Journal of Taibah University Medical Sciences (2023) 18(6), 1500–1506

Taibah University

Journal of Taibah University Medical Sciences

www.sciencedirect.com

Original Article

Fluoride levels in Almadinah Almunawwarah bottled water

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Received 13 October 2022; revised 12 May 2023; accepted 9 June 2023
; Available online 20 June 2023

لملخص العربي

الملخص العربي: الأهداف: كان الهدف من هذه الدراسة هو وصف مستويات الفلوريد في زجاجات المياه المعبأة والمتوفرة تجارياً ولتحديد دقة ملصقات مستويات الفلوريد على الزجاجات. **الطريقة**: تم الحصول على (28) ملصق مياة معبأة من أسواق المدينة المنورة. تم تخفيف عينات المياه بكميات متساوية من إجمالي عازلة تعديل القوة الأيونية في الإدارة العامة لخدمات المياه. تمت مقارنة جهود المحاليل الكهربية بشكل مباشر مع محاليل الفلوريد القياسية. تم أخذ قراءتين لكل عينة وتم تسجيل المتوسط. تم قياس مستويات أيون الفلوريد باستخدام قطب فلوريد أيون انتقائي ومقياس أيون رقمي. **النتائج**: كان متوسط مستويات الفلورايد للزجاجات حسب الملصق الموجود بالزجاجات 0.94 ±0.14 جزء في المليون. كان متوسط مستويات الفلوريد لمحتوى الفلورايد الفعلي بعد التحليل 1.13 ±0.31 جزء في المليون تم العثور على تضارب بين الملصقات التجاريه في الزجاجات وبين نتيجه التحليل الفعلي . وجدت نتيجة علامة تجارية واحدة فقط تناسبت بها مستويات الفلورايد على ملصقاتها وتحليل مستوى الفلورايد الفعلي. 85.71٪ فقط من العلامات التجارية كانت تحتوي على مستويات فلوريد ضمن نطاق الفلورايد المسموح به (0.6-1.5 جزء في المليون) ، 10.71٪ كان لديها مستويات فلوريد أعلى من نطاق الفلورايد المسموح به ، و 3.57٪ كان لديها مستويات فلوريد أقل من نطاق الفلورايد المسموح به. **الاستنتاجات**: في المملكة العربية السعودية تحتوي معظم زجاجات المياه المعبأة على مستويات من الفلوريد أعلى من المستويات المثالية والحيوية لمنع تسوس الأسنان. حيث وجد اختلاف في مستويات الفلوريد بين ما هو موجود على ملصقات العلامات التجارية وما وجد في التحليل الفعلي . لتحقيق الفوائد المرجوه والتجميلية اللازمة يجب التاكد من مستويات الفلورايد بدقة. يجب أن تستوفي المياه المعبأة معايير الجودة اللازمه لتجنب النتائج السلبية لارتفاع مستويات الفلوريد. يجب أن يكون أطباء الأسنان وأولياء الأمور على دراية بهذا التناقض

الكلمات المفتاحية: المدينة المنورة، مياه الشرب المعبأة، الفلورايد، الفلوروز، المملكة العربية السعودية

Abstract

Objectives: This research aimed to determine the fluoride levels in commercially available bottled waters and assess the accuracy of the fluoride levels labels on the bottles.

Methods: We obtained the labels from 28 water bottles from markets in Almadinah Almunawwarah. Water samples were diluted with an equal volume of total ionic strength adjustment buffer at the General Administration for Water Services. The electrode potential of each sample was then directly compared to standard fluoride solutions. For each sample, two readings were taken, and the average was recorded. Fluoride-ion levels were determined using a fluoride-ion-selective electrode and a digital readout ion meter.

Results: On average, the mean fluoride levels in the labelled bottles were 0.94 ± 0.14 PPM. The level of the actual fluoride content was 1.13 ± 0.31 PPM. Inconsistencies between the brand labels and true levels of fluoride were detected. Only one brand of bottled water was comparable in terms of the fluoride levels on the labels and the analysed fluoride levels. Only 85.71% of the brands tested had fluoride levels within the permissible fluoride range (0.6–1.5 PPM), 10.71% had fluoride levels above the permissible fluoride range, and 3.57% had fluoride levels below the permissible fluoride range.

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Peer review under responsibility of Taibah University.

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 https://doi.org/10.1016/j.jtumed.2023.06.005

Conclusions: In the KSA, most brands of bottled waters had fluoride levels above the ideal levels that are vital to the prevention of dental caries. There were differences in the fluoride levels recorded on the labels and the true levels determined in the laboratory. Fluoride levels must be accurately reported if we are to achieve necessary aesthetic and cosmetic benefits. Bottled water must meet critical quality standards to avoid the negative consequences of higher fluoride levels. Dentists and parents should be aware of this discrepancy.

Keywords: Almadinah Almunawwarah; Bottled water; Fluoride; Fluorosis; KSA

Introduction

The compound fluoride occurs naturally in all natural sources of water. Furthermore, fluoride is also the ionic form of the trace element fluorine which leaches from soils and rocks into the hydrosphere found in the cracks and spaces in soil, sand and rock.[1]

The presence of fluoride in potable water depends on the type or composition of soil and serves a vital function in nature by controlling water quality. Similarly, the amount of fluoride in groundwater is influenced by the climate, the composition of the host rock, and hydrogeology.[2]

Studies have demonstrated that fluoride is a harmless compound when used as recommended or when drunk in fluoride-containing water to remedy dental caries.[3] Furthermore, adequate fluoride consumption during the pre-eruptive stage of amelogenesis can protect against dental caries later in life. However, the main benefits of fluoride, however, occurs locally in the mouth, at the tooth surface.[4]

Fluoride intake varies widely according to various systemic and topical exposures to fluoride sources; these mechanisms represent the principal source in humans. The sources of fluoride other than water include exposure to beverages and food prepared with fluoridated water,[5–7] fluoridated salt and milk,[8] oral prophylactic procedures,[9] fluoridated toothpaste,[10] mouthwash rinses, cosmetics, and fluoride supplements (drops, tablets and lozenges).[7,11]

The development of dental caries depends on numerous factors. In due course, a complex interaction between acid-producing bacteria and fermentable carbohydrates can eventually demineralise the hard dental tissues, enamel, dentin and cementum.[12] To reduce the prevalence of dental caries, fluoride is taken regularly throughout the day to maintain acceptable fluoride levels at the tooth surface. Furthermore, fluoride has long been recognised as the most effective method for preventing dental caries. Fluoride can convert calcium hydroxyapatite crystals released by the enamel into calcium fluorapatite, which is more durable, resists acid demineralisation, and enhances remineralisation of the enamel.[1,13,14] For optimal oral health, the recommended fluoride level is 0.7 parts per million (PPM).[15] Public health research in the dental sector has established that fluoride is a double-edged sword because it can exert dose-dependent effects on teeth.[16] Excessive fluoride exposure can cause visible changes in the enamel structure, such as dental fluorosis, which manifests differently depending on the fluoride dose, the duration of exposure, and the stage of amelogenesis.[17] Dental fluorosis is a developmental disturbance of enamel and is produced by the chronic and excessive intake of high fluoride levels during amelogenesis, thus producing enamel with a lower mineral content, a greater porosity, and hypo-mineralisation of the fluorotic enamel.[18,19]

Fluorosis threatens the Saudi population because abundant well water is still consumed in remote areas of the country.[20–24] In addition, dental fluorosis varies significantly between regions; in the KSA, the Hail region is known to have the highest prevalence of fluorosis (74%). In terms of severity, mild to very mild fluorosis has been widely reported in the KSA. Some of the previous studies that determined the prevalence and severity of dental fluorosis also measured the levels of fluoride in well water, which was once the primary source of potable water. However, these studies are insufficient to make any firm conclusions; furthermore, none of these studies included measurements of fluoride topical use or the consumption of a fluoride-containing diet.[25,26]

Water, specifically potable water, is essential for life and can exert significant effects on the overall health of humans. As a result, numerous biological, chemical, and physical parameters are routinely monitored and quantified.[27] Furthermore, globally, there is a tendency to increase the use of natural drinks due to the increased enthusiasm for keeping fit; thus, the demand for these drinks continues to increase and is also being driven by population growth. Together with general unease relating to the taste and quality of water supplied by public water supply systems, these factors are encouraging increasing numbers of individuals to use bottled water.[14]

There is very little information relating to the levels of fluoride in the bottled water available for consumption in the KSA. However, in the KSA, and irrespective of the content and quality of tap water, most people frequently drink bottled water owing to its convenience when compared to tap water. Furthermore, there is a perception that bottled water is healthy for every person and child because it does not contain chemicals, has a pleasant taste, and is perceived to be highly pure.[28–31] Research has shown that the fluoride levels in bottled water can fluctuate and that above-optimal levels can negatively impact children and adolescents who drink bottled water as their primary source of potable water and have poor oral health.[27]

The primary potable water sources in the KSA are desalinated seawater and well water. The desalination method eliminates fluoride from seawater; therefore, until 2007, the

desalination public water supply in the KSA was not fluoridated.[32] Furthermore, potable water is obtained naturally from fluoridated underground wells.[33] Data relating to fluoride levels in water are essential for all health care providers, especially dental professionals, since the use of fluoride is a primary preventive model in dentistry.

There is significant demand for bottled potable water in the KSA, reaching 25.99 cubic meters in 2018. However, the water quality of commercially bottled water is in doubt because companies do not necessarily record the nutritional content of their products. Furthermore, in some countries, labelling the fluoride content of products is not legally required, and if the fluoride content is printed on the bottle label, it may not be useable.[34]

The fluoride content of bottled potable water may vary. It is vital to determine the levels of fluoride in water as high fluoride levels could produce dental fluorosis among infants and children. This is important given the growing variety of bottled water available in Almadinah Almunawwarah markets and the knowledge that fluoride in potable water is a critical population health strategy for the control and prevention of dental caries. Furthermore, before prescribing fluoride supplementation, healthcare providers should be aware of the fluoride levels of bottled potable water. The primary goal of this study was to provide information on the fluoride levels of commercially available bottled waters in the KSA. Our secondary goal was to verify the accuracy of fluoride levels on the labels on bottled water.

Materials and Methods

Twenty-eight bottles of water (and labels) were procured from the main markets in Almadinah Almunawwarah and kept in their original seal at room temperature. The bottled water was catalogued and numbered in alphabetical order based on brand name. We recorded the levels of fluoride given on the labels and measured the true levels of fluoride in a laboratory.

On the day of analysis, the water bottles were shaken, and the technician testing the water was given a 50-ml sample in a coded container; this ensured that the technician was blinded to the type and brand of water. At the General Administration for Water Services for the Almadinah Almunawwarah region, the water samples were mixed with an equal volume of total ionic strength adjustment buffer (TISAB, Mettler Toledo[1] DL 50, pH/ion-meter, USA). The solutions containing 25 ml of sample and 25 ml of TISAB were mixed for 3 min with a magnetic stirrer. The electrode potential of each sample was directly compared to those of fluoride standard solutions. For each sample, two readings were taken, and the average was calculated. The fluoride-ion level was measured with a fluoride-ion-selective electrode and a digital readout ion-meter (Mettler Toledo[1] DL 50, pH/ion-meter, USA).

The IBM Corp. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: USA, was used to collect descriptive data. To compare measurements for the first and second readings, we used the paired t-test and correlation analysis.

Results

The mean fluoride levels of the 28 different brands are shown in Table 1. Fluoride levels in the labelled bottles ranged from 0.75 to 1.49 PPM, with a mean of 0.94 ± 0.14 PPM. In contrast, the actual fluoride levels ranged between 0.03 and 1.86 PPM with a mean of 1.13 ± 0.31 PPM.

There were clear inconsistencies between the labelled fluoride levels and the actual fluoride levels (Table 1, Fluoride level (mg/dL) of three different batch numbers of each bottled water. Samples were measured twice and the mean fluoride level (mg/dL) was determined, Figure 1). However, only one bottled water brand (Safa, 3.57%) recorded accurate fluoride levels on their labels that matched the actual fluoride level.

Table 1: Fluoride level (mg/dL) of three different batch numbers of each bottled water. Samples were measured twice and the mean fluoride level was determined measured twice each, and the mean (±SD) fluoride content.

No.	Brand of bottled water	Labelled content fluoride level (mg/dL) (PPM) Mean (mg/dL)	Actual content fluoride level (mg/dL) (PPM) Mean (mg/dL)
1.	Al Ain	<1.50	1.22
2.	Al Aoun	0.85	1.24
3.	Al Dar	1.00	0.95
4.	Al Qassim	0.95	1.05
5.	Al Wadi	0.75	0.85
6.	Amjad[b]	0.80	0.03
7.	Aquafina	1.00	1.33
8.	Aqualand	1.00	1.07
9.	Arwa	0.8−1.2	1.00
10.	Azbah	0.9	1.18
11.	Berain	1.1	1.23
12.	Dallah	1	1.23
13.	Darouk	0.9	1.31
14.	Drua	0.85	0.87
15.	Hala[a]	0.9	1.86
16.	Hana	1.00	1.16
17.	Hilwah	0.80	0.96
18.	Mozen[a]	1.00	1.67
19.	Mowared	0.90	1.19
20.	Naqqi[a]	0.90	1.54
21.	Nestle	0.80	1.05
22.	Nova	1.00	1.05
23.	Panda	1.00	1.12
24.	Safa	1.00	1.00
25.	Sama	1.00	1.04
26.	Taibah	0.80	1.14
27.	Tania	0.90	1.01
28.	Veen	0.80	1.31

[a] Brands above the permissible fluoride levels.
[b] Brands below the permissible fluoride levels.

[1] www.mt.com/meter/pH.

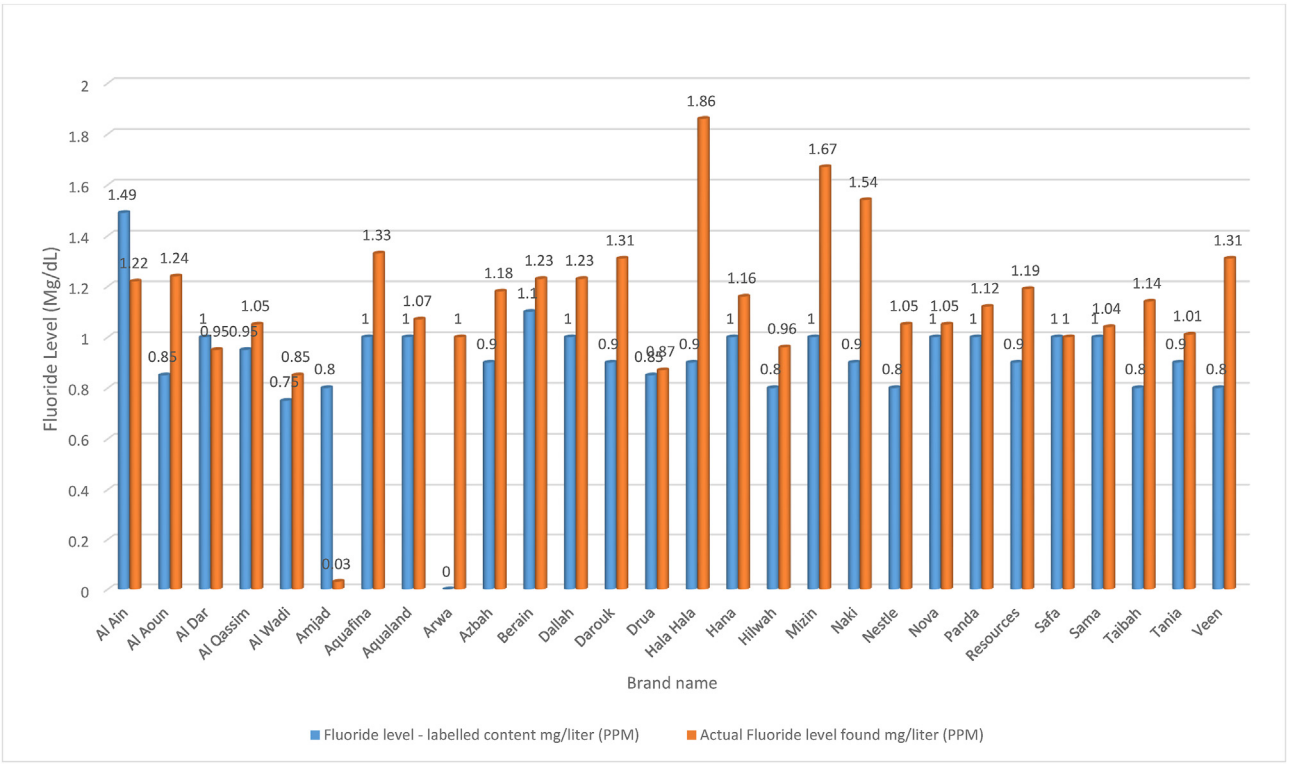

Figure 1: Comparison between fluoride levels on bottle labels and actual fluoride levels analysed in the laboratory.

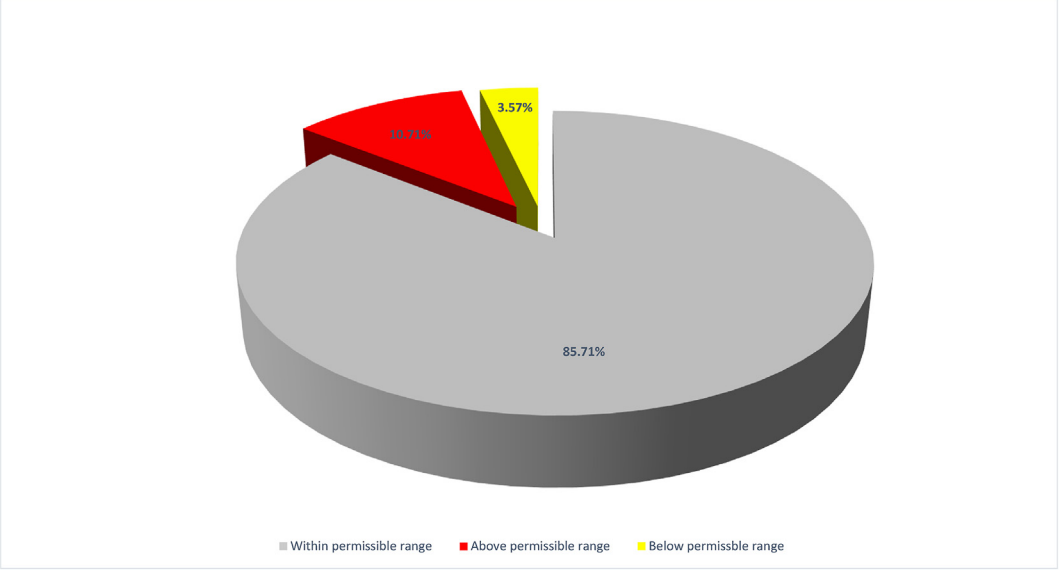

Figure 2: Brands within or above or below the permissible fluoride levels.

In the present study, 24 (85.71%) of the brands contained fluoride levels within the permissible fluoride range (0.6–1.5 PPM), whereas three brands (10.71%) had a fluoride level above the permissible fluoride range. One brand (3.57%) had fluoride levels below the permissible fluoride range (Figure 2). Interestingly, none of the labels specified the source or type of water in their bottles.

Discussion

This research was designed to determine the fluoride levels of bottled water in different brands available in the markets of Almadinah Almunawwarah in the KSA. In total, 28 brands of Saudi-produced bottled water

were collected from various supermarkets. The fluoride levels on the labels of these 28 brands ranged from 0.75 to 1.49 PPM. Laboratory analysis of the 28 labels revealed that fluoride levels actually ranged from 0.03 to 1.86 PPM.

The current study demonstrated that all samples of bottled water examined stated fluoride levels on their labels. However, only three brands had a fluoride level on their label that matched the reported analysis. These findings revealed a significant discrepancy between the reported and actual fluoride levels. Approximately 82% of the brands had higher fluoride levels than those stated on the labels. As a result, it is critical that the stated fluoride levels on the labels reflect the actual measurements to provide the consumer with the necessary information to choose which bottled water to purchase to achieve the desired health benefits.[35]

According to Cochrane et al., the fluoride level on the label allows the customer to be informed of the fluoride level and make an informed decision about the brand of water consumed.[36] Furthermore, Cochrane et al. asserted that these differences could be attributed to several water production locations for a single company and seasonal variations in fluoride levels from different water sources.[36] Similar discrepancies between labelled and actual levels have also been demonstrated in studies conducted in KSA[34] and other countries.[37–39]

In contrast, in the United States (51), only 5% of bottled water listed fluoride levels; this compared to 32% of bottled water brands in the United Kingdom.[14] In Canada, on the other hand, 100% of bottled water lists the fluoride levels on their labels. This is because food and drug act regulations require that the content and quantity of water constituents need to be clearly stated on their labels.[40,41]

Fluoride enters the human body through various routes, including potable water and beverages made with fluoridated water, food, toothpaste, mouthwashes, fluoride supplements, and drugs.[42–44] As a result, water is regarded as the primary and most common source of fluoride and, as such, is the primary source of potential toxicity.[44] On the other hand, excessive fluoride intake during tooth development, and particularly during the maturation stage, can initiate different problems, such as dental fluorosis and, in severe cases, skeletal fluorosis, which can inhibit the functionality of certain enzymes.[45]

Our analyses demonstrated that 85.71% of brands were within the permissible range of the Saudi Arabian Standards Organization (SASO) guidelines which specify that the maximum allowed limit of fluoride is 1.5 PPM in tap water, a figure that has been amended according to the MOH recommendation by implementing a minimum allowed limit between 0.6 and 0.8 PPM.[32] Furthermore, the WHO recommendations for hot climate countries are 0.6–1 PPM; however, 1.5 PPM needs to be reconsidered in light of the recommendations made by the local authorities.

The WHO guidelines recommended that the optimal fluoride levels in potable water remain below 1.0 PPM in warmer climate countries. However, levels can be as high as 1.2 PPM.[46] This discrepancy concerning fluoride levels is based on the hypothesis that perspiration in a colder climate is lower than in a hotter climate, and consequently, water consumption is lower. This suggestion was further sanctioned in 2004 when the WHO stated that dental fluorosis in warmer countries could develop at lower fluoride levels due to the higher consumption of potable water.[47] The WHO suggested a range between 0.5 and 1.0 PPM as the optimal fluoride level.[48] Even though the function of temperature has been given adequate consideration in determining the optimal fluoride levels for potable water in the past, the US public health service recently amended their temperature-based optimal fluoride level (0.7–1.2 PPM) in communal water supplies to a set value of 0.7 PPM.[49]

Bottled water fluoride content has consequences associated with fluoride supplements and the possible risk of dental fluorosis. Due to the higher amount of water consumption in hot climates than in temperate climates, the recommended level of fluoride in water for warm countries like KSA is 0.6–0.7 PPM.[50]

However, a study by Ramadan et al. in the KSA recommended a range between 0.32 and 0.42 PPM, placing all available bottled water above the recommended fluoride levels.[51] Furthermore, Brouwer et al. suggested a fluoride level of 0.6 PPM for Senegal[52] while Ramadan et al. suggested a fluoride level of 0.32 PPM for Sudan.[53]

The current study makes it difficult for dentists to plan caries-prevention therapy that includes fluoride supplements. Our data also present a problem with regards to recommending dental fluorosis prevention programs in communities consuming bottled water.

In the present study, all the actual fluoride levels higher than 0.75 PPM could produce dental fluorosis if such water is consumed by an infant or a young child and fluoride from other sources. Most fluoride levels in water bottles marketed in the KSA were above the SASO recommendations and appreciably higher than their counterparts in Lebanon, United Arab Emirates or Qatar.[54] Therefore, those who remain using bottled water with very high fluoride levels are at risk of severe adverse effects. Consequently, it is crucial that all related authorities take the necessary steps to contain the production of these products.

The disparities in fluoride level between different marketed brands can affect the dental health of infants and children. For infants, milk remains the principal dietary source of nutrition and systemic fluoride. While breastfeeding is encouraged for all infants, formula milk is still an option for replacing breast milk. Fluoride levels in bottled water can vary widely; this has implications for infants who use powdered formula milk prepared with bottled water. Elevated fluoride levels may increase the risk of fluorosis when powdered formula milk is prepared with fluoridated water and used as the primary nutritional source. As a result, an effective and safe fluoride prevention program necessitates knowledge of the specific fluoride levels in potable water in either public or bottled water supplies. Dentists should be aware that the fluoride content in potable water consumed by children should be within the KSA's permissible range when prescribing fluoride supplements.[32]

Conclusions

In the KSA, the bulk of the available bottled waters contained fluoride levels above the ideal levels that can

prevent dental caries; some were below the recommended level. In countries where bottled water is the primary source of fresh water, meeting the vital quality of bottled water is critical to avoiding the negative consequences of above-optimal fluoride levels.

We found that fluoride levels varied between brands on their labels and those reported by analysis. As a result, fluoride levels in bottled water must be accurately reported if the consumer is to achieve aesthetic and cosmetic benefits. In contrast, the consumer will not benefit from brands with less optimal fluoride levels if the total amount of fluoride consumed is less than the set standard limits.

Dentists and parents should be aware of the discrepancy between bottled water's fluoride levels and the labels. Furthermore, dentists should be aware of fluoride levels in the water consumed by their patients, irrespective of whether the water is packaged or tap water. Moreover, parents who use bottled water to prepare milk meals for their babies should be aware of the fluoride levels in the water used for meal preparation. Using water containing high fluoride levels will expose their children to the increased risk of dental fluorosis.

Recommendations

Since there is no uniformity in describing fluoride levels on bottled water labels, the current research recommends that fluoride levels in bottled water be monitored and fluoride levels on bottled water labels be the actual fluoride levels to assist consumers in making an accurate and reliable choice of the bottled water to be consumed and thus preventing any undesirable results.

It is vital that supervisory agencies and organisations be more vigilant with regards to preparing and implementing strategies. Furthermore, studies are needed to adjust the required range of fluoride levels according to the KSA climate and the WHO recommendations.

Source of funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

The authors have no conflict of interest to declare

Ethical approval

The Taibah University College of Dentistry Research Ethics Committee TUCDREC (TUCDREC20161126/Gamer) approved this study on 22/11/2016.

Authors' contributions

MOG conceived and designed the study, conducted research, provided research materials, collected, and organised data, and provided logistic support. AMR conducted research, provided research materials, collected, and organised data, analysed and interpreted data, and wrote the initial and final draft of the article. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

Acknowledgments

The authors would like to thank the General Administration for Water Services for Almadinah Almunawwarah region for their cooperation and for analysing the anonymous samples of bottled water provided.

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How to cite this article: Gamar Elanbya MO, Ramadan AM. Fluoride levels in Almadinah Almunawwarah bottled water. J Taibah Univ Med Sc 2023;18(6):1500−1506.