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SPATIAL DISTRIBUTION OF RISK FACTORS AND FLUORIDE LEVELS IN PUBLIC WATER SUPPLIES ON A MUNICIPAL SCALE

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Abstract

Fluoridation of public water supplies is an important measure to prevent dental caries and is linked to Sustainable Development Objective 6. This study aimed to evaluate the fluoride content of Ceará's municipalities. The research used secondary data from SISAGUA (municipality; year, date, source and point of collection; form of supply; supply system; chlorine and fluoride concentrations) and the IBGE (HDI, population, FIRJAN Municipal Development Index, and estimated population) for spatial distribution and the analysis of fluoride risk factors. Of the 26,390 samples collected, only 17.8% had ideal fluoride content, with a higher prevalence in samples collected in 2016, in isolated urban areas, in water supply systems, and in chlorine levels above the ideal. Of the 182 municipalities evaluated, 16.7% had most of the samples with ideal fluoride content. In a multivariate analysis, municipalities with a population below 30 thousand inhabitants had a prevalence of inadequate fluoride content (below or above the ideal) 2.12 (95% CI = 1.92-4.88) times higher than municipalities with large populations. It is concluded that less than a fifth of Ceará's population is exposed to adequate public water fluoride levels, and cities with fewer than 30,000 inhabitants are the most affected.

Keywords: Fluoride. Water Fluoridation. Environmental Health Surveillance. Health Geography.

Resumo / Resumen

DISTRIBUIÇÃO ESPACIAL DE FATORES DE RISCO E TEORES DE FLÚOR NA ÁGUA DE ABASTECIMENTO PÚBLICO EM ESCALA MUNICIPAL

Fluoretação das águas de abastecimento público é uma importante medida de prevenção da cárie dentária e está vinculada ao objetivo 6 do desenvolvimento sustentável. O estudo objetiva avaliar o teor de flúor nas águas de abastecimento em âmbito estadual. Utilizou-se dados secundários do SISAGUA (município; ano, data, procedência e ponto de coleta; forma de abastecimento; sistema de abastecimento; concentrações de cloro e fluoreto) e do IBGE (IDH, Índice FIRJAN de desenvolvimento municipal e população estimada) para analisar distribuição espacial e fatores de risco da fluoretação. Das 26.390 amostras, apenas 17,8% apresentavam teor de flúor ideal, com maior prevalência nas coletas realizadas em 2016, em áreas urbanas isoladas, em sistemas de abastecimento de água, e com presença de cloro acima do ideal. Dos 182 municípios avaliados, apenas 16,7% apresentaram maioria das amostras com teor ideal de flúor. Municípios com população inferior a 30 mil habitantes apresentaram prevalência de teor de flúor inadequado (abaixo ou acima do ideal) 2,12 (IC95%=1,92-4,88) vezes superior aos municípios com grandes populações (análise multivariada). Conclui-se que menos de 1/5 da população cearense está exposta a teores adequados de flúor nas águas de abastecimento público e cidades com população inferior a 30 mil habitantes são mais afetadas.

Palavras-chave: Flúor. Fluoretação das Águas. Vigilância em Saúde Ambiental. Geografia da Saúde.

DISTRIBUCIÓN ESPACIAL DE FACTORES DE RIESGO Y NIVELES DE FLÚOR EN ABASTECIMIENTO PÚBLICO DE AGUA A ESCALA MUNICIPAL

La fluoración de los suministros públicos de agua es una medida importante para prevenir la caries dental y está vinculada al objetivo 6 del desarrollo sostenible. El objetivo del estudio fue promover una evaluación estatal del contenido de fluoruro en el agua. Para eso, el análisis de datos secundarios del SISAGUA (ciudad, año, fecha, origen y punto de colecta; forma de abastecimiento; sistema de abastecimiento; concentraciones de cloro y flúor) y del IBGE (IDH, población, índice de desarrollo municipal FIRJAN y población estimada) para distribución espacial y análisis de factores de riesgo. De las 26.390 muestras recolectadas, solo el 17,8% presentó un contenido ideal de flúor, con mayor prevalencia en las recolectas realizadas en 2016, en áreas urbanas aisladas, en sistemas de abastecimiento de agua y con presencia de cloro por encima del óptimo ($p < 0,001$) . De los 182 municipios evaluados, solo el 16,7% tuvo la mayoría de muestras recolectadas con contenido ideal de flúor. En un análisis multivariado, los municipios con población menor de 30 mil habitantes tuvieron una prevalencia de contenido inadecuado de flúor (por debajo o por encima del ideal) 2,12 (IC95%=1,92-4,88) veces mayor que los municipios con gran población. Se concluye que menos de la quinta parte de la población de Ceará está expuesta a niveles adecuados de fluoruro en el suministro público de agua y las ciudades con población inferior a 30 mil habitantes son las más afectadas.

Palabras-clave: Flúor. Fluoración del agua. Vigilancia de la salud ambiental. Geografía de la Salud.

INTRODUCTION

The human right to quality water has been recognized by the United Nations (UN) since 2010 and is among the sustainable development objectives advocated by the organization and endorsed by Brazil (United Nations Brazil, 2022). The Sustainable Development Goals are a global call to action to end poverty, protect the environment and climate, and ensure that people everywhere can enjoy peace and prosperity. Number Six of the seventeen recommended objectives refers to drinking water and sanitation.

Fluoride content is the most critical water quality parameter for preventing and reducing the incidence of dental caries on a large scale (SILVA; HELLER, 2016). Although it is available topically in toothpaste and dental clinics, the systemic route through water fluoridation successfully prevents public health problems (RAMIRES; BUZALAF, 2007), offering the best cost-benefit in the prevention of dental caries (PETERSEN; OGAWA, 2016).

Since 1974, Federal Law 6.050, which requires water fluoridation units to be installed in all new and/or reformed water treatment plants, compelled the Brazilian government to invest in water fluoridation actions (BRASIL, 1974).

The Brazilian decision to add fluoride to public supply systems is due to its territorial extension, the low costs involved, and the universal nature of the benefits regardless of the population's socioeconomic condition. However, ideal fluorine levels must be uninterrupted for this benefit to be effective (KOZLOWSKI; PEREIRA, 2003).

The literature describes the ideal consumption of fluoride doses in the water based on the annual average of the maximum daily temperature. According to temperatures in Brazilian locations, fluoride levels should be between 0.6 and 0.8 mg F/l to prevent dental caries (FRAZÃO; PERES; CURY, 2011). Below-optimal levels are ineffective in preventing caries, while above-optimal levels increase the risk of dental and bone fluorosis (NORO; OLIVEIRA; LEITE, 2006).

A study by Frazão and Narvai (2017) showed an increase in the number of Brazilian municipalities with fluoridated water (from 67.7% to 76.3%) in the first decade of this millennium. However, this increase was influenced by factors such as the municipalities' size and human development index. In this context, it is necessary to investigate whether fluoridation occurs adequately, that is, at appropriate levels, to prevent dental caries (FRAZÃO; PERES; CURY, 2011). Moreover, investigating whether factors mediate these levels is essential for evaluating this critical public policy.

In this context, through Normative Instruction 01 of March 7, 2005, the Ministry of Health establishes the competencies of Environmental Health Surveillance in the three governmental spheres.

One of its attributions was the surveillance of water for human consumption, leading to the development of the National Program for Surveillance of Water Quality for Human Consumption (VIGIAGUA). In 2005, the Ministry of Health also issued Ordinance 518, which establishes the potability standards of drinking water, which includes fluoride content monitoring for effective surveillance of the population's supply.

Consequently, in 2005, VIGIAGUA was executed in the State of Ceará and is coordinated and monitored by the Environmental Surveillance Cell (CEVAM), which is part of the Secretariat of Surveillance and Regulation in Health's (SEVIR) Coordination of Surveillance in Environmental Health and Occupational Health (COVAT) in the state's Health Department. It aims to guarantee the population's access to quality water that meets potability standards and assesses their health risks (XAVIER et al., 2019).

However, despite VIGIAGUA's implementation in Ceará, this program has been ineffective in monitoring ideal fluoride levels because, before 2014, it was impossible to carry out laboratory control of these levels. Furthermore, there is no knowledge as to whether there are variables that mediate a possible variance between municipalities and over time in each one (RAMIRO et al., 2018).

Given the importance of controlling the fluoride content in reducing dental caries rates and protecting against dental bone fluorosis, the present study aims to promote the evaluation of fluoride content in water at a state level.

METHODOLOGY

TYPE OF STUDY AND TARGET POPULATION

This research developed an ecological study based on analyzing secondary data from the Water Quality Surveillance Information System for Human Consumption (SISAGUA) and the Brazilian Institute of Geography and Statistics (IBGE) of the municipalities of Ceará.

SAMPLE COLLECTION

The points determined by SISAGUA for water collection are defined by the municipalities based on the risk and vulnerability criteria of the population covered by the water supply system, with guidance from the Guide for Surveillance and Control of Water Quality for Human Consumption of the Ministry of Health (BRAZIL, 2006).

The employees responsible for the collection are trained, and the instruments are calibrated for this purpose. The samples, reviewed by the supervisor, are evaluated and interpreted later.

The electrometric method was used to analyze the samples employing an ion-specific electrode. The research assessed the total number of collections.

DATA EXTRACTION

The study's data source was the SISAGUA database from all Ceara's municipalities in the years available: 2014, 2015, and 2016. This information was exported to spreadsheets, where the following variables were selected: name and code of the municipality; Regional Health Coordination (Cres) where the municipality is located; year and date of collection of the water sample; form of supply (water supply system-SAA, collective alternative solution-SAC, individual alternative solution-SAI); name and code of the water supply system; origin of the collection (treatment plant, distribution system, intra-household); collection point; zone (rural, urban); description of the location (address); concentration of free residual chlorine in the water sample (value in mg/l) and fluoride concentration in the water sample (value in mg/l).

The data were obtained from the environmental surveillance center of the health promotion and protection coordination of the Health Department of Ceará.

The information was used to calculate the following indicators: Municipal annual average fluoride levels (in part per million [ppm]) for 2014, 2015, and 2016. After that, the samples were categorized by ranges of water fluoride content as suggested for locations with an average temperature between 26.3ºC and 32.5ºC; ideal content between 0.6-0.8 ppm fluoride per municipality/Cres (Regional Health Coordination) per year; sub-optimal fluoride content (below 0.6 ppm) per municipality/Cres per year; and above ideal fluoride content (>0.8 ppm) per municipality/Cres per year (CECOL/USP, 2011).

SOCIODEMOGRAPHIC PROFILE OF MUNICIPALITIES

As well as the samples, the municipalities were categorized according to the same parameter as the most frequent collection profile (below ideal, ideal, above ideal)12 and subsequently correlated with sociodemographic data. Next, information on the following indicators was accessed on the IBGE (Brazilian Institute of Geography and Statistics) website: the 2010 Human Development Index, the 2010 FIRJAN Municipal Development Index, and the 2019 population estimate (IBGE, 2020).

The FIRJAN Municipal Development Index (IFDM) analyzes three socioeconomic development aspects of over 5,000 Brazilian municipalities: Employment and Income, Education, and Health. Created in 2008, the index is composed exclusively of official public statistics provided by the Ministries of Labor, Education, and Health.

The index ranges from 0 to 1 point; the closer to 1, the greater the municipality's socioeconomic development. The data are available at https://www.firjan.com.br/ifdm/ (FIRJAN, 2020).

DATA ANALYSIS

The data were exported to the Statistical Package for the Social Sciences (SPSS) software, version 20.0 for Windows; the analyses were performed with a confidence level of 95%. The quantitative variables were categorized and crossed with the fluoride samples and municipalities using the chi-square and Fisher's exact tests. The QGIS 3.12 software was used to construct the georeferenced data.

RESULTS

ANALYSIS OF THE WATER SAMPLES

In total, 26,390 samples were collected and evaluated in 182 of Ceará's 184 municipalities. There was a median of 134 collections per municipality, ranging from 2 to 3,734 between 2014 and 2016. Only the municipalities of Abaiara and Barro, in the south of the state, did not have samples analyzed in this period. The fluoride content of most of the samples (63%) was below the ideal, 17.8% had an ideal content, and 19.2% had levels above the ideal ($p < 0.001$) (Table 1, Figure 1).

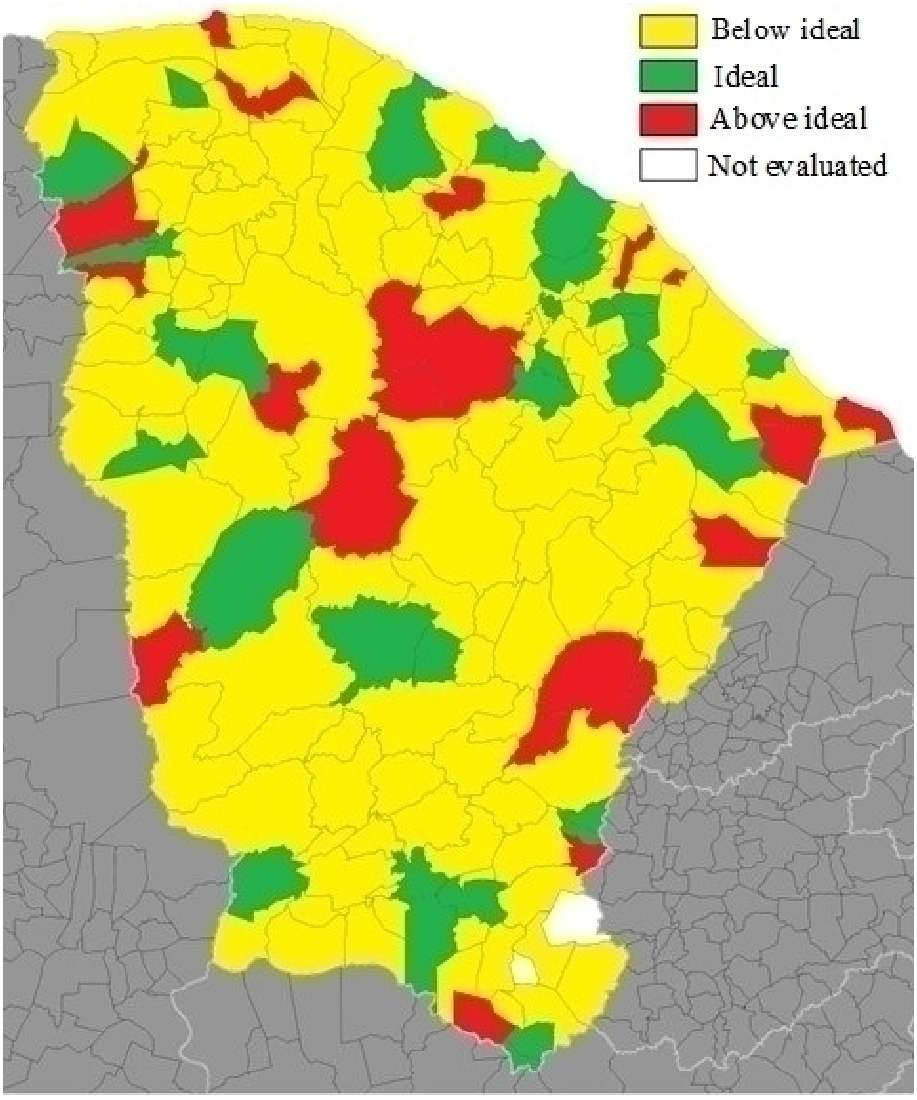

Figure 1 - Municipalities in Ceará with most samples below ideal, ideal, or above ideal for fluoride concentration in the water consumed by the population in the years 2014, 2015, and 2016.

The number of samples collected with above-optimal content was significantly higher in 2014 and

2015, while in 2016, the proportion of samples with ideal and below-optimal content was higher ($p < 0.001$). The samples collected in the rural area had a higher proportion of ideal or above ideal levels ($p < 0.001$). Samples from quilombola and riverine communities, nucleus/rural properties, villages/hamlets, settlement projects, and district headquarters had a significantly higher proportion of suboptimal samples than collections from isolated urban areas ($p < 0.001$) (Table 1).

	Total	Fluoride Content			p-Value
		Below Ideal	Ideal	Above Ideal	
Total	**26390**	**16624 (63.0%)**	**4707 (17.8%)**	**5059 (19.2%)**	**<0.001**
Year					
2014	9199 (34.9%)	5572 (60.6%)	1606 (17.5%)	2021 (22.0 %)*	***<0.001***
2015	9161 (34.7%)	5716 (62.4%)	1591 (17.4%)	1854 (20.2 %)*	
2016	8030 (30.4%)	5336 (66.4 %)*	1510 (18.8 %)*	1184 (14.7%)	
Zone					
Rural	2083 (8.1%)	1533 (73.6%)	269 (12.9 %)*	281 (13.5 %)*	***<0.001***
Urban	23667 (91.9%)	14669 (62.0 %)*	4320 (18.2%)	4678 (19.8%)	
Area Category					
Neighborhood	20995 (81.5%)	12701 (60.5 %)*	3967 (18.9%)	4327 (20.6%)	***<0.001***
Quilombola community	5 (0.0%)	5 (100.0 %)*	0 (0.0%)	0 (0.0%)	
Riverine community	4 (0.0%)	3 (75.0 %)*	1 (25.0%)	0 (0.0%)	
Nucleus / rural prop	131 (0.5%)	109 (83.2 %)*	21 (16.0%)	1 (0.8%)	
Village/hamlet	1931 (7.5%)	1408 (72.9 %)*	244 (12.6%)	279 (14.4%)	
Settlement project	12 (0.0%)	8 (66.7 %)*	3 (25.0%)	1 (8.3%)	
District headquarters	2592 (10.1%)	1942 (74.92 %)*	340 (13.12%)	310 (12.0%)	
Isolated urban area	80 (0.3%)	26 (32.5%)	13 (16.2 %)*	41 (51.2 %)*	
Form					
Water supply system	24698 (93.6%)	15279 (61.9 %)*	4559 (18.5 %)*	4860 (19.7%)	***<0.001***
Collective alternative solutions	958 (3.6%)	748 (78.1%)	86 (9.0%)	124 (12.9 %)*	
Individual workarounds	734 (2.8%)	597 (81.3%)	62 (8.4%)	75 (10.2 %)*	
Origin of Collection					
Treatment station	496 (1.9%)	292 (58.9%)	109 (22.0%)	95 (19.1 %)*	***<0.001***
Intradomiciliary	2009 (7.6%)	1443 (71.8%)	273 (13.6%)	293 (14.6 %)*	
Pickup point	144 (0.5%)	130 (90.3 %)*	9 (6.2%)	5 (3.5%)	
Distribution system	22484 (85.2%)	13775 (61.3%)	4213 (18.7%)	4496 (20.0 %)*	
Alternative solution	1257 (4.8%)	984 (78.3%)	103 (8.2%)	170 (13.5 %)*	
Free residual chlorine					
No chlorine	764 (6.7%)	578 (75.6 %)*	109 (14.3%)	77 (10.1%)	***<0.001***
Suboptimal	137 (1.2%)	84 (61.3%)	23 (16.8%)	30 (21.9 %)*	
Ideal	1945 (17.1%)	1284 (66.0%)	314 (16.1%)	347 (17.8 %)*	
Above ideal	8510 (74.9%)	5034 (59.1%)	1757 (20.6 %)*	1719 (20.2 %)*	

*p<0.05, Fisher's exact test or Pearson's chi-square (n, %).

Table 1 - Number of observations per year, zone, collection form, and chlorine content concerning water fluoridation in municipalities in the state of Ceará.

The samples collected from alternative collective and individual solutions had above-standard contents, while the samples from water supply systems had a higher prevalence of ideal or above ideal content ($p < 0.001$). Sampling from catchments showed a higher prevalence of lower than ideal fluoride content, while collections from treatment stations, intra-household, distribution systems, and alternative solutions demonstrated elevated frequencies of high fluoride content ($p < 0.001$) (Table 1).

SOCIODEMOGRAPHIC PROFILE OF MUNICIPALITIES IN CEARÁ AND ITS INFLUENCE ON THE FLUORIDE CONTENT OF WATER

In Ceará, the samples from most of the municipalities had a below-optimal fluoride rate (66.5%), in 32 of them, most of the samples had an ideal fluoride content (16.7%), and in 24 municipalities, most of the samples had an above-optimal fluoride content (12.5) ($p < 0.001$).

In 2010, most of these municipalities had an average HDI between 0.600 and 0.699 (71.4%). In the same year, the Municipal Development FIRJAN Index was between 0.6 and 0.8 (70.0%), and in 2019, the estimated population was between 15 and 30 thousand inhabitants (36.3%).

Regarding the collection points per municipality, most had between 101 and 200 water points sampled (40.1%). Their water systems were integrated (50.2%) and supplied by the Water and Sewage Company of the State of Ceará (CAGECE) (90.1%).

		Fluoride Content			
	Total	Below Ideal	Ideal	Above Ideal	P-Value
Total	**182**	**126 (66.5%)**	**32 (16.7%)**	**24 (12.5%)**	**<0.001**
Region					
Metropolitan area of Fortaleza	19 (10.4%)	9 (47.9%)	6 (31.6%)	4 (21.1%)	0.090
Interior	163 (89.6%)	117 (71.8%)	26 (16.0%)	20 (12.3%)	
2010 HDI					
0.500-0.599	48 (26.4%)	36 (75.0%)	8 (16.7%)	4 (8.3%)	0.714
0.600-0.699	130 (71.4%)	88 (67.7%)	23 (17.7%)	19 (14.6%)	
0.700-0.799	4 (2.2%)	2 (50.0%)	1 (25.0%)	1 (25.0%)	
2010 FIRJAN Index					
0.4-0.6	49 (28.8%)	38 (77.6%)	8 (16.3%)	3 (6.1%)	0.166
0.6-0.8	119 (70.0%)	75 (63.0%)	24 (20.2%)	20 (16.8%)	
>0.8	2 (1.2%)	1 (50.0%)	0 (0.0%)	1 (50.0%)	
2019 Population					
up to 15 thousand	51 (28.0%)	38 (74.5%)	9 (17.6%)	4 (7.8%)	0.391
15-30 thousand	66 (36.3%)	44 (66.7%)	12 (18.2%)	10 (15.2%)	
30-60 thousand	39 (21.4%)	27 (69.2%)	4 (10.3%)	8 (20.5%)	
>60 thousand	26 (14.3%)	17 (65.4%)	7 (26.9%)	2 (7.7%)	
Number of water sample points					
up to 50	25 (13.7%)	16 (64.0%)	3 (12.0%)	6 (24.0%)	0.296
51-100	38 (20.9%)	27 (71.1%)	4 (10.5%)	7 (18.4%)	
101-200	73 (40.1%)	52 (71.2%)	14 (19.2%)	7 (9.6%)	
>200	46 (25.3%)	31 (67.4%)	11 (23.9%)	4 (8.7%)	
Water System					
Isolated – underground spring	57 (31.1%)	41 (71.9%)	9 (15.8%)	7 (12.3%)	0.773
Isolated - surface/mixed water source	34 (18.7%)	23 (67.6%)	8 (23.5%)	3 (8.8%)	
Integrated system	91 (50.2%)	62 (68.1%)	15 (16.5%)	14 (15.4%)	
Supply Service					
SAAE	18 (9.9%)	12 (66.7%)	1 (5.6%)	5 (27.8%)	0.087
Cagece	164 (90.1%)	114 (69.5%)	31 (18.9%)	19 (11.6%)	

*p<0.05, Fisher's exact test or Pearson's chi-square (n, %). HDI = Human Development Index; SAAE = Autonomous Water and Sewage Service; CAGECE=Water and Sewage Company of the State of Ceará; 2010 FIRJAN Index = 2010 FIRJAN Index of Municipal Development.

Table 2- Sociodemographic profile and water distribution services of the municipalities and their influence on the municipal fluoride content.

The following variables were not significantly associated with the municipalities' available fluoride content: Region, 2010 HDI, 2010 FIRJAN Index, 2019 Population, Number of water collection points, and water system and supply service (Table 2). However, in the multivariate analysis, municipalities with a population of up to 30 thousand inhabitants evidenced 2.12 times (95% CI = 1.92-4.88) higher prevalence of inadequate fluoride rates (p=0.037) (Table 3).

	p-Value	Adjusted OR (95%CI)
Non-ideal fluoride level		
Region (Fortaleza metropolitan area)	0.315	0.55(0.17-1.76)
Number of collection points (up to 100)	0.717	1.21(0.43-3.37)
HDI (up to 0.699)	0.736	0.84(0.32-2.26)
FIRJAN Index (up to 0.6)	0.663	1.24(0.47-3.28)
Population (Up to 30,000)	0.037*	2.12(1.92-4.88)
Water system (isolated)	0.776	1.12(0.51-2.49)
Supply Service (SAAE)	0.148	4.69(0.58-38.01)

*p<0.05, multinomial logistic regression ; OR = Oddsratio ; 95%CI = 95% confidence interval of the adjusted OR. HDI = Human Development Index; FIRJAN Index 2010= FIRJAN Index of Municipal Development 2010; SAAE = Autonomous Water and Sewage Service.

Table 3 - Multivariate analysis of risk factors for inadequate municipal low fluoride rates in the state of Ceará.

DISCUSSION

A meager percentage of municipalities in Ceará had ideal fluoride levels in their public water supply. This fact is worrying given the WHO recommendations on the Guidelines for Drinking Water Quality (FAWELL et al., 2006) and Federal Law 6.050 (BRAZIL, 1974) on the need for the population to benefit from collective fluoridation coverage. It was also observed that small municipalities were 2.12 times more likely to have a non-ideal fluoride rate, demonstrating that size is a factor that influences water fluoridation in the state of Ceará.

In addition to their specific purposes, public health policies should act to reduce inequalities. However, this is not the case in all situations; frequently, implementing particular actions results in increased inequalities. Thus, it is imperative to analyze concrete circumstances of policy implementation so that adjustments can be made, if necessary. Thus, the objective of mapping the fluoride content of the municipalities of Ceará and evaluating risk factors at inadequate levels was to collaborate with public policies to provide information and contribute to planning and controlling government actions. Appropriate guidelines for fluoride use have a radical influence on oral health, improving overall health and quality of life for populations worldwide. These policies range from interventions at the population level to households at the individual level (WHELTON et al., 2019).

According to Narvai et al. (2014), since the consolidation of knowledge about the impact of toothpaste on the prevention of dental caries (FEATHERSTONE, 1999; NADANOVSKY; SHEIHAM, 1995), the need to continue investing in water fluoridation is up for debate. However, according to Horowitz (1996), water fluoridation remains effective, especially for at-risk populations, such as the population of the Northeast, the Brazilian region with the worst epidemiological data related to dental caries (SAINTRAIN et al., 2015). Furthermore, Antunes and Narvai (2010) considered that water fluoridation coverage in Brazil is extremely unequal, noting that there is more intervention in the southern and southeastern states, which concentrate most of the country's wealth. In contrast, it was insufficient in the northern and northeastern regions, demonstrating the relevance of this study in a northeastern state.

The prevalence of inadequate (below or above standard) fluoride content detected in municipalities with smaller populations (fewer than 30 thousand inhabitants), which had 2.12 times more chances of having a non-ideal fluoride rate, is corroborated by Saliba, Moimaz, and Tiano (2006). These researchers considered that small and medium-sized municipalities might have difficulties controlling the addition of fluoride in public water supplies due to the lack of laboratory and technical infrastructure.

In 2006, Saliba, Moimaz, and Tiano analyzed the fluoride content of the water supply of 40 small and medium-sized municipalities in São Paulo. Of the 144 water points sampled, 61.81% were classified as unacceptable. It was found that 33 of these municipalities carried out fluoridation; in 78.79% of them, the fluoride content varied between the points over the study period. Thus, it may be that most of these municipalities do not maintain adequate control over fluoride levels in the water supply since the addition of fluoride occurs discontinuously and mainly at levels outside the parameters. Similar data were found in the present study, with a great deal of variation in fluoride levels between the municipalities studied and within the municipalities themselves, varying by location and month of collection.

It's noteworthy that despite Federal Law No. 6.050 (BRASIL, 1974), which determines the mandatory fluoridation of Brazilian municipalities with water treatment plants, there are still several locations without access to fluoridated water. This is the case even though the consumption of fluoridated water allows the frequent exposure of the population to small daily levels of fluoride, a proven effective action in preventing dental disease (FIGUEIREDO, 2016).

Our research detected that most of the municipalities in Ceará (n=126; 68.4%) had some samples with a fluoride rate below the ideal, and most of the samples in 32 municipalities had ideal fluoride contents. In twenty-four municipalities, most samples collected had a fluoride content above the ideal.

This diversity of these results should consider that Fluoride (F) is known to have beneficial and adverse effects in humans, depending on the total intake (VEEPERV; KARRO, 2019). Even where treated water is available, it is common for groundwater to be a water source for the community, especially in rural regions. Examples have been observed in the rural area of Sobral-CE (MORAIS, 1999) and Catolé do Rocha-PB (MARTINS; FORTE; SAMPAIO, 2012). Consequently, a long-term groundwater monitoring study was conducted in Estonia to evaluate the occurrence of fluoride rates in the water and their relationship with the groundwater calcium content. It was noted that the occurrence of fluorides is correlated with variations in groundwater, such as the chemical type, which is the function of the proportional content of the main cations and anions (VEEPERV; KARRO, 2019). The calcium ion content in groundwater has an essential effect on fluorine concentration, as Ca removes F from water through the formation and precipitation of CaF2 (VEEPERV; KARRO, 2019). In our research, we could not investigate this issue in depth; however, our findings from the rural area, where groundwater use is more common, show statistically significant differences in the proportion of ideal or above ideal fluoride content.

According to Yarmolinsky et al. (2009), it is possible to accept slightly higher levels of fluoride in water if its occurrence is natural; that is to say, especially in contexts of water scarcity, it is acceptable to permit the ingestion of waters with 1.3 mg F/L or 1.4 mg F/L. The concentration of natural fluoride of 1.5 mg F/L is tolerable for consumption in Brazil if there is no acceptable cost-benefit technology to adjust/remove its excess (FRAZÃO et al., 2013). If we consider this indication, a slightly larger percentage of our sample may be regarded as adequate, but the vast majority of samples are outside the desirable standard.

The sampling in the quilombola and riverside communities, nucleus/rural property, village/village, settlement project, or district headquarters had a higher proportion of samples below the ideal and significantly higher compared to tests in isolated urban areas. These data reflect the social inequality that persists among less favored populations and the difficulty of some public policies in reducing social inequalities. For Frazão et al. (2013), fluoridation of public water supply is an essential national policy strategy for intervention on oral health inequalities. Moreover, this requires planning measures and constant improvement by both the health and environmental sectors.

A comparative study analyzed a quilombola community with a water supply with an adequate fluoride concentration (0.6 to 0.9 mgF/L), depending on the temperature, and another community not supplied by a fluoridated water network. The water analysis carried out by the UFRGS Ecology Center observed a negligible fluoride detection limit (0.12; 0.14; 0.10 mgF/L) in the waters collected in the supply source of this rural community. Consequently, this community had a higher caries index when compared to the community that had access to fluoridated water. Therefore, the supply of fluoridated water proves to be extremely important in the collective sphere (FIGUEIREDO, 2016) and for vulnerable populations, as already advocated by Horowitz (1996).

However, fluoride can also have adverse effects (NORO; OLIVEIRA; LEITE, 2006). Most samples in twenty-four municipalities had high fluoride contents; therefore, there are potential negative effects, such as dental and/or bone fluorosis, which must be considered in implementing this public policy. Research makes clear that fluorine only has an affinity for mineralized tissues. Thus, while there is a risk for teeth and bones, there are evident differences between the two. The critical period for teeth is limited to the child's age during dental development (the pre-eruptive systemic effect). For bones, however, the risk persists throughout the person's life. Therefore, the authors emphasize that knowledge of the fluorosis development mechanism is vital to understanding its occurrence's risk period and its consequent clinical relevance to the surveillance rules regulating optimal concentration (CURY et al., 2019).

CONCLUSION

Despite the contribution of the present study, it was not without limitations. Firstly, it is worth noting that it was based on secondary data, the municipalities themselves collected and analyzed the samples, so it is impossible to guarantee that the processing was homogenous. The research used three available years of data, raising the interest of conducting a study with a more extended period, thus making it possible to verify the plausible temporal influence on fluoride levels.

We conclude that most municipalities in Ceará do not fluoride their waters adequately, either having inefficacious levels below recommendations for the region or concentrations above them, thus risking dental and bone fluorosis. Additionally, we observed that population size influences fluoridation levels, demonstrating the inequity in implementing the water fluoridation policy in Ceará. International data are unequivocal in showing the positive impact of fluoride on the prevention of dental caries.

Therefore, it is imperative to adjust the water fluoridation policy in the state of Ceará so that its population can fully enjoy the benefits of this policy, which is implemented with public resources.

The reality of small municipalities, as analyzed in the territory of Ceará, is a reason for reflecting on regional urban planning. However, there must be a critical analysis of what this regional urban planning is, as it is directly associated with the development model adopted by the State of Ceará, which accentuates social inequalities. It is necessary to oppose this proposal critically, as Milton Santos (2007, p.11) tells us:

> "...at first, we considered [these theories] hostile to the interests of underdeveloped countries, and more recently, they appeared to us as the privileged instrument of the diffusion of capital, both to aggravate underdevelopment and to maintain the class structure and ensure the expansion of poverty. [...] Such theories, placed without greater rectitude at the exclusive service of capital and above all of international capital, proved indifferent to the fate of the vast majority of the national collectivities of the Third World."

Therefore, when discussing fluoridation in drinking water and the municipalities' responsibility to manage and conduct sanitation policies, it should be borne in mind that we are dealing with a process that has historically reproduced these territories' living conditions. It is necessary to break with this dynamic through Regional Urban Planning that considers the local potential and all the actors involved in the development process.

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