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FLUORIDE IN GROUNDWATER AND DENTAL FLUOROSIS IN THE MUNICIPALITY OF LAURO DE FREITAS, LOCATED IN THE METROPOLITAN REGION OF SALVADOR, BAHIA (BR)

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Abstract: The relationship between exposure to fluoride and human health, especially through drinking water, represents a topic that has been extensively studied by researchers in the geosciences and health. This article aimed to investigate the relationship between fluoride levels in groundwater and dental fluorosis in the municipality of Lauro de Freitas, located in the Metropolitan Region of Salvador (RMS), Bahia, Brazil. The interdisciplinary methodological approach included the cross-sectional study of the prevalence of dental fluorosis in 680 schoolchildren at 12 years of age (Dean Index) and the analysis of hydrochemical variables of 23 tubular wells associated with the Fissural Aquifer. The prevalence of dental fluorosis in schoolchildren aged 12 years in the city of Lauro de Freitas was 34% (32.5% in very mild to mild degrees; 1.5% moderate). A fluorosis profile was obtained similar to that observed in previous studies in the RMS, or in non-endemic areas and compatible with the level of fluoride in the water used in public supply. It is concluded that the fluorosis profile cannot be related to fluoride levels in groundwater (0.09 to 2.93 mg.L-1), where 35% of the samples exceeded the local optimal limit.
Keywords: Environment and Health, Fissural Aquifer, Fluoride, RMS, Human Dignity.

INTRODUCTION

Fluoridation of public water supplies has been one of the main oral and collective health measures related to the decline in dental caries in several countries (NARVAI, 2000; MARTHALER, 2004; RIGO et al., 2010). These authors also emphasize the role of toothpastes with fluoride in public health and of fluoride supplements in the diet. Pang and Vann (1996), Featherstone (2000) and Frazão et al. (2018) point out that one must consider the benefits of using fluoride as a health measure to reduce dental caries and the risks of increasing the prevalence of dental fluorosis.

In this context, it is noted that the levels of fluorine in natural waters may derive from geogenic sources, related, in particular, to igneous rocks and clay minerals (SINGH et al. 2018). Gupta et al. (2005) explain that fluorite is the most common fluorine source mineral in rocks, although fluorine can occur in other minerals, judging by amphiboles, micas, fluorapatite, topaz and cryolite. Thus, the chemical weathering of minerals that host fluorine in rocks allows the release of fluorine to environmental components, ie, to the atmosphere, soils, dust, water and biota (NASEEM et al., 2010).

It is noteworthy that the levels of fluorine in the waters may result from anthropogenic sources, associated with the most diverse activities, such as the use of phosphate fertilizers, use of glass manufacture and resulting from the burning of coal (COLOMBANI et al. 2018; LI et al. al. 2019; STEPEC et al. 2019). In addition, groundwater and other natural waters may contain fluoride levels related to natural or anthropogenic sources, where exposure from the consumption of surface or groundwater with toxic levels of fluoride represents an adverse condition to human health. (VIKAS et al., 2013; KOMATI; FIGUEIREDO, 2013; GONÇALVES et al., 2019).

Gallará et al. (2011) and Cury et al. (2019) describe dental fluorosis as a hypomineralization and increased porosity of the region immediately below the tooth enamel surface due to the chronic ingestion of toxic doses of fluoride, during the formation of the tooth germ, whose severity depends on the dose. It is also noteworthy that the adverse effect of toxic levels of fluoride on tooth enamel depends on individual differences in amelogenesis and exposure dose, whose children up to six years of age are the most susceptible (FUJIBAYASHI et al., 2011). Enamel changes from dental fluorosis can promote staining, loss of tooth structure, and aesthetic, functional, and psychosocial problems.

Narvai (2002) distinguished the pattern of contemporary, endemic iatrogenic dental fluorosis from the classic pattern of chronic endemic dental fluorosis, according to clinical manifestation and epidemiological profile. In the classical pattern, the prevalence and severity of dental fluorosis depend on the exposure dose by drinking water with toxic levels of fluoride, especially in groundwater, as described by Churchill (1931), Dean (1936), Dean et al. (1941) and Cangussu et al. (2002). Thus, the relationship between fluoride exposure through water intake and oral and systemic health is among the most studied topics in the health-environment relationship (SAEED; MALIK; KAMAL, 2020).

Dental fluorosis in contemporary societies is related to the chronic exposure of child populations to multiple sources of fluoride, subtly above what is tolerated, especially through the ingestion of water and toothpaste (NARVAI et al., 2013). This dental fluorosis profile is expressed by the proportions of mild to very mild degrees of severity, where moderate or severe degrees of fluorosis have a low frequency (MENEZES et al., 2002).

Oliveira Junior et al. (2006), Soares et al. (2012), Sampaio, Almeida and Silva (2019) found a high prevalence of dental fluorosis, although distributed in very mild to mild degrees, in the municipalities of Salvador and São Francisco do Conde, in the Metropolitan Region of Salvador (RMS), Bahia (BR). These authors obtained values for the prevalence of dental fluorosis in the RMS that were higher than the national or Northeast prevalence, based on information from the oral health survey of the SB Brazil Project (BRASIL, 2010).

In the municipality of Lauro de Freitas, which is part of the RMS, Bahia, Brazil, there is a gap in research on groundwater in terms of physical-chemical and microbiological quality standards, or in terms of their meanings for public and collective health. In this context, the research carried out by Oliveira (2014) stands out, which investigated the levels of fluoride in groundwater and its relationship with dental fluorosis in the municipality of Lauro de Freitas. This author relied on information from the oral health survey by the Health Department of the Municipality of Lauro de Freitas, Bahia, in 2013, which examined 12-year-old schoolchildren in the municipal network.

In this context, it was verified the similarity between the prevalence and the distribution of the degrees of severity of dental fluorosis in the cities of Lauro de Freitas, Salvador and São Francisco do Conde, in the RMS, Bahia, where the public supply service is the responsibility of the Empresa Baiana de Água e Saneamento S.A (EMBASA), which uses surface water sources for water supply. However, a small part of the population uses groundwater for domestic uses and human consumption. Therefore, this article aimed to investigate the relationship between fluoride levels in groundwater and the prevalence and severity of dental fluorosis in the municipality of Lauro de Freitas, Metropolitan Region of Salvador, Bahia, Northeast Brazil.

MATERIALS AND METHODS

STUDY AREA, CLIMATE AND HYDROGEOLOGY

The municipality of Lauro de Freitas, located in the Metropolitan Region of Salvador, is located between latitude 12o 52' S and longitude 38o 02' W, on the North Coast of Bahia, Brazil (Figure 1). This municipality has a territorial area of 57,664 km2 and in 2010, according to the IBGE (2010), had a total of 163,449 inhabitants, a Gross Domestic Product (GDP) of 3,652,178 thousand reais and the percentage of adequate sewage coverage was 80.5%.

It is noteworthy that the Human Development Index of the Municipality (HDI-M) of Lauro de Freitas, which started from 0.474 in 1991, indicative of low development, and reached a value of 0.754 in 2010, according to ATLAS BRASIL (2013). Furthermore, the political-economic and social importance of the municipality of Lauro de Freitas for the RMS is highlighted, in addition to representing a vector of growth and expansion of the metropolis, Salvador.

Lauro de Freitas is located in the domain of a hot and humid tropical climate, with a dry season in the summer and rain in the winter, average annual temperatures of minimum 22 °C and maximum of 31 °C (average of 25 °C) and average precipitation of 1800 to 2000 mm/year and the wettest period of April and June (INMET, 2016).

The local geology falls within the domains of high-grade metamorphic rocks of the Migimatitic/Graulitic Metamorphic Complex of the Salvador-Curaçá Belt, ranging in age from Archean to Paleoproterozoic, represented by granulites, granodiorites, granites, diorites and amphibolites (BIZZI et al, 2003; NASCIMENTO; BARBOSA, 2005) (Figure 2). Covered by Tertiary sediments of the Barreiras Group and by unconsolidated Quaternary deposits.

Thus, in the described climatic and geological contexts, among the most representative geomorphological units, the tablelands, the coastal plateau and the hills of the Recôncavo in the municipality of Lauro de Freitas stand out. Furthermore, the presence of heterogeneous phytophysiognomies associated with the Atlantic Forest Biome,

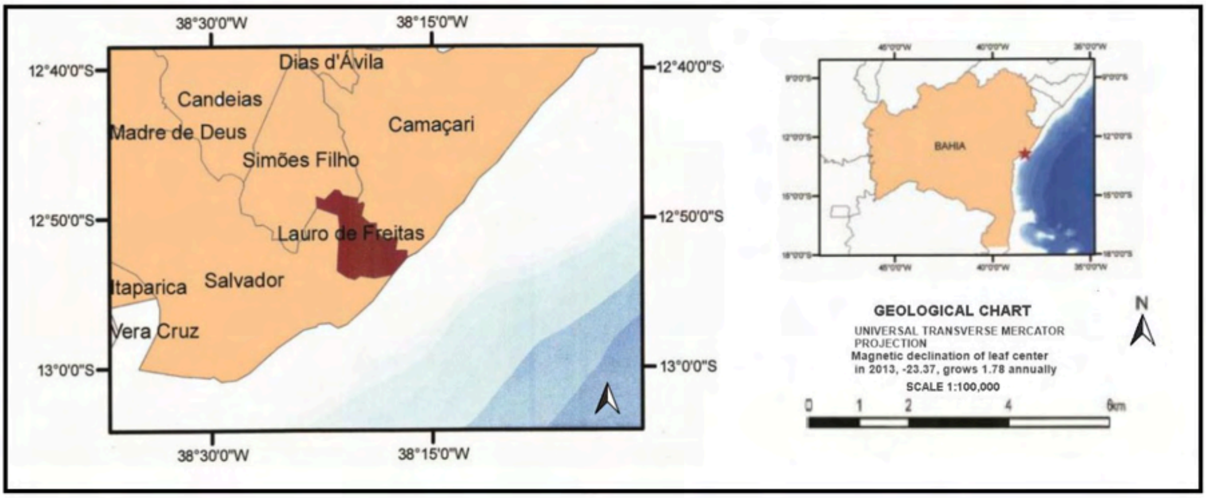

Figure 1 - Location and situation map of the municipality of Lauro de Freitas, Bahia.

Source: Prepared by the authors.

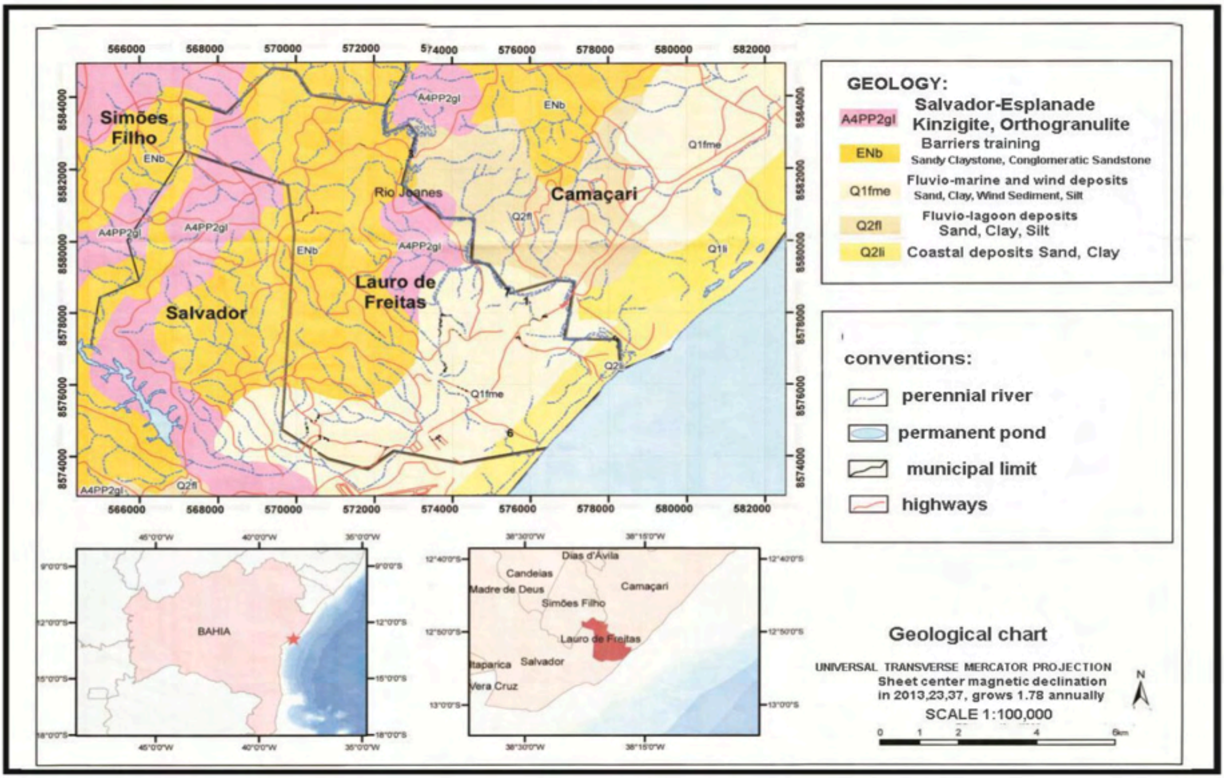

Figure 2 - Simplified geological map of the municipality of Lauro de Freitas, Bahia.

Source: Prepared by the authors.

covering the Dense Ombrophilous Forest and the Restinga, is highlighted.

The main watercourses of the Lauro de Freitas hydrographic network are the Joanes Rivers, which borders the Camaçari and empties into the ocean, and the Ipitanga River, which cuts through Lauro de Freitas and flows into the Joanes River. It is also possible to observe the occurrence of a series of small streams and less expressive rivers, such as Rio Sapato, Rio Goro and Rio Ipitanga, which are in an advanced state of degradation due to urbanization, forms of land use and by the discharge of liquid effluents in natura.

The municipality of Lauro de Freitas has a network of tubular wells capable of using groundwater to complement the public supply system. These tubular wells are registered in the Groundwater Information System (SIAGAS), a section of the Geological Service (CPRM), as well as small private wells, in localities, neighborhoods, condominiums, peripheral areas, and/or rural areas of the municipality.

It is noteworthy that the crystalline basement rocks are locally very fractured and, normally, underlain by the sediments of the Barreiras Group or by a thick alteration mantle, the regolith, or by the Tertium-Quaternary deposits. This way, the Fissural Aquifer System stands out, hosted in the fractured rocks of the crystalline basement, free, underpinned by the Tertium-Quaternary covers and by the regolith.

HEALTH RESEARCH: ASPECTS OF THE EPIDEMIOLOGY OF DENTAL FLUOROSIS

Data on the prevalence and severity of dental fluorosis in the municipality of Lauro de Freitas from the master's research by Oliveira (2014) were compiled, a cross-sectional investigation was carried out and a descriptive design was adopted from an epidemiological survey with schoolchildren at 12 years of age, of both sexes, enrolled at Escola Municipal Vila Praiana, in the Centro district, and residing in Lauro de Freitas, since birth, between November 2013 and January 2014. Children at 12 years of age have most of the permanent teeth erupted, which justifies the choice of this age group in the research of dental fluorosis (FEJERSKOV et al., 1994).

This oral health survey was coordinated by dentist Dr. Carlos Alberto Machado Coutinho, respecting the precepts of ethics in health research. The nature of the research, its objectives, methods, expected benefits, potential risks and inconveniences that it represents for the participants, and all stages of the evaluation of the prevalence and severity of fluorosis were previously informed to those involved in the study with the help of the Free and Informed Consent (ICF) and the Free and Informed Assent Term (TALE), aimed at children, in accordance with Resolution no. 466/2012 of the National Health Council (BRASIL, 2012).

Thus, the students were examined in public schools, based on the inclusion criteria of sample selection: (i) born and residing in the municipality of Lauro de Freitas, in the RMS, Bahia, until the date of the clinical study, according to the information made available by the Department of Education; (ii) the presence of the person in charge at the time of the examination and interview; and (iii) the sample included only children whose parents signed the informed consent.

Oral examinations were performed in schoolchildren at 12 years of age, following the recommendations of the Dean Index, as recommended by the World Health Organization - WHO (WHO, 1997) (Table 1). They were performed by a calibrated and trained dentist, with the aid of images provided by the National Oral Health Survey of SB Brasil 2010 (BRASIL, 2010), in a school environment with natural light, aided by a wooden spatula and gauze. In the calibration process, the dentist evaluated the agreement of the results, using the Kappa statistics (W.H.O, 1993), until an adequate inter-examiner agreement was obtained (Kappa= 0.72).

The sample was obtained from a population of 3,103 adolescents aged 12 years. In this context, a representative sample of 680 individuals was found, with the aid of an estimate by simple finite random sampling, without repetitions, with a proportion estimator (prevalence or incidence), with a significance level of 0.05% and the prevalence of schoolchildren at age 12 years was estimated based on research on dental fluorosis in the RMS by Cangussu et al. (2004), Oliveira Junior et al. (2006) and Soares et al. (2012).

RESEARCH IN GEOSCIENCES: HYDROCHEMISTRY AND HEALTH SURVEILLANCE

The geosciences approach focused on the analysis and interpretation of hydrochemical data, with emphasis on the distribution of fluoride levels, from 23 tubular wells in the wells register of the Groundwater Information System (SIAGAS), a section of the Geological Service (CPRM)), located in the fissure aquifer of the municipality of Lauro de Freitas, in the RMS, Bahia, Brazil.

Descriptive and multivariate statistical approaches were applied with the aid of Cluster Analysis (Cluster Analysis) of hydrochemical data (pH -hydrogenonic potential, turbidity, total dissolved solids - TDS, Ca2+, Mg2+, HCO3- -CO32-, Cl-, SO42- and Fe2+, total hardness - DT) obtained from the 23 tubular wells that were selected from the SIAGAS/ CPRM well register. Fluoride (F-) was read by colorimetry (SPADNS), with a fluorimeter. Furthermore, the levels of fluoride (F-) in surface water used in public supply were considered, which were measured between 2010 and 2015 by Empresa Baiana de Águas e Saneamento S.A. (EMBASA).

STATISTICAL AND GEOSTATISTICAL APPROACH

The statistical approach included descriptive analysis and the application of the cluster analysis technique. It is noteworthy that the application of Cluster Analysis uses the similarity between individuals to classify the samples hierarchically into groups, admitting all the variables determined for each individual (LANDIM, 2011). The Euclidean distance was adopted as a measure of distance or similarity between the sample points, together with the Ward method, for the analysis of the link between the groups. Furthermore, the geostatistical approach of ordinary kriging, with the aid of ArcGIS 9.0 software, provided the analysis of the spatial distribution of fluoride.

RESULTS AND DISCUSSION

GROUNDWATER QUALITY, GEOSCIENCES AND HEALTH

Local restrictions on potability were observed, as provided by Ordinance 888/21 (BRASIL, 2021) or W.H.O (2006) for the following hydrochemical variables: fluoride (35% of the samples; local optimal limit of 0.80 mg.L- 1), turbidity (26% of the samples; maximum value of 5.0 uT), chloride (13% of the samples; maximum value of 250.0 mg.L-1), STD (4% of the samples; maximum value of 500.0 mg.L-1), DT (4% of samples; maximum value of 500.0 mg.L-1) and pH (4% of samples; suggested value between 6.0 and 9.5) (Figure 3; Table 1).

The addition of aluminum sulfate and chlorine can be carried out for the oxidation of organic matter and disinfection and reduction of turbidity in samples that exceed the potability limit. Libânio (2016)

Classification	Value	Diagnostic Criteria
Normal	0	Fluorosis absent. Tooth enamel has usual translucency and semi-vitelliform structure, the surface is smooth, polished, light cream in color.
Questionable	1	Enamel has a slight difference from normal translucency and occasional whitish stains. Applicable if the "normal" classification is not justified.
Very light	2	Small, opaque, whitish spots occur, which spread unevenly across the tooth (<25% of the surface). It includes clear opacities between 1 and 2 mm at the tip of molar cusps (nevadas).
Lighr	3	White spots occur and the opacity is more extensive (< 50% of the surface).
Moderate	4	White spots occur on more than 50% of the tooth surface and wear is observed along with small brown spots. All tooth enamel is affected and areas subject to friction appear worn down. There may be brown or yellowish spots, often disfiguring.
Severe	5	Hypoplasia is generalized and the shape of the tooth itself may be affected. There is the presence of depressions in the enamel, which appears to be eroded. Widespread brown spots.

Table 1 – Criteria and values for classifying teeth with enamel lesions associated with fluorosis by the Dean Index (DEAN, 1934), recommended by the W.H.O. (1997).

Source: Modified from the national oral health survey of the Project: SB Brasil (2010).

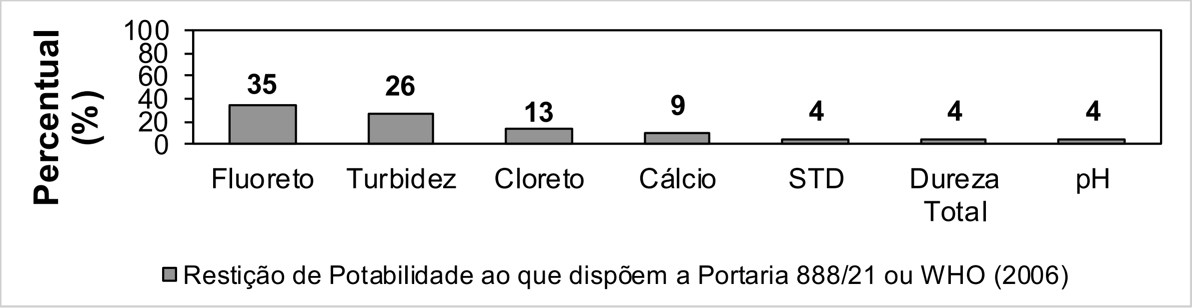

Figure 3 - Percentages of samples that exceeded the potability limit in relation to the provisions of Ordinance 888/21 (BRASIL, 2021) or WHO (2006) for hydrochemical variables.

Source: Prepared by the authors, based on data from selected wells from SIAGAS/CPRM.

points out that groundwater commonly has turbidity values lower than 1.0 uT. It relates water turbidity to clay and silt fractions and microorganisms, particulate organic and inorganic matter and precipitation of calcium carbonate in hard water, iron oxide and aluminum compounds in treated water.

It is pointed out that the DT levels of a water sample do not have a sanitary significance in themselves, but they promote inconvenience to the economy by reducing foam formation, increasing the consumption of soap and shampoos, making it difficult to cook food, or by causing incrustations in hot water pipes, boilers and heaters, due to carbonate precipitation.

Fluoride levels in groundwater samples from Lauro de Freitas were distributed between 0.09 and 2.93 mg.L-1 (Table 1), where 9% of the samples (n=2) exceeded the potability limit of 1.5 mg.L-1 based on WHO (2006) and Ordinance no. 888/21 (BRAZIL, 2021) (Figure 4).

It was found that the highest levels of fluoride in the south-central portion of Lauro de Freitas demand health surveillance (Figure 5). The distribution of optimal fluoride levels or low fluoride levels is observed in the northwest and extreme south-southeast. Furthermore, it is noteworthy that the consumption of water with an optimal level of fluoride contributes to the promotion of oral health, as long as it is accompanied by the application of hetero-control technologies.

Frazão et al. (2011) consider fluoride levels from 0.6 to 1.5 mg.L-1 in drinking water to be optimal for most Brazilian capitals. Mendes and Oliveira (2004) recommend the calculation of the optimal local potability limit for fluoride according to the average annual temperature of the regional air. This way, the local optimum limit of potability of fluoride (F-) (C) of water used for human consumption in Lauro de Freitas, Bahia, was obtained from the average regional air temperature (T), according to Galagan and Vermillion (1957) (Equations 1 and 2).

$$€(T) = 10,3 + 0,725T \quad \text{(Equation 1)}$$

$$C = 22,2/€ \quad \text{(Equation 2)}$$

Thus, a local optimal limit of fluoride potability of 0.80 mg.L-1 was obtained and the potential risks to oral health of children exposed to toxic levels of fluoride by prolonged ingestion of Lauro's water were reassessed. from Freitas. A total of 35% of the groundwater samples were found to exceed the local optimum potability limit for F- (Figure 5).

Cluster analysis allowed the classification of samples (n=23) into Hydrochemical and Water Quality Groups (G1, G2 and G3), with the aid of visual observation of the dendrogram, where the cut line marked at a distance of 60 (Figure 6). Samples were classified based on fluoride levels and their significance to oral health, whose G1c and G2b groups revealed the highest fluoride levels and epidemiological relevance to dental fluorosis.

Thus, the multivariate analysis allowed the differentiation of the Hydrochemical and Water Quality Groups, based on the distribution, in ascending order, of the levels of STD or DT in the samples, or according to the distribution, in descending order, of the levels of the F-, in the following pattern: G1 (G1a→G1b→G1c) → G2 (G2a→G2b) → G3 (Table 1). Furthermore, the medians of F- ranged from 0.42 mg.L-1 (G3) to 2.93 mg.L-1 (G2), where the fluoride level exceeded the local optimum potability limit in the samples of Subgroups G2b, G1c, G2a (II), especially in the locations of Centro Espírita Jacinto (LF23) and Condomínio Encontro das Águas IV (LF18) (Table 1).

Samples from each Hydrochemical and

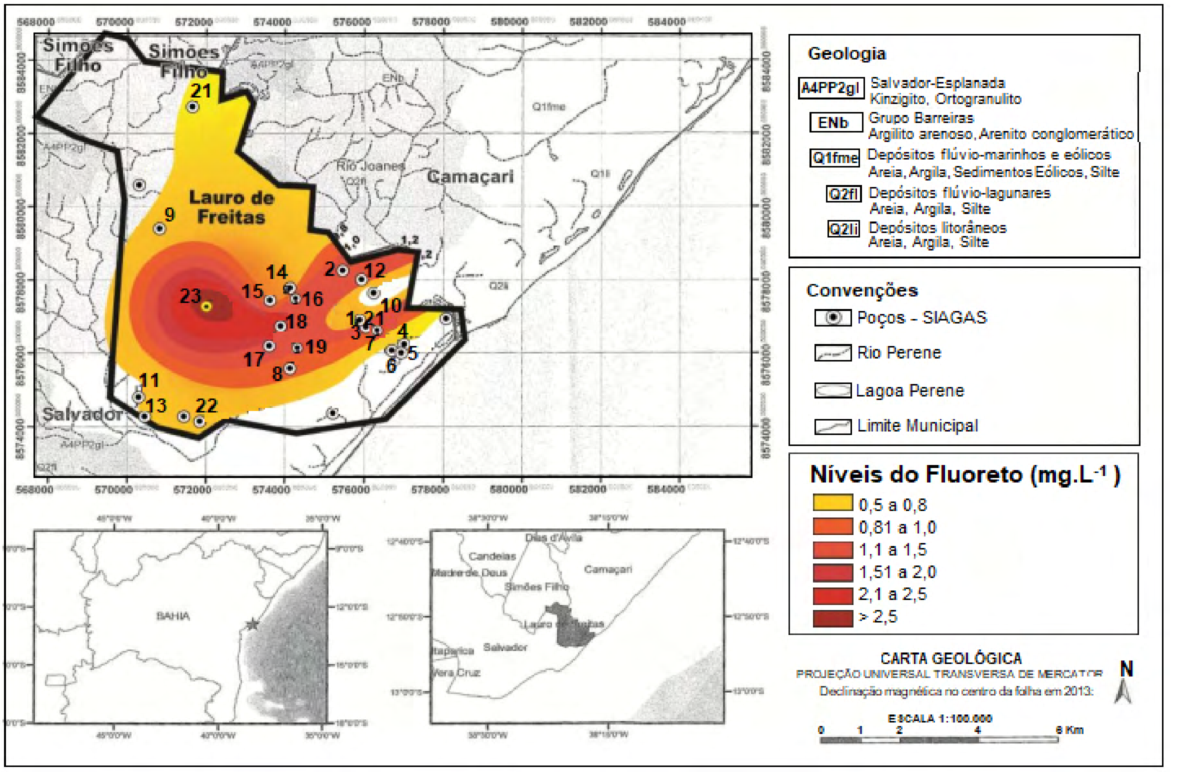

Figure 4 - Distribution map of fluoride levels in groundwater in the municipality of Lauro de Freitas, in the Metropolitan Region of Salvador, North Coast, Bahia, Brazil.

Source: Prepared by the authors, based on data from selected wells from SIAGAS/CPRM.

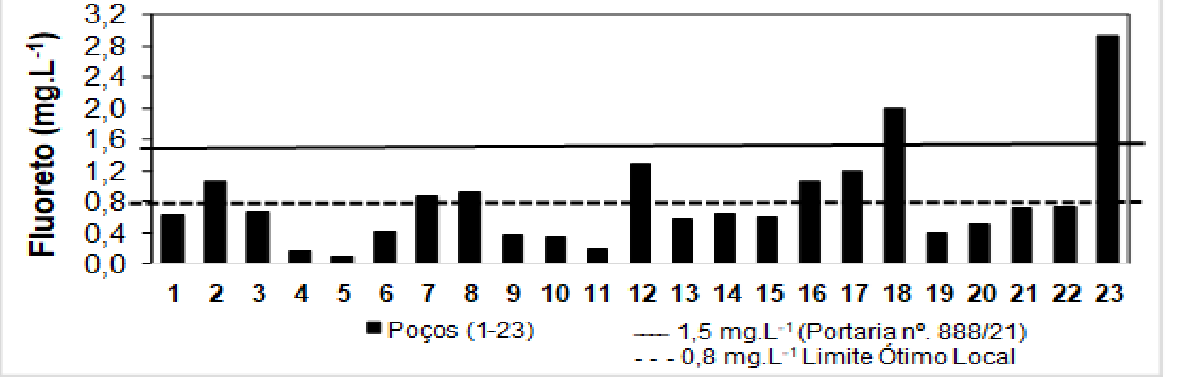

Figure 5 – Distribution of fluoride levels in the groundwater of Lauro de Freitas.

Source: Prepared by the authors, based on data from selected wells from SIAGAS/CPRM.

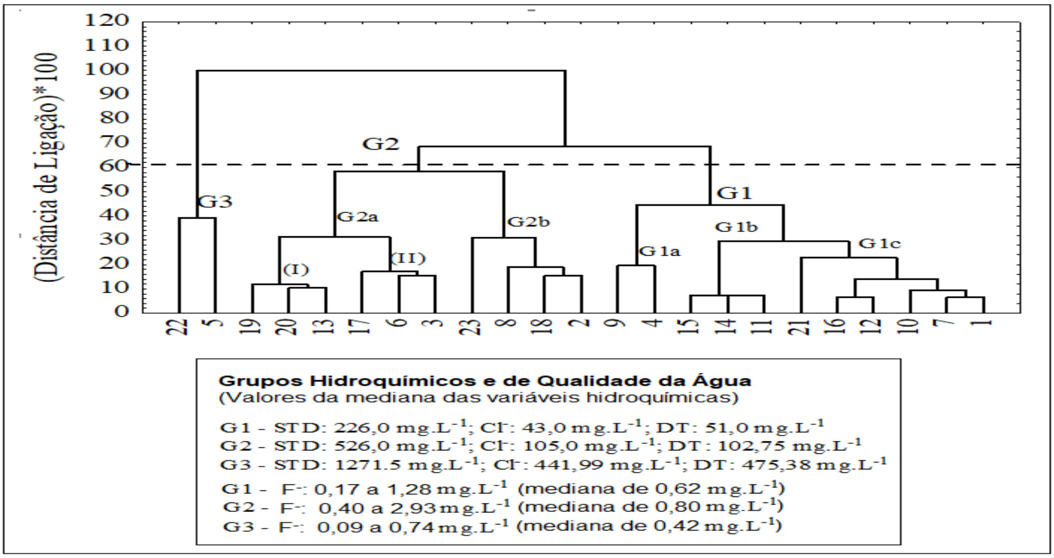

Figure 6 - Dendrogram of geochemical classification of groundwater in the municipality of Lauro de Freitas, Metropolitan Region of Salvador, North Coast, Bahia, Brazil.

Source: Prepared by the authors from data from the SIAGAS/CPRM well register.

Well	Place		UNT	mg.L-1						m (meters)	$m^3.h^{-1}$
		pH	turbidity	STD	Ca^{2+}	Cl^-	HCO_3^{2-}	F^-	DT	Depth	Q
Hydrochemical and Water Quality Group – G1											
Sub-group – G1c											
LF01	Cond. Miragem II[A]	7.15	4.40	238.00	21.05	43.00	89.00	0.62	81.00	40.00	9.00
LF07	Cond. Miragem IV [A]	7.40	4.10	326.00	27.05	68.00	126.50	0.88	93.00	60.00	0.83
LF10	Portão I [B]	7.20	4.50	377.80	23.30	76.00	70.00	0.34	96.00	60.00	3.05
LF12	Cond. Rio Joanes [B]	7.20	1.00	278.00	28.45	52.00	69.00	1.28	20.00	40.00	8.17
LF16	Cond. Encontro das Águas II [A]	7.05	3.90	226.00	13.35	80.00	52.00	1.06	55.00	60.00	0.86
LF21	Pq. Cantagalo [B]	8.30	0.50	305.50	73.87	41.24	116.50	0.71	102.09	50.00	8.89
Sub-group – G1b											
LF11	Itinga I [B]	6.55	0.70	76.60	6.07	37.50	12.50	0.18	25.00	50.00	32.97
LF14	Rua da Matriz [C]	6.56	4.25	166.00	3.20	59.00	12.20	0.65	3.00	8.20	-
LF15	Cond. Encontro das Águas [A]	6.85	1.80	114.00	12.38	22.00	51.50	0.59	51.00	51.00	1.47
Sub-group – G1a											
LF04	Cond. Vilas do Atlântico I [A]	5.90	3.24	62.40	4.12	22.00	7.00	0.17	17.00	60.00	6.16
LF09	Areia Branca I [B]	7.35	4.50	98.00	20.00	8.00	37.00	0.37	32.00	60.00	7.74
	G1 Median	**7.15**	**3.90**	**226.00**	**20.00**	**43.00**	**52.00**	**0.62**	**51.00**	**51.00**	**6.95**
Hydrochemical and Water Quality Group – G2											
Sub-group - G2b											
LF02	Cond. Miragem III [A]	7.30	3.20	506.00	18.69	370.00	116.00	1.06	77.00	40.00	0.53

LF18	Cond. Encontro das Águas IV [A]	7.95	3.40	648.00	17.48	172.00	110.83	2.00	72.00	50.00	0.20
LF08	FUSEB I [A]	7.90	0.90	932.00	20.00	430.00	167.00	0.91	230.00	60.00	4.39
LF23	Centro Espírita Jacinto [A]	7.89	0.98	222.00	67.60	31.80	106.00	2.93	122.00	113.0	1.55
Sub-group - G2a (II)											
LF03	Cond. Miragem IV [A]	7.15	15.00	454.00	50.45	90.00	191.00	0.68	208.00	40.00	23.98
LF06	Cond. Vilas do Atlântico IV [A]	7.60	7.50	620.00	20.00	120.00	201.00	0.42	112.00	60.00	5.62
LF17	Cond. Encontro das Águas III [A]	8.25	15.00	526.00	25.85	184.00	162.00	1.20	106.00	50.00	11.80
Sub-group - G2a (I)											
LF13	Itinga II [A]	7.20	16.00	200.00	16.58	23.00	82.00	0.58	68.30	31.00	19.80
LF20	Cond. Miragem I [A]	7.25	13.00	242.00	10.65	70.00	44.50	0.50	40.00	50.00	2.34
LF19	Cond. Encontro das Águas V [A]	7.10	19.00	258.00	3.20	50.00	124.00	0.40	99.50	50.00	1.69
	G2 Median	**7.45**	**10.25**	**480.00**	**19.35**	**105.00**	**120.00**	**0.80**	**102.75**	**50.00**	**5.62**
Hydrochemical and Water Quality Group - G3											
LF05	Cond. Vilas do Atlântico II [A]	7.90	1.00	1568.00	101.90	680.00	248.00	0.09	420.00	60.00	2.43
LF22	Jardim dos Pássaros I [B]	8.40	1.50	975.00	193.00	203.98	132.01	0.74	530.75	63.00	0.13
	G3 median	**8.15**	**1.25**	**1271.50**	**147.45**	**441.99**	**190.01**	**0.42**	**475.38**	**61.50**	**1.16**

Potability Limit of (F-) indicated by the decree, number: 888/21 (BRAZIL, 2021)	1.50 $mg.L^{-1}$
Adequate range of fluoride (F-) in drinking water for Brazilian capitals, estimated as a function of mean anal air temperature (FRAZÃO *et al.*, 2011).	0.60 a 1.50 $mg.L^{-1}$
Fluoride Levels in Groundwater in Lauro de Freitas	
Local Optimal Potability Limit of Fluoride (F^-)	0.80 $mg.L^{-1}$
Protection Factor against Caries or Dental Fluorosis	0.40 a 0.79 $mg.L^{-1}$
Risk Factor for Dental Fluorosis	> 0.80 $mg.L^{-1}$

[A] Disposed in the Granulitic Complex (Fissural Aquifer I); [B] Arranged in Archean Rocks (Granite) (Fissure II Aquifer); [C] Barreiras Group (Porous Aquifer); Q: specific flow; F-: fluoride; DT: total hardness; DC: carbonate hardness; DNC: non-carbonate hardness; EA: excess alkalinity.

Table 1 - Synthesis of the results of the grouping analysis and classification of groundwater samples from Lauro de Freitas in the Hydrochemical and Water Quality Groups.

Source: Prepared by the authors from data from the SIAGAS/CPRM well register.

Water Quality Group were also classified based on the relationship between fluoride levels in water and oral health risk (Figure 7; Table 1). It was made clear that the fluoride levels of Subgroups G1c and G2b represented a risk of dental fluorosis, respectively, for a total of 50% and 100% of the samples. It was also recorded that the fluoride levels of Subgroups G2a or G3 represented both a protective factor against dental caries and a protective factor against dental fluorosis for a total of 75% of the samples. Furthermore, the importance of groundwater fluoridation is highlighted if it is used in addition to human consumption in Subgroups G2a and G3.

The use of groundwater in the public supply of Lauro de Freitas was more relevant in the past, before the implementation of the Water Supply System, under the responsibility of EMBASA. This Supply System captures its water from the Paraguaçu, Joanes and Jacuípe rivers. Furthermore, groundwater can complement the supply system, in rural and peripheral areas, and, therefore, a comprehensive assessment of the quality of these sources and their meanings for health is demanded.

Thus, the presence of potentially toxic levels of fluoride, distributed locally, in groundwater samples from Lauro de Freitas demanded attention from competent managers regarding the application of viable and available cost-effective technologies for defluoridation of groundwater with toxic levels. of fluoride if intended for human consumption. Meenakshi and Maheshwari (2006); Bhatnagar et al. (2011) and Singh et al. (2016) reviewed available natural water defluoridation technologies. Castel et al. (2000); Amor et al. (2001); Kamble et al. (2010); Tchomgui-Kamga et al. (2010); Ansari et al. (2011); DaCosta et al. (2013); Rafique et al. (2012), several defluoridation technologies were highlighted, such as the application of adsorption systems with activated alumina, activated bone carbon, ion exchange resins, reverse osmosis systems, dialysis and the use of nanotechnology.

HEALTH RESEARCH: PREVALENCE OF DENTAL FLUOROSIS

The municipality of Lauro de Freitas had a child population of 17,640 inhabitants distributed in the age group from 0 (zero) to 6 years of age, a group susceptible to dental fluorosis, where it was observed that 51% of the individuals were male and 49% were male. female (Table 2). Furthermore, there was a population of 3,103 inhabitants at 12 years of age, where 18.13% were males and 17.77% were females when considering the total number of individuals aged 6 to 12 years old.

The results of the descriptive analysis of the profile of the prevalence and severity of fluorosis dental care in 680 schoolchildren at 12 years of age were synthesized in Table, number 3. It was verified a prevalence of dental fluorosis of 34% among those examined for both sexes, 12 years old, distributed in the categories of very mild severity (28%), mild (4.5%) and moderate (1.5%), based on the Index of Dean, according to the W.H.O. (World Health Organization) (2006).

In this context, the epidemiological profile of dental fluorosis in schoolchildren at 12 years of age (Dean Index) of Lauro de Freitas, in the present study, differed from that of classic chronic dental fluorosis (Table 4). It was found that the profile of dental fluorosis by Lauro de Freitas was close to the profile of dental fluorosis obtained in previous oral health studies developed in the municipalities of Salvador and São Francisco do Conde, in the RMS, Bahia, by Cangussu et al. (2004), Oliveira Junior et al. (2006), Almeida et al. (2012), Soares et al. (2012) and by Sampaio, Almeida and Silva (2019).

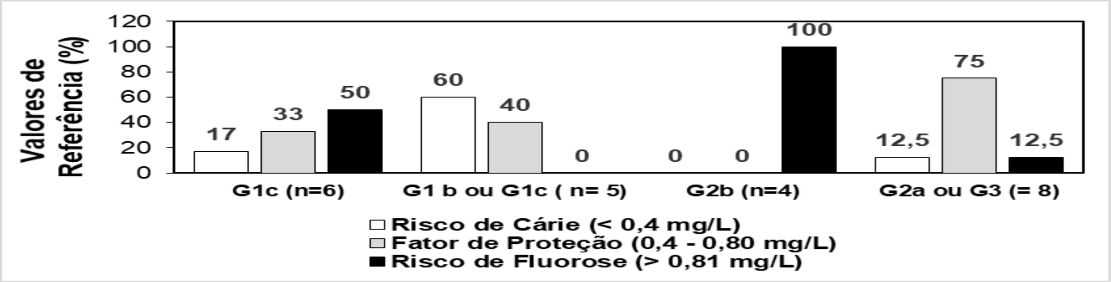

Figure 7 - Classification of samples according to fluoride levels and risk of dental fluorosis in groundwater in the municipality of Lauro de Freitas, Bahia, Brazil.

Source: Prepared by the authors, based on data from selected wells from SIAGAS/CPRM.

0 to 6 years							6 to 12 years						
Age	General	General (%)	Female	Female (%)	Male	Male (%)	Age	General	General (%)	Female	Female (%)	Male	Male (%)
Até 1 ano	5.153	29.21	2.450	28.33	2.703	30.06	7 anos	2.652	15.34	1.323	15.51	1.329	15.18
2 anos	2.472	14.01	1.208	13.97	1.264	14.06	8 anos	2.738	15.84	1.362	15.96	1.376	15.73
3 anos	2.456	13.92	1.214	14.04	1.242	13.80	9 anos	2.825	16.34	1.399	16.40	1.426	16.29
4 anos	2.471	14.00	1.231	14.24	1.240	13.79	10 anos	2.924	16.92	1.441	16.88	1.483	16.94
5 anos	2.513	14.24	1.256	14.53	1.257	13.98	11 anos	3.043	17.60	1.491	17.48	1.552	17.73
6 anos	2.575	14.62	1.288	14.89	1.287	14.31	12 anos	3.103	17.96	1.516	17.77	1.587	18.13
Total	17.640	100.0	8.647	100.0	8.993	100.0	Total	17.285	100.0	8.532	100.0	8.753	100.0

Table 2 - Distribution of the population of Lauro de Freitas (BA) by age group in 2012.

Source: Prepared by Oliveira (2014), based on data provided by the IBGE and the Department of Education of Lauro de Freitas, in the Metropolitan Region of Salvador, Brazil.

Dental Fluorosis	**Man**		**Woman**		**Total**	
	N	**%**	**N**	**%**	**N**	**%**
Absent (0) or Questionable (1)	247	66.04	202	66.00	449	66
Very light (2)	104	27.81	86	28.10	190	28
Light (3)	17	4.55	14	4.58	31	4.5
Moderate (4)	6	1.60	4	1.32	10	1.5
Total	374	55.00	306	45.0	680	100.0

Table 3 - Absolute and relative frequency of those examined in relation to dental fluorosis, based on the Dean Index, according to gender and from the categories of fluorosis severity in a sample of 12-year-old schoolchildren in the city of Lauro de Freitas, Bahia.

Source: Prepared by the authors based on data from Oliveira's dissertation (2014).

It was found that the profile of dental fluorosis in schoolchildren at 12 years of age (Dean Index) in the municipality of Lauro de Freitas, or in the RMS, was characterized by proportions of prevalence and severity that were higher than in the national health survey. mouthpiece of the SB Brazil Project (BRASIL, 2010). This national oral health survey revealed a national prevalence of dental fluorosis of 17% at 12 years of age (Dean Index), with 15% very mild or mild and 1.5% moderate or severe, where the lowest prevalence of fluorosis was obtained in the North region (10%) and the highest in the Southeast region (19%); as well as the prevalence of dental fluorosis in the Northeast Region (14.5%).

The proportions of fluorosis in Lauro de Freitas, Salvador São Francisco do Conde, in the RMS, Bahia, although considered high, were concentrated in the very mild to mild degrees (Table 4), which are expected by dentists and may be related to exposure children to multiple sources of fluoride, such as toothpastes and dietary fluoride supplements and drinking water with slightly higher than optimal fluoride levels. Fejerskov, Manji and Baelum (1990) and Lima-Arsati et al. (2018) consider that dental fluorosis is acceptable if associated with mild to very mild degrees of severity, because it does not make the affected tooth more susceptible to dental caries, if it does not reach the permanent maxillary incisors and does not impact esthetics.

Barbosa et al. (2018) point out that the consumption of fluoridated water can be considered as the main form of fluoride intake. In addition, the influence of other aspects, such as nutrition, physiology, physical and environmental factors, on the epidemiology of dental fluorosis must be considered (OLIVEIRA et al., 2018; REVELO-MEJÍA et al., 2021). Furthermore, studies that consider the relationship between health and environment and the social determinations of health, such as access to health and education and sociocultural and living conditions, are demanded.

It is noteworthy that Sampaio, Almeida and Silva (2019) obtained a prevalence of 65.55%, in very mild (24.14%), mild (28.54) and moderate (12.93%) degrees. of severity in schoolchildren at 12 years of age (Dean Index), enrolled in a Non-Governmental Organization (NGO), in the Cabula-Beirú health district, in the city of Salvador, Bahia. In addition, they found that a total of 100% of the children examined reported having oral health affecting their lives and had dental fluorosis, which revealed the negative impact of dental fluorosis on quality of life.

Dental fluorosis, with its sequelae to people's self-esteem, does not equally affect the population of Lauro de Freiras, or the municipalities of the RMS, because socioeconomic conditions are unequal to deal individually with the health-disease relationship, or to deal with the relationship health-environment. Lubchenco et al. (1991) emphasize that human health, the economy, social justice and national security have socio-cultural, environmental and ecological-distributive aspects where the due amplitude is usually neglected.

Thus, the importance of health surveillance of fluoride levels in public water supply for the promotion of oral health is highlighted. De Souza et al. (2013) highlight that water quality and health managers have scientific evidence of the effectiveness of water fluoridation for needy communities that are deprived of the right of other health policies. They also point out that part of these communities that are deprived of social rights and fundamental rights in Brazil do not have access to drinking water.

It is concluded that the profiles of dental

Author/Year	Study area	Status	Prevalence (%)	Severity (%)	F^{-} (mg.L^{-1})
Oliveira (2014) [A]	**Lauro de Freitas (BA)**, BR	**Não endêmica**	**34**	**32.5 leve e 1,5 moderada**	**0.70 (0.8 a 1.5)**
Cangussu et al. (2004) [A]	Salvador, RMS (BA), BR	Não endêmica	31.4	31.4 muito leve a leve	0.61 a 0.73
Oliveira Junior *et al.* (2006) [A]	Salvador, RMS (BA), BR	Não endêmica	31.4 (em 2001)	31.4 muito leve a leve	0.70
Oliveira Junior *et al.* (2006) [A]	Salvador, RMS (BA), BR	Não endêmica	32.62 (em 2004)	32.62 muito leve a leve	0.70
Almeida *et a*l. (2012) [A]	Salvador, RMS (BA), BR	Não endêmica	18.2	17.5 muito leve a leve	0.70
Soares *et al.* (2012) [A]	S. F. do Conde, RMS (BA), BR	Não endêmica	39.8	39.0 muito leve a leve	0.70
Sampaio *et a*l. (2019) [A]	Salvador (BA), BR	Não endêmica	65.5	52.64 muito leve a leve	0.70
Campos *et al.* (1998) [A]	Brasília, Distrito Federal, BR	Não endêmica	85,4	14 muito leve a 0,6 moderado	0.80
Forte *et al.* (2001) [B]	Princesa Isabel (PB), BR	Não endêmica	20	20.2 muito leve a leve	0.40
Maltz e Silva (2001) [B]	Porto Alegre (RS), BR	Não endêmica	32.6 (em 1998)	31.86 muito leve a leve	0.10-1.11
Maltz e Silva (2001) [B]	Arroio do Tigre (RS), BR	Não endêmica	29.7 (em 1998)	29.7 muito leve a leve	<0.20
Silva e Maltz (2001) [B]	Porto Alegre (RS), BR	Não endêmica	52.9	6.1 muito leve	0.70 a 1.0
Cangussu *et al.* (2001) [A]	Itatiba (SP), BR	Não endêmica	42.6	42.6 muito leve a leve	0.70
Alves *et al.* (2002) [A]	Marília (SP), BR	Não endêmica	4.2	4.2 muito leve a leve	0.70
Martins *et al.* (2003) [A]	Belo Horizonte (MG), BR	Não endêmica	31.2	31.2 muito leve a leve	0.74
Ditterich *et al.* (2003) [A]	Ponta Grossa (PR), BR	Não endêmica	24.4 (Urbana)	24.4 leve	0.70
Ditterich *et al.* (2003) [A]	Ponta Grossa (PR), BR	Não endêmica	9.7 (Rural)	9.7 muito leve a leve	0.70
Toass e Abegg (2005) [A]	Santa Tereza (RS), BR	Não endêmica	63.7	63.7 muito leve a leve	0.0 a 1.60
Bascariolo *et al.* (2006)	São Paulo (SP), BR	Não endêmica	49	49 muito leve a leve	0.70
Ramires *et a*l. (2007) [B]	Bauru (SP), BR	Não endêmica	37.6	28 leve	0.70
Ramires *et a*l. (2007) [B]	Bauru (SP), BR	Não endêmica	36	28 leve	0.70
Moro *et al.* (2009) [A]	Água Santa (RS), BR	Não endêmica	9.8	9.8 muito leve a leve	0.70 a 1.10

Rigo *et al.* (2014) [A]	Passo Fundo (RS), BR	Não endêmica	32.8	89.5 muito leve a leve	0.60 a 0.90
Spohr *et a*l. (2010) [A]	Pelotas (RS), BR	Não endêmica	21.9	-	0.50 a 0.81
Silva *et a*l. (2010) [A]	Sobradinho (RS), BR	Não endêmica	19.5	19.5 muito leve	0.70 a 0.80
Silva *et a*l. (2010) [A]	Sobradinho (RS), BR	Não endêmica	46.3	46.3 muito leve	0.70 a 0.80
Silva *et a*l. (2010) [A]	Tavares (RS), BR	Não endêmica	28.6	28.6 muito leve a leve	0.70 a 1.0
Teixeira *et al.* (2010) [A]	Fortaleza (CE), BR	Não endêmica	54	53.9 muito leve a leve	0.87
Furtado *et al.* (2012) [A]	Rafael Arruda (CE), BR	Não endêmica	66.4	32.5 leve	0.70
Moimaz *et al.* (2015) [A]	Araçatuba (SP), BR	Não endêmica	52.1	52.1 muito leve a leve	0.70
Moimaz *et al.* (2015) [A]	Araçatuba (SP), BR	Não endêmica	58.9	58.9 muito leve a leve	0.70 a 1.20
Paiato *et al.* (2015) [A]	Rio Grande da Serra (SP), BR	Não endêmica	57	57 muito leve a leve	0.60 a 0.80
Jordão *et al.* (2015) [A]	Goiânia (GO), BR	Não endêmica	5.6 (2003)	5.6 muito leve a leve	0.07
De Miranda e Cericato (2015) [A]	Ibirapuitã (RS), BR	Não endêmica	32	32 muito leve a leve	0.70 a 1.0
Garcia-Pérez *et al.* (2017) [B]	Morelos, México	Não endêmica	46.9	23.2 moderada/ grave	0.70 a 1.60
Uchôa e Saliba *et a*l. (1970) [A]	Pereira Preto (SP), BR	Endêmica	76	48 moderada/grave	12.5 a 17.5
Ando *et al.* (1975) [A]	Cosmópolis (SP), BR	Endêmica	88.6	38.9 moderada/ grave	9.5 a 11.0
Alcaide e Veronezi (1979) [A]	Icém (SP), BR	Endêmica	88.2	19.4 moderada/ grave	2.6 a 4.0
Capella *et al.* (1989) [A]	Urussanga (SC), BR	Endêmica	97.6	88 moderada/grave	1.2 a 5.6
Cortês *et al.* (1996) [B]	Olho d'Água (CE), BR	Endêmica	92	19 moderada/grave	2.0 a 3.0
Toassi e Abegg. (2005) [A]	Santa Tereza (RS), BR	Endêmica	56	8 moderada/grave	0 a 1.6
Fujibayashi *et al.* (2011) [A]	Campo Tenente (PR), BR	Endêmica	50	35 moderada/grave	1.2 a 2.0
Velásquez *et al.* (2006) [B]	Norte de Minas Gerais, BR	Endêmica	56-67	35 moderada/grave	0 a 3.9
Azcurra *et al.* (1995) [A]	Sampacho, Córdoba, ARG	Endêmica	78	25 moderada/grave	9.0
Loyola-Rodríguez *et al.* (2000) [A]	San Luis Potosí, MEX	Endêmica	78	46 moderada/grave	0.7 a 3.1

Dozal *et al.* (2005) [A]	Chihuahua, MEX	Endêmica	82	41 moderada/grave	0.7 a 8.6
Fordyce *et al.* (2007) [A]	Europa Central	Endêmica	60-90	-	2.0 a 7.0
Indermitte *et al.* (2009) [A]	Estônia, Europa Setentrional	Endêmica	7-89	-	1.0 a 4.0
Yadav *et al.* (2009) [A]	Distrito de Haryana, Índia	Endêmica	45-60	22-39 moderada/ grave	1.52 a 4.0
Vazquez-Alvarado *et al.* (2010) [A]	San Miguel Vindhó, MEX	Endêmica	85	41 moderada/grave	0.7 a 2.0
Ding *et al.* (2011) [A]	Inner Mongolia, China	Endêmica	42.6	20 moderada	0.24 a 2.84
Gallará *et al.* (2011) [A]	Córdoba, Argentina	Endêmica	76	17 moderada/grave	1.4 a 7.0
Gallará *et al.* (2011) [A]	Córdoba, ARG	Endêmica	87	22 moderada/grave	1.7 a 3.4
Juárez-Lópes *et a*l. (2011) [A]	La Llave, Quareto, MEX	Endêmica	98	70 moderada/grave	1.90
García *et al.* (2012) [A]	Córdoba, ARG	Endêmica	86.7	21 moderada/grave	0.96 a 2.87
Costa *et al.* (2013) [B]	Minas Gerais (MG), BR	Endêmica	62.7 (Rural)	34.6 moderada/ grave	Até 4.80
Jarquín-Yañez *et al.* (2015) [A]	Hidalgo, México	Endêmica	100	95 grave	4.10
Larquin *et al.* (2015) [A]	Camagüey (Cuba)	Endêmica	51	38 moderado e 8,8 grave	1.7 a 2.0
Chaudhry *et al.* (2017) [A]	Uttar Pradesh, Índica	Endêmica	27	30 moderada/grave	0.20 a 25.0
Haritash *et al.* (2018) [A]	Haryana, Índia	Endêmica	23-32	29-44 moderada a severa	0.5-2.40
De Souza *et al.* (2018) [B]	S. J. do Rio do Peixe (PB), BR	Endêmica	100	53 moderada/grave	0.11-9.33 (5.16)
Gevara *et al.* (2019) [B]	Nakuru, Rift Valley, Quênia	Endêmica	86	51 moderada/grave	0.05-72.0 (5.85)
SACHDEV *et al.* (2021) [A]	Uttar Pradesh, Índia	Endêmica	67.81 (Rural)	61.7 moderada/ grave	-
Gonçalves *et al.* (2022) [A]	Santana (BA), BR	Endêmica	53	17 moderada/grave	0.05-8.80

[A] Dean Index; [B] Thylstrup and Fejerskov Index.

Table 4 – Comparison of fluoride (F-) levels in groundwater and dental fluorosis profile in the municipality of Lauro de Freitas, Bahia (present study), with dental fluorosis profiles from previous studies of non-endemic and endemic areas in the Brazil and in the world.

Source: Prepared by the authors.

fluorosis of schoolchildren at 12 years of age in the municipalities of Lauro de Freitas, Salvador and São Francisco do Conde, in the RMS, differed from the profile of endemic chronic dental fluorosis, described by Narvai (2002), and, therefore, they did not, in general, demand special attention from oral health professionals, but require studies of the aesthetic, social and psychological aspects of fluorosis. There is a demand for attention from health professionals regarding the exposure of child populations to multiple sources of fluoride and for monitoring of fluoride in the public water supply of Lauro de Freitas and RMS, where groundwater must be included.

The prevalence of dental fluorosis in schoolchildren at 12 years of age in Lauro de Freitas needs to be better studied in terms of social aspects, consumption of water supply and exposure to multiple sources of fluoride. Furthermore, anthropogenic sources associated with urban-industrial activities in the RMS must be considered, such as atmospheric pollutants related to the Industrial Complex of the Camaçari Petrochemical Complex, which encompasses a variety of chemical, petrochemical and automobile industries.

CONCLUSIONS

The presence of local restrictions on the optimal local limit of potability of fluoride was verified for 35% of the groundwater samples from Lauro de Freitas, which is part of the Metropolitan Region of Salvador, Bahia, Brazil. Furthermore, it was made explicit that there was a demand for monitoring fluoride in groundwater and the importance of interdisciplinary studies and the training of professionals who consider the multiple relationships between health and the environment.

The application of multivariate analysis contributed to the discrimination of Hydrochemical and Water Quality Groups (G1, G2 and G3) and to the classification of samples based on fluoride levels and risks of dental fluorosis. It was revealed that Groups G1c and G2b had the highest relative levels of fluoride and epidemiological relevance of dental fluorosis.

A prevalence of dental fluorosis of 34% was obtained, with 32.5% of cases distributed in very mild to mild degrees, among schoolchildren examined at 12 years of age (Dean index) in the municipality of Lauro de Freitas, which is compatible with fluoride levels in public water supplies. These proportions of dental fluorosis differed from the chronic endemic fluorosis profile, being, however, considered similar to the epidemiological profile obtained by previous studies carried out in the Metropolitan Region of Salvador, Bahia, and compatible with the optimal level of fluoride in the water supply.

It is concluded that the results of the geosciences and health approaches diverged, because the profile of the prevalence and severity of dental fluorosis of schoolchildren at 12 years of age in Lauro de Freitas differed from the classic profile of endemic fluorosis. Furthermore, the presence of toxic levels of fluoride in the groundwater of this municipality was verified, as well as local restrictions on potability, where the consumption of these waters, without defluoridation, represents a risk factor for endemic dental fluorosis. The demand for oriented research was revealed in the search for the elucidation of the sources of fluoride for the groundwater of the municipality of Lauro de Freitas.

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