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Fluoride Concentration in Tap Water from Different Regions in Thailand

Konsentrasi Fluoride dalam Air Keran dari Berbagai Daerah di Thailand

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Abstract

Fluoride supplementation in drinking tap water is one of the well-known effective methods for dental caries prevention. However, overexposure to fluoride following excessive fluoride intake from drinking water leads to dental fluorosis. Therefore, the assessment of daily fluoride consumption is required to calculate the optimal fluoride intake. The present study investigated the fluoride concentration in tap water collected from different areas in Thailand. A total of 27 locations were selected. Three samples of tap water (500 mL each) were independently collected from one location. Each sample in the same location was collected from the same faucet of tap water and stored in different containers. The samples were collected by dental students or dentists who worked in the selected areas from March 2020 to June 2020. Briefly, the faucet was cleaned with the tap water and the water was run from the faucet for 1-2 mins. Then, water was collected in 500 mL bottles and immediately capped. Samples were then stored at room temperature in tightly sealed bottles until analysis. Findings showed that most samples contained fluoride at a concentration lower than 0.7 mg/mL. Further, the water pH was in the range of 6.81-8.37. These levels were lower than the cut-offs established by the World Health Organization (WHO) for maximum levels of fluoride and pH in drinking water. In conclusion, the present study demonstrated that fluoride levels in tap water from different regions in Thailand are lower than those recommended by WHO for fluoride levels in drinking water.

Keywords: fluoride; water; pH; fluorosis; dental

Abstrak

Suplementasi fluoride dalam air minum keran merupakan salah satu metode yang paling efektif untuk pencegahan karies gigi. Namun, paparan fluoride yang berlebihan setelah asupan fluoride yang berlebih dari air minum menyebabkan terjadinya fluorosis pada gigi. Oleh karena itu diperlukan penilaian konsumsi harian untuk menghitung asupan fluoride yang optimal. Penelitian ini menyelidiki tentang konsentrasi fluoride dalam air keran yang dikumpulkan dari berbagai daerah di Thailand. Sebanyak 27 lokasi dipilih. Tiga sampel air keran (masing-masing 500ml) dikumpulkan secara independen dari satu lokasi. Setiap sampel dilokasi yang sama dikumpulkan dari keran air keran yang sama dan disimpan dalam wadah yang berbeda. Pengambilan sampel dilakukan oleh mahasiswa kedokteran gigi atau dokter gigi yang bekerja di wilayah terpilih sejak Maret 2020 hingga Juni 2020. Prosedur yang dilakukan, kran dibersihkan dengan air keran dan kemudian air dialirkan kedalam keran selama 1-2 menit. Kemudian, air ditampung dalam botol 500 mL dan segera ditutup. Sampel kemudian disimpan pada suhu kamar dalam botol tertutup rapat sampai saat analisis. Hasil penelitian menunjukkan bahwa sebagian besar sampel mengandung fluoride pada konsentrasi lebih rendah dari 0,7 mg/mL. Sedangkan pH air berada pada kisaran 6.81-8,37. Tingkat ini lebih rendah dari batas yang ditetapkan oleh Organisasi kesehatan Dunia (WHO) untuk tingkat maksimum fluoride dan pH dalam air minum. Kesimpulan, penelitian ini menunjukkan bahwa kadar fluoride dalam air keran dari berbagai daerah di Thailand lebih rendah daripada yang direkomendasikan oleh WHO untuk kadar fluoride dalam air minun.

Kata kunci : fluoride; air; fluorosis; gigi.

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INTRODUCTION

Fluoride is a well-known chemical element for dental caries prevention since it enhances enamel remineralization, attenuates demineralization, and contains antibacterial activity [1]. Professional use of fluoride includes oral fluoride systemic supplementation and fluoride varnish applications [1,2]. In addition, topical fluoridated products such as toothpaste and mouthwash are recommended for home use to prevent caries [1-3]. In addition, fluoridated water in local communities is another approach utilized to reduce the risk and incidence of dental caries in many countries [1,4]. The addition of fluoride to the water supply has been reported as an effective protocol to prevent dental caries [5]. Caries incidence in communities that are supplied fluoridated water is lower than the others with no fluoridation [6,7]. In this regard, a study indicated that the caries prevention effect of fluoridated water was more prominent in primary dentition [6]. In permanent dentition, water fluoridation can also reduce caries prevalence. However, the systematic review and meta-analysis indicated that water fluoridation had a higher impact on caries prevention in the primary dentition [8]. The lack of water fluoridation is associated with the increase in severity and prevalence of dental caries [7]. The majority of dentists and medical practitioners perceive and agree that community water fluoridation may benefit caries prevention [9]. However, the perception of whether drinking water is properly fluoridated to prevent caries remains a concern [9]. A report demonstrated that only 33% of parents in Qatar allowed their children to consume fluoridated tap water even though they knew the benefit of fluoride in the prevention of tooth decay [10]. This could be due to the misunderstanding and unproven concerns concerning water fluoridation [10]. In Thailand, fluoride in the water is naturally derived and not through public water fluoridation approaches [11]. A milk-fluoridation public policy program was implemented in Thai schools since 2000 for 3- to 12-year-old children and this program was proved to be a cost-effective intervention for dental caries prevention [12]. However, such a milk-fluoridation program was discontinued.

Despite the positive influence of fluoride on tooth decay, it has been demonstrated that excessive fluoride intake leads to a marked increase in dental fluorosis [13]. Optimization of fluoride concentration in community tap water could control the prevalence rates of both tooth decay and dental fluorosis [14]. In this regard, the decrease of fluoride concentration from 0.7 ppm to 0.5 ppm could decrease the incidence of dental fluorosis while effectively preventing dental caries in investigated target groups [14]. Risk factors for dental fluorosis include early weaning, dietary fluoride supplementation, fluoridated toothpaste swallowing, fluoridated milk, and soft-drink consumption as well as community water fluoridation [13]. It has been shown that dental fluorosis risk is associated with fluoride intake during the age of 2-8 years old [15]. In vitro studies have shown that ameloblasts are sensitive to fluoride. In terms of cellular mechanisms, fluoride-induced apoptosis and oxidative stress reduced the expression of a gene associated with amelogenesis imperfecta (Fam83h) in ameloblasts [16-18]. Further, fluoride bound to enamel matrix protein can result in compromised crystal growth [19]. Fluoride exposure during secretory and maturation stages caused more severe enamel defects [20]. Hence, the control of fluoride consumption and modified fluoride exposure could be a crucial approach to manipulate the risk of both dental caries and fluorosis. In Thailand, urban communities are supplied with municipal water. Only a few rural communities use underground and rainwater. The pH of water affects tooth structure and morphology. A pH lower than 5.5 and 6.8 results in the erosion of enamel and root dentin, respectively.

Nowadays, tap water is a common source for household consumption even in urban areas. The present study investigated the fluoride concentration and pH in tap water collected from different areas in Thailand. The information from this study could be employed by dental personnel to safely calculate the optimal fluoride supplementation for high-caries risk individuals in those local areas.

MATERIALS AND METHODS

Municipal tap water was collected from central, northern, northeastern, southern, and eastern regions of Thailand (Fig. 1). A total of 27 locations were selected. Three samples of tap water (500 mL each) were independently collected from one location. Each sample in the same location was collected from the same faucet of tap water and stored in different containers. The samples were collected by dental students or dentists who worked in the selected areas from March 2020 to June 2020. Briefly, the faucet was cleaned with the tap water and the water was run from the faucet for 1-2 mins. Then, water was collected in 500 mL bottles and immediately capped [21]. Samples were then stored at room temperature in tightly sealed bottles until analysis [22].

Fluoride content was examined by a fluoride ion selective electrode (Versa Star, USA) [23]. Fluoride standard solution was employed as a reference for calibration. TISAB III solution was mixed with the sample at a 1:10 ratio. pH measurement was examined using pH meter [24]. A standard solution was employed for pH calibration. Each sample was evaluated three times by fluoride ion selective electrode and pH meter. The elec-

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trodes were rinsed three times with deionized water and dried before and after each measurement. The fluoride concentration was averaged from three independent samples collected at the same location.

Descriptive analysis of the data was conducted using Prism 8 (GraphPad Software, CA, USA). Average values were calculated from triplicate measurements for each sample. Then, the mean and standard deviation were calculated for each location.

RESULTS

In all collected tap water samples, fluoride concentrations were between 0.043 to 0.671 mg/L and pH values ranged from 6.81 to 8.37 (Table 1). There was no relation between pH values and fluoride concentration in the examined samples. Each sample was measured three times, and the difference in measured fluoride and pH values ranged from 0-0.012 and 0-0.04, respectively. Fluoride concentration in tap water measured in different regions did not have any marked difference. Two locations in Saraburi province (Sao Hai district and Wang Muang district) exhibited marginal fluoride levels close to guidelines established by Thailand's public policies. Wang Muang district and Sao Hai district in the Saraburi province had 0.671±0.0002 and 0.635±0.005 mg/L of fluoride, respectively.

DISCUSSIONS

In their guidelines, the WHO suggested a fluoride intake from drinking water at the concentration of 1.5 mg/L [25-27]. This value was based on the assumption that individuals have on average a 60 kg body weight and a 2L/day water intake [25-27]. High fluoride intake (with levels higher than 1.5 mg/L) appears to increase the risk of dental fluorosis. For countries located in tropical regions, the 0.8 mg/L fluoride concentration was set in the WHO guideline due to the potentially high volume of water consumption was seen in tropical climates [26,27]. However, Thailand's guideline is set at 0.7 mg/L for water fluoride intake daily (assuming 2L/day for a 60 kg weight person) [25,28].

For qualified drinking water, WHO guidelines indicate that the pH should range between 6.5 and 9.5 [29]. The pH of drinking water below or above the levels had corrosive effects on human tissues. All samples in the present study showed a pH within the range of those recommended by WHO for drinking water.

Among the different community locations, tap water at Wang Muang district and Sao Hai district in the Saraburi province exhibited relatively moderate fluoride levels. Wang Muang district and Sao Hai district had 0.671±0.0002 and 0.635±0.005 mg/L of fluoride, respectively. These concentrations of fluoride were near those cut-offs suggested in Thailand's public policy guidelines. The raw water source was not identified in this study and the samples were collected only at a one-time point from one water outlet. Hence, further extensive water collections and investigations should be performed to confirm the fluoride levels in those locations. These would be deemed necessary to study for example the source identification of raw water and seasonal effects on fluoride concentration. Tap water from the other sources in the present study had fluoride concentrations much lower compared to the cut-offs suggested in Thailand's public policy.

Despite those aforementioned locations, the remainning water samples from other regions and districts of Thailand had fluoride levels in tap water within the normal range (markedly below 0.7 mg/L). Fluoride concentrations found in this study were comparable to those published previously [30-32]. A study in Morocco showed the mean fluoride value was 0.94 mg/L in tap water [30]. Fluoride concentration was detected at a concentration lower than 0.81 mg/L in the water supply of the tropical region of Piaui State in Brazil [31]. The mean fluoride levels in tap water from Mexico City and Veracruz was 0.20 mg/L [32]. The fluoride in municipal water supply in other Asian developing regions such as Nepal was on average 0.09 mg/L [33]. This concentration was lower than those detected in natural water resources [33]. Taken together, the tap water in several regions and districts in Thailand exhibited safe values of fluoride in tap water that minimize the risk for dental and/or skeletal fluorosis.

One limitation of the present study is that source information was lacking. Tap water was collected from faucets without the data of water resources i.e. underground water, rainwater, or surface water, etc. The depth of the water wells was also not collected. Thus, the interpretation of our results must be carefully performed. Despite these limitations, there was no evidence of high fluoride content in the examined samples that surpassed cut-offs established by policy guidelines in Thailand.

In the northern part of Thailand, high fluoride concentration was reported in the drinking water resource of Chiang Mai and Lamphun province [34]. Tap water from village waterworks in the northern part of Thailand utilized underground water as a water resource. This tap water had a high fluoride concentration (5.94 ± 0.29 mg/L) compared with tap water from private wells (0.7 ± 0.05 mg/L) [25]. In urban communities in Thailand, people seldomly consume water directly from the tap. Thai residents usually employ tap water treatment tech-

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niques prior to drinking (for example by boiling or via filtration and/or purification systems). However, Thai individuals usually use raw tap water for cooking. To note that boiling alone does not affect the levels of fluoride in water, even if fluoride concentrations are increased due to the reduction of water volume [35]. However, suspended brushite and calcite in fluoridating water followed by a boiling step was proved to effectively reduce the fluoride concentration in tap water [36]. Interestingly, this method could be a simple and relatively low-cost technique for defluoridation of drinking water. In communities that exhibit high fluoride content in groundwater, a study showed that the implementation of reverse osmosis in tap water can be an affordable approach to reduce fluoride consumption from cooking and drinking with tap water [25], minimizing the risk for dental fluorosis. However, water treatment prior to consumption is not available in certain rural areas in Thailand. Therefore, the risk of high fluoride water intake on oral health must be communicated to locals by dental practitioners and authorities.

Despite the concern of overconsumption of fluoride from tap water in some areas, one must acknowledge that an optimal fluoride concentration in tap water is an effective procedure to control dental caries at a community level [1,5,14]. Hence, a survey of fluoride concentration in different water sources used for consumption (including tap water and bottled water) should be widely and regularly implemented. A study done in Mexico reported that fluoride concentrations in tap water but not in bottled beverages are not correlated with the severity of dental fluorosis [37]. Another study from the Gaza Strip demonstrated that the main source of total daily fluoride consumption in children is primarily eating foods followed by drinking beverages [38]. Hence, other sources of fluoride have to be taken into consideration to determine the total daily intake at each community level.

In conclusion, the present study demonstrated that fluoride levels in tap water from a different region in Thailand were lower (<0.7 mg/L) than those recommended by WHO for fluoride levels in drinking water. This information could be useful to calculate the optimal fluoride supplementation for those individuals in need, particularly the ones with high caries risk. Future investigations should be performed to establish standard protocols and public health policies to regularly quantify the fluoride levels in tap water and their contribution to the total daily fluoride intake. These protocols and policies would allow oral health care practitioners to consistently and safely calculate the optimal fluoride supplementation for each local community, particularly for individuals with high caries risk.

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TABLES

Table 1. Fluoride concentration and pH of tap water from five regions of Thailand

Province	District	Fluoride (mg/L)		pH	
		X	SD	X	SD
Central Region					
Nakhon Sawan	Mueang	0.125	0.001	7.800	0.003
Phetchabun	Lom Sak	0.102	0.001	8.200	0.006
Saraburi	Sao Hai	0.671	0.000	7.470	0.004
Saraburi	Wang Muang	0.635	0.005	7.540	0.008
Saraburi	Nong Khae	0.161	0.001	8.080	0.000
Saraburi	Ban Mo	0.180	0.000	7.800	0.004
Saraburi	Muak Lek	0.089	0.001	8.010	0.016
Ang Thong	Chaiyo	0.196	0.000	8.110	0.010
Sing Buri	Phrom Buri	0.235	0.011	7.740	0.002
Lop Buri	Mueang	0.126	0.000	8.010	0.007
Phra Nakhon Si Ayutthaya	Maha Rat	0.107	0.001	7.990	0.000
Bangkok	Pathumwan	0.157	0.002	7.870	0.013
Northern Region					
Chiang Rai	Mueang	0.157	0.001	7.770	0.010
North-eastern Region					
Ubon Ratchathani	Muang Sam Sip	0.134	0.000	8.370	0.000

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Ubon Ratchathani	Det Udom	0.043	0.004	7.300	0.002
Si Sa ket	Rasi Salai	0.136	0.002	7.010	0.007
Roi Et	Mueang	0.198	0.002	7.300	0.004
Nakhon Ratchasima	Pak Chong	0.110	0.008	7.950	0.081
Nakhon Ratchasima	Pak Chong Nong Nam Daeng	0.075	0.004	7.370	0.010
Southern region					
Nakhon Si Thammarat	Pak Phanang	0.081	0.001	6.810	0.011
Songkhla	Hat Yai	0.109	0.001	7.480	0.000
Eastern Region					
Sa Kaeo	Mueang	0.190	0.001	7.990	0.007
Prachin Buri	Kabin Buri	0.149	0.000	7.800	0.008
Chachoengsao	Phanom Sarakham	0.150	0.000	7.500	0.004

FIGURES

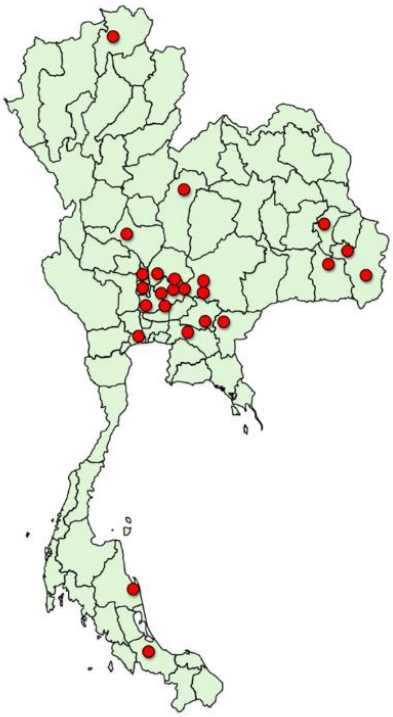

Figure 1. The Thailand map illustrated the locations included in the study.

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