External control of the public water supply in 29 Brazilian cities

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Abstract: The fluoridation of public water supplies is considered the most efficient public health measure for dental caries prevention. However, fluoride levels in the public water supply must be kept constant and adequate for the population to gain preventive benefit. The aim of this study was to analyze fluoride levels in the public water supply of 29 Brazilian municipalities during a 48-month period from November 2004 to October 2008. Three collection sites were defined for each source of municipal public water supply. Water samples were collected monthly and analyzed at the Research Laboratory of the Nucleus for Public Health (NEPESCO), Public Health Postgraduate Program, Araçatuba Dental School (UNESP). Of the 6862 samples analyzed, the fluoride levels of 53.5% (n = 3671) were within the recommended parameters, those of 30.4% (n = 2084) were below these parameters, and those of 16.1% (n = 1107) were above recommended values. Samples from the same collection site showed temporal variability in fluoride levels. Variation was also observed among samples from collection sites with different sources within the same municipality. Although 53.5% of the samples contained the recommended fluoride levels, these findings reinforce the importance of monitoring to minimize the risk of dental fluorosis and to achieve the maximum benefit in the prevention of dental caries.

Descriptors: Fluoridation; Fluorine; Water; Oral Health.

Introduction

The effect of fluoride in dental caries control is widely recognized. Among the proposed means of fluoride provision through public health measures, the fluoridation of water supplies has proven to be a safe, effective, simple, and economical way to significantly reduce the incidence of dental caries.[1–6] This method was first introduced in Grand Rapids, MI, USA, in 1942. In Brazil, the fluoridation of public water supplies began in 1953, and Baixo Guandu in the state of Espírito Santo was the first Brazilian city to have fluoridated water.[7] However, water fluoridation was not required in public water supply systems until 1975, when the approval of Federal Law No. 6050 mandated fluoridation in all cities with water treatment plants.[8]

After the implementation of public water supply fluoridation, the rate of dental caries declined considerably in the populations of several Brazilian cities, such as Barretos, SP (55% reduction after 10 years),[9] Campinas, SP (57% after 10 years),[10] Goiania, GO (57.1% after 9 years),[11] and

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Piracicaba, SP (79% after 25 years).[12] These reductions demonstrated the efficacy of this measure in disease control.

Natural levels of fluoride ions in water > 0.01 mg F/L are associated with decreased numbers of teeth with caries.[1] At levels > 1 mg F/L, teeth increasingly show signs of fluorosis, but no further reduction in the number of teeth affected by caries is achieved.[1,2] Previous studies have examined the relationship between fluoridated water and the occurrence of dental fluorosis. Catani *et al.*[13] evaluated the prevalence of dental fluorosis among schoolchildren in two cities in the state of São Paulo with different means of controlling optimal fluoride concentration in public water supplies; the fluoride concentration was homogeneous in the water of one city and variable in the other. The authors found that most fluorosis was mild, as expected in locations with appropriate fluoride levels,[14] and that the prevalence of fluorosis was higher among children in the city with better control of fluoride concentration. However, the study did not examine exposure to other fluoride sources,[13] which has increased the prevalence of dental fluorosis in recent decades.[15]

Thus, mechanisms must be developed to allow the adaptation of fluoride concentrations in public water supplies, thereby increasing the effectiveness of dental caries prevention and control and reducing the prevalence of dental fluorosis.[2,7] In addition to the control of fluoride concentrations performed by sanitation companies, external control by sanitary monitoring agencies or other public or private institutions is necessary. Such external control should include the monitoring and periodic review of fluoridation by institutions that are not directly responsible for water treatment and supply.[2] To achieve the maximum benefit in the prevention of dental caries, water fluoridation methods must be rigorously controlled to avoid unwanted effects associated with overdosing, as well as inefficient prevention resulting from underdosing.[7]

Given the importance of the continuous maintenance of fluoride levels within recommended limits, this study analyzed fluoride levels in the public water supplies of 29 Brazilian cities during a 48-month period. Fluoride concentrations were tested to determine whether they were within the recommended range, and temporal variability in fluoride levels within the study period was examined.

Methodology

In this longitudinal study conducted from November 2004 to October 2008, fluoride levels were analyzed in the public water supplies of 29 cities in northwestern São Paulo State, Brazil. The researchers obtained water supply system data from the secretaries of health, oral health coordinators, and those responsible for the public water supply in each municipality. All cities (n = 40) belonging to Regional Health Department II (RHDII) were considered for inclusion in the analysis; cities that did not fluoridate water (n = 4), those that did not send samples to the Laboratory of Research, Nucleus for Public Health (NEPESCO), Araçatuba Dental School (UNESP; n = 2), and those that reported the initiation of public water supply fluoridation after the start of the study period (n = 5) were excluded.

Determination of water collection sites

The collection sites were established based on the number and location of supply sources and water treatment plants (WTPs) in each municipality. Three collection sites for each water supply source or WTP were selected randomly using street addresses; to facilitate site access and prevent sample loss, the collection sites were located in public places such as schools, parks, and commercial properties.

Collection of water samples

The researchers collected samples in polyethylene bottles that had been decontaminated with deionized water and were identified with labels indicating the location of the collection site, date, and name of the collector.[16] The samples were collected once a month on a weekday and analyzed by the technical team within 7 days after collection.

Analysis of fluoride levels in water

Samples from 193 collection sites were analyzed monthly in duplicate for 48 months at the NEPESCO Laboratory of UNESP. Fluoride levels were determined using an ion analyzer (Model 940EA;

Orion Research, Inc., Beverly, USA) coupled to a specific electrode (Model 9609BN; Orion Research, Inc.) for fluoride. Equipment calibration was performed in triplicate to reduce the margin of error, taking into account the expected range of sample values (0.1-2.0 mg F/L). For this purpose, dilutions from a standard 100-mg/L fluoride solution (Model 940907; Orion Research, Inc.) were used; 1 mL was collected from each standard after the addition of 1 mL total ionic strength adjustor buffer (TISAB II; Orion Research, Inc.), an ionic pH adjustment buffer with non-complex strength that is used widely in fluorine analysis. The values obtained from duplicate analyses of samples after the addition of TISAB II (1:1), were transferred to a Microsoft Excel spreadsheet and converted from mV to mg F/L.

In accordance with the average maximum daily temperature, the optimal fluoride concentration in water intended for human consumption in São Paulo State, Brazil, is 0.7 mg F/L.[17] Thus, after mathematical rounding, water samples with average fluoride concentrations of 0.55-0.84 mg F/L were considered to fall within the recommended range of fluoride levels.

Results

During the 48 months, 6862 water samples were analyzed in duplicate from 193 collection sites in 29 participating municipalities (n = 13,724 analyses). Monthly samples were not collected from some sites due to transportation difficulties or political problems that interfered with site access.

Table 1 shows the number and percentage of samples from the public water supplies of each city, classified according to fluoride level. Of the 6862 samples analyzed, the fluoride levels of 53.5% (n = 3671) were within the recommended parameters, those of 30.4% (n = 2084) were below these parameters, and those of 16.1% (n = 1107) were above recommended values. The proportion of samples from each municipality that fell within the recommended range of fluoride concentration (0.55-0.84 mg F/L) ranged from 13.67% to 95.74%.

Table 2 presents the number of collection sites, means and standard deviations of fluoride level (mg F/L), and minimum and maximum concentrations (mg F/L) for samples from each municipality during the 48-month study period. Only four municipalities failed to maintain average fluoride concentrations within the recommended parameters.

Discussion

The fluoridation of public water supplies can efficiently provide public health benefits only through the constant evaluation of the fluoridation process to ensure that adequate fluoride levels are maintained. This monitoring should be conducted by the company responsible for water treatment and distribution and confirmed by an external health authority.[2] Analysis by another institution enables the cross-checking of results and promotes interaction between institutions in resolving problems arising from the method, equipment, and/or solutions used.

Only 53.5% of the samples analyzed in this study had fluoride levels within the recommended parameters. The relatively high percentage of samples falling outside of these parameters demonstrates the difficulty that cities face in maintaining constant fluoride levels in drinking water. The majority of samples with fluoride concentrations outside of the recommended range represented underdosing, which has no effect on dental fluorosis or other health risks but provides a minimal benefit in the prevention of dental caries. Variation in fluoride levels was found among samples taken from different collection sites in the same city (Tables 1 and 2), indicating the importance of selecting collection sites that are representative of the number and location of supply sources.

Saliba *et al.*[18] analyzed similar samples from northwestern São Paulo State during a 6-month period (November 2004 - April 2005), and found a lower percentage (38.19%) of water samples with fluoride levels within recommended parameters in comparison with the results of the present study. This temporal increase in the proportion of water samples with appropriate fluoride levels demonstrates the importance of longitudinal studies and the effectiveness of constant monitoring, which facilitates the operational control of water fluoridation procedures and improves the quality of public water supplies.[19-23] In another study of eight cities

Table 1 - Classification of samples from the public water supplies of 29 cities in São Paulo State, Brazil, according to fluoride concentration (mg F/L).

City	0.6 - 0.8 mg F/L		< 0.6 mg F/L		> 0.8 mg F/L		Total	
	n	%	n	%	n	%	n	%
Alto Alegre	125	88.65	14	9.93	2	1.42	141	100
Araçatuba	246	65.25	98	25.99	33	8.75	377	100
Auriflama	114	83.82	22	16.18	0	0	136	100
Bento de Abreu	99	68.75	40	27.78	5	3.47	144	100
Birigui	290	39.51	177	24.52	267	35.97	734	100
Brejo Alegre	95	71.97	30	22.73	7	5.3	132	100
Castilho	376	58.93	158	24.76	104	16.3	638	100
Coroados	134	93.06	1	0.69	9	6.25	144	100
Gabriel Monteiro	135	95.74	2	1.42	4	2.84	141	100
Guaraçai	60	13.67	336	76.54	43	9.79	439	100
Guararapes	106	76.81	16	11.59	16	11.59	138	100
Guzolândia	126	89.36	8	5.67	7	4.96	141	100
Ilha Solteira	118	86.13	17	12.41	2	1.46	137	100
Itapura	77	21.63	222	62.36	57	16.01	356	100
Lavínia	130	26	276	55.2	94	18.8	500	100
Lourdes	121	84.03	20	13.89	3	2.08	144	100
Mirandópolis	136	48.23	78	27.66	68	24.11	282	100
Murutinga do Sul	23	16.67	109	78.99	6	4.35	138	100
Nova Castilho	30	25.64	58	49.57	29	24.79	117	100
Nova Independência	91	36.99	125	50.81	30	12.2	246	100
Nova Luzitânia	42	56	33	44	0	0	75	100
Penápolis	118	83.69	5	3.55	18	12.77	141	100
Piacatú	121	84.03	19	13.19	4	2.78	144	100
Rubiácea	187	75.4	45	18.15	16	6.45	248	100
Santópolis do Aguapeí	120	94.49	4	3.15	3	2.36	127	100
Sud Mennucci	99	68.75	45	31.25	0	0	144	100
Suzanápolis	66	25.1	68	25.86	129	49.05	263	100
Turiúba	117	84.78	19	13.77	2	1.45	138	100
Valparaíso	169	47.34	39	10.92	149	41.74	357	100
Total	3671	53.5	2084	30.4	1107	16.1	6862	100

in northwestern São Paulo State conducted during a 36-month period from November 2004 to October 2007, Saliba *et al.*[24] found a higher proportion (77.4%) of water samples with fluoride levels within recommended parameters. However, it should be noted that these eight cities used a single water source. Our findings highlight the importance of longitudinal studies that monitor fluoride levels in public water supplies, especially for cities in which multiple water sources are integrated into the water supply system, where it is more difficult to control fluoride levels throughout the network.

In a study that monitored municipal control of fluoride levels in Niteroi, RJ, Brazil for 1 year, Maia

Table 2 - Number of collection sites, mean fluoride level (mg F/L), minimum and maximum concentrations (mg F/L), and standard deviations for water samples from 29 cities in São Paulo State, Brazil, during the 48-month study period.

City	Number of collection sites	Mean fluoride level (mg F/L)	Minimum concentration (mg F/L)	Maximum concentration (mg F/L)	Standard deviation
Alto Alegre	3	0.64	0.35	0.88	0.08
Araçatuba	9	0.66	0.07	1.13	0.15
Auriflama	3	0.57	0.01	0.77	0.21
Bento de Abreu	3	0.62	0.1	1.20	0.14
Birigui	43	0.70	0.01	1.67	0.33
Brejo Alegre	3	0.66	0.43	1.05	0.12
Castilho	15	0.70	0.28	2.65	0.29
Coroados	3	0.70	0.55	0.95	0.08
Gabriel Monteiro	3	0.69	0.50	0.91	0.07
Guaraçai	12	0.48	0.14	3.28	0.37
Guararapes	3	0.68	0.3	1.06	0.13
Guzolândia	3	0.69	0.3	0.95	0.10
Ilha Solteira	3	0.67	0.11	5.07	0.44
Itapura	12	0.45	0.04	1.57	0.34
Lavínia	12	0.53	0.02	1.76	0.34
Lourdes	3	0.63	0.33	0.92	0.08
Mirandópolis	6	0.71	0.05	2.72	0.30
Murutinga do Sul	3	0.42	0.13	1.11	0.18
Nova Castilho	3	0.67	0.09	2.21	0.43
Nova Independência	6	0.55	0.09	1.83	0.34
Nova Luzitânia	3	0.58	0.23	0.77	0.11
Penápolis	3	0.70	0.5	1.0	0.10
Piacatú	3	0.67	0.4	2.32	0.25
Rubiácea	6	0.65	0.06	1.37	0.14
Santópolis do Aguapeí	3	0.68	0.32	1.08	0.08
Sud Mennucci	3	0.58	0.4	0.82	0.07
Suzanápolis	9	0.79	0.17	1.53	0.33
Turiúba	3	0.61	0.43	0.91	0.07
Valparaíso	9	0.77	0.02	1.16	0.20
Total	193	0.64	0.01	5.07	0.28

et al.[25] found that treated water showed a wide variation in fluoride concentration (0.03-1.49 mg F/L) and 96% of samples had inadequate concentrations. Thus, the operational control of water fluoridation was inadequate in terms of maintaining fluoride levels in the public water supply.[25] These findings indicate that the external control of water fluoridation may safely and reliably prevent large variations in fluoride levels in public water supplies. Only 3.4% of our samples had fluoride levels > 1.2 mg F/L, and municipalities promptly corrected such fluoride overdosing to avoid the risk of dental fluorosis. During the study period, some cities achieved recommended fluoride levels within 1 month after being

informed of analytical results. Municipalities with fewer water sources demonstrated greater control of fluoride levels in drinking water.

Conclusion

Although the majority of water samples from Brazilian municipalities analyzed in this study had appropriate fluoride levels, many samples fell outside of the recommended parameters. This inability to efficiently control fluoride levels can reduce the effectiveness of preventive measures or increase inhabitants' risk of developing dental fluorosis. The great variability in fluoride concentrations among samples and municipalities reinforces the importance of external monitoring of the fluoridation of public water supplies, which facilitates operational control in cities and contributes to the improvement of residents' oral health status and quality of life.

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