Occurrence of Fluorosis due to Geothermal Sources in a Northern Thailand Subdistrict

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SUMMARY: In northern Thailand, more than 40 hot springs are known and are commonly associated with fluorite deposits. A geological study indicated that the high fluoride concentrations in domestic drinking water originated from geothermal sites and their activities. The purpose of this study was to assess the occurrence of dental fluorosis due to the geothermal sources in the Doi Hang Sub-district, Muang District, Chiang Rai Province in northern Thailand.

Mottled enamel was assessed according to the Deans Index in 304 primary school children, age 6-15 years. In parallel the water quality, including fluoride concentration, was determined for environmental waters and for drinking water. For the analysis quality control the ion balance was checked. Furthermore, the fluoride concentration in affected children was measured.

Environmental waters contained from 0.2 to 18.9 mg F/L. The fluoride concentration appears to be related to the concentration of sodium. The drinking water samples contained from 0.1 to 2.3 mg F/L. The Dean's Community Fluorosis Index was found for the studied area in total to be 0.25. This demonstrates that fluorosis occurs, but not as a major public health problem. However, the most serious cases was found at Ban Pong Na Kham nearby geothermal sources, where the fluoride levels in drinking water and ground water were also high.

Thus the study indicates that occurring fluorosis is related the geothermal sources.

Key words: Dental fluorosis, geothermal site, Chiang Rai province, Thailand, Dean's Index.

INTRODUCTION

Dental Fluorosis. The chronic toxic effect of fluoride ion can be seen in children's teeth. Fluorotoxicosis was reported in Nakorn Chiang Mai Hospital [6]. In the affected area, the concentration of fluoride ion is generally high in the deeper wells. This suggests that the concealed underground fractures or faults, covered by the alluvium are controlling the fluoride ion distribution. Fluoride concentration was also used as a chemical indicator for the direction of concealed fractures in the area [5].

Dental fluorosis is a diffuse symmetric hypo-mineralisation deficiency (irregular calcification) and disorder of ameloblasts (enamel-forming cells). Fluorosis is irreversible and only occurs with exposure to fluoride when the enamel is developing. Secondary incisor teeth start forming as a babies 3-6 months old, molars are

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developed at six to eight years of age and wisdom teeth are formed by 12 years of age [7].

The urinary fluoride level is widely regarded as one of the best indices of fluoride intake. The significance of urinary fluoride concentration varies with individuals and circumstances of intake. Urinary fluoride concentration may fluctuate with variable amounts consumed [8].

Geothermal waters. A geological study indicated that the high concentration of fluoride in the domestic drinking water in northern Thailand was resulted from the intrusion of geothermal water into the groundwater resources. Thus and earthquake could effect the release of fluoride and consequently, could increase the fluoride contents in the groundwater –based domestic water [5].

Man has used geothermal waters since earliest time for a variety of purposes. Hot spring, fumarole and geyser have been known in areas of high geothermal heat flow from underneath. In northern Thailand, more than 40 hot springs have been studied and are known to occur scattered throughout the region [4].

MacDonald *et al* (1977) [1] discussed that fluorite mineralisation is commonly related to the hot springs, and this has been interpreted to be further evidence for a tertiary granitic intrusion events. Numerous hot springs in northern Thailand are commonly associated with the margins of granitic intrusions and/or with major fault zones.

In Muang District Chiang Rai province, the level of fluoride of water in the geothermal well at Ban Pong Na Khum was 37 mg/L [6]. Tambon Doi Hang, Amphoe Muang, Changwat Chiang Rai is in the risk area of geothermal sources and faults. Water resources may therefore be contaminated with fluoride and cause fluorotoxicosis.

Study objective. The objective of the study is to assess the dental fluorosis and the pollution of environmental as well as drinking water with fluoride, probably due geothermal sources.

MATERIALS AND METHOD

Site selection. Thermal water resources at Ban Pha Soet and Ban Pong Na Kham are selected as the main area of the present study. The area covered two geothermal sites and adjacent areas along the Mae Kok river including 4 primary schools, cf. Figure 1.

Purpose of the study. The purpose of the present study was to assess the relation of geothermal sources to the causes of fluorosis at Doi Hang Subdistrict, Muang District, Chiang Rai Province, Northern Thailand.

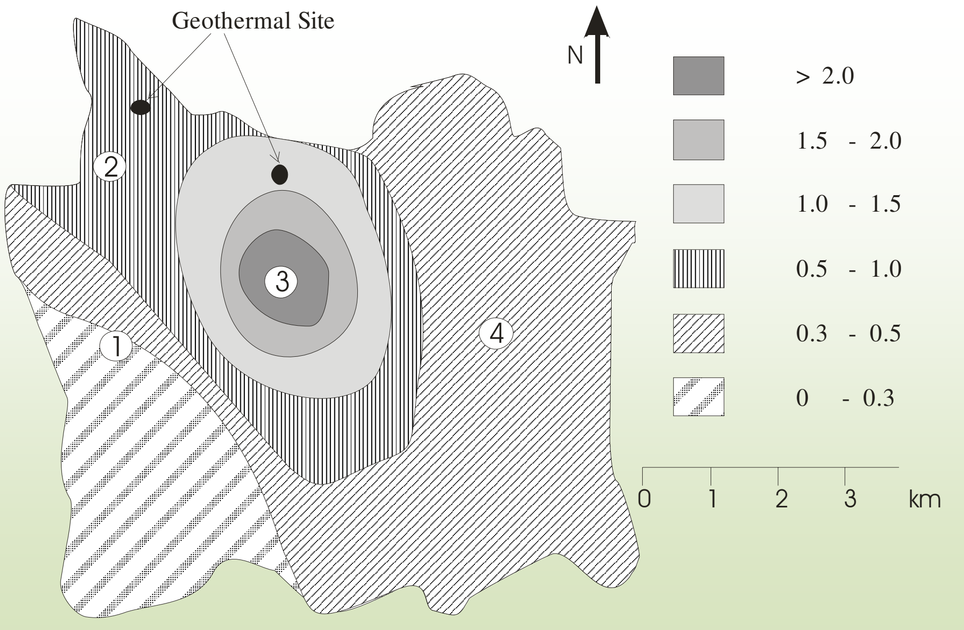

FIGURE 1. Map of the studied Doi Hang sub-district, indicating the fluoride concentrations in mg/L of the drinking water consumed by the school children.

Sampling. Water samples were collected in the rainy season during June- September 1999 and in the dry season during November-December 1999. For the cation analyses Approximately 500 mL water samples for detecting cation elements were preserved with 1 % nitric acid. Another 1000 mL sample was taken without acid preservation for anion analysis. School children drinking water samples were collected only from drinking water of positive mottled enamel children.

The investigation of mottled enamel among school children age 6-15 years old from 4 primary schools was performed by a dentist with the assistance of the Chiang Rai Dental Health Center. The presence of mottled enamel of all permanent incissors and first molars, using FI (fluorosis index of Dean,1934)

Analysis. Cations viz. Ca, Mg, Na, K, Fe, and Mn were measured using an atomic absorption spectrophotometer (AAS, PE 2830). Alkalinity and acidity were measured by titration. Fluoride was measured using an ion selective electrode. pH and conductivity were measured by pH meter and conductivity meter respectively. Sulphate and nitrate were analysed using spectrophotometer with reagent power pillows. The determination of chloride was performed by argentometric titration. All analyses were carried out in the Geochemical Laboratory at the Geological Science Department, Faculty of Science, Chiang Mai University. In all cases the procedures of the Standard Method for the Examination of Water and Wastewater (APHA, 1992) were followed.

Data analysis and interpretation. The interpretation of samples that determined by AAS using " AF. EXE" according to Prewett and Promphutha, 1999 [2].

Quality control. The ion balance was checked as a quality control of the data. The difference between the sum of cation equivalents and the sum of anion equivalents was tolerated at a level of maximum 5 %. The formula being as follow is:

$$\frac{(\,\Sigma\ \text{m eqv Anions}\ +\ \Sigma\ \text{m eqv Cations}\,)\ \cdot\ 100}{\Sigma\ \text{m eqv Anions}\ +\ \Sigma\ \text{m eqv Cations}} \leq 10\ \%$$

TABLE 1. The studied sites and the found occurrence of fluorosis in terms of Dean's Index.

Site	Persons	Normal 0 No	Normal 0 %	Trace 0.5 No	Trace 0.5 %	V. mild 1 No	V. mild 1 %	Mild 2 No	Mild 2 %	Moderate 3 No	Moderate 3 %	Severe 4 No	Severe 4 %	Dean CFI
1	68	51	75.0	7	10.3	10	14.7	0	0	0	0	0	0	0.20
2	80	61	76.3	9	11.3	7	8.8	3	3.8	0	0	0	0	0.22
3	78	60	76.9	4	5.1	10	12.8	2	2.6	2	2.6	0	0	0.28
4	78	50	64.1	21	26.9	3	3.8	4	5.1	0	0	0	0	0.27
All	304	222	73.0	41	13.5	30	9.9	9	3.0	2	0.7	0	0	0.25

Scores according to Dean 1934

RESULTS

Dean's Index In total the teeth of 304 school children at age between 6 and 15 were examined according mottled enamel scale of Dean 1934. The results of the dental examinations, including the children's geographical distribution, are shown in Table 1. The Dean's Community Fluorosis Index is calculated according the formula:

$$\text{Community Fluorosis Index CFI} = \frac{\Sigma\ \text{Scores}\ \cdot\ \text{No in each score group}}{\text{Number of cases examined}}$$

Thus from Table 1 the CFI at the four mentioned sites were, 0.20, 0.22, 0.28 and 0.27 respectively. For the whole area on average:

$$\text{CFI} = \frac{\{(41\ \cdot\ 0.5)\ +\ (30\ \cdot\ 1.0)\ +\ (9\ \cdot\ 2)\ +\ (2\ \cdot\ 3)\}}{304} = 0.25$$

Water quality. The result of analyses of the environmental water samples and children drinking water samples in the selected sites are shown in Table 2 and 3.

TABLE 2. Chemical data of environmental samples, taken in the wet and dry seasons. Each figure is an average of 2-4 measurements.

	F^- mg/L		Conductivity µS/cm		Ca^{2+} mg/L		Mg^{2+} mg/L		Na^+ mg/L		K^+ mg/L		pH	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Stream/River Water														
	0.2	0.1	83	100	4.8	10.0	4.2	5.3	2.7	4.0	2.0	2.0	6.8	7.3
Geothermal Water														
	18.2	18.9	553	250	3.9	3.1	0.1	4.9	49.0	95.8	3.1	3.1	9.4	7.3
Geothermal Water mixed with Stream Water														
	1.7	5.4	73	250	7.9	2.8	2.9	4.1	45.4	77.4	2.7	2.1	7.8	6.9
Mountain Tap Water														
	0.2	0.2	90	128	3.2	7.1	5.6	6.7	4.5	5.9	2.1	2.2	6.4	7.4
Village Tap Water														
	0.2	0.1	103	189	3.1	19.0	9.5	9.7	5.1	7.7	4.1	4.1	9.0	7.4
Groundwater														
	0.8	0.6	114	195	5.6	20.8	5.5	4.9	16.8	8.9	3.1	1.4	7.3	7.4
Shallow Well Water														
	0.2	0.2	145	224	5.3	25.9	10.5	9.5	4.9	7.0	2.2	2.2	7.1	7.3

Table 3. The fluoride concentrations in drinking water for the studied sites. The water source is indicated.

Site	Water Source	No	Wet	Dry
1	Mountain Tap	7	– 0.2	0.1 - 0.2
	Stream	6	0.1	< 0.1-0.5
	Groundwater	2	0.1 – 0.2	0.1
2	Mountain Tap	15	– 0.3	< 0.1 – 0.5
	Rain	1	0.2	0.2
3	Shallow Well	5	– 0.5	< 0.1 – 2.3
	Village Tap	8	– 0.4	– 0.2
	Mountain Tap	3	0.1	0.1 – 0.2
4	Shallow Well	12	-	<0.1 – 0.3
	Village Tap	3	-	< 0.1

Fluoride level in urine. The urinary fluoride level is widely regarded as one of the best indicators of fluoride intakes [8]. The urinary fluoride concentrations were measured for children with mottled enamel. The results are shown in Table 4.

Table 4. Urine fluoride level of positive mottled enamel school children at different ages. s.d. is the standard deviation

No	Age, years	Fluoride concentrations, mg/L		
		Mean	± s.d.	Min. – Max.
5	<7	0.62	± 0.21	0.38 – 0.82
10	7	0.66	± 0.37	0.13 – 1.30
7	8	0.60	± 0.16	0.30 – 0.81
13	9	0.71	± 0.52	0.13 – 1.87
8	10	0.74	± 0.51	0.23 – 1.71
5	11	0.65	± 0.13	0.49 – 0.86
5	12	0.80	± 0.33	0.32 – 1.17
53	< 7 - 12	0.68	± 0.31	0.13 – 1.87

DISCUSSION

Two cases of mottled enamel Dean's score 3, i.e. moderate, were found. Score 4 fluorosis cases, i.e. severe fluorosis, were not detected. The Dean's Community Fluorosis Index was found for the studied area in total to be 0.25, i.e. in the questionable area. This demonstrates that fluorosis occurs, but not as a major public health problem.

Fluoride levels in environmental water samples ranged from 0.1 to 18.9 mg/L. The levels were highest in the geothermal water samples and geothermal water mixing with stream, Table 2. In groundwater at Ban Pong Na Kham the levels reached 2.3 mg/L while the others at Ban Yang Kham Nu and Ban Pha Soet , the levels were lower. Fluoride levels in other types of natural water were not more than 1 mg/L. Mapping fluoride levels in the study site area, Figure 1, shows that the fluoride level at in the different sites varies according to distance from geothermal sources. This is interpreted as a clear indication of the geothermal sites as sources for fluoride in the environmental waters and in the drinking water.

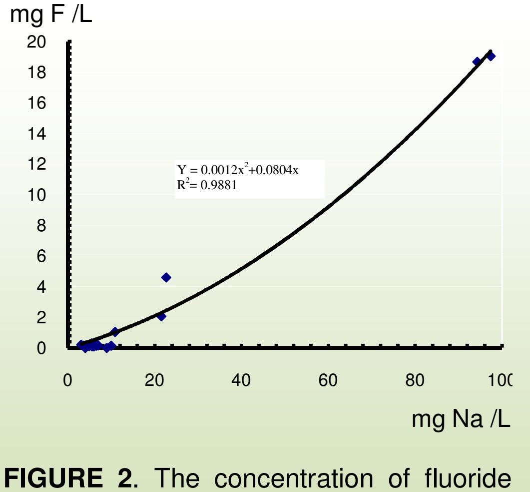

FIGURE 2. The concentration of fluoride vs. concentration of sodium in environmental water samples

Another indication of the relationship is the fluoride concentration in the environmental samples seems to be related to the salinity in general and sodium concentration in particular, cf. figure 2. Unfortunately the data are too few to allow for derivation of a reliable correlation.

Fluoride levels in drinking water samples ranged from < 0.1 to 2.3 mg/L. The highest fluoride levels was in site 3 (Rong Rian Ban Pong Na Kham) which is in an area of geothermal activity, where two cases of mottled enamel (Dean score 4) were found. This is interpreted as a clear indication of a relation between the geothermal sites and the occurrence of fluorosis.

The mottled enamel pattern found in the study area seems to be closely related to the use of the different water types for drinking. Those, in the area, who used mountain and village tap water for drinking, were less affected by fluorotoxicosis. The investigation of mottled enamel in school children aged 6-15 years old was performed in 4 primary schools.

Hodge et al. (1970) [8] reported that the fluoride concentration in urine varies with the age group, increasing from age 1 to12 years. The fluoride levels in the urine samples of this study ranged from 0.6 to 0.8 mg/L. However, the observed biological variation as compared to the few numbers of tested children does not allow for a similar conclusion.

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