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Information and conformity coverage of fluoride in tap water: demographic and socioeconomic differentials among Brazilian municipalities

Cobertura da informação e da conformidade do fluoreto na água de abastecimento: diferenciais demográficos e socioeconômicos dos municípios brasileiros

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ABSTRACT

Introduction: Access to safe water is an important global health challenge and a fundamental human right. The quality of the water consumed by the population is guaranteed through continuous verification and control of substances such as fluoride. Although there has been an improvement in practices for adjusting the concentration of fluoride in water, situations of non-compliance are still identified in different territories and countries. **Objective:** To verify whether the fluoride concentration in the water supply systems of Brazilian municipalities was in accordance with the expected standard for preventing dental caries, taking into account the demographic, socioeconomic, and management characteristics of the municipalities. **Method:** An ecological study was carried out to assess the coverage of fluoride surveillance records and their compliance in Brazil in 2018, based on the optimal concentration range recommended by the Collaborating Center of the Ministry of Health on Surveillance in Oral Health (0.445 and 0.944 mg F/L). For this, fluoride concentration data were collected in the Information System for the Surveillance of Water Quality for Human Consumption (SISAGUA). **Results:** Of the municipalities with water supply systems that kept records updated, 38.5% had valid information and 42.2% had 80% or more fluoride records within the expected range for preventing dental caries. Information and conformity coverage were higher in municipalities with 50 thousand or more habitants; with high or very high HDI; Gini index < 0.49; higher GDP per capita and per capita expenditure on health surveillance. **Conclusions:** Information and conformity coverage were higher in municipalities with better socioeconomic indicators and management performance, suggesting the necessity of adjusting water surveillance policy strategies aiming to dental caries control at population level.

KEYWORDS: Fluoride; Water Quality; Information Systems; Public Health

RESUMO

Introdução: O acesso à água segura é um desafio importante em saúde global e um direito humano fundamental. A qualidade da água consumida pela população é garantida por meio da verificação contínua e do controle de substâncias, como o fluoreto. Embora tenha havido uma melhora nas práticas de ajuste da concentração de fluoreto na água, ainda são identificadas situações de desconformidade em diferentes territórios e países. **Objetivo:** Verificar se a concentração de fluoreto nos sistemas de abastecimento de água dos municípios brasileiros estava de acordo com o padrão esperado para prevenir a cárie dentária, levando em consideração as características demográficas, socioeconômicas e de gestão dos municípios. **Método:** Realizou-se um estudo ecológico para avaliar a cobertura dos registros de vigilância do fluoreto e sua conformidade com os sistemas de abastecimento de água no Brasil em 2018, com base no intervalo ótimo de concentração recomendada pelo Centro Colaborador do Ministério da Saúde em Vigilância da Saúde

Bucal (0,445-0,944 mg F/L). Para isso, foram coletados dados de concentração do fluoreto no Sistema de Informação de Vigilância da Qualidade da Água para Consumo Humano. **Resultados:** Dos municípios providos por sistemas de abastecimento de água e que mantinham registros atualizados, 38,5% tinham informação válida e 42,2% destes apresentavam 80,0% ou mais dos registros de fluoreto dentro do intervalo esperado para prevenção da cárie dentária. A cobertura da informação e da conformidade foram mais altas nos municípios com 50 mil habitantes ou mais; com IDH alto e muito alto; com índice de Gini < 0,49; com PIB *per capita* e despesa *per capita* em vigilância sanitária mais elevadas. **Conclusões:** A cobertura da informação e da conformidade foi maior nos municípios com os melhores indicadores socioeconômicos e de desempenho da gestão, sugerindo a necessidade do ajuste das estratégias da política de vigilância de qualidade da água visando o controle da cárie dentária em nível populacional.

PALAVRAS-CHAVE: Fluoreto; Qualidade da Água; Sistemas de Informação; Saúde Pública

INTRODUCTION

Among the challenges facing global health, access to safe water stands out as a fundamental human right and a component of the sustainable development agenda. From its capture in water sources and management in distribution networks to geopolitical and ethical issues inherent in the planning of public policies and water management to ensure universal access, water is the focus of proposals for guidelines and quality standards based on evidence aimed at contextual identification of hazards and risk management, as well as the establishment of water safety plans (WSP), health goals and independent surveillance[1,2]. Monitoring population exposure to fluoride in water is internationally recognized as an important requirement for surveillance systems, accepting naturally occurring values of up to 1.5 mg F/L and adjusted values for caries prevention purposes of between 0.5 and 1.0 mg F/L[2]. Mapping and testing the concentration of fluoride in drinking water are recommendations to countries approved at the 74th World Health Assembly in 2021[3].

In Brazil, proper water monitoring based on the dynamics of environmental surveillance includes, among other routines, measures to control physical, chemical, and biological characteristics. These measures are an essential part of complying with the WSP, as well as the potability standards required by national legislation[4,5]. In this context, the control of the quality of water consumed by the population is the responsibility of the National Water Quality Surveillance Program for Human Consumption (VIGIAGUA), coordinated by the Health Surveillance Secretariat of the Ministry of Health[6], which is responsible for defining the guidelines for actions that must be adopted continuously by public health authorities, in line with the standards established in Ordinance No. 888, of May 4, 2021[5]. These guidelines include instructions for local authorities to implement the sampling plan for monitoring the quality of water for human consumption, including the basic parameters of interest, the minimum number of samples, the frequency of monitoring and the criteria for selecting priority areas and points for collection.[7]

The quality of water intended for the population is ensured by continuously checking the concentrations of substances contained in solution, during and after the treatment of water until its final consumption. Among these substances is fluoride, both naturally occurring and that resulting from water treatment processes. The process of fluoridating public water supplies is a public health intervention technology applied in several countries, including high, low and middle-income countries such as Brazil, where the measure has been mandatory by law since 1974[8]. In recent decades, there has been a significant improvement in practices for adjusting the concentration of fluoride in water under the guidance of operational control guidelines and independent surveillance. However, situations of non-compliance are still identified in different territories and countries[9,10,11,12].

These situations of non-compliance can vary between countries and within the same country, but most studies refer to specific locations within a country[13,9]. Meta-analyses covering studies on specific localities within the same country are important for synthesizing the findings published in different years[14], but they do not describe the situations covering the entire territory of the country for a given year. A study of all Brazilian municipalities inferred that the implementation of the national water surveillance program in relation to the fluoride parameter, after experiencing an initial stage of expansion until 2008, was practically stagnant in 2015. Only 32.5% of the municipalities adequately fed the national program's information system, i.e., they entered accurate data correctly on a regular basis and, of these, 40.1% had 80% or more of records within the concentration range expected for the prevention of dental caries (0.445-0.944 mg F/L)[15]. However, no information was provided on the socio-economic characteristics of the municipalities. In addition, the lack of implementation of the public policy at municipal level may be related to the performance of municipal management in which expenditure is insufficient to ensure the availability of the necessary resources for the collection and transportation of samples to accredited laboratories[16]. Investigating municipal characteristics related to these non-compliances trough comprehensive studies is essential to produce knowledge about the associated factors and to guide public policy makers and all those interested in the intersectoral management of public water supply quality.

The aim was therefore to evaluate the coverage of fluoride concentration records and their compliance with the expected standard for preventing dental caries in water supply systems, according to the demographic, socioeconomic and management performance characteristics of Brazilian municipalities.

METHOD

To achieve this objective, an ecological study was carried out on the coverage of fluoride surveillance records and their compliance in water supply systems for 2018, with all Brazilian municipalities as the units of analysis. The fluoride concentration data was obtained from the Information System for the Surveillance of Water Quality for Human Consumption (SISAGUA), maintained by VIGIAGUA. The sources of data on the characteristics of the municipalities were: the Brazilian Institute of Geography and Statistics (IBGE), the Atlas of Human Development in Brazil, and the Accounting Data Collection System, maintained by the National Treasury Secretariat. The municipalities were described according to geographical, demographic, socio-economic and management performance variables.

Study variables

Record coverage was defined by the number and percentage of municipalities with valid information in relation to surveillance data on fluoride concentration in water supply systems. To do this, a protocol was adopted to critique the records, excluding municipalities with less than four months of information in the system, null values and outliers[15,17]. The fluoride concentration records in each municipality were distributed into four categories according to the risk/benefit binomial for dental caries and fluorosis, in accordance with the recommendations of the document Technical Consensus on the Classification of Public Water Supplies According to Fluoride Content[18], approved at a seminar held in 2011 by the Ministry of Health's Collaborating Center in Oral Health Surveillance (CECOL). The levels from 0.000 to 0.444 mg F/L were included in the "below the optimal range" category; from 0.445 to 0.944 mg F/L in the "optimal range" category; from 0.945 to 1.444 mg F/L, "above the optimal range"; and > 1.444 mg F/L in the "unsafe" category. The percentages of each range were calculated and the compliance rate was defined as the percentage of Brazilian municipalities with valid information that had 80% or more of fluoride records in the optimal range for caries prevention (0.445-0.944 mg F/L), a value that indicates a very good quality of fluoride concentration adjustment[12].

The geographic variable was defined by the macro-region to which the municipality belongs (North, Northeast, Southeast, South, and Midwest) and the demographic variable corresponded to the estimated number of inhabitants distributed into three categories: less than 10,000, from 10 to 50,000, and more than 50,000 inhabitants as adopted by some researchers.[15,19]

The socio-economic variables were the Gini index, Gross Domestic Product (GDP) *per capita*, and the Municipal Human Development Index (MHDI). The Gini index makes it possible to assess the degree of concentration of household income in a given population, quantifying the economic inequalities between the rich and the poor in the same territory. The value ranges from zero - a situation of maximum equality - to one - a condition of extreme inequality. It is calculated from responses to the National Household Sample Survey carried out by the IBGE. The figures for each municipality refer to 2010 (the latest information available) and were analyzed according to two categories based on the median value. GDP *per capita* corresponds to the sum of all goods and services produced in each municipality in a year, divided by the number of inhabitants. It is an indicator that makes it possible to compare the strength of each municipality's economy regardless of differences in population size. The values in Reais refer to 2018 and have been separated into quartiles. The HDI adopted by the United Nations Development Programme (UNDP) corresponds to a value from zero to one, standardized from a geometric mean, combining three dimensions of human development: life expectancy, education, and income. The values were classified into three categories: < 0.600, which equates to very low and low HDI; 0.600 to 0.699, which corresponds to medium HDI; and ≥ 0.700, which equates to high and very high HDI[20].

In order to measure the performance of municipal management, the value in Reais corresponding to municipal expenditure on health surveillance per inhabitant, recorded for 2018, was used. This is an economic-fiscal factor that seeks to express the municipality's ability to spend on functions related to health surveillance, which includes spending on environmental surveillance activities, especially water surveillance[21].

Data processing and calculation

The data for the surveillance module recorded for 2018 was extracted from the Open Data Portal on September 6, 2020. The database contained 36 variables and 2,679,268 observations on all physicochemical parameters covering Brazilian municipalities. This article examined the data equivalent to: (1) geographical region; (2) Federation Unit; (3) name of municipality; (4) IBGE code; (5) name of supply method (Water Supply System - WSS); (6) date of registration; and (7) concentration value of the fluoride parameter.

The information on the fluoride parameter was extracted using the RStudio computer tool and then submitted to the critical analysis protocol by applying the three filters mentioned above[15,17].

Next, the fluoride concentration values were classified and grouped according to the aforementioned criteria. Next, the values for each category of municipality were related to the independent variables, using Excel® software. The 5,570 municipalities were then distributed according to Brazilian macro-regions, demographic size, Gini index, GDP *per capita*, MHDI, and expenditure on health surveillance *per capita*. Tables were then built for descriptive analysis of the data and maps were made using the QGIS® application.

RESULTS

Of the total of 5,570 municipalities, 4,659 (83.6%) had a water supply system, 519 (9.3%) had no records on the type of supply, and the rest (392) were provided by alternative solutions. After applying the data review procedures, 113,105 records were

included. Their distribution by macro-region and federation unit is shown in Table 1. Of the fluoride records, 61.5% were included in the optimal concentration range for preventing dental caries (0.445 to 0.944 mg F/L), with the North (67.7%), Southeast (87.5%), and Midwest (66.7%) macro-regions standing out positively with values higher than the national value. Only two of the seven states in the North macro-region had valid records. In the Southeast macro-region, Rio de Janeiro and Minas Gerais had

Table 1. Records of fluoride in water according to concentration intervals, macro-region, and federative unit in municipalities with water supply systems. Brazil, 2018.

Macro-region and UF	Fluoride concentration records (mg F/L)								
	Below the optima range (0.001-0.444)		Within the optimal range (0.445-0.944)		Above the optimal range (0.945-1.444)		Unsafe (>1.444)		Total
	N	%	N	%	N	%	N	%	N
North	**68**	**4.3**	**1,064**	**67.7**	**438**	**27.8**	**3**	**0.2**	**1,573**
Acre	0	0.0	0	0.0	0	0.0	0	0.0	0
Amapá	0	0.0	0	0.0	0	0.0	0	0.0	0
Amazonas	68	5.2	891	68.2	348	26.6	0	0.0	1,307
Pará	0	0.0	0	0.0	0	0.0	0	0.0	0
Rondônia	0	0.0	0	0.0	0	0.0	0	0.0	0
Roraima	0	0.0	0	0.0	0	0.0	0	0.0	0
Tocantins	0	0.0	173	65.0	90	33.8	3	1.1	266
North East	**4,930**	**60.5**	**2,749**	**33.8**	**382**	**4.7**	**83**	**1.0**	**8,144**
Alagoas	27	52.9	16	31.4	8	15.7	0	0.0	51
Bahia	29	17.7	85	51.8	40	24.4	10	6.1	164
Ceará	4,415	59.8	2,576	34.9	319	4.3	71	1.0	7,381
Maranhão	373	94.2	16	4.0	5	1.3	2	0.5	396
Paraíba	57	100.0	0	0.0	0	0.0	0	0.0	57
Pernambuco	0	0.0	0	0.0	0	0.0	0	0.0	0
Piauí	29	38.2	42	55.3	5	6.6	0	0.0	76
Rio Grande do Norte	0	0.0	0	0.0	0	0.0	0	0.0	0
Sergipe	0	0.0	14	73.7	5	26.3	0	0.0	19
South East	**3,314**	**9.0**	**32,387**	**87.5**	**1,089**	**2.9**	**226**	**0.6**	**37,016**
Espírito Santo	258	23.5	826	75.4	12	1.1	0	0.0	1,096
Minas Gerais	948	38.4	1,430	57.9	63	2.6	29	1.2	2,470
Rio de Janeiro	736	28.0	1,401	53.2	446	16.9	49	1.9	2,632
São Paulo	1,372	4.5	28,730	93.2	568	1.8	148	0.5	30,818
South	**26,912**	**47.7**	**31,031**	**44.9**	**4,673**	**6.8**	**471**	**0.7**	**63,087**
Paraná	5,789	30.6	10,861	57.5	2,099	11.1	140	0.7	18,889
Rio Grande do Sul	19,548	56.2	14,261	41.0	804	2.3	171	0.5	34,784
Santa Catarina	1,575	16.7	5,909	62.8	1,770	18.8	160	1.7	9,414
Midwest	**784**	**23.9**	**2.190**	**66.7**	**250**	**7.6**	**61**	**1.9**	**3,285**
Federal District*	9	7.6	104	87.4	6	5.0	0	0.0	119
Goiás	472	28.9	915	55.9	204	12.5	45	2.8	1,636
Mato Grosso	205	19.9	786	76.2	26	2.5	14	1.4	1,031
Mato Grosso do Sul	98	19.6	385	77.2	14	2.8	2	0.4	499
Brazil	**36,008**	**31.8**	**69,421**	**61.5**	**6,832**	**6.0**	**844**	**0.7**	**113,105**

Source: Data base from consultation of the information system (SISAGUA), 2018.
UF: Federative Unit; F: Fluoride; L: Liter.
Percentages relative to the row values.
*Only data from Brasília concerning the pilot plan was considered, thus excluding the other administrative regions.

a lower percentage than the national average. The percentage of records in the concentration range below the optimal level was 31.8% for the country as a whole, with four states in the Northeast macro-region and one state in the South macro-region having values higher than the national average. At national level, 6.0% of the records had values above the optimal range (0.945 to 1.444 mg F/L), with percentages above 20.0% in the following states: Tocantins (33.8%) and Amazonas (26.6%) located in the Northern macro-region, and Sergipe (26.3%) and Bahia (24.4%) belonging to the Northern macro-region. Only 0.7% of the records were unsafe, with the state of Bahia standing out with 6.1% of the records.

According to Table 2, 38.5% of Brazilian municipalities adequately fed the information system. Municipalities belonging to the South (85.0%) and Southeast (41.9%) macro-regions; with a population of more than 50,000 inhabitants (49.2%); with income inequality of less than 0.49 (51.3%); GDP *per capita* of more than R$19,845 (56.6%); high and very high levels of human development (67.5%) and expenditure on health surveillance of more than R$9.44 per inhabitant in 2018 (59.2%) had percentages above the national figure.

Regarding the compliance rate, which represents the Brazilian municipalities with 80.0% or more of the samples within the optimal range (0.445 to 0.944 mg F/L), 42.2% of the municipalities had records within this range, indicating a very good quality of fluoride concentration adjustment. This figure was higher in municipalities belonging to the Southeast (77.9%) and Midwest (41.5%) macro-regions; with a population of more than

Table 2. Distribution of municipalities with water supply systems according to valid information on fluoride concentration data, compliance rate, and geographical, demographic, socioeconomic, and management performance variables. Brazil, 2018.

Variable	Total		Valid information		Compliance*	
	N	% [a]	N	%[b]	N	%[b]
Total	**4,659**	**100.0**	**1,794**	**38.5**	**757**	**42.2**
Macro-region						
North	300	6.4	3	1.0	0	0.0
North East	1,247	26.8	173	13.9	14	8.1
South East	1,634	35.1	684	41.9	533	77.9
South	1,051	22.6	893	85.0	193	21.6
Midwest	427	9.2	41	9.6	17	41.5
Population size						
< 10 thousand	2,007	43.1	776	38.7	306	39.4
10 to 50 thousand	2,030	43.6	712	35.1	278	39.0
> 50 thousand	622	13.4	306	49.2	173	56.5
Gini index[c]						
< 0.49	2,268	48.7	1,163	51.3	531	45.7
≥ 0.49	2,386	51.3	628	26.3	226	36.0
GDP *per capita* (reais)[c]						
< 19,846	2,329	50.0	415	12.2	156	34.3
> 19,845	2,330	50.0	1,379	56.6	601	40.7
HS expenditure *per capita* (reais)[c]						
< 9.45	2,329	50.0	415	17.8	156	37.6
> 9.44	2,330	50.0	1,379	59.2	601	43.6
MHDI[d]						
Very low and low	908	19.5	52	5.7	4	7.7
Medium	1,913	41.1	502	26.2	132	26.3
High and very high	1,833	39.4	1,237	67.5	621	50.2

Source: Data base from consultation of the information system (SISAGUA), 2018.
GDP: Gross Domestic Product; HS: Health Surveillance; MHDI: Municipal Human Development Index.
[a] Percentages relative to the values in the column.
[b] Percentages relative to the row values.
[c] Variable categorized by median.
[d] Very low and low: < 0.600; medium: 0.600 to 0.699; high and very high: ≥ 0.700.
* Among the municipalities with valid information, those with 80.0% or more of the samples within the optimal range (0.445-0.944 mg F/L).
Note: The municipalities of Balneário Rincão/SC, Mojuí dos Campos/PA, Paraíso das Águas/MS, Pescaria Brava/SC, and Pinto Bandeira/RS did not provide data on the Gini index and MHDI for 2018. stagnation

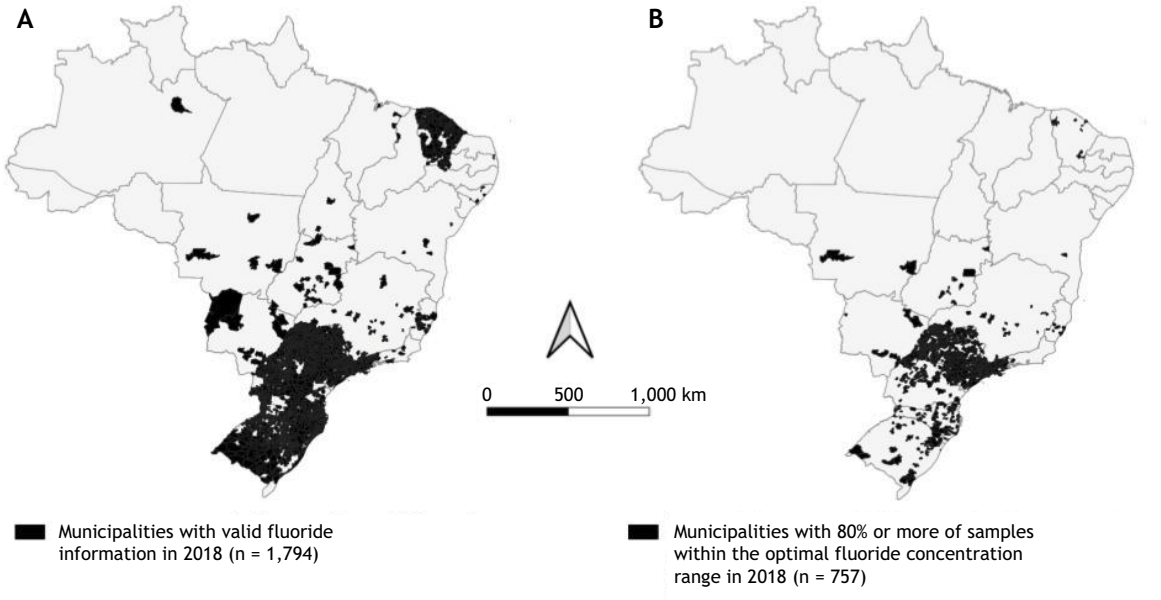

Figure 1. (A) Spatial distribution of municipalities with valid information on fluoride levels in water supply systems. Brazil, 2018 and (B) Spatial distribution of municipalities that met the expected fluoride compliance for dental caries prevention. Brazil, 2018.

50,000 inhabitants (56.5%); with income inequality of less than 0.49 (45.7%); expenditure on health surveillance of more than R$9.44 per inhabitant in 2018 (43.6%) and a high or very high level of human development (50.2%).

Figures 1A and 1B show the spatial distribution of municipalities that provided valid information and municipalities that met the expected fluoride compliance for preventing dental caries.

DISCUSSION

Mapping fluoride compliance in water supply systems measured by the water quality surveillance program run by the Unified Health System (SUS) is an essential activity to independently support the process of evaluating the quality of the public water fluoridation policy implemented in Brazil since the 1970s. The findings showed that the coverage of valid information reached 38.5% of Brazilian municipalities. Of these, 42.2% had a very good level of quality in terms of adjusting the concentration of fluoride in the water. The information produced made it possible to identify differences associated with the geographic, demographic, socioeconomic and management performance characteristics of the municipalities that showed weaknesses in terms of feeding the water surveillance system in relation to the fluoride parameter, an intersectoral policy of importance for both oral health and sanitation in Brazil.

The results are important for managers, professionals, and others interested in the observed standards of potability and safety of water for human consumption.

Several studies have checked the completeness of epidemiological databases and only one has evaluated this attribute for data on the coverage of water supply systems recorded on SISAGUA[22]. Regarding the coverage of information on the fluoride parameter, two previous studies[15,23] showed a similar situation at national level to this study. In view of the results, it can be hypothesized that between 2008 and 2018 the implementation of the surveillance policy in relation to the fluoride parameter did not expand, maintaining a picture of important stagnation in the country. However, significant variations were found in relation to the macro-regions. While in the Midwest and Northeast, information coverage worsened (32.8% to 9.6% and 21.7% to 13.9% respectively), in the South, it improved (67.9% to 85.0%). On the other hand, regarding demographic size, the inequalities between municipalities and the values observed were similar. In the percentage of municipalities with 50,000 or more inhabitants that fed adequately, the system went from 47.0% to 49.2% between 2008 and 2018. The percentage was 14.1 percentage points higher than in the lowest category, a difference similar to that observed in 2008 (14.2 p.p.).

An unprecedented result was that information coverage was higher in municipalities with higher *per capita* GDP and *per capita* expenditure on health surveillance. Municipal characteristics related to the level of human development and income inequality as measured by the Gini index were also reflected in higher information coverage. Regarding the latter, coverage was higher in the 50.0% of municipalities with lower income inequality. The findings confirmed the importance of municipal characteristics in relation to information coverage. There are no studies exploring the effects of these characteristics,

either alone or together, on information coverage as an outcome of the surveillance system. As the country's social and economic development is marked by profound inequalities in which access to public goods such as drinking water, sanitary drainage and electricity has followed a trajectory in which the increase in coverage in the Midwest, Northeast and North macro-regions occurred many years after its increase in the South and Southeast macro-regions[24], one hypothesis to be tested is whether the effect of municipal characteristics would be similar in all macro-regions or only in some of them. It would also be important to assess which of these municipal characteristics would be independently associated with information coverage in the presence of the others. With regard to sanitation and the presence of fluoride in water, some studies have shown the importance of the geographical location of the municipality in the country[25,26]. Future research could test these hypotheses in order to more closely measure the strength, magnitude and direction of the association between municipal characteristics and information coverage.

The findings suggest the need for complementary measures in the sectoral management of surveillance policy. The criterion for including municipal data in the analysis was not restrictive, as it depended on the presence of records for four or more months of the year. Although the number of samples varies according to population size, the minimum number is 60 samples per year, which is equivalent to five per month. Although, exceptionally, the sampling plan can be reduced in those municipalities where water fluoridation is not carried out and the history of the natural occurrence of fluoride is known, the adjustment of fluoride concentration in water supply systems is a procedure required by federal law in the country, and the collection of water samples by the local health authority is demanded by the VIGIAGUA's guideline. Failure to comply makes those responsible subject to sanitary and public prosecutor sanctions.

The results corresponding to the percentage of municipalities with 80.0% or more of the samples within the optimal range for preventing dental caries (0.445 to 0.944 mg F/L) were lower than the value obtained by Belotti et al.[12] and similar to the figure reported by Paulino et al.[15]. The difference compared to the first study is due to the number of small and medium-sized municipalities in the current study, which together cover more than 80.0% of all Brazilian municipalities, thus increasing *per capita* spending to meet the water quality standard. Regarding the second study, the similarity can be attributed to the low quality of information in both years, which influenced the compliance analysis. Similarly to what was mentioned for the previous outcome, it would be important to compare the strength of each variable, separately and in combination, in relation to municipalities with very good quality in relation to fluoride levels in water, which was higher in certain geographic macro-regions, and in municipalities with higher GDP *per capita* and level of human development.

Exploring the municipal characteristics associated with the outcome in the Brazilian state with the highest public policy coverage, Belotti et al.[12] found a positive association with higher values of human development (above 0.761), population size (> 100,000 inhabitants) and GDP *per capita*. Another study in a Brazilian metropolitan region showed a strong positive correlation with population size[27].

This study shows that, given the magnitude of the inequalities in information coverage and compliance, it is necessary for the health management of water quality to promote fluoride surveillance. These discrepancies reflect difficulties in including fluoride on the agenda of local health authorities and limitations in the process of agreement between managers at different levels of the SUS who are responsible for environmental surveillance. According to some researchers, in addition to local asymmetries and the different management capacities of the levels of government, it is necessary to develop mechanisms to understand what happens "at the frontline", i.e., in the sub-national units responsible for implementing the policies, incorporating these learnings into the redesign of strategies and seeking new institutional arrangements focused on the idea of coordination and governance in order to adapt the policies to the different local realities[28]. A study covering Brazilian municipalities with more than 50,000 inhabitants showed that in order to achieve an advanced degree of implementation of water quality surveillance in relation to fluoride in all units of the federation, coordination mechanisms and the process of governance of this policy in this institutional sub-sector of the health sector should be improved. The ability to ensure good quality information depends not only on investment and resources in health surveillance, but above all on interaction mechanisms between the levels of government, surveillance bodies and specialists to implement activities in a comprehensive manner[29]. A survey involving agents from the sectors involved in water quality management in the state of Mato Grosso do Sul showed the importance of improving collaboration and intersectoral coordination mechanisms for the effective implementation of public policy on adjusting fluoride concentrations in water supply systems[30]. In this sense, organized efforts aimed at implementing WSP, a global policy guideline aimed at improving water access and potability[2], can make a significant contribution to overcoming the difficulties encountered in water management in the Brazilian context.[31]

Some methodological aspects are worth discussing. The criterion for classifying the concentration values of the samples was adopted because it simultaneously takes into account the benefit and risk of exposure to fluoride, as it improves the options for interpreting and attributing meaning to the characteristics of the samples, representing a more up-to-date technical-scientific reference available to Brazilian researchers.

In order to produce subsidies for updating Brazilian legislation, researchers reviewed the knowledge on fluoride concentration in water for human consumption and concluded that daily exposure to water with fluoride concentration > 0.9 mg/L represents a risk to teeth in children under eight years of age and that consumers should be expressly informed of this risk by water distribution companies. In addition, considering the expansion of the national water fluoridation program to

regions with a typically tropical climate, Ordinance No. 635 of December 26, 1975, relating to fluoride added to public water supplies, should be revised[8]. The concentration ranges contained in Chart I of Annex 1 of Annex XXI of Consolidation Ordinance 5, of September 28, 2017, although they have legal-normative value, reproduce a reference adopted in 1975 that does not take into account current knowledge about the benefits and risks of exposure to fluoride, and should therefore be updated.

The study design did not allow us to investigate causality between the selected variables, but it did provide promising hypotheses for future studies. Another limitation of the study relates to the lack of information on the structure of local water surveillance bodies to carry out the activities of planning, collecting, and analyzing samples in laboratories, investigating, and disseminating information. It can be assumed that a large part of the differences observed could be linked to the heterogeneity of the structures of these bodies. Despite this aspect, a positive point of the study was the use of municipal expenditure on health surveillance per inhabitant as an indicator variable of municipal management performance[21]. However, it is important to point out that in some Brazilian municipalities, water quality surveillance is not exclusively the responsibility of health surveillance.

CONCLUSIONS

The coverage of information and compliance was higher in the municipalities with the best socioeconomic and management performance indicators, suggesting the adjustment of water quality surveillance policy strategies in order to increase the coverage of information and compliance of fluoride concentration in the water supply with a view to controlling dental caries at the population level.

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Authors' Contribution

Paulino CM, Frazão P - Conception, planning (study design), acquisition, analysis, data interpretation, and writing of the work. Belotti L - Conception, planning (study design), acquisition, analysis, and data interpretation. All the authors approved the final version of the work.

Conflict of Interest

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