Biol Trace Elem Res (2016) 174:471–476
DOI 10.1007/s12011-016-0718-z

Fluoride Content of Bottled Drinking Waters in Qatar

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Received: 21 March 2016 / Accepted: 19 April 2016 / Published online: 27 April 2016

Abstract Fluoridation of drinking water has been recognized as one of the most effective ways of achieving community-wide exposure to the caries prevention effects of fluoride (F). A vast majority of people in Qatar use bottled water for drinking. Use of bottled water without knowing the F level may expose children to dental caries risk if the F level is lower than optimal or to dental fluorosis if the F level is too high. The aim of this study was to determine the F concentration of bottled water available in Qatar. A total of 32 brands of bottled water were evaluated. The F concentrations displayed on the labels were recorded. The F ion-selective electrode method was used to measure the F concentration in water samples, and three measurements were taken for every sample to ensure reproducibility. The p value was set at 0.05. The F concentration ranged from 0.06 to 3.0 ppm with a mean value of 0.8 ppm (±0.88). The F levels were provided by the manufacturers on the labels of 60 % of the samples, but this was significantly lower than the measured F levels ($p < 0.0001$). Moreover, bottled water that was produced in Saudi Arabia had significantly higher levels of F when compared to those produced in other countries ($p < 0.05$). There was a wide variation in the F levels in the different brands of bottled water. Furthermore, there was a significant disparity between the F levels which were measured and those that were provided on the labels.

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Keywords Fluoride · Bottled drinking water · Ion-selective electrode · Qatar

Introduction

It is well established that exposure to fluoride (F) for a prolonged period through drinking of fluoridated water or industrial F emission causes serious health problems not only in humans but also in domestic animals [1–7]. Principally, it damages teeth (dental fluorosis) and bones (skeletal fluorosis) [1–9]. Alternatively, an optimal level of fluoride in drinking water has caries-preventive effects [10–12]. Furthermore, a constant supply of low levels of intra-oral F is well accepted as being the most beneficial way of preventing dental caries [13, 14].

The State of Qatar covers a land area of 11,437 km^2 and has a population of approximately 2,423,175 inhabitants as on January 31, 2016 [15]. The major sources of drinking water in Qatar are desalinated sea water and groundwater. The process of desalination removes F from the sea water; therefore, the public supply of water in Qatar is not fluoridated. However, the water which comes from underground wells is naturally fluoridated [16].

Regardless of the quality and content of the tap water supply, the majority of the people in Qatar use bottled water for drinking. This is primarily because of the perception that bottled water is healthier for everyone including children [17–20]. People find it convenient to purchase bottled water and believe it to be devoid of chemicals and harmful bacteria [21, 22]. Some bottled waters available in the markets in Qatar were manufactured locally, but majority of them were imported from different countries, including Saudi Arabia, the United Arab Emirates, and other European countries.

The caries prevalence amongst children and adolescents in Qatar has reached "critical" levels and is the second highest detected in the Eastern Mediterranean region [23]. The high caries rate has been attributed to high frequency of sugar intake, which is a consequence of the lack of awareness of oral health and community-based dental health education programs [24]. In view of this fact, and the knowledge that F in drinking water provides a key population health strategy for the prevention and control of dental caries, it is prudent to assess the F levels in bottled drinking water. Therefore, the objective of this study was to determine the F concentration of bottled water available in commercial markets in Qatar.

Materials and Methods

A total of 32 brands of bottled water were purchased from eight major supermarkets and grocery stores in the city of Doha, Qatar, and then stored at room temperature until they were analyzed. They were categorized and numbered according to alphabetical order based on the brand name. Additionally, number, bottle size, water type, the country of origin, batch number, and the F level according to the information provided on the labels were recorded.

Estimation of F Concentration in Bottled Water

The F ion-selective method (F ISE) (model 94-09, Orion Research, Inc., USA) was used to determine the F concentration in the bottled waters. Two operators performed the measurement process. The first was aware of the brand number, and hence, this operator prepared the samples for analysis, while the second operator, who made the measurements using the electrode and the pH/mV meter, was blinded for the brand name. This second operator entered the mV readings on the data collection sheet opposite to the number of the water sample.

Sample Preparation

After thorough shaking of the bottled water, a 90-ml sample, of the water to be tested, was pipetted into a small clear plastic vial (150 ml) with the number of the sample affixed on the vial. Then, 10 ml of total ionic strength adjusting buffer III (TISAB III, Orion Research, Inc. USA) was added to the water sample and stirred. In the case of sparkling water, the bottles were stirred until no air bubbles were released from the sample before a reading was performed.

Measurement Taking

When the electrode was dipped in the prepared sample, care was taken to ensure intimate contact between the solution and the electrode tip without any air bubbles between and without the electrode touching the bottom or walls of the vial. The temperature of the sample was maintained at 25 ± 0.5 °C. This was easily achieved by working in a secured air-conditioned room with a controlled average temperature and by monitoring the temperature of each sample which was shown in the ion analyzer screen. The electrode was retained in the solution until a stable reading indicated by "ready" was noted on the pH/mV meter screen. The mV reading was then taken at that point and recorded in the calibration curve table to be automatically converted to F concentration as a part-per-million value. The electrode was thoroughly rinsed with de-ionized water after every measurement and shaken to prevent solution contamination. The electrode tip was never rubbed or wiped in strict accordance with the manufacturer's instructions. Each water sample was measured three times by the same investigator with different prepared samples every time and on different days to ensure reliability and reproducibility. The p value was set at 0.05.

Results

The mean measured F contents of the 32 different brand samples are shown in Table 1. The ANOVA test demonstrated that there was no statistically significant difference between the three F level readings performed for each brand of bottled water ($p = 0.99$). The F concentration in the bottled water ranged between 0.06 and 3.0 ppm with a mean of 0.8 ppm (±0.88); 62.5 % of the samples had F levels of less than 0.7 ppm, a minority (9.4 %) had levels between 0.7 and 1.2 ppm, and 28.1 % had F levels more than 1.2 ppm F. Notably, of the eight brands (25 %) which had levels that ranged from 1.89 to 3.0 ppm, seven had been produced in Saudi Arabia.

Amongst the 19 (59.38 %) brands of bottled water that displayed the F levels on their labels, only one brand, "Hania" recorded the exact F level as displayed. There was a disparity in the measured levels of F and those printed by the manufacturer (Table 1). The paired sample t test showed that this difference was statistically significant ($p < 0.0001$).

Only three of the 32 tested brands (9.38 %) were locally produced in Qatar, and nine were produced in Saudi Arabia, eight in the UAE, four in France, and three in Lebanon (Table 1). The ANOVA test (Table 2) showed a statistically significant difference in the F levels of brands produced in different countries ($p < 0.001$). When the Bonferroni multiple comparisons test was performed, it was found that the Saudi Arabia-produced brands had significantly higher levels of F than those produced in Qatar, UAE, and Lebanon (Table 3). The F concentrations of the bottled water which were produced in Saudi Arabia ranged from 0.8 to 2.26 ppm with a mean value of 1.86 ppm

Table 1 The 32 bottled waters collected from markets in Qatar

Country of origin	Brand name	F on label (ppm)	Measured F [mean ± SD] (ppm)
Saudi Arabia	Aloyoun	0.8	1.97 ± 0.047
	Al-Qassim	0.95	2.01 ± 0.032
	Baby Water	0.1	1.4 ± 0.036
	Hada	0.8	2.26 ± 0.053
	Hana	0.85	1.91 ± 0.081
	Hania	0.8	0.8 ± 0.042
	Mozn	1.0	2.25 ± 0.061
	Nestle	0.9	2.21 ± 0.028
	Safa	1.0	1.89 ± 0.0
UAE	Al Ain	NS	0.08 ± 0.012
	Aquafina	NS	0.06 ± 0.006
	Dibba	NS	0.08 ± 0.01
	Gulfa	NS	0.08 ± 0.006
	Jeema	0.2	0.23 ± 0.006
	Lulu	NS	0.06 ± 0.015
	Masafi	NS	0.06 ± 0.017
	Viva	NS	0.09 ± 0.01
France	Carrefour	NS	0.19 ± 0.015
	Evian	NS	0.25 ± 0.021
	Vauban	1.3	3.0 ± 0.132
	Volvic	NS	0.57 ± 0.032
Qatar	Al-Manhal	0.9	0.77 ± 0.029
	Aqua-Gulf	<1.0	0.1 ± 0.0
	Rayyan	0.7	0.94 ± 0.017
Lebanon	Rim	0.1	0.4 ± 0.021
	Sannine	0.25	0.28 ± 0.017
	Tannourine	NS	0.23 ± 0.01
UK	Highland	<0.1	0.21 ± 0.017
	Buxton	NS	0.55 ± 0.036
Bahrain	Arwa	<0.01	0.06 ± 0.006
Turkey	Hayawiya	NS	0.28 ± 0.03
Italy	Acqua Panna	<0.1	0.29 ± 0.017

NS not specified

(±0.48). Notably, the labels of all the brands produced in Saudi Arabia had declared F levels, which were lower than the actual measured levels. Further, none of the brands stated the type or source of the water.

Table 2 The F levels in the bottled waters from Qatar according to the country of origin

Country of origin[a]	Number of samples	Mean F ± SD (ppm)
Saudi Arabia	9	1.86 ± 0.48
UAE	8	0.09 ± 0.06
France	4	1.0 ± 1.34
Qatar	3	0.6 ± 0.44
Lebanon	3	0.3 ± 0.09

[a] Countries with less than three products were excluded from the comparison

Table 3 Bonferroni multiple comparison tests to compare the mean F levels of bottled water according to country of origin

Comparison	*p* value
France vs. Lebanon	$p > 0.05$
France vs. Qatar	$p > 0.05$
France vs. Saudi Arabia	$p > 0.05$
France vs. UAE	$p > 0.05$
Lebanon vs. Qatar	$p > 0.05$
Lebanon vs. Saudi Arabia	$p < 0.01$
Lebanon vs. UAE	$p > 0.05$
Qatar vs. Saudi Arabia	$p < 0.05$
Qatar vs. UAE	$p > 0.05$
Saudi Arabia vs. UAE	$p < 0.001$

Discussion

The F levels in the different brands of bottled waters varied widely, from a negligible 0.06 ppm to a very high 3 ppm. This disparity has been noted worldwide in a number of studies that measured F levels in drinking water [19–21, 25–32]. There are many different methods available for the measurement of F concentration. However, F ISE method is considered to be an ideal and scientific approach to measuring F concentration and hence utilized in this study [17, 25–27, 30, 31, 33–38].

The proportion of the bottled water samples that stated the F levels on the label was 60 %—relatively high compared to findings of some other published studies [17, 27, 39, 40]. Less than 5 % of the bottled water in the USA [17, 39] had the F content listed on the labels, while in the UK, up to 32 % of the bottled waters listed the F levels [27, 40]. Contrarily, in Canada, 100 % of bottled water products had the F level listed on the labels [25] since bottled water is regulated under the Food and Drugs Act and Regulations as a food product which mandates that the label should disclose the content and quantity of the constituents of water. Thus, for any bottled water to be commercially available in Canada, all the ingredients must be declared on the label [41]. Likewise, all bottled waters produced in Saudi Arabia had the F levels displayed on the labels [29].

The F levels which were provided by the manufacturers on the labels of bottled waters were significantly lower than those values measured during the course of this investigation. These findings present a challenge for the dentist to plan caries-preventive therapy that would involve F treatment. Also, it would pose a problem to give advice for the prevention of dental fluorosis in children who use bottled water. At best, the levels on the label, if provided, are unreliable. Furthermore, brands which were promoted as being especially manufactured for babies were found to have higher F concentrations than indicated by the producers. Occasionally, some F levels were provided as a range, for instance, "Aqua Gulf," which quoted a very wide range of 0.0 to 1.0 ppm. These types of data are of no value to the dentist, even if the actual level does lie somewhere within the indicated range.

Until 2011, the US Centre for Disease Control and Prevention (CDC) recommended that the amount of F in drinking water should range from 0.7 ppm in warmer climate to 1.2 ppm in cooler climate. Reviews about the drinking habits of children have shown that due to air-conditioning and other factors, children drink similar amounts of water and fluoridated beverages [42]. After years of review and evaluation, the CDC, the US Environmental Protection Agency (EPA), and the US Public Health Service (PHS) recommend the amount of F in drinking water to be 0.7 ppm [43]. Only two tested products, Al-Manhal (0.77 ± 0.029 ppm) and Hania (0.8 ± 0.042 ppm), had F levels close to the recommended value of 0.7 ppm.

The Qatar General Electricity and Water Corporation has set the maximum permissible level of F in drinking water at 1.5 ppm [44]. These values are based on an extensive guidelines set by the World Health Organization (WHO) which recommends that to maximize beneficial effects and minimize harmful effects, the level of F in drinking water should be ideally set between 0.7 and 1.2 ppm with a maximum of 1.5 ppm [45]. Whilst it would regulate the content and quantity of the constituents of bottled drinking water produced locally, the role of the corporation in monitoring and regulating the bottled water produced outside of Qatar is unclear. This explains why all the bottled waters produced in Qatar had F levels less than 1.5 ppm while those bottled water produced elsewhere had F concentration as high as 3.0 ppm. Consequently, those sections of the population who adhere to the brands that have very high levels of F are subject to severe adverse effects of F. Hence, it is vital that all concerned authorities take necessary action to restrict the import and sale of these products.

A study conducted in a single medical complex in Qatar demonstrated that 55.29 % of the 4800 examined patients had dental fluorosis of some degree [46]. Though the present study does not demonstrate a causal relationship between F concentration in bottled water and dental fluorosis, the high prevalence rate of dental fluorosis highlights the need for stricter monitoring of the content of bottled water available in the country.

More than half of samples did not reveal the source of the water, so it was not feasible to analyze the effect of the water type on the F concentration. Furthermore, the levels of F in the samples produced in Saudi Arabia were significantly higher than those produced in Qatar, UAE, or Lebanon. This finding is consistent with the work of Khan and Chohan [29] who tested 21 samples of bottled waters produced in Saudi Arabia and found that approximately 70 % of the samples contained F levels higher than 0.8 ppm. Consequently, it would be advisable to avoid using bottled waters produced in Saudi Arabia for preparing food and drink of young children and infants.

The dental health of children who use bottled water for drinking is affected by the level of F in the water. Appropriate amount of F provides caries-preventive effects, while less than the optimal amount may result in them being deprived of the beneficial effects of F. Conversely, higher than the optimal levels of F could result in dental and/or skeletal fluorosis. The F concentration of drinking water and the age of the patient are the essential factors which should be considered in charting a preventive regime. For a dentist to determine an oral health plan, the brand of the bottled water used by the patient must be known. Parents should be cautioned about the consequences of changing brands.

In the present study, 53 % of the bottled waters in Qatar contained F levels of less than 0.3 ppm, 9.4 % of the bottled

waters contained levels between 0.3 and 0.7 ppm, and 37.6 % of bottled waters had levels of greater than 0.7 ppm. So, most of the waters tested had less than the optimal F content for the prevention of dental caries in children. This finding is consistent with those of previous studies which found that most of the bottled water samples contained less than the optimum F concentration [19–21, 25, 27–29].

The differences in the F level of the different brands have implications on the dental health of infants and children. The primary source of nutrition and systemic F for infants is milk. Whilst breastfeeding is recommended for all infants, formula milk is still an option to replace breast milk. The wide variations in F levels found in bottled waters have ramifications for infants who are fed with powdered formula milk prepared using bottled water. When the infant formula concentrate is mixed with the fluoridated water and used as the primary source of nutrition, the resultant high F levels may increase the risk for developing fluorosis.

In the present study, "Baby Water," which was promoted as being especially produced for babies, contained F at a level well above that recommended for infants (1.4 ppm). Hence, if a parent used this product for the preparation of formula milk and concentrated drinks for their infant, the amount of F ingested from this mixture would accentuate the deleterious effect of excessive F intake.

The contents of bottled waters should be accurately displayed on the label so that parents can control the F intake of their child and avoid giving a greater than optimum dose of F. Furthermore, stricter regulations by the concerned administrative authorities seem to be needed to implement this and to make it an essential requirement for all bottled waters.

Conclusions

Majority of the bottled waters available in Qatar had F levels below the optimum level needed for the prevention of dental caries; 62.5 % of the samples had concentration of less than 0.7 ppm. Conversely, 28 % of the bottled water contained very high levels of F, more than 1.2 ppm. There was a significant disparity between the F levels stated by the manufacturer on the bottle label and the values measured during the investigation. Bottled waters produced in Saudi Arabia had high F levels, with a mean F level of 1.86 ppm.

Acknowledgments None.

Compliance with Ethical Standards

Funding The authors did not receive any funding for the project.

Conflict of Interest The authors declare that they have no conflicts of interest.

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