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"Gheorghe Asachi" Technical University of Iasi, Romania

CONTAMINATED FLUORIDE IN BIOLOGICAL SAMPLES FROM MOUNTAINOUS AREAS IN THAILAND

Sanhawat Chaiwong[1], Tippawan Chaiwong[2], Chanin Umponstira[3*]

[1]School of Public Health, Walailak University, Nakhon Si Thammarat 80160, Thailand
[2]Emergency Room Department, Dok Kham Tai Hospital, Phayao 56120, Thailand
[3]Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok Thailand 65000

Abstract

The aims of the paper were to determine the contamination of fluoride in edible plants, meat and poultry products in contaminated areas. The urine samples from 373 village health volunteers living in 21 villages in Ma Khuea Chae sub-district, Lamphun province, Thailand, were collected and the fluoride concentration was measured by Ion Selective Electrode. Their village health volunteers were selected for further surveys regarding the consumption of edible plants, meat and poultry products which were produced in the areas. The results showed that the highest concentrations of fluoride in urine were found in Village 21: Ban Hong Ko Muang Song (7.07 ± 3.57 μg mL^{-1}), Village 15: Ban Nong Hiang (6.26 ± 2.01 μg mL^{-1}) and Village 9:Ban Pa Pao (4.73 ± 2.79 μg mL^{-1}). The total average of fluoride from the 21 villages was 3.50 ± 2.72 μg L^{-1}. There were 12 villages with a value of fluoride in urine higher than the standard recommendation, compared to the rest of the villages. The means of urinary fluoride residues in both male and female samples were slightly higher than the normal range (female > male). In addition, the average levels of contamination of fluoride on edible plants, meat and poultry products were significantly higher than the standard range in their villages. The residents of these areas were likely to risk the intake of fluoride to their bodies from the surrounding contaminated environment..

Keywords: edible plant, fluoride, meat, poultry products, village health volunteers

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1. Introduction

Fluorine is the thirteenth most abundant element in the earth's crust and is widely dispersed in nature. The long-term consumption of food and beverages containing F^- in excess of 1.5 mg L^{-1} is able to result in mineralized tissue impacting upon tooth enamel and leads to dental and skeletal complications (Liteplo et al., 2002; Meenakshi and Maheshwari, 2006; WHO, 1994). Ma Khuea Chae sub-district, Thailand, is abundant with natural resources. The district headquarters is about 15 km from Muang district. The geography of the Lamphun site is a high-fluoride anomalous zone located near the conspicuous Mae Tha fault that is likely to be associated with ground water resources. Because of the location in the Palaeozoic rock on the eastern part of the Chaing Mai basin which covers Chaing Mai and Lamphun provinces (Wood and Singharajwarapan, 2014; Yokart et al., 2003), this area contains a lot of Batholith of biotite – granite – in the Palaeozoic rock. Biotite $(K(MgFe)^3$ $(AlSi_3O_{10})$ $(FOH)_2$ is known to be a source of fluoride in the environment which can be transferred from granitic rocks to ground water through dissolution (Chae et al., 2006; Chae et al., 2007; Nordstrom et al., 1989). The highest concentration of F^- was found in water (WHO, 2004). The F^- content was 35% for deep wells which was at least 1.5 mg L^{-1} while that of shallow wells was only 7% (Chuah et al., 2016). A survey of 2,702 ground water samples for F^- contamination in 12 risk areas in Lamphun province by the Inter-Country Center for

* Author to whom all correspondence should be addressed: e-mail: chaninum@nu.ac.th

Oral Health (ICOH) showed that the highest F^- level was in Sun Pa Tiang of Ma Khuea Chae sub-districts of Muang district, at around 17 mg L^{-1} (Athikhomrungsarit, 2002). Chaiwong et al. (2017) investigated the urinary fluoride of village health volunteers living in 21 villages in Ma Khuea Chae sub-district in Lamphun province. The results showed that 51.3% of urine samples had a greater F^- level than standard (0.2 – 3.2 mg L^{-1}) (Baselt, 1980). F^- has been found in different components in Lamphun province as Theerawasttanasiri et al. (2018) found that people living in Lamphun used unsafe drinking water as 44% contained F^- higher than 0.7 mg L^{-1}, while 54% of villages and 46% of households used unsafe drinking water and found maternal urine fluoride (MUF) of exposed persons was higher than for those with low exposure. Meanwhile, pregnant women who had F^- levels in excess of 0.5 mg L^{-1} were associated with increased proportions of low birth weight. (Theerawasttanasiri et al., 2018). Linked to the study of McGrady et al. (2012) for water consumption in endemic areas, the prevalence of dental fluorosis for subjects consuming drinking and cooking water >0.9 mg L^{-1} F rose to 37.3%.

In Lumphun province in northern Thailand, the high-fluoride waters are presented from a nearby geothermal field. The F^- content in fluoridated endemic areas was higher than in non-fluoridated endemic areas. Therefore, the villages in Ma Khuea Chae sub-district can be considered as F^- contaminated areas. Previous studies revealed that the F^- was presented in the soil, vegetable, and grain crops (cereals, legumes, and oilseeds) (Chyi, 2003; Rao, 1984; Ranjan and Yasmin, 2015). The wheat, rice, and red chillies are variously contaminated in line with the proportion of their roots as they are grown in fluoride contaminated areas (Kumari et al., 1995). Chemicals, the coal industry, and food processing could cause fluoride contamination (Bartram and Pedley, 1996; Gautam et al., 2010; Mukherjee and Singh, 2018), and therefore it is necessary to examine the fluoride level in edible plants, meat, and poultry products in the fluoride contaminated areas.

Previous studies revealed fluoride to affect several systems in the human body, while the study of endocrine glands of Shashi and Singla (2013) reported that the serum TSH level was significantly increased in the fluoride exposed group. Due to increased ingestion in endemic fluoride areas there can be alteration of thyroid function hormones (TSH, T3, FT3, T4, FT4, rT3) and changes in the activities of deiodinase enzymes among the three deiodinases, especially D1 which is expressed in the thyroid gland. The D1 activity in the liver and kidneys is stimulated in hyperthyroidism and decreased in hypothyroidism as a result of the positive feedback of T3 on D1 production (O'Mara et al., 1993). Fernando et al. (2019) found that F^- concentrations in serum and urine affected renal function when observed in patients with chronic kidney disease (CKD). Urinary fluoride levels showed a significant difference with CKD stage between exposed and unexposed groups. Furthermore, NRC (2006) established the dose of fluoride exposure for long time effects on skeletal fluorosis at around 0.05 mg/kg/day.

Human beings have been exposed to fluoride via the food chain from soil to plants and plants to animals (Batra et al., 1995; Jha et al., 2013; Yi and Cao, 2008). However, the awareness of people living in several contaminated areas on F^- contamination and its effects on health is weak (Chuah et al., 2016; Chaiwong et al., 2017). The present study aimed to investigate the urinary fluoride of the village health volunteers (VHVs) living in 21 villages in Ma Khuea Chae sub-district, Lamphun province, Thailand, and determine the contamination of fluoride in edible plants, meat, and poultry products surveyed in contaminated areas.

2. Material and methods

2.1. Study area

Ma Khuea Chae is located in the center of Lamphun province and lies between 18.573821° latitude and 99.134547°longitude (Weather atlas, 2019). The elevation is 514 metres. The district has an area of 12 km^2. It is bounded by Tha Pa Duk Mae Tha district in the east, Ban Thi district to the north, Ban Klang in the south, and Uoo Mong and Muang Nga sub-districts of Muang district in the west. Lamphun's climate is classified as tropical. The summers are much rainier than the winters in Lamphun. This climate is considered to be Aw according to the Koppen-Geiger climate classification. For weather in Lamphun from 2016 to 2018, the average annual temperatures were 27.2, 27.5, and 26.8 °C respectively. About 1313.4 mm (119 days), 1076 mm (101 days) and 980.7 mm (108 days) of precipitation fell each year, respectively, and average relative humidity (%) was 72.00, 69.90 and 72.00 for the period (The Thai Meteorological Department, 2019).

The urine of 373 village health volunteers (VHVs) from Ma Khuea Chae sub-district were collected to determine the residue of fluoride. The VHVs had been living in this area for over 10 years and drinking ground water consisting of 1.5 mg L^{-1} F^- on average. The VHVs with the urine content in excess of 0.7 mg L^{-1} were eligible for interviews about their dietary behaviour and demographic data consumption for fluoride investigation. Edible plant, meat, and poultry products from the contaminated areas were collected to determine F^- levels. The method in this study was proposed by Malde et al. (2001) with a slight modification. Samples were dried and incinerated to become ashes in a muffle furnace. The fluoride analysis was determined with the help of an Orion fluoride ion-selective electrode (Model 9609).

The following reagents were needed: total ionic strength activity buffer (TISAB) (pH 5); sodium citrate ($Na_3C_6H_3O_7 \cdot 2H_2O$); ethylene dinitrilotetracetic acid (EDTA); sodium hydroxide; sodium chloride; sodium fluoride. The necesary equipments were: polyethylene bottles; fluoride ion-selective electrode

(ISE); pH/millivolt meter, reading to ± 0.5 mV; pH electrode.

2.2. General analytical procedure

2.2.1. Sample preparation

The newly harvested vegetables were cut into small pieces, dried under ambient temperature, and then crushed into powder by a mortar and pestle. An amount of 2.50 or 5.00 mL of 8 mol L^{-1} sodium hydroxide solution was added to the samples and carefully mixed. The incineration temperature for the muffle furnace was first set at 200ºC for 1 hour, and then increased to 525ºC for 3 hours. The distilled water (10.0 – 15.0 mL) was added after the crucibles were cooled. The fusion cake in the crucibles was then further dissolved with a hot plate. The pH of sample solutions was adjusted by using concentrated hydrochloric acid. The pH was decreased from 12.0 – 13.0 to 8.0 – 8.5. The final pH was adjusted to 7.2 – 7.5 by using dilute hydrochloric acid. The sample solution was put into a 50.00 mL plastic volumetric flask and diluted to the required volume with distilled water. The solutions were stored in 50.00 mL airtight plastic until analyzed. Sample solutions were analyzed by using a fluoride ion-selective electrode. The electrode was soaked in distilled water and dried prior to measurement. Both reagent blank and deionized water were used for the blank determination and the standard solution preparation.

2.2.2. Urinary fluoride determination (8308 Method, NIOSH 1994)

To measure urinary fluoride concentrations, the first-void sample in the morning was collected. The measurement was conducted with a fluoride ion-selective electrode (Orion model 4 star) according to the standardized procedures at the Inter-Country Centre for Oral Health (ICOH), Department of Health, Ministry of Public Health. An amount of 1.00 mL of urine was added to an equal volume of TISAB buffer to adjust the pH to 5.0 – 5.5 for determination. The solution was then cooled to room temperature prior to being transfered into a 1 liter volumetric flask. The solution was then diluted to the flask mark with distilled water. All containers (polyethylene tubes and bottles) were cleaned to maximum purity in distilled water, soaked in 1% nitric acid overnight, and then soaked in deionized water for 24 hours before storage in the box until use. Recoveries were reported between 94 to 100%. Precision, based on the analysis of 10 specimens in triplicate, was estimated to be better than precision of 0.04. The analytical detection limit (mean: 0.06 mg L^{-1}) was calculated as the mean blank value plus two times the standard deviation.

2.2.3. Statistical analysis

1. Descriptive statistics; frequency, percentage, mean, standard deviation, minimum, and maximum were used.

2. Independent t – test was used to compare between the two groups in terms of gender ($p < 0.05$).

3. Results and discussion

The results showed that the most village health volunteers age were between 51-60 years old and lived in the village more than 5 years.They had education at the primary school level and no experience of fluoride contamination in drinking water and food (Table 1).

Table 1. Demographic data of village health volunteers **(**VHVs**) (**N = 373**)**

	Item		***N***	**%**
1.	**Age (year)**			
		< 30 years	3	0.74
		Between 31 – 40 years	25	6.67
		Between 41 – 50 years	97	25.93
		Between 51 - 60 years	181	48.64
		> 61 years	67	18.02
2.	**Gender**			
		Male	147	39.51
		Female	226	60.49
3.	**Marriage status**			
		Single	7	1.98
		Married	297	79.50
		Widow	48	12.84
		divorce /separate	21	5.68
4.	**Weight (Kg)**			
		< 50 kg	90	24.13
		Between 51-60 kg	166	44.50
		Between 61-70 kg	80	21.45
		Between 71-80 kg	25	6.70
		> 81 kg	12	3.22
5.	**Height (cm)**			
		< 150.0 cm	77	20.98
		Between1 51-16 0 cm	179	47.90
		Between1 61-17 0cm	98	26.17
		> 171 cm	19	4.95

6.	**Education**				
		Primary school		253	67.83
		Secondary school (level 1 – 3)		58	15.55
		Secondary school (level 4 – 6)		44	11.80
		High school diploma		8	2.14
		Bachelor		8	2.14
		Higher than bachelor		2	0.54
7.	**Careers**				
		Unemployed		2	0.49
		Agriculture		55	14.58
		Government officer/state enterprise		4	0.99
		Private business		91	24.44
		Employee		221	59.50
8.	**Income**				
		< 90 EUR		84	22.47
		Between 90 – 150 EUR		74	19.75
		Between 151 – 300 EUR		131	35.32
		Between 301 – 600 EUR		41	10.86
		> 600 EUR		43	11.60
9.	**Housing**				
		Owner		326	87.40
		Living with father and/or mother		29	7.77
		Living with father in law and/or mother in law		13	3.49
		Other		5	1.34
10.	**Location**				
		Same location since birth		293	78.52
		Migration		80	21.48
			Migrated less than 1 year ago	2	2.50
			Migrated 1-2 years ago	10	12.50
			Migrated 3-5 years ago	13	16.25
			Migrated more than 5 years ago	55	68.75
11.	**Sources of supply water for drinking (answered more than 1 answer)**				
		Rain		3	0.57
		Groundwater		32	6.10
		Government supplied		103	19.62
		Surface water		30	65.14
		Bottled water		342	2.29
		Commercially filtered		12	0.57
		Other		3	0.53
12.	**Drinking water improved quality**				
	12.1	Untreated		48	12.87
	12.2	Treated		325	87.13
		12.2.1	Filtrated	197	60.62
		12.2.2	Boiled	72	22.15
		12.2.3	Other	56	17.23
13.	**Sources of cooked water (answered more than 1 answer)**				
		Rain		33	6.16
		Groundwater		27	5.04
		Government supplied		127	23.69
		Surface water		26	4.85
		Bottled water		311	58.02
		Commercially filtered		10	1.87
		Other		2	0.37
	13.1	Untreated		21	5.63
	13.2	Treated		352	94.37
		13.2.1	Filtrated	152	43.18
		13.2.2	Boiled	79	22.44
		13.2.3	Other	121	34.38
14.	**The history of urinary fluoride investigation**				
		Yes		0	0.00
		No		373	100.00
15.	**Known fluoride in water (i.g. groundwater, water supply) in areas**				
		Known		0	0.00
		Unknown		373	100.00

3.1. The average of urinary fluoride in VHVs living in the 21 villages

The results of the amount of F^- in the urine of village health volunteers (VHVs) in the 21 villages of Ma Khuea Chae sub-district are presented in the Fig. 1. According to the Fig. 1, the village 21 Ban Hong Ko Muang Song (mean = 7.07±3.57 mg L^{-1}), Village 15: Ban Nong Hiang (mean = 6.26±2.01 mg L^{-1}), and Village 9:Ban Pa Pao (mean = 4.73±2.79 mg L^{-1}). The total mean of urinary fluoride was 3.50 ± 2.72 mg L^{-1}.

The results of the amount of F^- in the urine of village health volunteers (VHVs) in the 21 villages of Ma Khuea Chae sub-district in terms of gender are presented in the Fig. 2. According to Fig. 2, the mean F^- level by gender:male = 3.49 mg L^{-1} (SD. = 2.71, min – max = 0.10 – 17.50 mg L^{-1}) and female = 3.50 mg L^{-1} (SD = 2.73, min – max = 0.11 – 13.10 mg L^{-1}). There was not a significant difference between male and female (P>.05). Notably, there were 9 villages where the average for females was greater than that of males. According of Figs. 1 and 2, among the 21 villages, there were 12 villages (57.14%) with a value of F^- in urine higher than the standard recommendation (3.20 mg L^{-1}). Varied concentrations of F^- exist in different components of the environment such as rocks, soil, water, air, plants, and animals. In this study, the highest concentration of F^- was found in 12 villages which indicated the fact that the living environment of people has been contaminated by F^-. The F^- could exist in different sources such as drinking water and the food chain, including vegetables, fruits, meats, and poultry. That different results for the F^- level were found in VHVs might be due to two major factors: food habit consumption behaviours and contaminated living areas (Chaiwong et al., 2017).

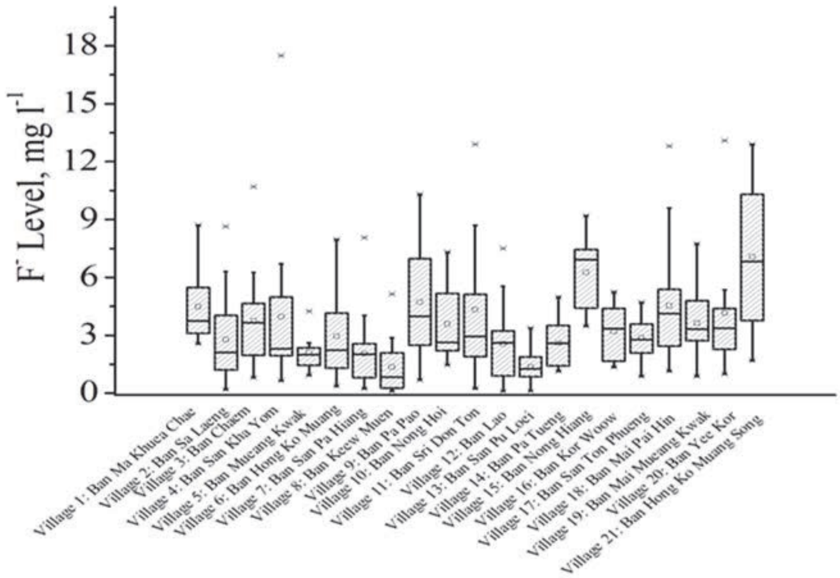

Fig. 1. The amount of F^- in the urine of village health volunteers (VHVs) in the 21villages of Ma Khuea Chae sub-district (Chaiwong et al., 2017)

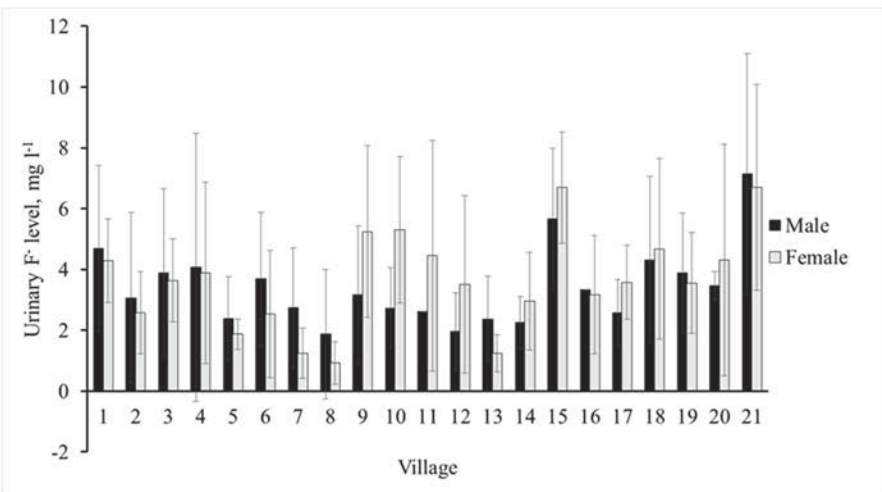

Fig. 2. The amount of F^- in the urine of village health volunteers (VHVs) in the 21 villages of Ma Khuea Chae sub-district in terms of gender (N = 373) (Chaiwong et al., 2017)

3.2. The average of F^- in fruits grown in contaminated areas

Results for F- in fruits grown in contaminated areas are presented in Table 2. The highest amount of F^- was found in *Hylocercus undatus (Haw) Brit. & Rose*. (480 mg/kg), *Carica papaya L.* (480 mg/kg), and *Mangidera indica* (460 mg/kg). The lowest amount was in *Dimocarpus longan* and *Tamarindus indica*. Anthropogenic activities might cause F^- contamination in certain areas.

In this study, the *Hylocercus undatus (Haw) Brit. & Rose*, *Carica papaya L.* and *Mangidera indica* in particular were able to accumulate the F^- at the higher level compared to their counterparts.

3.3. The average of F^- in edible plants grown in contaminated areas

The average levels of F^- in edible plants grown in contaminated areas are presented in Table 3.

Table 2. The values for F^- in fruits grown in contaminated areas (N=5)

Type of fruits	*F^- level (mg L^{-1})**	*F^- level (mg/kg dry weight)*
Psidium guajava	0.87	330.00
Hylocercus undatus (Haw) Brit. & Rose	2.15	480.00
Carica papaya L.	1.85	480.00
Musa acuminata Colla	0.39	200.00
Mangidera indica	0.83	460.00
Dimocarpus longan	0.46	150.00
Tamarindus indica	0.51	150.00

**The average value of F^- (mg L^{-1}) was added in table. Inaddition, the procedure to convert mg L^{-1} to mg/kg dry weight was inserted;*
Mean = 1.01 F mg L^{-1}, SD. = 0.71, Min – Max = 0.39 – 2.15; Mean = 560 F mg/kg dry weight, SD. = 0.15, Min – Max = 150.00 – 480.00 F mg/kg dry weight.

Table 3. The amount of F^- in edible plants grown in contaminated areas (N = 5)

Part/variety	*Type of plant*	*F^- level (mg L^{-1})**	*F^- level (mg/kg dry weight)*
Young plants	*Cucurbita moschata Decne*	0.20	230.00
	Acacia Insuavis, Lace	0.27	720.00
	Leucaena leucocephala	0.62	450.00
	Coccinia grandis	0.54	1,030.00
	Sesbania grandiflora	0.30	320.00
	Moringa oleifera Lam.	0.22	370.00
	Basella alba	0.89	250.00
	Sechium edule	0.12	350.00
	Momordica charantia L.	0.32	910.00
Mature plants	*Ocimum sanctum*	0.34	430.00
	Brassica pekinensis	0.81	460.00
	Brassica juncea (L.) Czern. & Coss.	2.58	3,070.00
	Brassica chinensis L. var. parachinesis Tsen & Lee.	0.42	480.00
	Piper sarmentosum	0.17	440.00
Whole plants	*Ipomoea aquatica*	0.17	640.00
	Gymnema inodorum	0.64	420.00
	Neptunia oleracea	0.91	770.00
Food crops	*Solanum virginianum L.*	0.43	170.00
	Vigna unguiculata ssp. sesquipedalis	0.47	120.00
	Solanum melongena	0.28	120.00
	Solanum torvum	0.63	460.00
	Lablab purpureus	0.97	620.00
	Trichosanthes anguina Linn.	0.59	250.00
	Luffa acutangula (Linn.) Roxb.	0.29	130.00
Cooked plants	*Citrus aurantifolia (Christm.) Swingle*	0.59	140.00
	Citrus hystrix	0.14	1,060.00
	Cymbopogon citratus	0.47	270.00
	Capsicum annuum	1.09	1,130.00
	Capsicum annuum 'Bird's Eye'	0.10	110.00

**The average value of F^- (mg L^{-1}) was added in table. Inaddition, the procedure to convert mg L^{-1} to mg/kg dry weight was inserted.*
Young plant; Mean = 510.00 F mg/kg dry weight, SD. = 0.30, Min – Max = 230.00 – 1,030.00 F mg/kg dry weight.
Mean = 0.39 F mg L^{-1}, SD. = 0.25, Min – Max = 0.12 – 0.89 mg L^{-1}.
Mature plants ; Mean = 980.00 F mg/kg dry weight, SD. = 1.17, Min – Max = 430.00 - 3,070.00 F mg/kg dry weight.
Mean = 0.86 F mg L^{-1}, SD. = 0.99, Min – Max = 0.17 – 2.58 mg L^{-1}.
Whole plants ; Mean = 610.00 F mg/kg dry weight, SD. = 0.17, Min – Max = 420.00 - 770.00 F mg/kg dry weight.
Mean = 0.57 F mg L^{-1}, SD. = 0.37, Min – Max = 0.17 – 0.91 mg L^{-1}.
Food crops ;Mean = 270.00 F mg/kg dry weight, SD. = 0.20, Min – Max = 120.00 - 620.00 F mg/kg dry weight.
Mean = 0.52 F mg L^{-1}, SD. = 0.24, Min – Max = 0.28 – 0.97 mg L^{-1}.
Cooked plants; Mean = 540.00 F mg/kg dry weight, SD. = 0.51, Min – Max = 110.00 - 1,130.00 F mg/kg dry weight.
Mean = 0.48 F mg L^{-1}, SD. = 0.41, Min – Max = 0.10 – 1.09 mg L^{-1}.

Table 4. Amount of F^- in meat and poultry in contaminated areas (N = 5)

Type of meat and poultry	*F^- level (mg L^{-1})**	*F^- level (mg/kg dry weight)*
Bos taurus	1.02	810.00
Gallus gallus	0.48	100.00
Oreochromis niloticus	0.34	100.00

**The average value of F^- (mg L^{-1}) was added in table. Inaddition, the procedure to convert mg L^{-1} to mg/kg dry weight was inserted.*
Meat & poultry; = 336.67 F mg/kg dry weight, SD. = 409.92, Min – Max = 100.00 - 810.00 F mg/kg dry weight.
Mean = 0.61 F mg L^{-1}, SD. = 0.40, Min – Max = 0.34 – 1.02 mg L^{-1}.

The concentration of F^- varies greatly in different parts and/or varieties of plants. Among young plants, *Coccinia grandis* (1,030 mg/kg), *Momordica charantia* L. (910 mg/kg) and *Acacia Insuavis, Lac*e (720 mg/kg) contained the highest amount of F^- compared to other young plants. For the mature edible plants, the highest concentration was found for *Brassica juncea (L.) Czern & Coss* (3,070 mg/kg), *Brassica chinensis L. var. parachinesis Tsen & Lee* (480 mg/kg) and *Brassica pekinensis* (460 mg/kg), respectively. Meanwhile, the highest F^- level was found for the *Neptunia olerace* (770 mg/kg) for whole plants, followed by *Ipomoea aquatica* (640 mg/kg) and *Gymnema inodorum* (420 mg/kg). For food crops, the highest concentration was found in *Lablab purpureus* (620 mg/kg), followed by S*olanum torvum* (460 mg/kg) and *Trichosanthes anguina Linn*. (250 mg/kg) while that of the cooked plants was in *Capsicum annuum* (1,130 mg/kg), *Citrus hystrix* (1,060 mg/kg) and *Cymbopogon citratus* (270 mg/kg), respectively. Results of F^- level determination in edible plants grown in contaminated areas revealed that many edible plants contained significantly high levels of F^- compared to counterparts such as *Brassica juncea (L.) Czern. & Coss* (3,070.00 mg/kg dry weight), *Citrus hystrix* (1,060.00 mg/kg dry weight) and *Coccinia grandis* (1,030.00 mg/kg dry weight). In India, the F^- concentration in common edible crops and dietary vegetables was in the vicinity of phosphate from 54.10 – 87.50 F µg/g dry weight (US EPA, 1985). Meanwhile, the average concentration of F^- was found in China in the range between 0.31 – 52.00 mg/kg (Liteplo et al., 2002). Results indicated that different parts and/or varieties accumulated different concentrations of F^-, which can be supported by previous research. Jha et al. (2013) showed that F^- accumulation followed the order of soil>root>shoot>grain. Saini et al. (2013) found a significant translocation of F^- from the root into aerial parts; the roots accumulated the larger portion of the F^- (63.1024 µg/g) followed by the shoots (30.492 µg/g). The F^- is more soluble in soil and water; the fluoride enters the plant roots through a passive diffusion process, and then the F^- is moved through the apoplastic and symplastic pathways in a unidirectional distal movement into the shoot via the xylem (Pant et al., 2008).

3.4. The average of F^- meat and poultry in contaminated areas

Table 4 shows the results for F^- in meat and poultry in contaminated areas**.** For the amount of F^- in meat and poultry farmed in contaminated areas, the highest concentrations were found in *Bos taurus* (810 mg/kg), while *Gallus gallus* (100 mg/kg) and *Oreochromis niloticus* (100 mg/kg) contained a similar amount. Compared with the reports of Liteplo et al. (2002), US EPA (1985), and Slooff et al. (1988), the concentration of F^- is higher than in Canada and the USA (range 0.06 – 4.57 mg/kg). Animals, through the ingestion of plants and water, can be contaminated by F^-. The amount of F^- depends on the type of animal, feeding strategy, and human activities. Ma Khuea Chae sub-district is located on the Lamphun site. It is a high-fluoride anomalous zone located near the conspicuous Mae Tha geological areas located in the Palaeozoic rock on the eastern part of the Chiang Mai basin (Yokart et al., 2003).

Rock can contain higher amounts of fluoride even than soil (Piispanen, 1992; Edmunds and Smedley, 2013). The weathering and infiltration of rainfall through these rocks might increase the fluoride concentration in groundwater. The results of the fluoride concentration ranging from 100.00 to 800.00 mg/kg (mean = 490.00 mg/kg) were significantly higher than the maximum contaminant level, which is recommended by the EPA (EPA, 1985) and WHO (WHO, 1984) for foods (4.00 mg/kg) and for the dose capable of causing illness (0.30 mg/kg).

So, the prevention (technology and strategy) of fluoride contamination in the community is important:

1. Educational and community-based programmes should be designed to prevent disease and the impact on human health in endemic areas, improving health and enhancing the quality of life. Health educational programmes should cover four elements including perception of severity, susceptibility, barriers, and benefits of preventing the fluoride impact.

2. Social support involve positive assistance and perceptions from networks of friends and family. It can be done via public relations and media concerning fluoride in the community in terms of how to avoid exposure to fluoride. Social support is linked to individuals feeling valued and cared for by society in addition to how well the person is embedded into a network of communication and social obligation (Melika et al., 2015).

3. Government policy is also important. Commercial bottled drinking water must be screened and analyzed for fluoride before sale, and it is necessary to decrease the concentration of fluoride in the case of higher concentrations of fluoride than the standard in drinking water.

4. Conclusion

The highest concentration of F^- was found for Village 21: Ban Hong Ko Muang Song, Village 15: Ban Nong Hiang, and Village 9: Ban Pa Pao, respectively. The mean value in males was 3.49 mg L^{-1} while the mean in females was 3.50 mg L^{-1}. The total average of F^- from village 21 was 3.50 mg L^{-1} (the normal range of the mean of urinary fluoride = 0.20 – 3.20 mg/L).

There were 12 villages with a value of F^- in urine higher than the standard recommendation (3.20 mg/L). The F^- levels for *Hylocercus undatus (Haw) Brit. & Rose*. *Carica papaya L.* and *Mangidera indica* were 0.48, 0.48, and 0.46 mg/g, respectively. The content of F^- of all the vegetables ranged from 0.10 to 3.07 mg/g (mean = 0.49 mg/g). The mean F^- levels in the plants followed the order: mature plants > cooked plants > young plants > whole plants > fruits > food crops. A significantly high level of F^- compared to counterparts was found in *Coccinia grandis* (1.03 mg/g), *Brassica juncea (L.) Czern. & Coss* (3.07 mg/g) and *Citrus hystrix* (1.06 mg/g). The F^- levels in meat and poultry followed the order: *Bos Taurus* > *Gallus gallus* and *Oreochromis niloticus.* The concentration range was 0.10 to 0.80 mg/g (mean = 0.49 mg/g).

The values are significantly higher than the maximum contaminant level recommended by the EPA and WHO for food (4.00 mg/kg) and for a dose capable of causing illness (0.30 mg/kg). Plants are important vectors of the element in all ecosystems since human beings and animals consume the plants.

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