal do Sul was 62.38%. However, at that time, the levels of fluoride in the water varied between 1.2 and 5.6 ppm, differing from what was verified in our study. The current levels are on average 0.86 ppm of fluoride, justifying that the current prevalence in Cocal do Sul is 24.5%.

The average fluoride content in the supply water, between 2004 and 2015, in Cocal do Sul was 0.86 and in Morro da Fumaça 0.85. In Maringá (PR), in 2010, fluoride levels were evaluated monthly, and the annual average was 0.77 ppm of fluoride [5]. Catani *et al.* [13] published a study carried out in 2001 and 2002, in which they evaluated monthly two cities in the state of São Paulo. However, the study did not present the average fluoride content in the supply waters, only cited the minimum and maximum levels of each city, ranging from 0.6 to 0.8 in one and 0.3 to 1.2 ppm in the other. The city that had the greatest variation in fluoride concentration had a lower prevalence of dental fluorosis (31.4%), compared to 79.9%. In our study, the city of Cocal do Sul had the highest discrepancy between minimum and maximum values and had

the highest prevalence of fluorosis (24.5%). The city of Morro da Fumaça had a prevalence of 14.6%.

The Ordinance No. 421, from May 13, 2016, considering the recommended limits for the concentration of fluoride in the function of the average daily maximum temperatures in the State of Santa Catarina, established that the level of concentration of the fluoride in human drinking water is 0.8 mg/L, with a minimum of 0.7 mg/L and a maximum of 1.0 mg/L [32]. From the obtained data, we can verify that the annual averages of the cities of Cocal do Sul and Morro da Fumaça are within the ideal standards according to the Ordinance of Santa Catarina.

Forni [17] found high variability in the prevalence of dental fluorosis in children and adolescents aged 6 to 12 years: 49.4% in the city of São Paulo, 54.8% in São Vicente, 59.4% in São Caetano, 84.0% in Ribeiro Pires, and 95.4% in Rio Grande da Serra, differing from that of our study, in which there was no statistically difference for prevalence of fluorosis among the studied cities. Narvai *et al.* [27] published a study evaluating the level of fluorosis in 12-year-old children in the city of São Paulo, and the values found were 43.8% in 1998, 33.7% in 2002, 40.3% in 2008, and 38.1% in 2010. However, this was a study that started from secondary data obtained in epidemiological surveys.

Buscariolo *et al.* [7] published a study in which the prevalence of fluorosis was 49% in children from 6 to 16 years of age. In the 12-year-old children, the prevalence was 50%, but in the study the authors used the Thylstrup and Fejerskov (TF) index, which had different criteria for defining the clinical signs, perhaps for this reason the prevalence was higher. On the other hand, Barros and Mattos [4] performed a study in which the prevalence of fluorosis (Dean's index) was 11.4% in 12-year-old schoolchildren from Ouro Preto. In that study, 34% of the children presented lesions classified as questionable, which were not considered fluorosis. In the study by Moura *et al.* [24] the TF scale was used, and the prevalence of fluorosis was 61.5%; of these, 70.9% were TF 1, which in comparison with the Dean index is the questionable classification, which some authors consider as non-fluorosis, perhaps explaining the reason for the high prevalence in relation to our study. Rigo [30] published a study in which the prevalence of fluorosis in adolescents between 12 and 19 years of age was 32.8%. By using the Dean's index, the "questionable" classification was considered fluorosis, following assertions by Fejerskov *et al.* [16], who consider "questionable fluorosis" because it does not fit into

the classification of normal, due to alterations in the dental enamel, characterizing a pathology. In the study of Rigo [30], the “questionable” classification had a prevalence of 8.7%. In our study, no child was classified in the “questionable” classification. In the study by Spohr *et al.* [35] the results showed a high prevalence of dental fluorosis (90.3%) in children, in which 68.4% of them were in the questionable classification of the Dean index. In the study by Silva *et al.* [33] in Sobradinho, the prevalence of fluorosis was 87.8% and in Tavares, 94.6%. The questionable classification was 41.5% in Sobradinho and 66.1% in Tavares.

The Dean index is divided into six categories (normal enamel, questionable fluoride, very light, light, moderate, and severe), showing bilaterally, symmetry and nebulosity as manifestations. The “questionable” classification is controversial in the academic world and can generate confusion, but according to Spohr *et al.* [35] some studies choose to use this category as presence of dental fluorosis because of its importance in areas where the causal factor of dental fluorosis was exactly between the maximum of the harmless amount and the minimum of the quantity capable of producing very slight forms. Even considering the limitations, several population-based studies, in different Brazilian cities, made use of the Dean index [3, 11, 25, 29].

In relation to the swallowing of dentifrices, no clinically relevant difference between the cities occurred, and on average 48.5% swallowed it, differing from other studies: 63.36% [23] and 67% [37]. According to Cardoso *et al.* [10], a child ingests on average 70% or more of the amount of toothpaste used at each toothbrushing, so the amount of toothpaste used in the toothbrush should be small, so that the systemic effects are minimized.

In this transversal study, bias may have occurred due to the use of a questionnaire filled by the parents. Further studies are necessary to determine, with greater reliability, the percentage of children who swallow fluoridated dentifrices.

Other limitations of the study were the number of participants, because 103 of the 200 did not respond to the questionnaire or did not sign the Free and Clarified Consent Form, as well as the impossibility of obtaining data on the waters of both cities, since Siságua had no data available throughout the study period.

It is suggested that the study be replicated with a larger number of students and compared with other cities belonging to the southern region of Santa Catarina.

Conclusion

Among the study population, most of the children did not have any degree of fluorosis. The cases of dental fluorosis were classified as little severity and with low esthetic impairment.

It can be concluded that the two participating cities, located in southern Santa Catarina, have the fluoride levels in the supply waters within the limits considered adequate and safe for the population, thus presenting low risk to dental fluorosis.

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