

# Proportion of Trace Elements from Airborne PM<sub>10</sub> in Chiang Mai City Using Pixe Technique

Suchart Kiatwattanacharoen<sup>1,2</sup>, \*Tippawan Prapamontol<sup>2</sup>,  
Somsorn Singharat<sup>3</sup>, Somporn Chantrara<sup>4</sup>,  
Prasak Thavornyutikarn<sup>4</sup>

**Abstract-** Elevated level of ambient particulate matter with aerodynamic diameter less than 10 micrometer (PM<sub>10</sub>) in Chiang Mai city often occurred during February to April. Trace elements on PM<sub>10</sub> were identified using Particle-Induced X-ray Emission (PIXE). Leaves and stalks of eight plants commonly found in Chiang Mai-Lamphun basin were burnt in the control combustion chamber and PM<sub>10</sub> sample was collected on the micropore polycarbonate filter using GENT air sampler according to International Atomic Energy Agency (IAEA) standard. Multiple elements were detected including Si, S, Cl, K, Ca, Ti, Cr, Mn and Fe. Ambient PM<sub>10</sub> samples (n=27) were also collected from Chiang Mai University main campus as clean area and Saraphi district, a sub-urban of Chiang Mai city. There were predominantly found K, Ca, and S which were similar to biomass burning in the chamber. The cluster analysis showed that ambient PM<sub>10</sub> levels from both sites were highly correlated with rice, teak and Yangna biomass burning-

## Index Terms-

## 1 INTRODUCTION

Since the smog episode in 2007, upper northern Thailand provinces have been facing high level of air pollution especially during February to March. Air pollution has been reportedly affecting people health with increasing incidence rate of patient with respiratory disease. The number of patients admitted with airway problems was higher than that of previous years (1). Eight provinces of upper northern Thailand including Chiang Mai, Chiang Rai, Lamphun, Lampang, Phrae, Nan, Phayao, Mae Hong Son and one of lower northern part of Thailand, Tak province have had elevated levels of particulate matters with aerodynamic diameter less than 10 micrometer (PM<sub>10</sub>) exceeded the control level (>120 µg m<sup>-3</sup>, 24 hours average level).

Main causes of airborne PM<sub>10</sub> and smog/haze are forest fire in both from in-bound and neighboring countries i.e. Lao, Myanmar, Vietnam and Cambodia. The other source is burning of post-harvest biomass, branch and paddy remains such as rice and corn fields (2). To date, study about sources of air pollutants did not clarify of their origins, or even cause and effect to personal health.

Thus, the objective of this study is to use a nuclear analytical technique called Proton Induce X-Ray Emissions (PIXE) which fast and non-destructive technique to identify source of air pollution composition from each sources.

## 2 MATERIALS AND METHODS

**Study design:** It was a cross-sectional study of PM<sub>10</sub> collection from 4 March 2010 to 7 May 2010.

**Study sites:** There were 2 sampling sites. One was located at the ground floor of the Research Institute for Health Sciences (RIHES) Building 3, Chiang Mai University main campus as a clean area. The other site was at Wat Nantaram (WT) school, Saraphi district, a sub-urban of Chiang Mai city.

**Apparatus:** GENT Air Samplers [International Atomic Energy Agency (IAEA), Austria] were employed to collect PM<sub>10</sub> samples using micropore polycarbonate filters, diameter 47 mm, 8.0 µm (Nuclepore, Track-Etch membrane, Whatman, USA). The sampler was installed about 1.5 meters above the ground with metal case as shown in Figure 1. PIXE and GUPIXWIN software.

<sup>1</sup>Environmental Science PhD Program, Faculty of Science

<sup>2</sup>Environment and Health Research Unit, Research Institute for Health Sciences

<sup>3</sup>Department of Physics, Faculty of Science

<sup>4</sup>Department of Chemistry, Faculty of Science

Chiang Mai University, Chiang Mai 50200, Thailand

\*Corresponding Author: Tel: +6653942526,

Email: [tprapamontol@yahoo.com](mailto:tprapamontol@yahoo.com)

**PM<sub>10</sub> collection method:** The Gent Air Sampler was collecting PM<sub>10</sub> for 24 hour samples with the flow rate of 15 liter per minute. The PM<sub>10</sub> level on the filter was estimated by gravimetric method. Pre-weight filter was installed in the filter holder before start timer and adjust air flow rate and closing top cover of air sampler. After 24 hours collected sample, the filter was kept at least 24 hours in the vacuum desiccator for moisture removal. The filter was weighed again as post weighted. PM<sub>10</sub> level was calculated as following.



Figure 1. Gent Air Sampler at sampling site for collecting PM<sub>10</sub>

$$\text{Total PM}_{10} (\mu\text{g}/\text{m}^3) = [1000 \times (\text{post weight} - \text{pre weight}) \text{ g}] / (15 \text{ l min}^{-1} \times 1,440 \text{ min} \times 10^6)$$

**Controlled combustion chamber study:** Eight dried plant samples which commonly found in upper northern Thailand were collected and burned in the controlled combustion chamber at Division of Environmental Science, Faculty of Science, Chiang Mai University, Thailand (3). Eight plants included bamboo (*Bambusa vulgaris*), longan (*Dimocarpus longan*), lychee (*Litchi chinensis*), corn (*Zea mays*), grass (*Echinochloa crusgalli*), teak (*Tectona grandis*), rice (*Oryza sativa*) and Yangna (*Dipterocarpus alatus*). PM<sub>10</sub> samples were collected from the chamber.

**Trace element analysis:** PM<sub>10</sub> samples from plant burning in controlled chamber and ambient air of RIHES and WT School were analyzed by PIXE at the Ion Beam Physics & Application Research Unit of Chiang Mai University. Samples were exposed high energy beam with 3 MeV Photon energy for 6 min.

The GUPIXWIN was application software using for analyzing trace elements data collected from PIXE. The concentrations of trace elements which derived from hitting high energy beam in specific area (13.46 cm<sup>2</sup>) were calculated in ng cm<sup>-2</sup>. Total sample area of PM<sub>10</sub> collected filter was the total volume of ambient air collected for 24 hours (1,440 min) via Gent air sampler with 15 liters per min and then convert to μg m<sup>-3</sup> or ppm by the following formula.

$$\text{Concentration } (\mu\text{g}/\text{m}^3) = (A \text{ ng cm}^{-2} \times 10^3 \times 13.46 \text{ cm}^2) / (15 \text{ m}^3 \text{ min}^{-1} \times 1,440 \text{ min})$$

A = Concentration of trace element in specific analyzed area of proton beam in PIXE technique (ng cm<sup>-2</sup>)

**Cluster analysis:** The proportions between trace elements and Ca were calculated and then tested for cluster analysis using computer-based software. Euclidean distance and dendrogram were used to group the samples.

### 3 RESULTS

The mean±SD PM<sub>10</sub> level of 24 hours average at WT school sampling site was significantly higher than those from the RIHES sampling site (Table 1). Thailand and World Health Organization (WHO) Standard PM<sub>10</sub> level of 24 hour average are 120 and 50 μg m<sup>-3</sup>, respectively (4, 5). Therefore, mean PM<sub>10</sub> levels of these 2 sites are not exceeded Thailand standard but WT sampling site had mean PM<sub>10</sub> level exceeded WHO standard level. The result from RIHES site indicated that the main campus of Chiang Mai University deserves to be a clean area while WT site which is sub-urban area of Chiang Mai city indicated slightly particulate air pollution. However, both sites had the highest PM<sub>10</sub> level which exceeded Thailand standard on 16 Mar 2010.

Table1. The mean of PM<sub>10</sub> level of 24 hours average at WT school and RIHES sampling sites collected from 4 March 2010 to 7 May 2010

Sampling site	PM <sub>10</sub> weight mass (µg m <sup>-3</sup> )		
	Mean (± SD)	Min-Max	Day with highest PM <sub>10</sub>
RIHES (n=30)	57.1 (±38.5)	5.0-125.0	16 Mar 2010
WT school (n=16)	80.9 (±49.5)	27.3-205.7	16 Mar 2010

PM<sub>10</sub> filters of 8 plants burning and 2 sampling sites (RIHES and WT School) were analyzed for trace elements using PIXE technique and GUPIX software. The concentrations of 10 trace elements are shown in Table 2.

Table 2. Trace elements of PM<sub>10</sub> from 8 plants burning in control combustion chamber and 2 sampling sites (RIHES and WT School)

PM <sub>10</sub> sample	Concentrations of trace elements (µg m <sup>-3</sup> )									
	AL	Si	S	Cl	K	Ca	Ti	Cr	Mn	Fe
Plant burning										
Bamboo ( <i>Bambusa vulgaris</i> )	92	20	11	56.	51.	14.	N	N	N	39.
Longan ( <i>Dimocarpus longan</i> )	8.9	5.9	3.5	63	98	91	D	D	D	72
Lychee ( <i>Litchi chinensis</i> )	57	20	95.	34	46	17.	N	11.	N	17.
Corn ( <i>Zea mays</i> )	2.5	4.6	62	9.1	3.1	67	D	65	D	28
Grass ( <i>Echinochloa crusgalli</i> )	95	24	15	59.	31.	4.2	N	0.0	N	16.
Teak ( <i>Tectona grandis</i> )	4.0	4.7	0.3	21	32	6	D	0	D	34
Rice ( <i>Oryza sativa</i> )	78	N	73.	16	23	9.3	N	1.6	N	21.
	6.8	D	27	2.3	6.2	0	D	2	D	41
	67	13	38.	30.	28.	5.0	N	0.0	N	5.7
	0.5	4.3	72	93	22	8	D	0	D	7
	1.0	24	99.	1.6	1.4	19	5.6	11.	N	70.
	83	8.1	85	49	23	6.2	7	57	D	09
	1.1	43	80	1.8	3.4	20	N	N	N	0.7
	08	7.8	3.2	52	49	5.5	D	D	D	2

Yangna ( <i>Dipterocarpus alatus</i> )	87	15	98.	14	21	19.	4.9	6.0	N	14.
Sampling site	6.4	4.8	38	3.6	9.8	70	5	5	D	66
RIHES	1.5	59	19	22.	21	23	18.	31.	7.5	18
WT school	92	0.6	6.5	62	0.7	0.3	72	84	5	1.1
	1.1	67	23	19.	19	1.0	19.	8.5	8.7	18
	76	1.2	7.5	65	1.6	06	76	4	3	9.3

ND =Not detected

PM<sub>10</sub> bound trace elements from burning leaves of 8 plants (bamboo, longan, lychee, corn, grass, teak and rice and Yangna) in control combustion chamber were measured. Six elements including Al, S, Cl, K, Ca, and Fe were found in all types of plants. Cr was detected in corn, rice, teak and Yangna and Ti was found in teak and Yangna. Si was not found in corn while Mn was not detected in any plant burning. Comparing the concentration, rice burning gave the highest concentration of Al, S, Cl, K and Ca.

All 10 elements were found in PM<sub>10</sub> samples from RIHES and WT school sites. Most concentrations of trace elements from both sites were not much different from each other. Specially, Ca concentration from RIHES site (230.3 µg m<sup>-3</sup>) was 3.5-fold lower than from WT school site (1,006 µg m<sup>-3</sup>) and Cr concentration from RIHES site (31.84 µg m<sup>-3</sup>) was 4-fold higher than WT school (8.54 µg m<sup>-3</sup>).

Since Ca is the abundance of elements in Earth's crust, the proportions between other elements and Ca were calculated and shown in Table 3.

Table 3. Proportions of the concentrations between each trace element to potassium

PM <sub>10</sub> samples	Proportions							
	Si/C a	S/C a	Cl/C a	K/C a	Ti/C a	Cr/ Ca	Mn/ Ca	Fe/ Ca
Plant burning								
Bamboo ( <i>Bambusa vulgaris</i> )	13.8	7.6	3.8	3.5	0.0	0.0	0.0	2.7

Longan ( <i>Dimocarpus longan</i> )	11.6	5.4	19.8	26.2	0.0	0.7	0.0	1.0
Lychee ( <i>Litchi chinensis</i> ),	57.4	35.3	13.9	7.4	0.0	0.0	0.0	3.8
Corn ( <i>Zea mays</i> )	0.0	7.9	17.4	25.4	0.0	0.3	0.0	2.3
Grass ( <i>Echinochloa crus-galli</i> )	26.4	7.6	6.1	5.6	0.0	0.0	0.0	1.1
Teak ( <i>Tectona grandis</i> )	1.3	0.5	8.4	7.2	0.0	0.1	0.0	0.4
Rice ( <i>Oryza sativa</i> )	2.1	3.9	9.0	16.8	0.0	0.0	0.0	0.0
Yangna ( <i>Dipterocarpus alatus</i> )	7.9	5.0	7.3	11.2	0.2	0.3	0.0	0.7
Sampling site								
RIHES	2.6	0.8	0.1	0.9	0.1	0.1	0.0	0.8
WT School	0.7	0.2	0.0	0.2	0.0	0.0	0.0	0.2

Corn	.181	.030	.932	.000	.259	.099	.035	.079	.203	.212
Grass	.035	.177	.381	.259	.000	.146	.156	.081	.142	.166
Teak	.052	.131	.936	.099	.146	.000	.021	.016	.023	.025
Rice	.076	.062	.886	.035	.156	.021	.000	.014	.072	.078
Yangna	.024	.083	.731	.079	.081	.016	.014	.000	.042	.052
RIHES	.041	.239	.942	.203	.142	.023	.072	.042	.000	.000
WT school	.054	.257	1.000	.212	.166	.025	.078	.052	.000	.000

Euclidean distance was used to measure distance between samples. The low Euclidean distance (closing to 0) shows high similarity between the samples. The results are shown in Table 6 and Figure 2.

Table 4. Euclidean Distance among trace elements from 8 plants and PM<sub>10</sub> samples from RIHES and WT school sites.

Case	Proximity Matrix: rescaled Euclidean Distance									
	Bamboo	Longan	Lychee	Corn	Grass	Teak	Rice	Yangna	RIHES	WT school
Bamboo	.000	.166	.592	.181	.035	.052	.076	.024	.041	.054
Longan	.166	.000	.721	.030	.177	.131	.062	.083	.239	.257
Lychee	.592	.721	.000	.932	.381	.936	.886	.731	.942	1.000

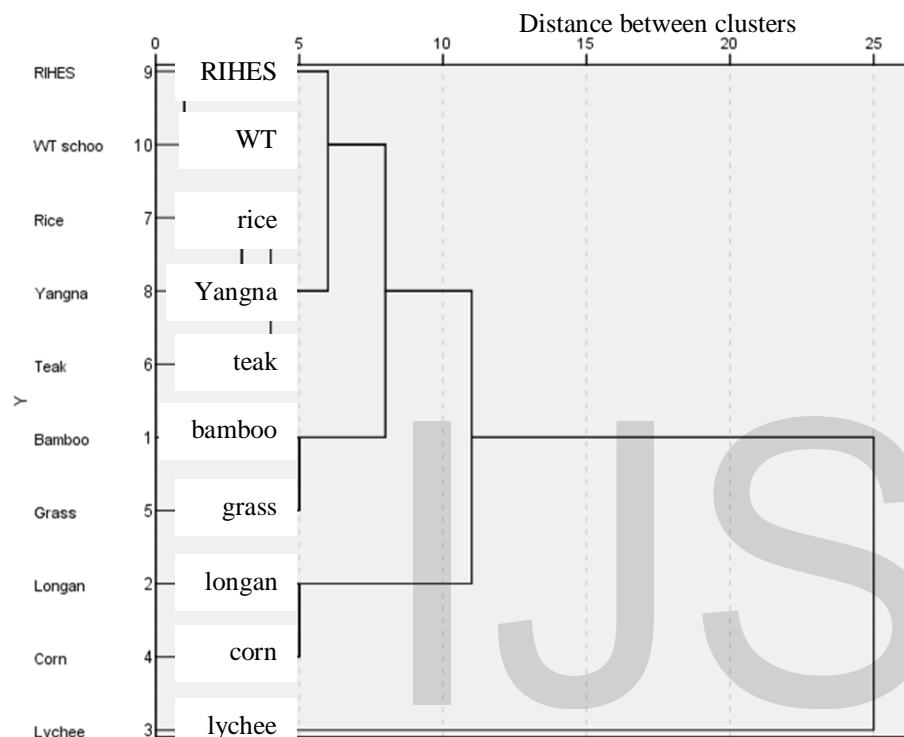


Figure 2. Dendrogram of rescaled Euclidean distance

It was noticeably that values of same sample on the diagonal were 0, since a case does not differ from itself. Therefore, distance between WT School and RIHES samples at 0 suggested the same cluster of trace elements pattern from these two sites. Considering the dendrogram, there were 5 clusters consisted of 1 (WT School and RIHES), 2 (rice, teak and Yangna), 3 (bamboo and grass), 4 (longan and corn) and 5 (lychee). Cluster 1 was more similar to cluster 2 than cluster 3, 4 and 5, respectively. This can be explained that the major source of PM<sub>10</sub> in WT School and RIHES sites may be from rice, teak and Yangna burning. Whereas bamboo

and grass might be the subordinately possible sources and longan and corn were the minor source.

#### 4 DISCUSSION

PM<sub>10</sub> concentrations from RIHES and WT School sites in this study (57.1 and 80.9  $\mu\text{g m}^{-3}$ , respectively) were slightly higher than the previous study which reported PM<sub>10</sub> concentration (40.4  $\mu\text{g m}^{-3}$ ) collected in Chiang Mai and Lumphun provinces in dry season, 2006 (6). It could be from the different number of hotspot which occurred in each year. However, in March of the same year (2010), PM<sub>10</sub> concentrations in this study were very high as well as another study which collected samples in Chiang Mai University (3).

PIXE technique which is high sensitive and non-destructive analytical technique is useful to identify trace element in PM<sub>10</sub> samples. PM<sub>10</sub> samples from WT School and RIHES were found major trace elements such as Al, Si, S, Cl, K, Ca, Ti, Cr, Mn and Fe. PM<sub>10</sub> concentrations

The ratio of proportion of elements are characterizing for each sample are apply to evaluate source of biomass burning because of each sampling sites was different related the plants in each area. Since Ca was abundant element, it was used to standardize the concentrations of the elements. K which is the major element in fertilizer was highly detected in the commercial plants such as longan, corn and rice. Heavy metals such as Cr, Ti and Mn were not found in any plant samples. Noticeably, Mn, octane-added material in gasohol fuel, was presented in PM<sub>10</sub> samples from RIHES and WT school sites but not found in any samples from plant burning.

The previous study pointed that the vegetative burning was the largest PM<sub>10</sub> contributor in Chiang Mai and Lamphun ambient air (2). However, it did not identify the type of plant. This study had selected the predominantly-found plant around Chiang Mai-Lamphun basin. Teak, bamboo, grass and Yangna are forest trees normally found in Saraphi and Suthep hill areas where WT School and RIHES sites take place, respectively, whereas rice, corn, longan and lychee are important commercial crops in both areas. From the cluster analysis, the highly possible sources of PM<sub>10</sub> in WT School and RIHES sites were from burning of rice, teak, Yangna, bamboo and grass. Since teak, Yangna, bamboo and grass are all forest plants, the main source of PM<sub>10</sub> in these sites was forest fire. According

to hotspot data (7), sample collecting period was in dry season and at the same time as highest forest fires occurring in these area. Field burning is a normal part of field preparation for cultivation of field crops such as rice and corn. Therefore, in these areas, PM<sub>10</sub> from lychee and longan burning was not as much as rice and corn burning.

## 5 CONCLUSIONS

The PM<sub>10</sub> samples collected from WT school were slightly higher than RIHES site because PM<sub>10</sub> from WT school may be affected by traffic whereas RIHES site which places in the University is a cleaner area. Euclidean distance showed that the source of PM<sub>10</sub> in both sites of this study was from forest fire and burning of local plants including rice, teak, Yangna, bamboo and grass. This study offers the proportion of trace elements from PIXE technique to identify source of PM<sub>10</sub>.

## REFERENCES

- [1] Pollution control department. 2011. *Report air pollution information 2005-2010*. Available: <http://www.pcd.go.th/AirQuality/Regional/DefaultThai.cfm> (online at 11/02/2011 (in Thai).
- [2] Pengchai P, Chantara S, Sopajaree K, Wangkarn S, Tengcharoenkul U, Rayanakorn M. (2009). Seasonal variation, risk assessment and source estimation of PM 10 and PM10-bound PAHs in the ambient air of Chiang Mai and Lamphun, Thailand. *Environ Monit Assess.* 154(1-4):197-218
- [3] Wiriya W, Prapamontol T, Chantara S. (2013). PM10-bound polycyclic aromatic hydrocarbons in Chiang Mai (Thailand): Seasonal variations, source identification, health risk assessment and their relationship to air-mass movement. *Atmos Res.* 124: 109–122. Bandhu HK, Puri S, Garg ML, Singh B,
- [4] U.S. Environmental Protection Agency, (2006). *National Ambient Air Quality Standard*. [Online]. Available. <http://www.epa.gov/air/criterai.html>
- [5] Pollution Control Department (2011). *Regional area air quality data*, 2 August 2011,

Available from:  
<<http://www.pcd.go.th/AirQuality/Regional/QueryAirThai.cfm?task=default>>

- [6] Chantara S, Wangkarn S, Sangchan W, Rayanakorn M. (2010). Spatial and Temporal Variations of Ambient PM10-bound Polycyclic Aromatic Hydrocarbons in Chiang Mai and Lamphun Provinces, Thailand. *Desalination and Water Treatment* 19: 17-25.
- [7] Forest Fire Control Division, National Park, Wildlife and Plant Conservation. (2010). *Forest fire statistics*. [Online]. Available. [http://www.dnp.go.th/forestfire/hotspot/Hotspot\\_statistics53.htm](http://www.dnp.go.th/forestfire/hotspot/Hotspot_statistics53.htm)