CHAPTER IV
RESULTS

The PM-10 sampling was conducted in three seasons; 1) winter during December 2002 to February 2003, 2) hot season during March to May 2003, and 3) rainy season during June to August 2003. Before starting, the instruments to be used were prepared and tested for their efficiencies and applicability to be used in this research. The personal air sampling instrument selected for this study has been used intensively in industrial hygiene work, but it was not obvious that the instrument would be suitable to be used under more general environment conditions. In fact, there were some limitations of the instruments that had to be accommodated before using these instruments in this research. These included battery lifetime, noise and carrier bag.

The results are presented four parts;

4.1) performance of the method

4.2) personal, indoor, outdoor and roadside PM-10 concentrations

4.3) the relationships among personal, indoor and outdoor PM-10 concentrations and the factors affecting their relationships, and

4.4) Identification of the possible relationships of personal exposure PM-10 materials with other PM-10 materials based on the trace element composition

4.1 Performance of the method

4.1.1 Sampling site characteristics

In total, 14 shop houses and 28 participants participated in the measurements of PM-10. Among the 14 shop houses in this study, ten shop houses are 4-story buildings, two of them are 3-stories tall, and the remainder includes a 5- and a 2-story building. Eleven buildings, H1-H11, are along the Sky Train route and 2 of them, H1 and H5, are located under the Nana and Phromphong Sky Train Station alignment,

respectively. The people in twelve of the shop houses still run their businesses regularly. Most of the shop houses were closed on Sunday. There were 4 houses (H1, H2, H4 and H5) whose first floors, the shop area, are fitted with an air conditioning system. All the houses used LPG as fuel for cooking and most of them do cooking once in a day. The kitchens were on the 1st floor except for H1, H5 and H9 that had their kitchens on the 2nd floor. The characteristics of the houses were noted as presented in Table 4.1. An example of the floor plan of a shop house is illustrated as in Figure 4.1.
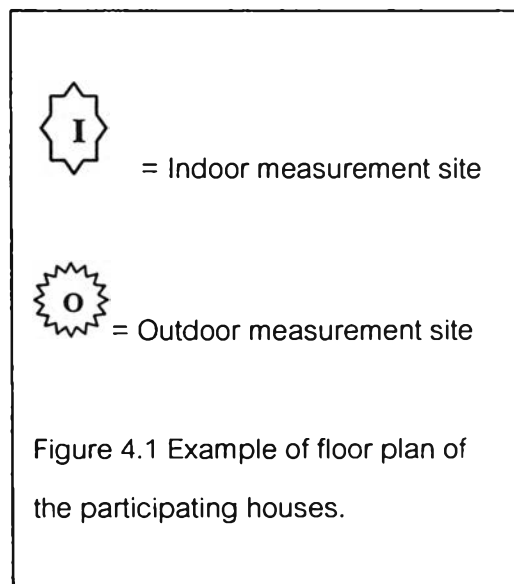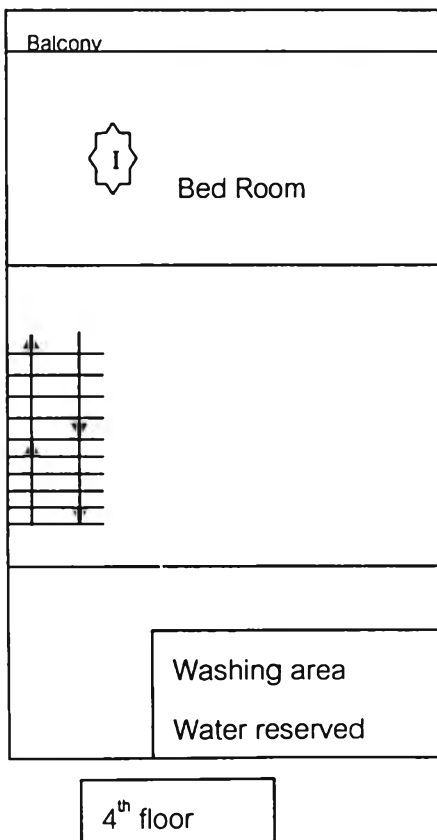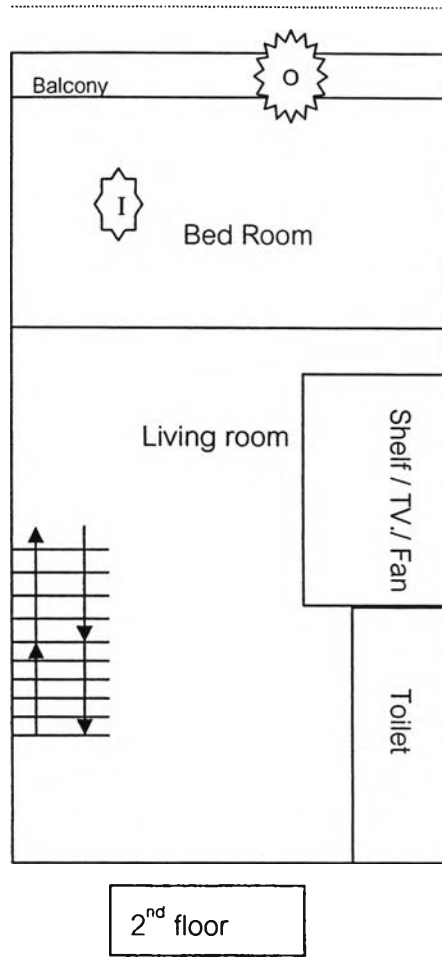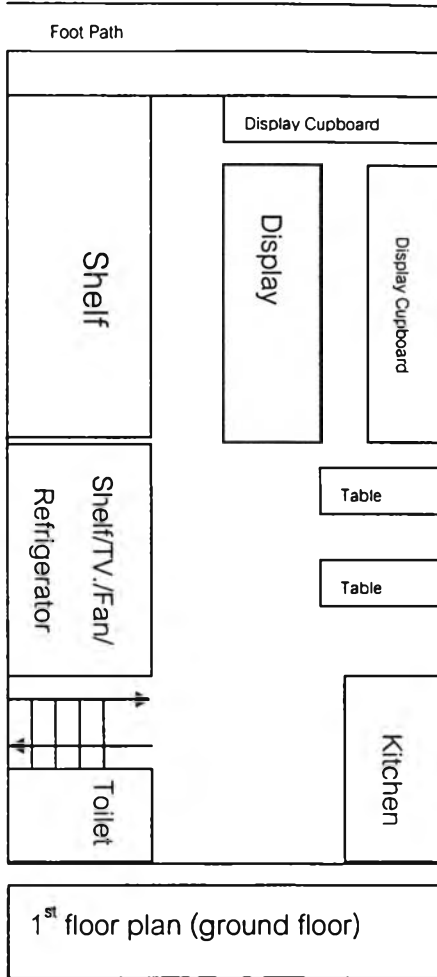
Table 4.1: The characteristics of the participating shop houses

	No. of storey	Location of the house		1st floor fitted with A/C	Floor with Kitchen	Remarks
		Kms^a	L/R^b			
$H1^c$	4	7	Left	Yes	2nd	Near bus stop
H2	4	6.2	Right	Yes	1st	At the corner of the road
H3	4	6	Left	No	1st	
H4	4	6	Left	Yes	1st	
$H5^c$	4	5.1	Left	Yes	2nd	
H6	2	5	Left	No	1st	Bedroom not on the roadside
H7	3	4.9	Right	No	1st	
H8	3	4.5	Left	No	1st	Near bus stop
H9	4	3	Left	No	2nd	Near bus stop
H10	4	0.01	Right	No	1st	Near the traffic light
H11	4	3	Left	No	1st	No business
H12	5	1	Right	No	1st	
H13	4	4	Left	No	1st	
H14	4	4	Right	No	1st	No business, park car inside

a The distance between the house and On-Nuch monitoring station (approximately)

b The house is located on the left or right side of Sukhumvit Road facing from the Ploenchit Road end of Sukhumvit Road.

c A house that is under a sky train station alignment, H1 is under the Nana Station and H5 is under the Phromphong Station.

Foot Path

Display Cupboard

Display

Display Cupboard

Shelf

Shelf/TV./Fan/ Refrigerator

Table

Table

Toilet

Kitchen

1st floor plan (ground floor)

Balcony

O

I

Bed Room

Living room

Shelf / TV./ Fan

Toilet

2nd floor

Balcony

I

Bed Room

Washing area

Water reserved

4th floor

I = Indoor measurement site

O = Outdoor measurement site

Figure 4.1 Example of floor plan of the participating houses.

4.1.2 Sampling equipment

Pump: 12 air sampler pumps (model 224-PCXR 8, SKC Inc., USA.) were used for indoor, outdoor and personal PM-10 measurements. This air sampler pump was connected with the PEM, so that particles smaller than 10 μm were collected on a 37 mm Teflon filter (PTFE). This model pump has some advantageous characteristics in that it can be programmed to draw air intermittently by setting the sampling period, and the pump period. The operator can also set the pump starting time. However, the usual battery lifetime of the pump is typically about 12-14 hrs depending on the flow rate during operation. Therefore, the batteries of the pumps were modified to use five 3000mAh metal hydride batteries as shown in Figure 4.2 and then tested for effectiveness for this study. All of the modified batteries could be used for PM-10 measurement for a whole day sampling period (24 hours) without any battery changing or charging. This is more convenient for both participant and researcher.
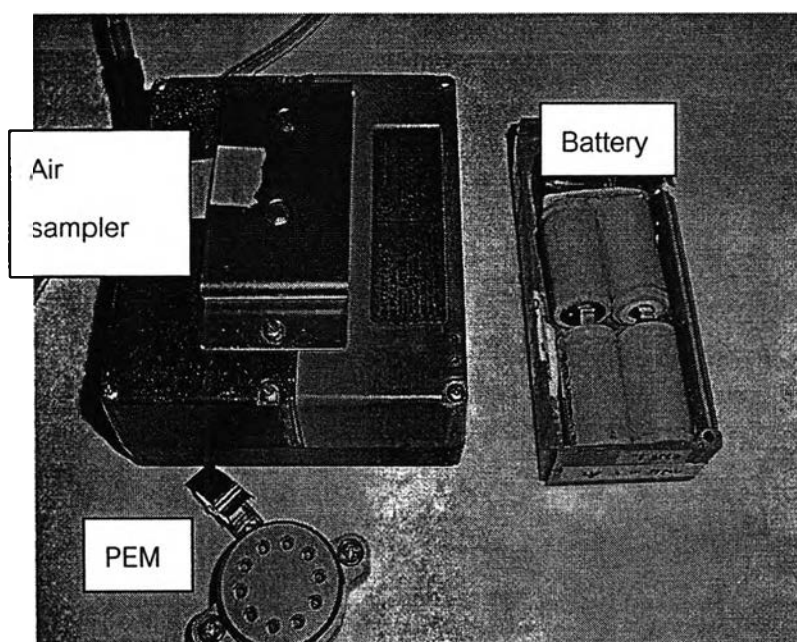
Figure 4.2 PEM and Battery of the air sampler instrument

Noise: During the pump operation, the noise of the pump would frequently annoy the participants and stakeholders. For indoor measurements, the pump was put into wooden box lined with acoustic board to reduce the noise level, bringing the total weight of the instrument to 2.8 kg. For personal measurements in which the

participants have to carry the PEM, a bag designed with acoustic board lining, as shown in Figure 4.3 is used instead of the wooden box so that the weight of the personal sampling instrument was 1.8 kg.
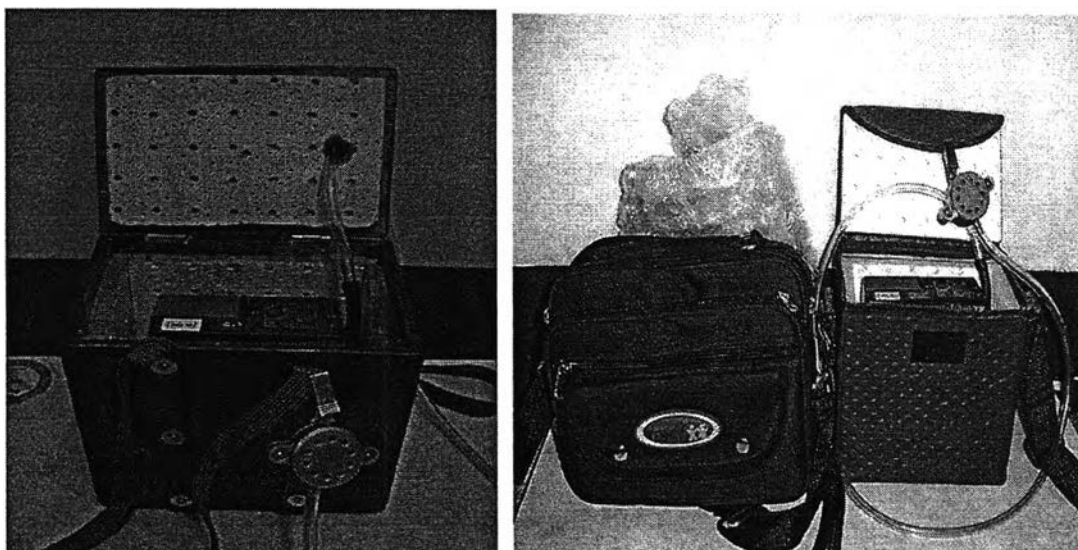

Figure 4.3 Samplers lined with acoustic material; Left: indoor, Right: personal instrument

4.1.3 Flow rate

Flow rates were measured at the beginning and the end of each 24-hr sampling period with Dry-Cal, a primary calibration device. Then the average pump flow rate and the total elapsed time were used to calculate the sampling volume. The pre-sampling flow was adjusted to be 4 L/min $\pm$ 5%. If the post-sampling flow had changed more than $\pm$ 5%, the sample was excluded. Most of pre- and post-sampling flows were within 5% as shown in Table 4.2. There were 7 samples for which post-sampling flows were not within 5% of the pre-sampling flow and those samples were excluded.

Table 4.2 Distribution of pre-sampling, post-sampling and average flow rate (l/min)

N = 804	Mean	SD	Minimum	Maximum
Pre-sampling flow rate	4.001	0.030	3.800	4.078
Post-sampling flow rate	3.980	0.074	3.651	4.276
Average flow rate	3.990	0.045		

4.1.4 Precision of PM-10 measurement by PEM instrument

The precision of the method was assessed by placing 5 sets of PEM sampling instruments close together in the same room and then performing the PM-10 sampling with flow rate and sampling time as designed. Then the PM-10 concentrations and the relative standard deviation of the results were calculated. The experiments were carried out 3 times for comparison. The relative standard deviations of the method were less than 5% with values of 4.88, 3.33 and 5.26%, as presented in Table 4.3. The results suggested that the PEM instrument could be used to measure PM-10 with high precision.

Table 4.3 Relative standard deviations of the method

Pump No.	PM 10 concentration(mg/m^3)		
	1st experiment	2nd experiment	3rd experiment
1.	0.039	0.062	0.062
2.	0.043	0.060	0.055
3.	0.041	0.057	0.054
4.	0.041	0.061	0.056
5.	-	0.058	0.058
Mean	0.041	0.060	0.057
SD.	0.002	0.002	0.003
RSD.	4.88	3.33	5.26

4.1.5 Standard deviation of weighing and reweighing

Because of the sensitivity of the microbalance, the temperature and humidity of the weighing room had to be controlled (Temperature: 23 ± 5 °C; Relative Humidity RH: 45 ± 5%). The stability of the weighing procedure was determined by weighing a filter ten times and then calculating the standard deviations as presented in Table 4.4. The standard deviations of the filter weights were in a range from 0.001 to

0.003 mg. The results indicated that the weighing results were stable and thus, the weighing procedure was acceptable.

Table 4.4 Standard deviation of weighing

Filter no.	Filter weight (mg.)								
	1002	2003	2001	2002	3101	3102	3103	3151	3152
	101.943	104.166	102.866	96.77	92.519	89.124	100.481	95.176	93.279
	101.945	104.163	102.866	96.77	92.521	89.124	100.48	95.173	93.278
	101.945	104.167	102.868	96.768	92.523	89.128	100.482	95.174	93.277
	101.945	104.17	102.867	96.772	92.52	89.129	100.482	95.172	93.279
	101.946	104.169	102.868	96.77	92.522	89.13	100.48	95.176	93.279
	101.944	104.169	102.868	96.768	92.522	89.126	100.48	95.173	93.277
	101.946	104.171	102.869	96.772	92.52	89.129	100.48	95.171	93.276
	101.945	104.17	102.866	96.772	92.523	89.128	100.482	95.173	93.278
	101.944	104.165	102.865	96.774	92.52	89.128	100.482	95.171	93.275
	-	104.163	102.87	96.774	92.525	89.131	100.481	95.174	93.278
Mean	101.945	104.167	102.867	96.771	92.522	89.128	100.481	95.173	93.278
SD.	0.001	0.003	0.002	0.002	0.002	0.002	0.001	0.002	0.001

After sampling, the filters which were kept in the plastic container and sealed with parafilm tape and foil were refrigerated at $4^{\circ}C$ and the filters were weighed after equilibrating at the weighing room condition for at least 24 hours. In order to detect any changes of mass of PM-10 on the filters that might have been caused by conditions during the preservation period, the sampled filters were reweighed. After the first weighing, the sampled filters were stored in the refrigerator for 2 months and then a second weighing was done, following the same procedures as described. Thirty two filters were randomly selected to be reweighed. The result showed that there was no significant difference in the weights between the first and second weighing as verified by using a paired T-test as shown in Table 4.5.

Table 4.5 Descriptive Statistics of reweighing of PM-10 sampled filters

Statistical Data	Variable 1	Variable 2
Mean of all filter weights: mg.	95.469	95.468
SD. of all filter weights: mg.	3.156	3.157
Observations	32	32
Avg. weight difference between 1st and 2nd weighing	0.001 mg.	
P(T<=t) two-tail	0.082	

4.1.6 Field blanks

Field blanks were obtained to ensure the integrity of the collection procedures by placing a PTFE filter in the filter holder with no air sampler pump and without handling in the shop house, but which then underwent all of the procedures as did the sampler. The mean mass increase on the field blanks of PM-10 measurements in shop houses was 11.5 µg (n=135; SD 8.3; range 0.0 to 37.5). The detection limit of PM-10 measurement, which was calculated by 3 times of standard deviation of field blanks and divided by sample volume of 2.82 m^3, is presented in Table 4.6. All sampled filters were corrected with the corresponding field blank. The results showed that PM-10 concentrations of all samples were higher than the detection limit.

Table 4.6: The distribution of mass increase on field blank (µg)

	N	Mean	SD.	Range	Detection limit: $µg/m^3$
Season1: Winter	45	16.1	10.0	0.0 to 37.5	10.6
Season2: Hot	45	8.1	5.2	0.0 to 23.5	5.5
Season3: Rain	45	10.3	6.9	0.0 to 31.0	7.3
All	135	11.5	8.3	0.0 to 37.5	8.8

4.1.7 Field comparison

Because of the differences in PM-10 measurement methods, the high volume PM-10 Sampler and the PEM instruments, these two methods were assessed to

determine the data comparability by placing a PEM instrument near the High Volume PM-10 sampler at On-Nuch station for a 24 hr collocation-sampling study. The results showed that the PEM and the High Volume air sampler were significantly correlated (r = 0.98; n = 18) and the estimated regression equation was PEM = 1.304 x Hi-Volume as shown in Figure 4.4. The result indicated that these two instruments were comparable and could reflect the day-to-day variation of PM-10 consistently although the PM 10 concentration obtained from the PEM was higher than that from the High Volume PM-10 Sampler.
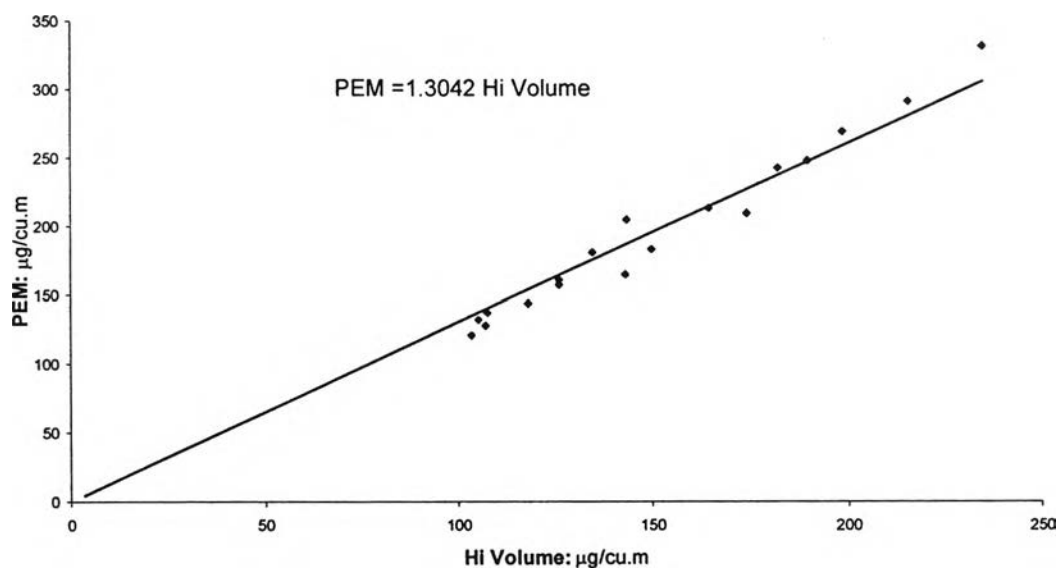

Figure 4.4 Correlation of PM-10 concentrations obtained by PEM and High Volume air sampler at On-Nuch roadside station

In addition, a High Volume PM-10 Sampler from PCD and the identical one from this study were placed close together for 10 days. The result showed that the PM-10 measurement by this method in this study is in good agreement with the PCD measurement (r = 0.998; n= 7) as shown in Figure 4.5.
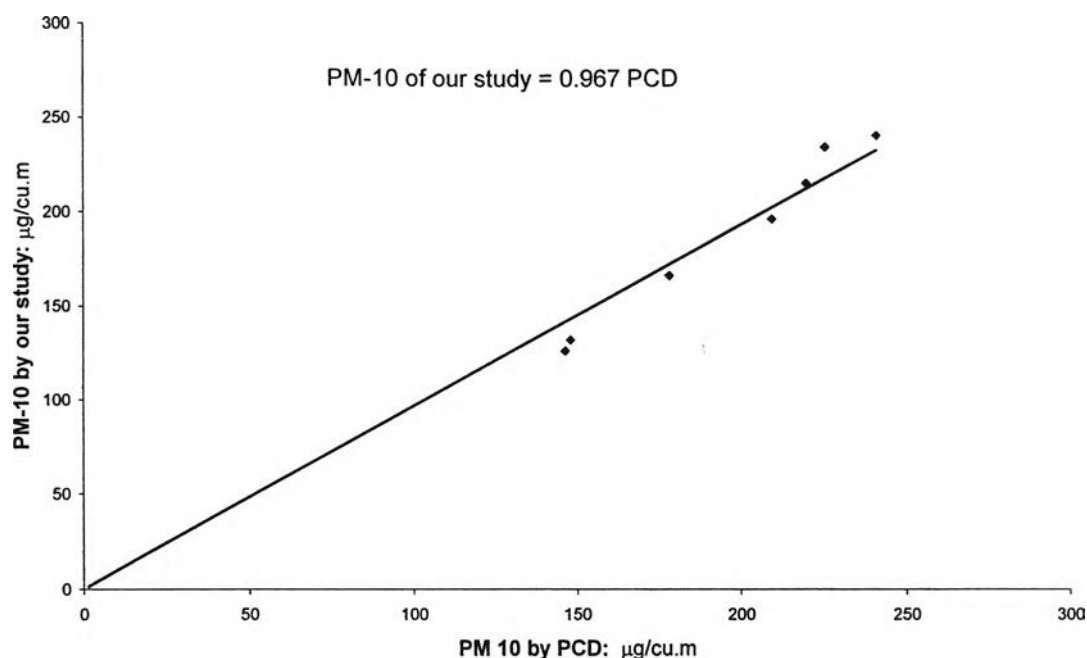
PM-10 of our study = 0.967 PCD

Figure 4.5 Correlation between PM-10 concentration by High Volume air sampler of PCD and of our study

4.2 Personal, indoor, outdoor and roadside PM-10 concentrations

4.2.1 Distribution of PM-10 concentrations

4.2.1.1 Ambient roadside PM-10 concentrations

For each house/participant, the individual means of personal, indoor, outdoor, and ambient roadside PM-10 concentrations were calculated from eight to nine measurements except for H3 where the concentrations were obtained from fifteen to eighteen measurements. However, ambient roadside PM-10 concentrations were concurrently measured at On-Nuch station, so that overall 135 measurements were taken (45 measurements for each season).

Figure 4.6 shows the data for ambient PM-10 concentrations measured by the High-volume air sampler during the study. The ambient roadside PM-10 concentrations were on average 155.0 $\mu g/m^3$, with a range from 85.2 to 248.1 $\mu g/m^3$. The average of ambient PM-10 concentrations in winter was higher than those in the hot and rainy season, which were 189.3, 141.7 and 133.8 $\mu g/m^3$ respectively.
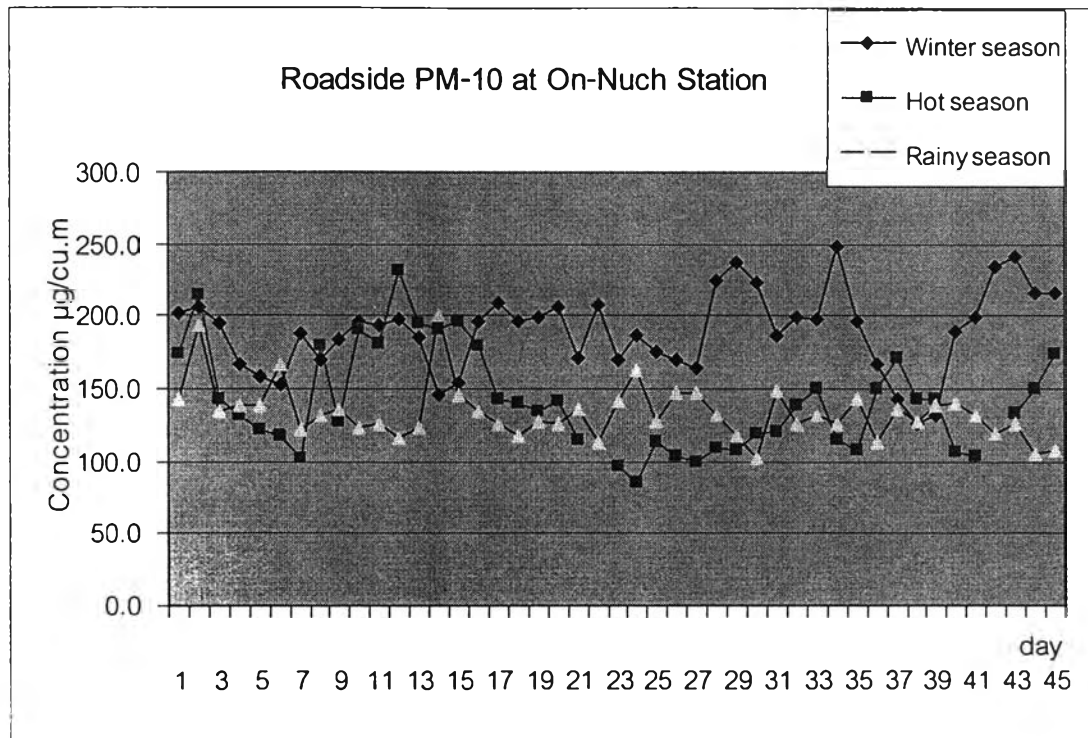
Figure 4.6 Roadside PM-10 concentrations monitored at On-Nuch Station during in

winter, hot and rainy season

4.2.1.2 The overall mean of indoor, outdoor, ambient roadside and personal PM-10 concentrations

Three indoor sampling locations on the 1st, 2nd, and 4th floors were measured in each shop house during each measurement day. An exception was that for H1 and H6 there were only two indoor sampling sites, 1st floor and 2nd floor, because the H1 occupants permitted sampling to be carried out no higher than the 2nd floor and H6 is a 2 story building. H7 and H8 are 3-story buildings so that their 3rd floor PM-10 concentrations were included with the 4th floor concentrations. In order to get a single indoor concentration, the 1st, 2nd and 4th floor PM-10 concentrations of each day were summed and then divided by 3. From the total of 792 samples measured by PEM, 27 samples were lost due to pump failure, decreasing of the flow rate, or filter damage. Only 2 samples of a total of 135 ambient samples measured by the High-volume sampler were lost due to pump failure.

Table 4.7 presents the data indicating the overall mean values of PM-10 concentrations at each sampling location. According to the results of indoor measurements, the overall mean of the first floor PM-10 concentrations was higher than those of the second and fourth floors, being 87.5, 67.1 and 63.8 $\mu g/m^3$ respectively, and the variation in PM-10 concentrations of the 1st floor was also more than observed for the other floors. In addition, the overall mean of personal exposure PM-10 concentrations, 81.6 $\mu g/m^3$ lies between those of indoor PM-10 concentrations, 74.6 $\mu g/m^3$ and outdoor PM-10 concentrations, 130.7$\mu g/m^3$. The overall mean of outdoor concentrations measured by PEM was statistically less than the overall mean of ambient concentration measured at the On-Nuch roadside station ($p = 0.037$).

Table 4.7 Descriptive statistics of the overall means of indoor, 1st floor, 2nd floor and 4th floor, outdoor, ambient roadside and personal PM-10 concentrations

Sampling site	N	# ( )*	PM-10 concentrations: $\mu g/m^3$			
			Mean	SD	Median	Range
1st floor	14	134 (1)	87.5	31.5	81.8	37.7 to 163.8
2nd floor	14	130 (5)	67.1	18.6	64.4	38.9 to 101.7
4th floor	12	111 (6)	63.8	13.3	61.3	39.8 to 84.3
Indoor	14	**	74.6	19.5	73.1	38.7 to 122.1
Outdoor	14	131 (4)	130.7	39.0	115.5	91.4 to 207.8
Ambient	1	133 (2)	155.0	29.7	156.1	85.2 to 248.1
Person	28	259 (11)	81.6	14.3	81.5	41.0 to 155.4

* # Total number of observations, ( ) Numbers of missing data

** Calculated from 1st, 2nd, and 4th floor readings to obtain overall number

The distributions of the individual PM-10 concentrations of personal exposure and for each sampling location, indoor, outdoor, and ambient, for each shop house are presented in Appendix B. Considering the variations throughout the simultaneous sampling locations, the averages for outdoor PM-10 concentrations of each house exceeded both the averages for indoor and personal PM-10 concentrations

and most of the averages for personal PM-10 concentrations were higher than those for the indoors readings. The overall mean of the outdoor PM-10 concentrations significantly exceeded those of personal and indoor concentrations as verified by t-test ($p < 0.001$). Conversely, the overall means of personal and indoor concentrations showed no statistical difference ($p = 0.428$).

4.2.2 Comparison of PM-10 concentrations of the 1st, 2nd, and 4th floor

Investigation of PM-10 concentrations of each floor showed that PM-10 indoor levels fluctuated widely from house to house and floor to floor (Table 4.8). The highest indoor concentration was 163.8 $\mu g/m^3$ found in H12, while the lowest was 37.7 $\mu g/m^3$ found in H7. To determine the differences of PM-10 concentrations between floors and between different shop houses, PM-10 concentrations of each floor were compared by Two-Way ANOVA and Multiple Comparison: Least-Significant Difference method. The results revealed that both factors, floor levels and houses, significantly influenced the PM-10 concentrations ($p < 0.05$). In addition, the overall mean of the 1st floor PM-10 concentrations was significantly different from the 2nd and 4th floor ($p < 0.001$) means, whereas the overall mean PM-10 concentration of the 2nd floor was statistically similar to that of the 4th floor ($p = 0.297$).

The differences in PM-10 levels among floors were further examined for each house by using Random Block Design-Analysis of Variance (RBD-ANOVA) except that H1 and H6 were tested by using Paired T-Test as shown in Table 4.8. The results showed that for most of the shop houses, 12 of the 14 shop houses, the PM-10 levels of each floor were statistically different ($p < 0.05$). The highest difference in indoor PM-10 concentrations was 87.0 $\mu g/m^3$, which was between the 1st floor and the 4th floor PM-10 concentration of H12. Only for H5 and H7, were the PM-10 concentrations of each floor level not significantly different.

Table 4.8 Comparison of indoor PM-10 concentrations between the 1st, 2nd and 4th floor PM-10 concentrations of each house

| | PM-10 concentration: Mean $\pm$ SD   unit: $\mu g/m^3$ | | | P-Value |
	1st floor	2nd floor	4th floor	(RBD-ANOVA)
H1	61.3 ± 13.6	84.0 ± 16.4	NA	0.006 (Paired t-test)
H2	59.5 ± 19.2	43.6 ± 13.4^a	56.0 ± 24.7	0.005
H3	87.5 ± 25.5^b	62.6 ± 17.0^c	56.0 ± 12.0^d	0.000
H4	69.5 ± 18.5	66.1 ± 14.5	59.5 ± 14.9^a	0.026
H5	66.8 ± 25.9	56.7 ± 31.0^a	58.8 ± 17.1	0.082
H6	117.4 ± 30.1	46.8 ± 16.7	NA	0.000 (Paired t-test)
H7	37.7 ± 16.6^a	38.9 ± 13.2	39.8 ± 13.5	0.425
H8	77.7 ± 31.4	58.9 ± 25.7	63.0 ± 21.5	0.032
H9	114.9 ± 35.3	73.2 ± 24.5	78.3 ± 22.9	0.000
H10	103.7 ± 70.8	72.4 ± 24.8^a	75.0 ± 39.7^a	0.039
H11	76.0 ± 19.6	101.7 ± 33.9	84.3 ± 29.5	0.023
H12	163.8 ± 48.1	$97.9 \pm 3 3.6^a$	76.8 ± 24.8^a	0.000
H13	85.9 ± 18.4	73.4 ± 14.7	69.5 ± 17.5	0.000
H14	103.2 ± 47.3	62.8 ± 37.2	$48.1 \pm 1 8.2$	0.000

Note: number of observation for each floor = 9

a: number of observation = 8; missing data = 1

b: number of observation = 18

c: number of observation = 17; missing data = 1

d: number of observation = 15; missing data = 3

4.2.3 Comparison of personal exposure concentrations

A total of 28 adults participating in the study have ages ranging from 20 to 75 and had been living and working in the shop houses. All participants live upstairs in the homes and most of them spent more than 95% of their time indoors. The average time spent indoors was about 23 hrs 15 minutes and average time spent outdoors was

about 45 minutes (range; 0 to 600 min) each day. Most of the shop houses were open on Monday to Sunday at noon. Personal PM-10 concentrations were substantially variable (range from 41.0 to 155.4 $\mu g/m^3$) as presented in Table 4.9.

Table 4.9 Comparison of personal PM-10 concentrations of the two participants in the same shop house

	Mean of personal PM-10 concentration; $\mu g/m^3$				P1 vs. P2	
	N	Person1: P1	N	Person2: P2	P-Value	n*
H 1	8	44.6 ± 10.5	8	44.8 ± 10.9	0.814	8
H 2	9	89.7 ± 23.6	8	72.7 ± 17.9	0.067	8
H 3	16	78.7 ± 18.9	16	88.3 ± 23.1	0.015	14
H 4	9	69.1 ± 21.0	9	84.6 ± 30.8	0.067	9
H 5	9	65.1 ± 24.4	9	64.7 ± 23.0	0.953	9
H 6	9	66.6 ± 35.1	8	103.8 ± 38.0	0.009	8
H 7	8	41.4 ± 17.4	9	44.1 ± 17.7	0.699	8
H 8	9	65.0 ± 26.5	9	74.4 ± 31.4	0.224	9
H 9	9	101.2 ± 32.8	9	106.9 ± 37.7	0.451	9
H 10	9	95.0 ± 61.1	9	102.6 ± 68.9	0.041	9
H 11	9	103.3 ± 34.3	9	97.7 ± 27.9	0.208	9
H 12	9	154.7 ± 48.5	9	155.4 ± 33.4	0.953	9
H 13	8	96.2 ± 32.7	8	84.2 ± 16.3	0.834	7
H 14	9	41.03 ± 19.4	9	49.8 ± 16.7	0.007	9

* Number of paired observation data

From the results, the difference between the two personal concentrations for people living in the same shop house ranged from 0.2 to 43.3 $\mu g/m^3$, with a mean of 10.5 $\mu g/m^3$. Comparing personal exposure concentrations of each house by the Paired T-Test, it was found that there were 4 houses, H3, H6 and H10 and H14 where personal PM-10 concentrations of the two participants were significantly different ($p < 0.05$).

4.3 The relationships among personal, indoor and outdoor PM-10 concentrations and factors affecting their relationships

4.3.1 The relationship between outdoor and ambient roadside PM-10 concentrations

The individual correlations and regressions between outdoor and ambient PM -10 concentrations for each of the houses were analyzed and calculated for the overall set of houses. The distributions of individual correlations and regression coefficients were not normally distributed as tested by the Shapiro-Wilk Statistical approach (p<0.01). The correlation coefficients varied widely with a median of 0.789 which could be interpreted to mean that the outdoor concentrations were quite well correlated with the ambient roadside PM-10 concentrations as presented in Table 4.10. However, it was found that there were three negative coefficients between the outdoor and ambient PM-10 concentrations (listed in Appendix C) indicating that, on these measurement days, the outdoor PM-10 concentrations were different from the ambient PM-10 concentrations.

Table 4.10 Correlation and regression models between outdoor and ambient roadside PM-10 concentrations

	$PM10_{outdoor} = PM10_{ambient}$: n = 14		
	Correlation coefficient	Intercept ($\mu g/m^3$)	Slope (Regression coefficient)
Mean	0.515	71.858	0.355
Median	0.789	27.261	0.695
SD.	0.616	185.229	1.088
Range	-0.676 to 0.984	-68.35 to 651.88	-2.946 to 1.424

4.3.2 The relationships among personal, indoor and outdoor PM-10 concentrations

Regression and correlation analyses were used to determine the individual relations between personal, indoor and outdoor concentrations, with the three

following models: model 1 (person-outdoor), model 2 (person-indoor) and model 3 (indoor-outdoor). The distributions of individual correlations, which were not normally distributed as verified by the Shapiro-Wilk Statistical approach: $p < 0.01$, were presented in Table 4.11. Median regression and correlation coefficients for the three models were statistically significant ($p < 0.001$) but the median intercepts for the three models were not significantly deviated from zero ($p > 0.05$).

Table 4.11 Correlation and regression models among personal, indoor and outdoor PM-10 concentrations

	Model 1 (n= 28) $PM10_{person} = PM10_{outdoor}$		Model 2 (n= 28) $PM10_{person} = PM10_{indoor}$		Model 3 (n= 14) $PM10_{indoor} = PM10_{outdoor}$	
	Median	Range	Median	Range	Median	Range
Intercept $\mu g/m^3$*	21.2	-114.8, 78.9	2.9	-50.2, 78.8	4.6	-67.6,131.4
Slope**	0.488	-0.167,1.503	1.071	0.485,1.718	0.461	-0.289,1.066
Pearson' s R**	0.706	-0.798,0.937	0.865	0.548, 0.980	0.824	-0.826,0.981

* Median intercepts for three models were not significant (Wilcoxon Signed Rank Test; p = 0.05)

** Median regression and correlation coefficients for three models were significant (Wilcoxon Signed Rank Test; p = 0.05)

For both model 1 (person-outdoor) and model 3 (indoor-outdoor), the correlation coefficients fluctuated more than did model 2 (person-indoor) as their correlations were distributed from strongly positive to strongly negative. In contrast, all the individual correlations of model 2 were higher than 0.5 with a range of 0.432. The higher median correlation coefficient of model 2 than that determined for model 1 indicated that personal exposure concentrations were in better agreement with indoor PM-10 levels than with the outdoor levels. Examination into the individual correlation coefficients of model 1 revealed that there were three negative correlation coefficients (-

0.049, -0.772 and -0.798) of which the two highest values belonged to the two participants in H14 where their cars were generally parked inside the house. Similar to model 1, the correlation coefficient of model 3 (indoor-outdoor) of H14 was strongly negative (-0.826). Conversely, the correlation coefficients for model 2 (person-indoor) of the two participants of H14 were strongly positive (0.846 and 0.938). Excluding the data from H14, increased the median correlation coefficient for model 1 from 0.706 to 0.760 and from 0.824 to 0.828 for model 3 while the median correlation coefficient of model 2 was not changed from 0.865.

4.3.3 Factors Affecting Personal PM-10 Exposure Concentrations

The results of PM-10 concentrations showed that indoor concentrations were considerably below personal PM-10 concentrations while the outdoor concentrations exceeded personal PM-10 levels. Thus, outdoor PM-10 levels could better serve as a basis for estimating personal exposure concentrations. The reason for using outdoor concentrations instead of ambient PM-10 concentration was that the correlation coefficient between outdoor-and ambient PM-10 concentrations showed some negative correlations meaning that ambient PM-10 concentrations would not always reflect the outdoor PM-10 concentrations of the shop houses properly. To determine the factors affecting the personal PM-10 exposure levels, outdoor PM-10 concentrations as well as other environmental factors and personal activities were evaluated by multiple regression analysis (detailed results in Appendix D).

From Table 4.12, six variables--outdoor concentration, winter season, door of the 1st floor kept open, bedroom with air conditioning system, incense burning and exposure to tobacco smoke--have significant influences on personal PM-10 concentrations ($p < 0.001$). All of these six factors accounted for approximately 42% of the variability of personal exposure concentrations. The other 9 factors, for example cooking, exercise, time spent outdoors, cleaning, building location and proximity to the Sky Train station (an elevated electric light rail system) , were not significant contributing effects to personal PM-10 levels ($p > 0.05$).

Table 4.12 Categorized variables examined in multiple step-wise regression analysis

Environmental Factors		Personal activities	
Characteristic examined	P-Value	Characteristic examined	P-Value
Outdoor concentration; $\mu g/m^3$	0.000	Cleaning; Yes/No	0.132
Season: Winter	0.000	Gold sleeve paper burning; Yes/No	0.315
: Summer	0.51		
: Rainy	0.51	Cooking; Yes/No	0.287
Door of 1st floor; Opened/Closed	0.000	Incense burning; Yes/No	0.001
Bedroom; at 1st floor or Else	0.345	Exercise; Yes/No	0.560
House location; Left/Right (of the road)	0.063	Expose to tobacco Smoke; Yes/No	0.000
Raining on the measurement day; Yes/No	0.166	Time spent outdoors; Minutes	0.645
Under Sky train station alignment; Yes/No	0.509	Using air conditioned system in a bedroom; Yes/ No	0.000

The results in Table 4.13 indicate that the most influential factor affecting personal exposures was outdoor PM-10 concentrations with a standardized coefficient of 0.312. Measurement in the winter as well as exposure to tobacco smoke was shown to be similarly correlated to personal PM-10 levels. Although, participants were non-smokers with no smokers in their households, they could still be exposed to tobacco smoke from their friends or customers or elsewhere. Incense burning also contributed to increases in personal PM-10 levels. Conversely, sleeping in a bedroom with an air conditioning system had a negative effect on personal PM-10 levels, indicating that living in a room equipped with an air conditioning system tended to lower the personal PM-10 levels. Nonetheless, the intercept of the exposure model was significant. This suggested that there possibly were other determinants or other factors influencing personal exposure that may not be included in the models, for example, time in vehicle, time spent on each floor or rate of movement.

Table 4.13 Estimation of factors affecting personal concentrations (n=251)*

	Parameter Estimate	Std Error	Standardized coefficients	mean of variables
Intercept[b]	40.67	6.20		
Exposed to tobacco smoke	19.53	5.06	0.205	0.24
Winter season	17.98	4.50	0.205	0.33
Outdoor PM-10 conc.	0.23	0.40	0.312	129.43
Door of 1st floor open/closed	25.38	4.32	0.309	0.47
Bedroom with A/C system	-18.63	4.36	-0.214	0.67
Incense	30.45	9.26	0.171	0.056

* Correlation of Model: $r = 0.645$, $r^2 = 0.415$, adjusted $r^2 = 0.401$

b Intercept was significant ($p = 0.000$), unit: $\mu g/m^3$

4.4 Identification of the possible relationships of personal exposure PM-10 materials with other PM-10 materials based on the trace element composition

To identify the possible relationships among the sources of PM-10, the particulate matter collected on the filters from personal, indoor and outdoor measurements were further analyzed to determine the chemical compositions. Because the filters were Teflon and the ICP/MS analytical method is a destructive method, only elemental compositions were determined while some components, for example carbon contents, cations and anions could not be determined. Therefore, the possible relationships of personal PM-10 materials were identified based on the trace element compositions. A concern at the beginning of the study was whether or not a source of indoor generated PM-10 materials existed that would affect any relationships among the particulate types studied. Addressing this concern was the major objective of carrying out the elemental analysis study.

4.4.1 Chemical composition analysis

4.4.1.1 Chemical concentrations

The sampled filters were extracted with hot acid digestion and were analyzed by ICP/MS. Eighteen elemental species were determined, specifically

Ag, Al, As, Ba, Ca, Cd, Cr, Cu, Fe, In, K, Mg, Mn, Na, Ni, Pb, V, and Zn. Determination of the detection limits and percent recoveries of these elements were performed as shown in Appendix E. The elemental concentrations of the samples were compared with the corresponding detection limits. The concentrations should be more than the detection limits, otherwise the determined concentrations were reported as null. Then, the concentrations of different elements were corrected by their corresponding percent recoveries and were transformed to a unit of $\mu g/m^3$.

Table 4.14 Average concentration of elemental compositions

	Elemental concentration: Mean (unit: ng/m^3)		
	Outdoor n=111	Indoor n =308	Person n=222
Concentration: $\mu g/m^3$	125.8	71.9	78.9
Ag	1.2	1.3	2.1
Al	577.8	285.3	364.7
As	4.0	7.1	6.7
Ba	115.1	43.7	128.8
Ca	4043.7	1681.7	2205.3
Cd	1.2	1.2	1.0
Cr	136.2	226.0	200.2
Cu	74.6	1.7	53.9
Fe	109.6	185.9	164.5
In	0.9	0.9	0.8
K	1592.4	1216.2	1293.0
Mg	542.3	216.1	266.4
Mn	56.2	50.6	44.5
Na	774.9	517.5	513.5
Ni	86.7	175.5	169.8
Pb	54.5	38.2	38.5
V	144.7	203.7	185.5
Zn	435.2	291.4	323.1

For determining the PM-10 sources, all the 259 personal PM-10 samples from 28 subjects were pooled into one data set. This procedure was also carried out for the indoor and outdoor PM-10 samples. Thus three data sets for elemental concentrations were created. The average concentrations of each element of these three data sets were shown in Table 4.14. The elements which showed quite low concentrations were In, Ag and Cd with in a range of 1 ng/m^3 while the concentrations of Ca and K were a thousandfold higher than those of the low amount elements. It was found that the concentrations of the elements of all types varied widely as presented in Figure 4.7.
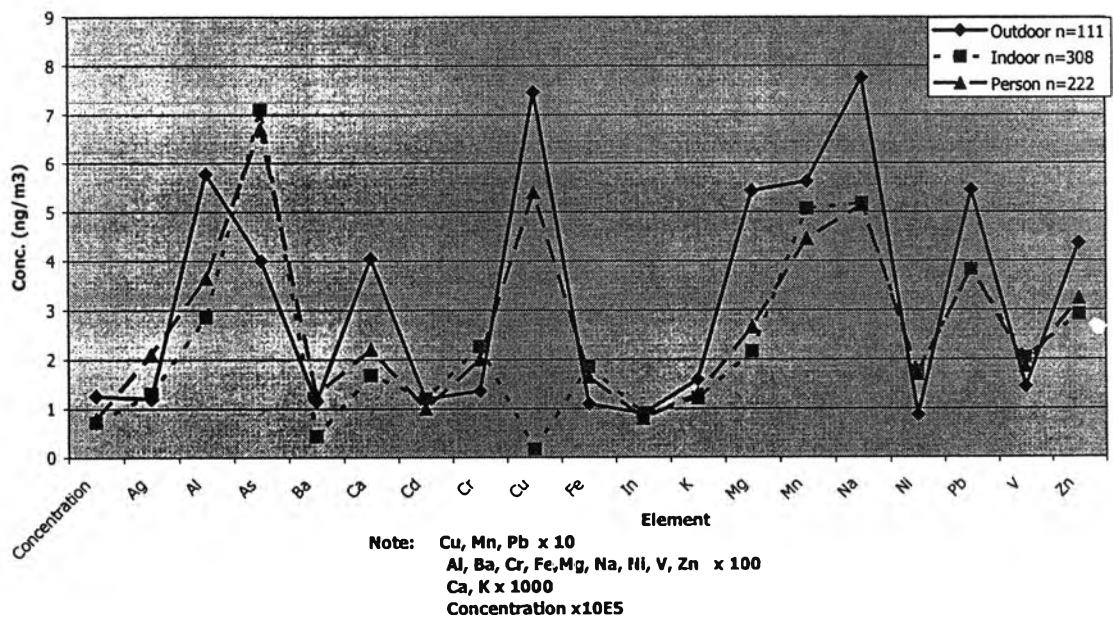

Figure 4.7 Average concentrations of elements in personal, indoor and outdoor PM-10 samples

4.4.1.2 Indoor/outdoor ratio of the elements

The average indoor to outdoor ratios of the different elements were presented in Table 4.15. The indoor to outdoor ratios varied widely from element to element ranging from a minimum of 0.46 for Ba to a maximum of 2. 72 for the Cr ratio. However, the result showed that most of the indoor to outdoor ratios of the elements were close to 1. The lower ratio may have been due to the intrusion of outdoor air while

the higher ratio would probably be due to other PM-10 sources of these particular elements inside the houses. However the cutoff value was arbitrary. Nevertheless, there were some elements where the indoor to outdoor ratios were higher than 2 such as Ag, Cr, Ni, and V. as shown in Figure 4.8.

Table 4.15 Average elemental ratios among outdoor, indoor and personal PM-10

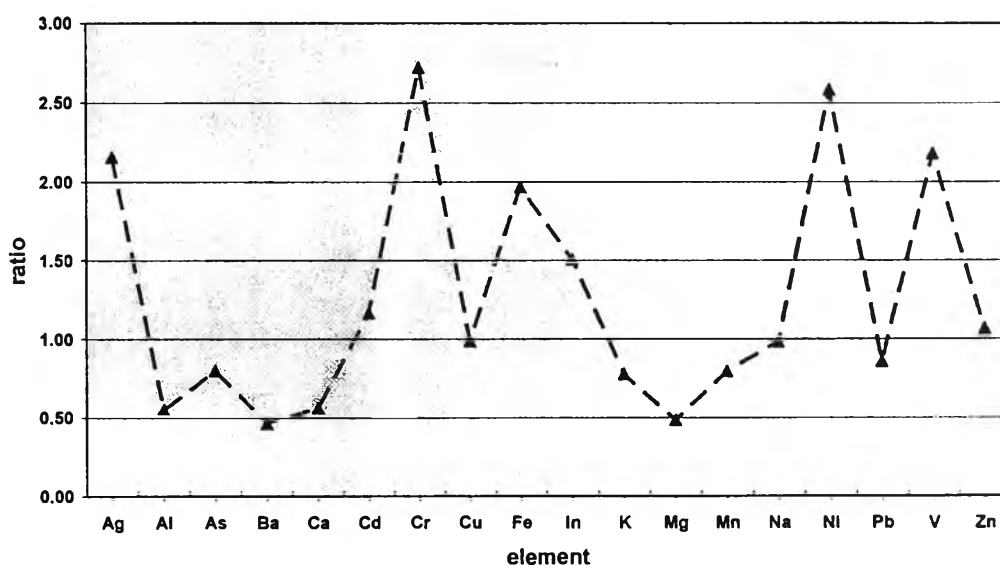| Element | Indoor/Outdoor | | Element | Indoor/Outdoor | |
	N	Mean		N	Mean
Ag	93	2.16	In	71	1.51
Al	101	0.55	K	107	0.78
As	12	0.8	Mg	109	0.48
Ba	111	0.46	Mn	106	0.8
Ca	109	0.56	Na	96	0.98
Cd	62	1.17	Ni	34	2.58
Cr	58	2.72	Pb	104	0.86
Cu	105	0.99	V	77	2.18
Fe	50	1.97	Zn	103	1.07

Figure 4.8 Average indoor to outdoor ratios of the elemental composition

4.4.1.3 The correlations of elements among personal, indoor and outdoor PM-10

Correlations among the different elements were determined using the Pearson correlation coefficient approach for all pairs of elements. The relationships among the indoor, outdoor and personal PM-10 are presented in three types of correlations. These are personal–outdoor, personal–indoor and indoor–outdoor as shown in Table 4.16.

Table 4.16 Correlations of elements among outdoor, indoor and personal PM-10

Element	Correlation coefficient		
	Personal-Outdoor	Personal-Indoor	Indoor-Outdoor
Ag	0.196	0.053	0.073
Al	0.108	0.069	0.118
As	0.046	0.375	0.317
Ba	-0.062	-0.046	0.373
Ca	0.173	0.535	0.271
Cd	0.568	0.299	0.537
Cr	0.073	0.046	0.072
Cu	0.05	0.069	0.059
Fe	0.052	0.041	0.009
In	0.568	0.324	0.542
K	0.58	0.686	0.704
Mg	0.101	0.594	0.390
Mn	0.056	0.164	-0.060
Na	0.32	0.469	0.456
Ni	0.045	0.025	0.006
Pb	0.398	0.464	0.439
V	0.067	0.042	0.051
Zn	0.419	0.506	0.533

The correlations fluctuated from element to element and from type to type of correlation with a range of slightly negative to high positive correlation. Ba showed a negative correlation between personal-outdoor and personal-indoor. In addition, the Mn correlation between indoor and outdoor was also slightly negative. Most of the elements showed low relationships in all aspects of the correlation analysis. Only the correlation coefficient for K was higher than 0.5 in all three type of correlations.

4.4.2 FA/MR on personal PM-10 sample

The elemental composition of the PM-10 material was used to identify possible source relationships. A varimax rotated PCA was applied to this elemental data, yielding the components (factors) as shown in Figure 4.9. Only components with an eigenvalue more than 1 were retained and thus five factors were obtained.
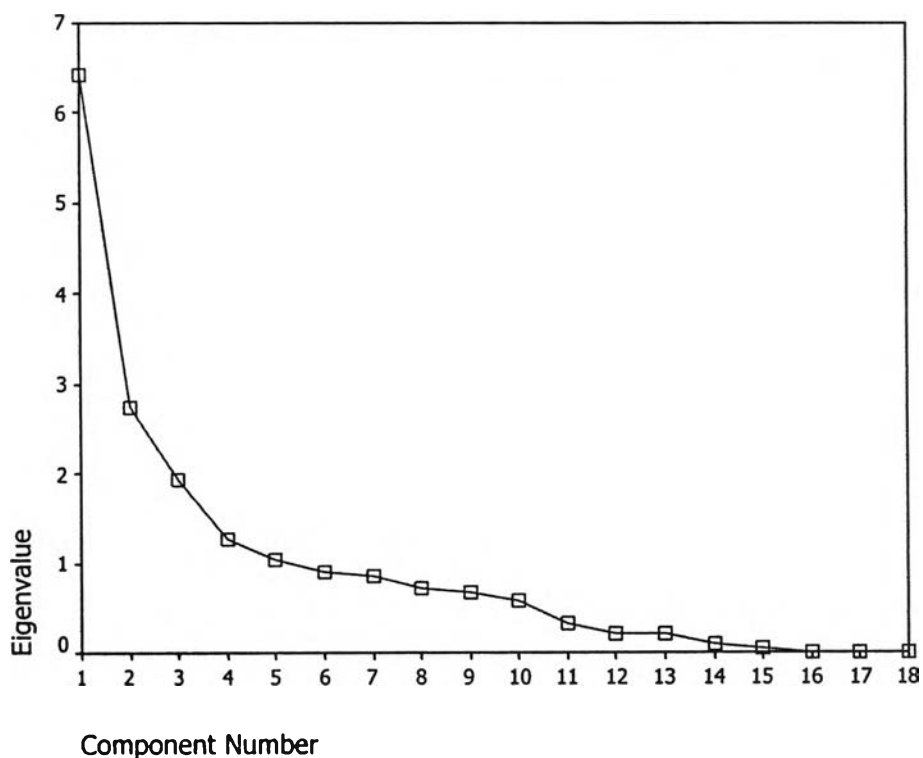

Figure 4.9 Scree plot of each component (factor) for personal data set

The correlation coefficients (factor loading) of each element with each component are noted in Table 4.17. The elements with factor loading values more than 0.5 were grouped into the same component. Generally, consideration of factor loading allowed a simple interpretation that each factor might represent a single source type of

PM-10. Thus, the probable source types were also purposed in Table 4.17. These five factors accounted for 74 % of the variance in the elemental data set of person PM-10 (Appendix F).

Table 4.17 Component matrix with varimax rotation of personal PM-10

Element	Component				
	1	2	3	4	5
Cr	.969	-4.137E-02	4.098E-02	.157	3.314E-02
V	.968	-3.852E-02	4.109E-02	.163	2.891E-02
Fe	.958	-4.458E-02	3.860E-02	.188	3.135E-02
Ni	.939	-4.726E-02	2.778E-02	.189	2.617E-02
Cu	.910	.164	5.787E-02	.135	1.614E-02
Mn	.899	.135	.101	9.890E-02	1.953E-03
Ag	.585	-.127	9.206E-03	-8.380E-02	-.109
Mg	-5.455E-02	.830	1.099E-02	.317	-4.630E-02
Ca	2.220E-02	.765	-9.838E-03	.200	-3.335E-02
K	3.461E-02	.656	.230	-2.651E-02	-5.813E-02
Al	1.905E-02	.596	-1.750E-02	-.169	3.953E-05
Na	-7.314E-02	.389	-.175	.204	-4.299E-02
In	6.043E-02	4.782E-02	.981	.110	-4.155E-03
Cd	8.778E-02	-1.253E-03	.978	9.148E-02	4.005E-03
Zn	.280	.158	7.056E-02	.860	-4.167E-02
Pb	.363	.169	.209	.791	-5.986E-02
Ba	-3.812E-02	-3.708E-02	-8.656E-03	2.699E-02	.815
As	3.622E-02	-8.475E-02	9.366E-03	-.101	.792
Eigenvalue	5.89	2.34	2.07	1.76	1.32
% of Variance	32.73	13.02	11.50	9.81	7.34
Probable source type	Oil combustion/ Petrol vehicle	Soil/Crustal	Steel industry	Zinc-smelter/Refuse incineration	Brake dust/Refuse incineration

The first component (factor 1) showed high loading of Cr, V, Fe, Ni, Cu, Mn and Ag, which accounted for approximately one third (33%) of the data variability. Consequently, the first factor appeared to have similarities to particulates previously assigned to both refinery/oil combustion and petrol vehicle, based upon the source data reported by Okamoto et al. (51) and Harrison et al. (55) Chromium (Cr) and V were the tracer elements of oil combustion while Fe, Cu, Ni and Mn were the tracers for petrol vehicles. The second factor showed similarities to soil particles because of the highly correlation with Mg, Ca, K and Al, which are usually found in earth crustal components as reported by Lucarelli et al. (52) Janssen et al. (56) and Yakovleva et al. (57). The third factor showed similarities to steel industry products due to the high loading of In and Cd as reported by Huang et al. (58). The final two components could be interpreted as zinc smelter components, refuse incineration and brake dust based upon the data of Sweet et al. (59) and Hildemann et al. (60). Ba was the tracer of brake dust while Pb and Zn would be emitted from both zinc smelter and refuse incineration. Arsenic also may be emitted from refuse incineration. These categorizations represent a convenient way to differentiate the types of PM-10 materials identified, however care must be taken in concluding that these actually represent the sources in this case because there is only limited knowledge of possible sources of these types in the immediate neighborhood of this study. Additional study would be required to confirm these possible source relationships.

The contributions from these five identified types of particulate materials to daily personal PM-10 were determined by using multiple linear regression analysis. The Absolute Principal Component Scores (APCS) were calculated for each identified factor and for each sample. Consequently, these APCS were used as independent variables while personal PM-10 concentrations were used as dependent variables in multiple regression analysis which yielded estimates of regression coefficients. The source contributions were then estimated as the product of the regression coefficients, which were employed to convert the APCS into pollutant source mass contributions.

The stepwise regression of the personal PM-10 mass on these five APCS yielded significant regression coefficients and the model explained approximately 42%

of the variability in the personal PM-10 data. Table 4.18 showed that the correlation coefficient of the model was 0.651. Only two source types (soil/crustal and steel industry components) were significantly associated with the variations of personal PM-10 mass concentrations (p<0.05). The constant was also significant (p<0.001) meaning that the contributing concentration of an unidentified source was approximately 36.9 $\mu g/m^3$.

Table 4.18 Result of multiple regression analysis of personal PM-10 concentrations

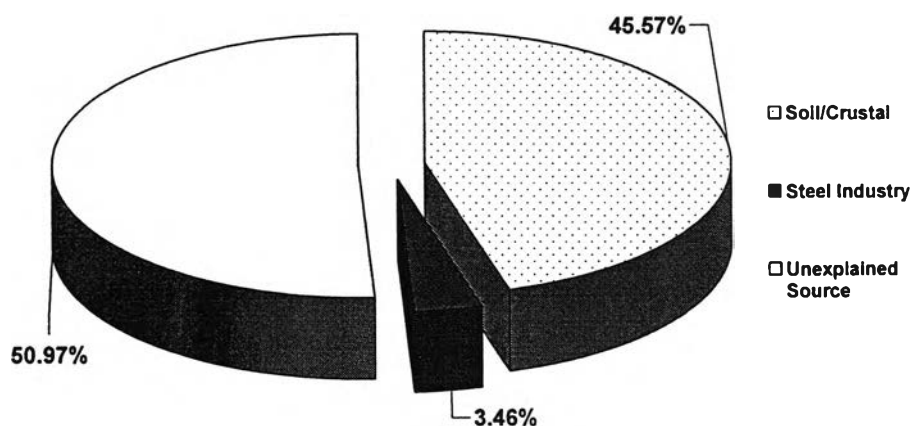| Component/Factor	Regression Coefficient	P-Value of Regression Coefficient	P-Value of Model	R of Model
Constant	36.891	0.000	0.000	0.651
1. Oil combustion/Petrol vehicle type	-	0.528		
2. Soil/Crustal type	26.641	0.000		
3. Steel industry type	6.382	0.003		
4. Zinc-smelter/Refuse incineration type	-	0.946		
5. Brake dust/Refuse incineration type	-	0.468		

Figure 4.10 Estimated source type contributions to personal PM-10

From the regression analysis, the source contributions were then estimated by inserting the APCS of these two significant factors into the equation

resulting in the source contributions shown in Figure 4.10. The figure demonstrated that the major source was the soil/crustal type which contributed to personal PM-10 at approximately 45.6% of the total, whereas that of steel industry type was only 3.5%. For more than 50% of personal PM-10 concentrations, the source could not be derived by factor analysis and multiple regression analysis.

4.4.3 FA/MR on indoor PM-10 concentrations

The procedure used in this analysis was similar to that of the personal PM-10 concentrations. The mass of elements of indoor PM-10 were analyzed using a correlation matrix. Then, a varimax rotated PCA was applied to derive the component matrix. Figure 4.11 presents the components with their eigenvalue. Based on the factor loading, the elements with factor loading more than 0.5 were included into the same component and the probable source types were also noted in Table 4.19. These five factors accounted for 77 % of the variability in the elemental data of indoor PM-10 (Appendix G).
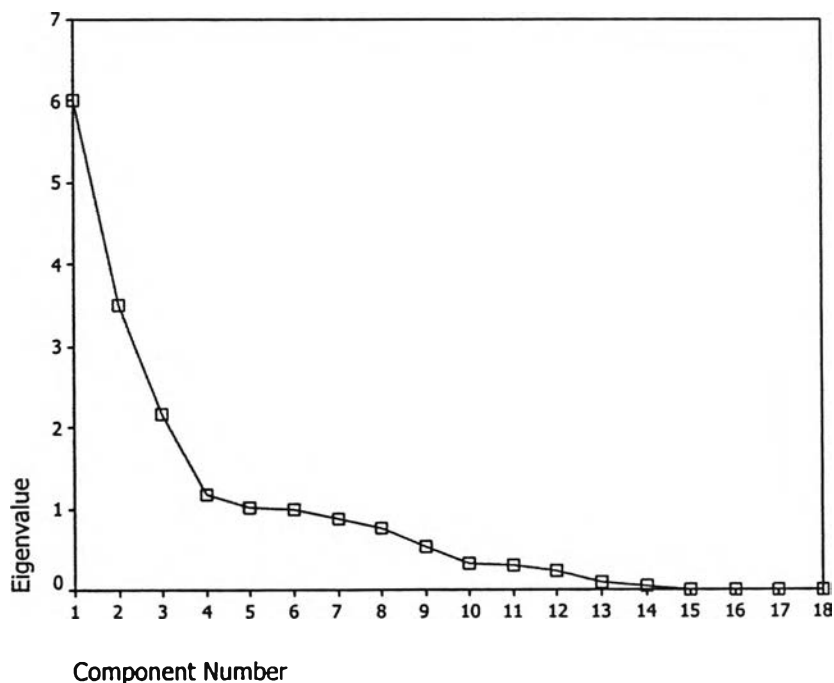

Figure 4.11 Scree plot of each component for indoor PM-10 data set

Table 4.19 Component matrix with varimax rotation of indoor PM-10

Element	Component				
	1	2	3	4	5
Cr	.992	-9.644E-03	1.734E-02	8.713E-02	-3.314E-02
V	.990	-5.634E-03	1.670E-02	9.925E-02	-3.642E-02
Ni	.982	-8.563E-03	2.010E-02	.114	-2.812E-02
Fe	.982	-4.979E-03	1.885E-02	.123	-3.560E-02
Cu	.964	.118	2.370E-02	2.397E-02	-1.518E-02
Mn	.957	4.394E-02	2.518E-02	-3.738E-03	-3.092E-02
Ba	-5.507E-02	.836	-4.324E-02	6.494E-02	-.192
Mg	-2.807E-02	.821	-3.333E-02	.329	-1.538E-02
Ca	-1.290E-02	.780	1.299E-02	.190	-.203
Al	5.106E-02	.639	1.998E-03	-8.244E-02	.346
K	9.286E-02	.612	.207	9.049E-02	-3.460E-02
Na	7.365E-02	.494	8.035E-02	-5.682E-02	.383
In	4.316E-03	6.864E-02	.984	6.022E-02	3.076E-02
Cd	3.151E-02	3.798E-02	.983	4.228E-02	1.337E-02
Zn	.142	.222	-1.534E-02	.876	7.662E-03
Pb	.124	.202	.498	.704	-2.746E-03
As	-2.901E-02	-8.888E-02	-2.596E-02	9.118E-02	.832
Ag	.162	4.100E-02	-4.991E-02	.213	-.266
Eigenvalue	5.824	3.131	2.243	1.534	1.116
% of Variance	32.355	17.394	12.458	8.523	6.202
Probable source type	Oil combustion /Petrol vehicle	Soil/Crustal/ Road dust	Steel industry	Zinc smelter /Refuse incinerator	Refuse incineration

The first component (factor 1) showed high loading of Cr, V, Fe, Ni, Cu, and Mn which accounted for approximately 32% of the variance of the data, while the second factor, which accounted for about 17% of the variance, was highly associated

with Ba, Mg, Ca, Al and K. The first factor was identified as the refinery/oil combustion and petrol vehicle type while the second factor was interpreted as the soil/crustal type. However, Ba was the tracer of brake dust so that the second factor may have been connected to road dust. The third factor appeared to be similar to particulates emitted from steel industry due to the high loading of In and Cd. The final two components could be interpreted as zinc smelter and refuse incineration types.

From multiple regression analysis, the results showed that only three factors were significantly associated with the variations of indoor PM-10 mass concentrations. These were factor 2, factor 4, and factor 5 as shown in Table 4.20. The model was significant (p<0.001) and the correlation coefficient of the model was 0.684. These three factors accounted for 47% of the variance of indoor PM-10 mass concentrations. The constant was also significant (p<0.001) and thus the contribution concentration of unidentified sources was approximately 42.9 $\mu g/m^3$. The second, the fourth and the fifth factor were significantly related with the mass of indoor PM-10 (p<0.001, p<0.041, and p<0.001 respectively).

Table 4.20 Results of multiple regression analysis for indoor PM-10

Component/Factor	Regression Coefficient	P-Value of Regression Coefficient	P-Value of Model	R of Model
Constant	42.912	0.000	0.000	0.709
1. Oil combustion/Petrol vehicle type	-	0.195		
2. Soil/Crustal/Road dust type	14.453	0.000		
3. Steel industry type	-	0.770		
4. Zinc smelter/Refuse incineration type	8.413	0.041		
5. Refuse incineration type	9.663	0.000		

Results from the regression analysis revealed the source contributions to indoor PM-10 as shown in Figure 4.12. The figure demonstrated that the major source was soil/crustal or road dust type which contributed to indoor PM-10 approximately 25% whereas that of the refuse incineration type was at 11%. Zinc smelter component type

contributed approximately 10% to indoor PM-10 concentrations. For more than 50% of the indoor PM-10 concentrations, the source could not be derived.
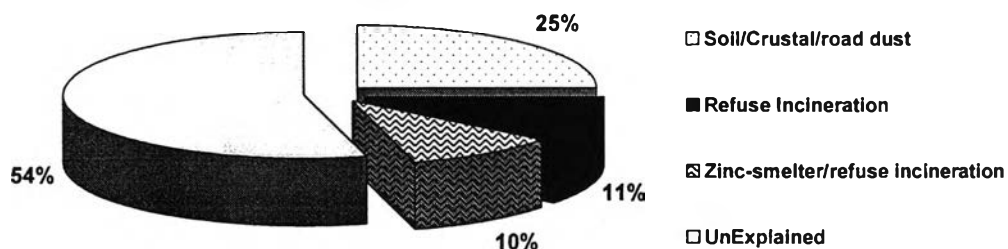

Figure 4.12 Estimated source type contributions to indoor PM-10

4.4.4 FA/MR on outdoor PM-10 concentrations

The analysis procedure was similar to that of the personal PM-10 data. The mass of elements of outdoor PM-10 were analyzed using a correlation matrix. Then, a varimax rotated PCA was applied to create the component matrix.
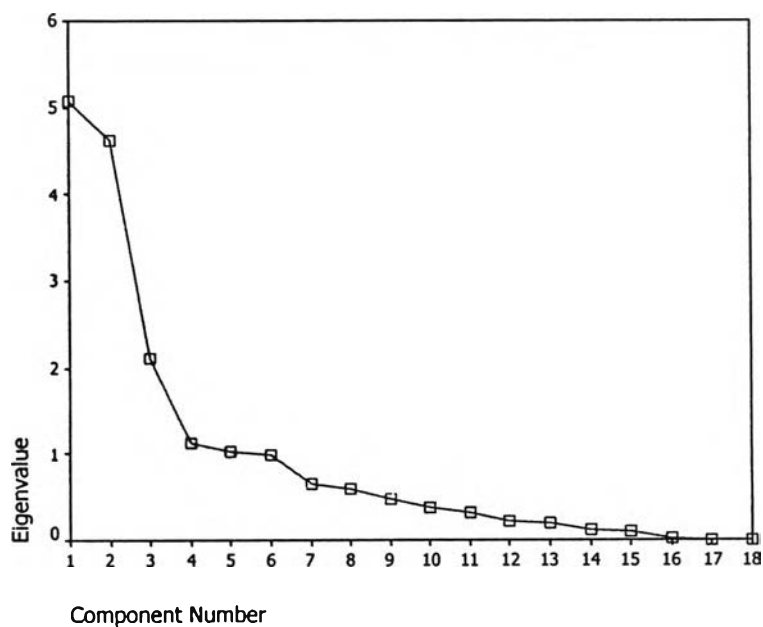

Figure 4.13 Scree plot of each component for outdoor PM-10 data set

Figure 4.13 showed the components with their eigenvalue for which only five components had an eigenvalue greater than 1. Based upon the factor loading, the elements with factor loading more than 0.5 were included into the same component (factor) and the probable source types were also noted in Table 4.21.

Table 4.21 Component Matrix with Varimax rotation of outdoor PM-10

Element	Component				
	1	2	3	4	5
Ca	.925	-9.452E-02	-2.822E-02	6.997E-02	8.116E-02
Mg	.907	-5.887E-02	-1.896E-02	.164	-5.645E-02
Al	.893	-1.673E-02	-6.963E-02	.178	-1.898E-02
Ba	.862	6.486E-04	7.923E-03	4.793E-02	7.140E-02
Zn	.675	-5.594E-02	.139	6.302E-02	-.388
Pb	.619	-1.521E-02	.293	1.113E-02	-.402
Mn	.615	.606	7.973E-02	.104	7.885E-02
Fe	-3.814E-02	.954	5.201E-02	5.250E-02	-6.057E-02
V	-4.882E-02	.941	7.561E-02	4.733E-02	2.797E-02
Cr	-8.202E-02	.937	6.828E-02	6.204E-02	2.941E-02
Ni	-6.035E-02	.930	5.630E-02	5.886E-02	-5.436E-02
Ag	-1.976E-03	.762	-.151	-.185	-.116
Cu	.430	.451	-5.510E-02	-.232	.292
Cd	-1.126E-02	4.462E-02	.980	-2.691E-02	-1.760E-02
In	6.491E-02	4.076E-02	.979	-1.034E-02	-4.304E-02
Na	.175	2.829E-02	-.167	.827	-.206
K	.303	3.269E-02	.221	.642	.382
As	-6.519E-02	-8.141E-02	-2.021E-02	-1.730E-02	.657
Eigenvalue	4.765	4.717	2.155	1.278	1.063
% of Variance	26.473	26.203	11.975	7.099	5.906
Probable source type	Soil/Crustal/ Road dust	Oil combustion/ Refinery	Steel industry	Sea salt	Refuse incineration

These five factors accounted for 78 % of the variance of the outdoor PM-10 data set (Appendix H). The first component (factor 1) showed high loading of Ca, Mg, Al, Ba, Zn, Pb, and Mn which accounted for approximately 26% of the variance of the data. The first factor appeared to represent soil/crustal and road dust type. The second factor, which accounted for about 26% of the variance, could probably be interpreted as oil combustion/refinery component types because of a high association with Cr, Fe, V, Ni, and Ag. The third factor seemed to be similar to steel industry emission components due to the high loading of In and Cd. The fourth factor would be similar to sea salt particulates since it was connected with Na and K as reported by Lucarelli et al. (52) and Yakovleva et al. 1999 (57). The final component would be interpreted as similar to refuse incineration derived particulates.

From multiple regression analysis, the results showed that only 2 factors were significantly associated with the variations of outdoor PM-10 mass concentrations. These were factor 1 and factor 5 as shown in Table 4.22. The model was significant ($p < 0.001$) and the correlation coefficient of the model was 0.823. These 2 factors accounted for 68% of the variance of outdoor PM-10 mass concentrations. The constant was also significant ($p < 0.001$) and thus the contribution concentration of an unidentified sources was approximately 52.7 $\mu g/m^3$. The first and the fifth factor were significantly related with the mass of outdoor PM-10 ($p < 0.001$, and $p = 0.019$ respectively).

Table 4.22 Results of multiple regression analysis for outdoor PM-10

Component/Factor	Regression Coefficient	P-Value of Regression Coefficient	P-Value of Model	R of Model
Constant	52.718	0.000	0.000	0.823
1. Soil/ Crustal/ Road dust type	45.253	0.000		
2. Oil combustion/ Refinery type	-	0.297		
3. Steel industry type	-	0.776		
4. Sea salt type	-	0.860		
5. Refuse incineration type	7.289	0.019		

The result from the regression analysis revealed possible source contributions to outdoor PM-10 as shown in Figure 4.14. The figure demonstrated that the major source was soil/crustal or road dust type of materials, which contributed to outdoor PM-10 at approximately 45% whereas that of material similar to that produced by refuse incineration was at 5%. However more than 50% of outdoor PM-10 concentrations, sources could not be derived.
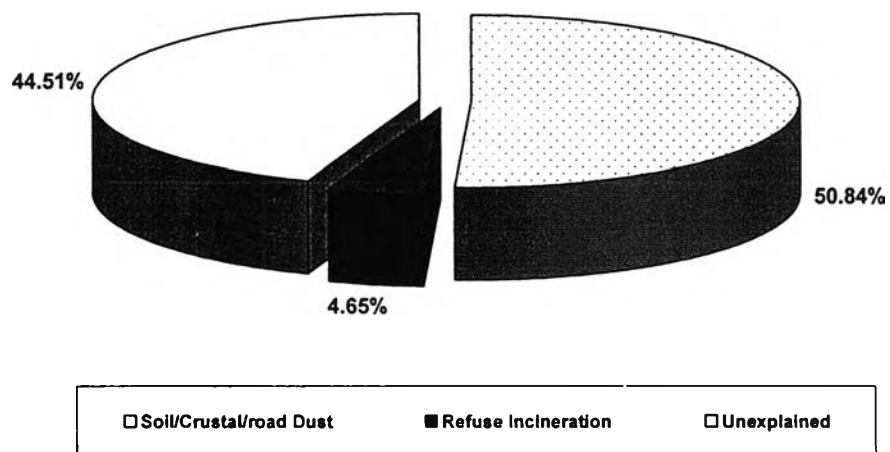

Figure 4.14 Estimated source type contributions to outdoor PM-10