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| ORIGINAL

Fluoride in Mozambique: retrospective study

Flúor em Moçambique: estudo retrospectivo

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ABSTRACT

Objective: The study aims to analyse the fluoride concentration in the water supply of the capital of each province of Mozambique, 2019 and compare with previous data 1978 and 2008. **Methods**: The water supply in cities of Mozambique were analysed in 1978, 2008 and 2019 and water from Tete's River in 1978 and 2019. The fluoride concentration of the water samples was determined in duplicate, using the ion-sensitive electrode (Orion 9609), coupled to a potentiometer (Procyon, model 720), adopting a significance level of 5%. **Results**: The average fluoride concentration found in the years 1978, 2008 and 2019 was 0.31, 0.33 and 0.14 mg F/L, respectively. The fluoride concentrations collected from household taps in 1978, 2008 and 2019 were: Cabo Delgado/Pemba (0.62, 0.28 and 0.07 mg F/L), Niassa/Lichinga (0.18, 0.98 and 0.07 mg F/L), Nampula/Nampula (0.18, 0.01 and 0.06 mg F/L), Zambézia/Quelimane (0.81, 0.37 and 0.15 mg F/L), Tete/Tete (1.00, 0.97 and 0 .46 mg F/L), Sofala/Beira (0.00, 0.01 and 0.10mg F/L), Manica/Chimoio (0.04, 0.01 and 0.07 mg F/L), Inhambane/Inhambane (0.00, 0.05 and 0.19 mg F/L), Gaza/Xai-Xai (0.01, 0.06 and 0.06 mg F/L) and Maputo (0.23, 0.36 and 0.23 mg F/L), respectively. In the waters of the Zambeze River was 5.5 mg F/L in 1978 and 0.12 mg F/L in 2019. There was no significant change between the fluoride concentrations in the water collected from the taps during the periods studied (p=0.83), however there was a significant difference in the water collected from the river (p<0.05). **Conclusion**: Tete' River showed a significant reduction in fluoride concentration, and in the piped water collected in all municipalities, the fluoride content was below optimum.

Indexing terms: Dental fluorosis. Fluorine. Oral health. Mozambique.

RESUMO

***Objetivo**: O estudo visa analisar a concentração de flúor no abastecimento de água da capital de cada província de Moçambique, 2019 e comparar com dados anteriores de 1978 e 2008. **Métodos**: A água de abastecimento das cidades de Moçambique foi analisada em 1978, 2008 e 2019 e a água do Rio Tete em 1978 e 2019. A concentração de flúor das amostras de água foi determinada em duplicata, utilizando o eletrodo íon-sensível (Orion 9609), acoplado a um potenciômetro (Procyon, modelo 720), adotando-se nível de significância de 5%. **Resultados**: A concentração média de flúor encontrada nos anos de 1978, 2008 e 2019 foi de 0,31, 0,33 e 0,14 mg F/L, respectivamente. As concentrações de flúor recolhidas nas torneiras das casas em 1978, 2008 e 2019 foram: Cabo Delgado/Pemba (0,62, 0,28 e 0,07 mg F/L), Niassa/Lichinga (0,18, 0,98 e 0,07 mg F/L), Nampula/Nampula (0,18, 0,01 e 0,06 mg F/L), Zambézia /Quelimane (0,81, 0,37 e 0,15 mg F/L), Tete/Tete (1,00, 0,97 e 0,46 mg F/L), Sofala/Beira (0,00, 0,01 e 0,10 mg F/L), Manica/Chimoio (0,04, 0,01 e 0,07 mg F/L), Inhambane/Inhambane (0,00 , 0,05 e 0,19 mg F/L), Gaza/Xai-Xai (0,01, 0,06 e 0,06 mg F/L) e Maputo (0,23, 0,36 e 0,23 mg F/L), respectivamente. Nas águas do rio Zambeze foi de 5,5 mg F/L em 1978 e 0,12 mg F/L em 2019. Não houve alteração significativa entre as concentrações de flúor na água coletada das torneiras durante os períodos estudados (p=0,83), porém houve diferença significativa na água captada no Rio (p<0,05). **Conclusão**: O Rio Tete apresentou redução significativa na concentração de flúor, e na água das torneiras coletada em todas as cidades, o teor de flúor estava abaixo do ideal.*

***Termos de indexação**: Fluorose dentária. Flúor. Saúde bucal. Moçambique.*

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INTRODUTION

Fluorine is the ionic form of the element fluorine, the 13th most abundant element in the Earth's crust. Fluorine is negatively charged and combines with positive ions (calcium or sodium) to form stable compounds (calcium fluoride or sodium fluoride). In humans, fluoride is primarily associated with calcified tissues (bones and teeth) due to its high affinity for calcium [1]. The discovery effects of fluorides as toxic for human and as preventive and therapeutic for dental caries began in 1945 and 1946, in the United States of America and Canada [2].

Although, the World Health Organization (W H O) has set the fluoride guideline limit of 1.5 milligram of fluoride per litter of water (mg F/L) in drinking water, over 260 million people globally consume drinking water with high fluoride concentration above the WHO [3] standard Six countries in continental America, eight in Asia and the Middle East, and fourteen in Africa consume water with fluoride concentration greater than 1.5 mg F/L in drinking water [4].

The effects of fluoride are of interest for two reasons, first, due to its toxicity caused by multiple exposure to fluorides implies a greater risk of developing dental fluorosis, caused by chronic fluoride intoxication, ingested in large concentrations, during the period of enamel formation and calcification, resulting in hypoplastic or hypomineralized enamel, induced different degrees of fluorosis. In addition to dental fluorosis, there are other complications associated with overuse of fluoride consumption, namely skeletal fluorosis, muscle degeneration, skin rashes, depression, abdominal pain, urinary tract malfunction, reduced immunity, tingling sensation in the fingers and feet, excessive thirst, and neurological manifestations similar to pathological changes that occur in patients with Alzheimer's disease [5]. Aggeborn and Öhman [6] found that fluoride exposure through drinking water no interfere on cognitive development.

In Africa, high fluoride levels have been reported mostly in the Great East African Rift Valley which extends from Jordan valley down through Sudan, Ethiopia, Uganda, Kenya, Tanzania, Ghana, Malawi, Nigeria, Algeria and the Republic of South Africa Kenya, Tanzania, and Ethiopia (figure 1) [4]. In Mozambique, Tete's province, located in the central region,

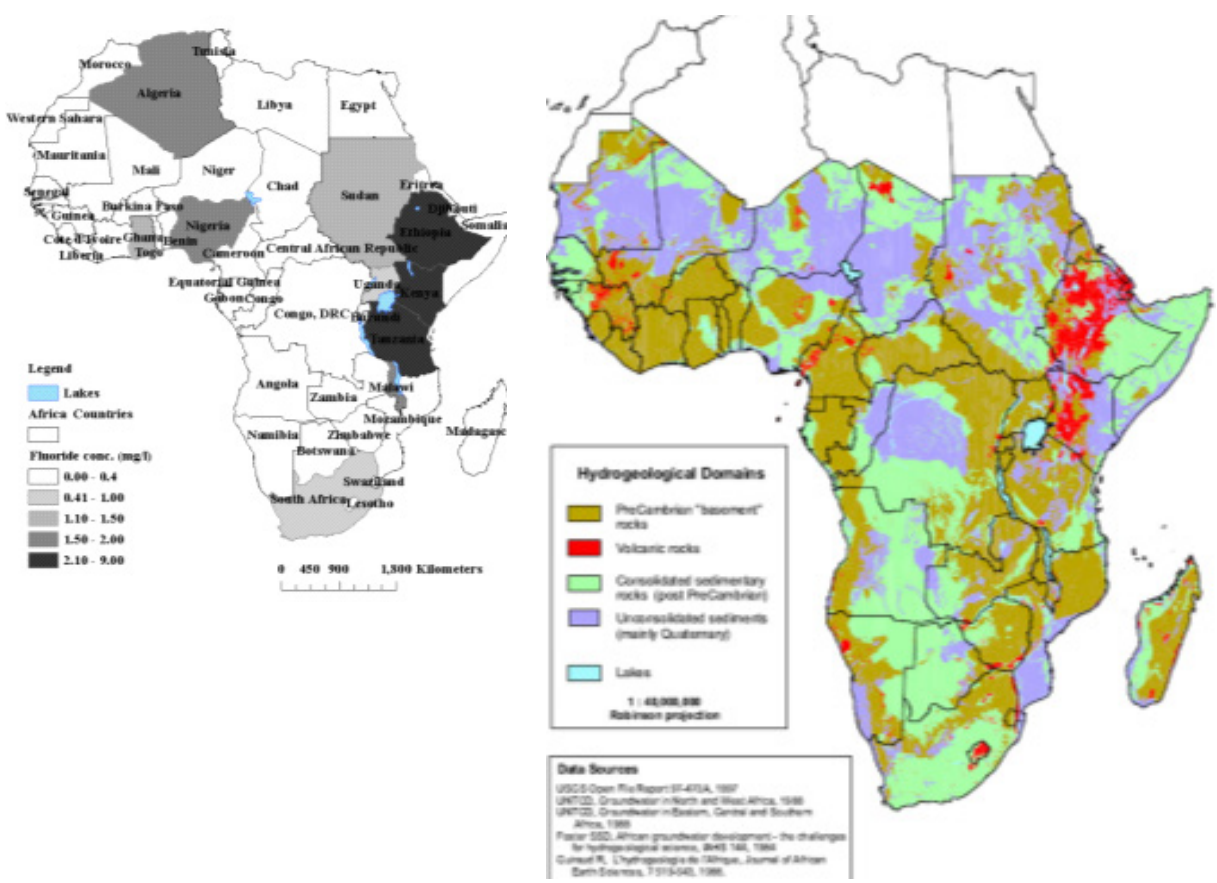

Figure 1. Map of Africa showing countries with high fluoride in water.

crossed by the Zambeze River and borders Malawi, was found a high prevalence of fluorosis [7], In southern Malawi have been surveyed and found high-fluoride groundwater concentrations to vary between 0.1 and 14.0 mgF/L [8].

Second, for its effectiveness when used properly, fluoride strengthens tooth enamel and prevents caries, tooth decay, tooth loss, and cavities. Fluoride concentrated in plaque and saliva inhibits enamel demineralization and enhances remineralization. As cariogenic bacteria metabolize carbohydrates and produce acid, fluoride is released from dental plaque in response to reduced pH at the dental plaque interface. The released fluoride and the fluoride present in the saliva are then absorbed, along with calcium and phosphate, by the demineralized enamel to establish an improved crystalline structure of the enamel. This improved structure is more resistant to acids and contains more fluorine and less carbonate [9].

In Eastern Europe and Central Asia and low- and middle-income countries of Africa, Asia, and Latin America has been observed inadequate exposure to fluoride leading high levels of dental caries, when associated with high consumption of sugars. The lack of preventive programmes with adequate fluoride is further complicated by the fact that these countries have a shortage of oral health personnel and the capacity of health systems is mostly limited to treatment of symptoms or emergency oral health care. In children and adults suffering from severe tooth decay, teeth are often left untreated or they are extracted to relieve oral pain or discomfort [9]. Thereby, the WHO recommends that studies must be carried out epidemiological tests every five years to control water fluoridation and its real consequences and benefit [10].

Thus, this study aims to evaluate fluoride concentrations in drinking water in the provincial capitals of Mozambican territory in the year of 2019 and compare with data from previous years 1978 and 2008.

METHODS

This is a retrospective, descriptive and analytical study.

Study location

The study was conducted in Mozambique, where is located on the eastern coast of southern Africa, bordered on the north by Tanzania, on the northwest by Malawi and Zambia, on the west by Zimbabwe, on the east by the Mozambique Channel and the Indian Ocean, and on the south and southwest by South Africa and Swaziland. According to the 2017 National Institute of Health Census Mozambique has an estimated population of 31,616,078 inhabitants, and has an area of 801,590 km² and it is political-administrative divided into 11, provinces, namely, Maputo City, Maputo Province, Gaza, Inhambane, Sofala, Manica, Tete, Zambezia, Nampula, Cabo Delgado and Niassa [11]. Mozambique's climate is tropical and subtropical and there are two seasons, a summer season from October to March, and a winter season from April to September. The average maximum temperature is 30.2°C (86.36°F) and minimum temperature is 14.8°C (58.64°F) [12]. The estimated coverage of people with access to water potable in urban and rural areas is 64% and 17%, respectively [13].

Water analysis

Water supplies samples were collected in eleven municipalities in Mozambique, in 3 periods 1978, 2008 and 2019 and water sample from the Zambeze River, in Tete, in 2 periods, 1978 and 2019. These samples were packaged in a polyethylene bottle with a lid and properly identified (figure 2). Zambeze River from Tete province was chosen due to the prevalence of fluorosis in the province. The samples collected in 2019 were analysed in the biochemistry laboratory of the Faculty of Dentistry of Bauru at the University of São Paulo, Brazil.

Figure 2. Samples were packaged in a polyethylene bottle.

The collections were carried out in duplicates directly from the taps in the residents' homes. The fluoride concentration of the water samples was determined in duplicate. For water analysis was used an ion-specific electrode as an effective method for monitoring fluoride levels in drinking-water which is generally accepted as the accepted gold standard method, the ion-sensitive electrode (Orion 9609), coupled to a potentiometer (Procyon, model 720).

RESULTS

Student's t test was applied, adopting a significance level of 5%. The average fluoride concentration found in the years 1978, 2008 and 2019 was 0.31mgF/L, 0.33mgF/L and 0.14 mgF/L, respectively. The fluoride concentrations collected from household taps in 1978, 2008 and 2019 were: Cabo Delgado/Pemba (0.62, 0.28 and 0.07mgF/L), Niassa/Lichinga (0.18, 0.98 and 0.07mgF/L), Nampula/Nampula (0.18, 0.01 and 0.06 mgF/L), Zambézia/Quelimane (0.81, 0.37 and 0.15mgF/L), Tete/Tete (1.00, 0.97 and 0.46mgF/L), Sofala/Beira (0.00, 0.01 and 0.10 mgF/L), Manica/Chimoio (0.04, 0.01 and 0.07 mgF/L), Inhambane/Inhambane (0.00, 0.05 and 0.19 mgF/L), Gaza/Xai-Xai (0.01, 0.06 and 0.06 mgF/L) and Maputo (0.23, 0.36 and 0.23 mgF/L), respectively (table 1). The fluoride concentration in the waters of the

Table 1. Fluoride level in Mozambique.

Province (city, river)	Fluoride Level (mgF/litro)		
	1978	2008	2019
Niassa (Lichinga)	0.18	0.98	0.07
Niassa (Lake Niassa)	NI	NI	0.06
Cabo Delgado (Pemba)	0.62	0.28	0.07
Nampula (Nampula)	0.18	0.095	0.06
Zambézia (Quelimane)	0.81	0.37	0.15
Zambézia (Gurúe)	0.08	NI	NI
Tete (Tete)	1.00	0.97	0.46
Tete (Zambeze river)	5.60	NI	0.12
Sofala (Beira)	0.00	0.095	0.10
Sofala (Gorongonza)	0.05	NI	NI
Manica (Chimoio)	0.28	0.095	0.07
Inhambane (Inhambane)	0.00	0.05	0.19
Inhambane (Vilanculos)	0.08	NI	NI
Inhambane (Maxixe)	NI	NI	0.08
Gaza (Xai-Xai)	0.01	0.06	0.06
Maputo Província (Matola)	NI	0.37	0.19
Maputo Cidade (Maputo)	0.23	0.36	0.23
MEAN	0.31	0.33	0.14

Note: NI: No information.

Zambeze River was 5.5mgF/L in 1978 and 0.12mgF/L in 2019. There was no significant change between the fluoride concentrations in the water collected from the taps during the studied periods ($p=0.83$), however there was a significant difference in the water collected from the Zambeze River in Tete ($p<0.05$).

DISCUSSION

Fluoride research from over 60 years ago established 1.0 mgF/L as the most appropriate concentration of fluoride in drinking-water. Because people in hot climates drink more water than those in moderate climates, this figure of 1.0 mgF/L was modified into a range (0.7-1.2 mgF/L). By the 1990s, however, it became clear that these standards were not appropriate for all parts of the world. In other parts of the world, especially the tropical and subtropical areas of Africa and Asia, the variety of dietary practices found in many different races and cultures meant that the recommended range had probably never been appropriate. The most appropriate concentration for Hong Kong would be around 0.8 mgF/L. However, fluorosis in children was found to be still unacceptably high at that level and the concentration was reduced in several stages to 0.5 mgF/L in 1988 [14].

The appropriate fluoride content and acceptable range are defined according to the temperature variation on site. The average of the maximum daily temperatures of the locality, obtained in the period of one year, must be taken into account, in order to calculate of the optimal concentration and its minimum and maximum limits. In Brazil, the matter was regulated by Resolution MS-GM-518, of 3/25/2004, where the maximum value fluoride allowance is 1.5 ppmF, or 1.5 mgF/L. In most of the Brazilian territory, however, the ideal fluoride content in water is 0.7 ppm. or 0.7 mg of fluorine per litre [15].

According to O'Mullane et al. [2], 27 countries with naturally fluoridated water supplied to an estimated 239,903,000 million people. However, it should be stressed that, in many instances, the naturally occurring fluoride level is in excess of the optimum, for example, in China, India, Argentina, Tanzania, Zambia and Zimbabwe. It is estimated that the number of people around the world whose water supplies contain naturally fluoridated water at the optimum level for oral health are around 50 million. The East Africa Rift Valley has its northern origin in the Jordanian Valley in West Asia and continues to Northeast Africa, and then south through, Sudan, Eritrea, Ethiopia, Kenya, Uganda, Tanzania and Malawi.

In 1978, Mozambique analysed the fluoride content in drinking water in the main cities of Mozambique and in the Zambeze province and Tete's river, presented the highest levels of the fluoride [16]. In 2008, studies by Mapengo et al, also founded fluoride's level far below the optimal amount in many cities of Mozambique, with the exception of Niassa and Tete where the fluoride level was above 0.7mgF/L, recommended by Brazilian regulation, that sustain the standard fluoride recommendation for tropical countries, as Mozambique with average annual temperatures ranging from 26.3oC to 32.5oC is 0.7ppm [15]. Thus, the optimal concentration of fluoride varies according to climatic conditions with the range 0.5mg-1.0mgF/L, recommends by WHO as normal fluoride concentrations in drinking water [17]. Similarly, American Dental Association, accepts levels of 0.7 – 1.2 mg F/L, also depending on weather conditions, sea level, average daily maximum temperatures and the frequency of water intake in region [18].

There was significant reduction in the fluoride content in the water of the Zambeze River, from 5mgF/L in 1978 to 0.12mgF/L in 2019. On the other hand, from 1978 to 2008, the level of fluoride in tap water remained stable at 1mg/F/L, and reduced in 2019 to 0.46 mgF/L. This levels of fluoride in the waters of Zamzeze River, may be related to the fluorosis reported by Cossa and Cardoso [6], where the prevalence of dental fluorosis was 88.1%, with a higher frequency female 49.1%. And fluoride content in tap water in Tete, may be related to higher occurrence of mild cases in the age group of 5-11 years 16.6% and of moderate cases in the age group of 12-18 years in 14.5% [6], once Tete has high temperatures.

The reason for the significant reduction in fluoride content in the Zambezi River, in the province of Tete, Mozambique, is not known, since no studies were found on filter fluoride content or water treatment methods to remove fluoride from the water. However, the literature shows several different methods of water defluoridation.

In 2019 data, the highest fluoride concentration in drinking water was 0.5mg F/L in tap water Tete. This value can show positive effects in reducing dental caries. In contrast observed in Tete, the rest of cities presented values of fluoride concentrations between 0.05 and 0.40mg F/L, similar amount found in Maputo, where the level of fluoride in water consumption in urban schools was 0.4 ppmF, and suburban schools, 0.2 ppmF [19].

These low levels of fluoride may be related to the high incidence of dental caries in the developing countries where a high burden of disease was observed from 1990 to 2010, and in terms of disability-adjusted life years (DALYs), the regional average of the weight of dental caries increased from 42% to 78% [20].

According to Petersen, Member States must ensure that populations benefit from appropriate use of fluoride through systematic fluoridation programmes, for example, in drinking-water, salt or milk, and to the provision of affordable fluoride toothpaste [21]. Inadequate levels of fluoride in water have ethical implications, therefore, it is also an ethical imperative to know the content of fluoride normally found in the natural waters source, before making them available for human consumption.

CONCLUSION

It is concluded that the waters of the Tete River showed a significant reduction in fluoride concentration, and in the piped water collected in all municipalities, the fluoride content was below the ideal for tropical countries such as Mozambique.

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Collaborators

MAAM Domingos, conceptualization (equal), data curation (equal), formal analysis (equal), investigation (equal), methodology (equal), supervision (equal) and writing – original draft (equal). SHC Sales Peres, conceptualization (equal), formal analysis (equal), investigation (equal), methodology (equal), project administration (equal), supervision (equal) and validation (equal).

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