FLUORIDE IN WATER CONSUMED BY CHILDREN IN REMOTE AREAS OF THAILAND

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Abstract. The objective of this study was to analyze fluoride content in water for drinking and for use in remote areas of Thailand. Water was sampled from schools and villages along the border by Multiple Stratified Cluster Random Sampling. Fluoride levels of 214 water samples from 48 schools and 48 villages were assessed in triplicate by fluoride ion electrode. The fluoride content in different regions and types of water were statistically analyzed by Kruskal-Wallis test at a significance level of 0.05. Results showed that fluoride in drinking water and water for use from the schools and villages were 0.01-0.37 ppm, 0.01-0.19 ppm, 0.01-0.87 ppm and 0.01-0.92 ppm, respectively. There was no difference in fluoride content in drinking water from various regions (p=0.23). However, there was a statistical difference in fluoride level in water for use (p=0.04, p=0.01) in various regions. The highest fluoride content was found in samples from the central and eastern region (0.19±0.24 ppm and 0.29±0.28 ppm respectively). When comparing types of water, *ie* ground water, surface water and rain water, there were differences in fluoride content (p=0.00). Underground water had the highest fluoride content (0.31±0.23 ppm).

INTRODUCTION

Dental caries is still a significant dental health problem in Thailand (Dental Health Division, 1994). It is generally accepted that using fluoride is effective for the prevention of dental caries. The important mechanisms of caries prevention are enhancement of remineralization, inhibition of demineralization and formation of fluorapatite, which increases resistance to caries formation (Ripa *et al*, 1986). Optimally fluoridated water (0.6 ppm) can decrease the incidence of dental caries by 50-70% and is considered the best measure for caries prevention (Ismail, 1994; Mathewson and Primosch, 1995). The American Dental Association recommended fluoride supplement in the case of inadequate fluoride in drinking water. The dosage of supplemental fluoride depends on the fluoride content of the water, age and medical history of the child, in order to prevent any excessive intake of fluoride and toxicity. Excessive fluoride intake for a long period causes chronic toxicity in bones and teeth, of which dental fluoride is the most common (Weeks *et al*, 1993; Lalumandier and Rozier, 1995). Currently, supplemental fluoride has been adjusted to reduce the chronic toxicity of fluoride. In areas where fluoride in drinking water is less than 0.3 ppm, the recommendation was changed from starting supplemental fluoride at birth, to starting at 6 months of age. During the period 6 months - 3 years of age the child should consume 0.25 mg/day. Supplemental fluoride at a dose of 0.50 mg was recommended for children aged 3-6 years, rather than being previously recommended for 2-3 years. A dose of 1 mg was recommended for children aged more than 6 years, rather than 3 years. If fluoride in drinking water were 0.3-0.6 ppm, supplemental fluoride should begin at 3 years of age and only half of the dose recommended for fluoride content less than 0.3 ppm should be used (AAPD, 1999-2000).

Fluoride contents were different among regions and types of water. Songpisal *et al* (1983) studied water in Bangkok between March 1978 and February 1979. They found the average fluoride content in tap water was 0.12±0.04 ppm. The level varied seasonally, reaching a minimum in summer and gradually increasing to reach a peak in mid-winter. In addition, they found that the fluoride content of ground water ranged from 0.12-0.32 ppm, which was higher than tap water (Songpisal *et al*, 1983). In the National Dental Health Survey in 1994, fluoride content was measured from water samples and revealed values of less than 0.1 to 2.86

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ppm (Dental Health Division, 1994). In remote areas of Thailand there are reduced chances of access to dental services due to the difficulties of transportation. Preventive dental measures planning at the community level seems to be very important. Supplement of fluoride in drinking water is difficult since there are many sources of drinking water. In addition, water used for food preparation is one source that children may consume. Therefore, analysis of fluoride in water is important for providing baseline data for preventive dental measure planning in remote areas. The objective of this study is to analyze the fluoride content of water in remote areas of Thailand.

MATERIALS AND METHODS

Sources of water

We sampled water for drinking and for use from schools and villages located in remote areas along the border of Thailand (Fig 1). Forty-eight Schools in 37 provinces of Thailand were sampled from 173 schools which are under the jurisdiction of the Department of Border Patrol Police using Multiple Stratified Cluster Random Sampling. The villages were where the schools were located. Sixty milliliters of water were collected and the sources of water were recorded during the period 19 July and 8 October 1999.

Analysis of fluoride content

Fluoride content was measured by adding adjustment buffer (TISAB III) to the water sample at a ratio of 1:10 to provide constant ionic strength, decomplex fluoride and adjust pH. Free fluoride ion content was read by fluoride electrode (Orion Model 96-04,96-09) which was directly attached to an ion analyzer (ORION Model 940, ORION, USA). Each sample was measured in triplicate and the accuracy of measurement was evaluated each day by measuring a standard solution before and after performance.

Statistical analysis

Fluoride content was statistically analysed and compared using the Kruskal-Wallis test at a significance level of 0.05.

RESULTS

Sources of water

A total of 214 samples of water was collected from various sources in remote areas of Thailand, as shown in Table 1. Among these, 50 samples were drinking water collected from schools and 49 drinking water samples collected from villages. Sixty-five samples and 50 samples were water for use collected from schools and villages, respectively. Most of the water for drinking both in schools (82.0%) and villages (71.4%) was rain water. Less common sources of drinking water in schools were mountain tap water (6.0%), village tap water (6.0%), well water (2.0%), ground water (2.0%) and pond water (2.0%). Other sources of drinking water in villages were mountain tap water (16.3%), well (8.2%) and canal or stream (4.1%). Water for use came from many sources, *ie* in schools they used rain water (29.2%) and mountain tap

Table 1
Sources of water in schools and villages.

Water source	Drinking water		Water for use	
	School No. (%)	Village No. (%)	School No. (%)	Village No. (%)
Rain	41 (82.0)	35 (71.4)	19 (29.2)	5 (10.0)
Tap water (mountain)	3 (6.0)	8 (16.3)	17 (26.2)	16 (32.0)
Tap water (village)	3 (6.0)	-	9 (13.8)	11 (22.0)
Well	1 (2.0)	4 (8.2)	4 (6.2)	9 (18.0)
Ground water	1 (2.0)	-	5 (7.1)	3 (6.0)
Pond	1 (2.0)	-	6 (9.2)	-
Canal/stream	-	2 (4.1)	5 (7.7)	6 (12.0)
Total	50	49	65	50

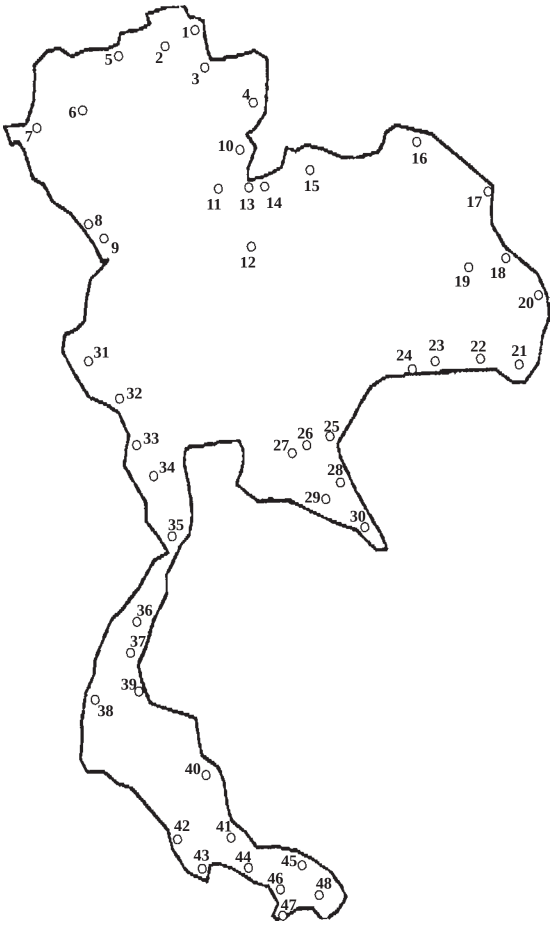

Fig 1–Locations of water samples.

No	Name of School	District	Province
1	Bamrung 87	Mae Faluang	Chiang Rai
2	Ban Doi Lan	Mae Suai	Chiang Rai
3	Betty Dumen	Pong	Phayao
4	Pirayanukhro 3	Mae Charim	Nan
5	Hiangthai Thamrong	Mae Ai	Chiang Mai
6	Ban Mae Long	Mae Chaem	Chiang Mai
7	Ban Mae La-ngiu	Mae La Noi	Mae Hong Son
8	Suksasongkhro 2	Mae Sot	Tak
9	Ban Mo-Koe	Phop Phra	Tak
10	Bun Tham-Bun Phring	Ban Khok	Uttaradit
11	A-Thon Uthit	Nakhon Thai	Phitsanulok
12	Ban Pongtabak	Chon Daen	Phetchabun
13	Ban Na-Po	Na Haeo	Loei
14	Chaloemratbamrung	Dan Sai	Loei
15	Ban Huaiwiang-ngam	Nayung	Udon Thani
16	Ban Huaidokmai	Bung Kan	Nong Khai
17	Ban Hat sai-pe	Tha Uthen	Nakhon Phanom
18	Ban Pakho	Chanuman	Amnat Charoen
19	Ban Si Sawat	Loeng Nok Tha	Yasothon
20	Ban Pak La	Khong Chiam	Ubon Ratchathani
21	Ban Pa Mai	Buntharik	Ubon Ratchathani
22	Ban Nongyai	Kantharalak	Si Sa Ket
23	Ban Tatum	Sangkha	Surin
24	Ban Khoksalaeng	Phanomdongrak	Surin
25	Pracharatbamrung	Aranyaprathet	Sa Kaeo
26	Ban Wangsithong	Wang Nam Yen	Sa Kaeo
27	Ban Na-Isan	Sanam Chai Khet	Chachoengsao
28	Ban Nongbon	Soi Dao	Chanthaburi
29	Ban Hangmaeo	Kaeng Hang Maeo	Chanthaburi
30	Ban Thakum	Muang	Trat
31	Wichitwittayakhan	Thong Pha Phum	Kanchanaburi
32	Hengkelthai	Sai Yok	Kanchanaburi
33	Ban Thamhin	Suan Phung	Ratchaburi
34	Na-re-suanbanhuaisok	Kaeng Kra Chan	Phetchaburi
35	Ban Khaochao	Pranburi	Prachuap Khiri Khan
36	Ban Tha Lanthong	Tha Sae	Chumphon
37	Ban Khuan Samuk-kee	Sawi	Chumphon
38	Ban Naiwong	La-un	Ranong
39	Ban Koh-toei	Tha Chana	Surat Thani
40	Ban Khaowang	Ronphibun	Nakhon Si Thammarat
41	Ban Khuannokwa	Pak Phayun	Phatthalung
42	Santiratprachabamrung	Palian	Trang
43	Ban San Daeng	Khuan Ka Long	Satun
44	Su-Muanchonkeera	Sadao	Songkhla
45	Pirayanukhro 4	Mayo	Pattani
46	SangWanwit 4	Than To	Yala
47	Sutantanonchalupp	Betong	Yala
48	Ban Tu-ngo	Si Sakhon	Narathiwat

water (26.2%) and in the villages, they used mountain tap water (32.0%) and village tap water (22.0%).

Fluoride content

The fluoride content of drinking water from schools ranged from 0.01-0.37 ppm, while water for drinking in villages contain 0.01-0.19 ppm of fluoride (Table 2). The maximum level of fluoride was found in a drinking water sample from Piriyanukroh School in Mayo district of Pattani Province. A water sample from Koh Tei village in Tha Chana district, Surat Thani Province had the highest fluoride content. The maximum levels of fluoride in water for use from schools and villages were 0.87 and 0.92 ppm, respectively as shown in Table 2, and were from Hengkel Thai School, and

Table 2
Water fluoride content in 115 samples collected from schools and 99 samples from villages.

Place	Fluoride content in drinking water (ppm)			Fluoride content in water for use (ppm)		
	Min	Max	Mean±SD	Min	Max	Mean±SD
School	0.01	0.37	0.04±0.06	0.01	0.87	0.10±0.14
Village	0.01	0.19	0.04±0.04	0.01	0.92	0.13±0.19

Table 3
Water fluoride content in remote areas of different regions.

Condition	Fluoride content (ppm)				
	Central and east	Northeast	North	South	p-value
Drinking water (school)					
No. of samples	12	14	12	12	
F content (min)	0.01	0.01	0.01	0.01	
F content (max)	0.13	0.14	0.37	0.03	
Mean±SD	0.04±0.04	0.05±0.05	0.05±0.11	0.02±0.01	0.23
Drinking water (village)					
No. of samples	11	12	13	13	
F content (min)	0.01	0.01	0.01	0.01	
F content (max)	0.12	0.11	0.16	0.19	
Mean±SD	0.04±0.04	0.03±0.03	0.06±0.05	0.04±0.05	0.23
Water for use (school)					
No. of samples	15	17	18	15	
F content (min)	0.02	0.01	0.01	0.01	
F content (max)	0.87	0.18	0.34	0.37	
Mean±SD	0.19±0.24[a]	0.05±0.04	0.08±0.08	0.09±0.12	0.04
Water for use (village)					
No. of samples	11	12	13	14	
F content (min)	0.02	0.02	0.03	0.01	
F content (max)	0.92	0.18	0.37	0.73	
Mean±SD	0.29±0.28[a]	0.07±0.05	0.10±0.09	0.11±0.19	0.01

[a]significant difference

Mackeyo village Sai Yok district, Kanchanaburi Province. Water for use that had a fluoride content greater than 0.5 ppm was found in samples from Banna Isan School (0.58 ppm) in Samam Chaikhet district, Chachoengsao Province and from Sutantanont village (0.73 ppm) of Betong district, Yala Province.

When the water fluoride content was considered by region, the eastern region was included in the central region since there were only 2 schools in remote areas of the eastern region. The number of water samples for drinking and for use collected from schools and villages in remote areas of the central, northeast, north and south of Thailand are shown in Table 3. There was no difference in fluoride content when comparing drinking water in schools and villages from various regions (p=0.23), but there was a statistical difference where water samples for use from schools (p=0.04) and from villages (p=0.01) were compared.

There was a significant difference (p=0.04) when comparing the total fluoride content in water from various regions (Table 4). Water collected from the central region, which also includes schools in the eastern region, had the highest fluoride level of 0.92 ppm compared to 0.32, 0.37 and 0.73 ppm

Table 4
Fluoride content in water samples from different regions (p=0.04).

Region	Number	Minimum	Maximum	Mean±SD
Central and east	50	0.01	0.92	0.133±0.207
Northeast	55	0.01	0.32	0.053±0.058
North	56	0.01	0.37	0.073±0.081
South	53	0.01	0.73	0.068±0.120
Total	214	0.01	0.92	0.081±0.130

Means indicated by different letters showed significant difference.

Table 5
Fluoride content and types of water (p=0.00).

Water types (number)	Fluoride content (ppm)		
	Min	Max	Mean ±SD
Rain water (97)	0.01	0.09	0.03±.03
Surface water (109)	0.01	0.92	0.11±.15
Ground water (8)	0.04	0.65	0.31±.23[a]

[a]significant difference

found in water samples from the northeast, north and south, respectively.

When the 3 types of water, rain water, surface water (including mountain tap water, village tap water, wells, ponds, canal and stream) and ground water, were compared, we found a difference in fluoride content (p=0.00) (Table 5). Ground water contained fluoride 0.04-0.65 ppm, which was higher than other water types. Rain water contained 0.01-0.099 ppm while surface water contained 0.01-0.92 ppm.

DISCUSSION

Our study showed that the water fluoride content of villages and schools in remote areas was 0.01-0.37 ppm, which was lower than the preventive level for caries. When comparing drinking water from each region, there was no significant difference in the fluoride content. The reason may be that most drinking water (82.0% in schools and 71.4% in villages) were rain water, which had low fluoride levels, *ie* 0.01-0.09 ppm. Our study gave the same result as the previously reported values of 0.002-0.02 ppm (Smith and Ekstand, 1996). Children who drank rainwater would gain less fluoride than the recommended level for caries prevention (Dental Health Division, 1998). Since there might be an inadequate amount of rainwater for drinking all year round, in some regions they drink boiled water which was water for use, mostly for a short period in summer.

The maximum fluoride content of water for use in the central and eastern regions was 0.92 ppm, and 0.73 ppm in the southern regions.

When comparing fluoride content in water for use among various regions there were significant differences (Table 3), related to the different sources of water. So it is possible that fluoride in water for use might be different. These findings are in contrast to the comparison of fluoride in drinking water from different regions, which was not significantly different, since most drinking water was rainwater (Table 1). Water for use from the central and eastern region had higher fluoride compared with the other regions, where the highest was from Kanchanaburi and Chachoengsao Provinces. The finding of the present study differs from a previous dicussion, which reported that the northern region had many sources of fluoride mineral, and thus water from this region had high fluoride content (Songpisal *et al*, 1983). When fluoride in various types of water was compared, we found the highest level in ground water, which agreed with the previous study of Songpisal *et al* (1983). In the USA, ground water contained fluoride as high as 76 ppm. In Finland, it had been found to contain 1.0-2.0 ppm. The reason for high fluoride content in ground water was its greater chance of passing into underground mineral sources and its accumulation better than surface water (Smith and Ekstrand, 1996).

Since the fluoride content in water for use was found to be at a higher level than the recommended level (0.5 ppm), this should be taken into consideration when planning preventive dental measures. Considering fluoride in drinking water only may not be enough in planning for fluoride substitution because children might drink various types of water when rainwater is lacking, especially during summer.

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