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; Lalumanandier 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 ppm.
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>
<thead>
<tr>
<th>Water source</th>
<th>Drinking water</th>
<th>Water for use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>School No. (%)</td>
<td>Village No. (%)</td>
</tr>
<tr>
<td>Rain</td>
<td>41 (82.0)</td>
<td>35 (71.4)</td>
</tr>
<tr>
<td>Tap water (mountain)</td>
<td>3 (6.0)</td>
<td>8 (16.3)</td>
</tr>
<tr>
<td>Tap water (village)</td>
<td>3 (6.0)</td>
<td></td>
</tr>
<tr>
<td>Well</td>
<td>1 (2.0)</td>
<td>4 (8.2)</td>
</tr>
<tr>
<td>Ground water</td>
<td>1 (2.0)</td>
<td></td>
</tr>
<tr>
<td>Pond</td>
<td>1 (2.0)</td>
<td></td>
</tr>
<tr>
<td>Canal/stream</td>
<td></td>
<td>2 (4.1)</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>49</td>
</tr>
</tbody>
</table>
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 contained 0.01-0.19 ppm of fluoride (Table 2). The maximum level of fluoride was found in a drinking water sample from Pirayanukhro 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

No | Name of School         | District    | Province     |
---|------------------------|-------------|--------------|
1  | Bamrung 87             | Mae Faluang | Chiang Rai   |
2  | Ban Doi Lan            | Mae Sui     | 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- ngu        | Mae La Noi  | Mae Hong Son |
8  | Sukasongsongkro 2      | Mae Sot     | Tak          |
9  | Ban Mo-Koe             | Phop Phra   | Tak          |
10 | Bun Tham-Bun Phring    | Ban Khok    | Utraradit    |
11 | A-Thon Uthit           | Nakhon Thai | Phitsanulok  |
12 | Ban Pongtabak          | Chon Daen   | Phetchabun   |
13 | Ban Na-Po              | Na Hao      | Loei         |
14 | Chaloemratbamrung      | Dan Sai     | Loei         |
15 | Ban Huaiwart-ngam      | Nayung      | Udorn Thani  |
16 | Ban Huaidokmai         | Bung Kan    | Nong Khai    |
17 | Ban Hat sai-pe         | Tha Uthen   | Nakorn Phanom|
18 | Ban Pakho              | Channuman   | Amnat Charoen|
19 | Ban Si Sawat           | Loeng Nok Tha | Yasothon   |
20 | Ban Pak La             | Khong Chiam | Ubon Rakthathani |
21 | Ban Pa Mai             | Buntharik   | Ubon Rakthathani |
22 | Ban Nongyai            | Kantharalak | Si Sa Ket    |
23 | Ban Tatum              | Sangkha     | Surin        |
24 | Ban Khoksaalaeng       | Phanomdongkrak | Surin      |
25 | Pracharatbamrung       | Aranyapraphet | 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 Hangmao            | 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   | Nakorn Si Thammarat |
41 | Ban Khuanokwa          | Pak Phayun  | Phatthalung  |
42 | Santiraprachabamrung   | Palian      | Trang        |
43 | Ban San Daeng          | Khuan Ka Long | Satun       |
44 | Su-Muanchonkeera       | Sadao       | Songkhla     |
45 | Pirayanukhro 4         | Mayo        | Pattani      |
46 | Sang Wanwit 4          | Than To     | Yala         |
47 | Sutantanonchalepp      | Betong      | Yala         |
48 | Ban Tu-ngo             | Si Sakorn   | Narathiwat   |
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.
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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 Ekstrand, 1996). 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 discussion, 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

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

<table>
<thead>
<tr>
<th>Region</th>
<th>Number</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central and east</td>
<td>50</td>
<td>0.01</td>
<td>0.92</td>
<td>0.133±0.207</td>
</tr>
<tr>
<td>Northeast</td>
<td>55</td>
<td>0.01</td>
<td>0.32</td>
<td>0.053±0.058</td>
</tr>
<tr>
<td>North</td>
<td>56</td>
<td>0.01</td>
<td>0.37</td>
<td>0.073±0.081</td>
</tr>
<tr>
<td>South</td>
<td>53</td>
<td>0.01</td>
<td>0.73</td>
<td>0.068±0.120</td>
</tr>
<tr>
<td>Total</td>
<td>214</td>
<td>0.01</td>
<td>0.92</td>
<td>0.081±0.130</td>
</tr>
</tbody>
</table>

Means indicated by different letters showed significant difference.

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

<table>
<thead>
<tr>
<th>Water types (number)</th>
<th>Fluoride content (ppm)</th>
<th>Min</th>
<th>Max</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain water (97)</td>
<td></td>
<td>0.01</td>
<td>0.09</td>
<td>0.03±0.03</td>
</tr>
<tr>
<td>Surface water (109)</td>
<td></td>
<td>0.01</td>
<td>0.92</td>
<td>0.11±0.15</td>
</tr>
<tr>
<td>Ground water (8)</td>
<td></td>
<td>0.04</td>
<td>0.65</td>
<td>0.31±0.23 a</td>
</tr>
</tbody>
</table>

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.
not be enough in planning for fluoride substitution because children might drink various types of water when rainwater is lacking, especially during summer.

ACKNOWLEDGEMENTS

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