APPENDICES

APPENDIX A

PM10 calculation

A-1 Calculation of mini volume air sampler flow calibration

Sampling site : The roof top of the nine-storey Science Complex Building1, Chiang Mai University (SCB1-CMU)

Calibration date : 15 July 2010

Time : 8.40 am

Ambient temperature : 305.15 K (T_{act})

Ambient barometric pressure : 727 mmHg (P_{act})

Q_{ind} (L/min)	ΔH (inches of water)
6.50	3.40
6.00	2.91
5.50	2.37
5.00	1.99
4.50	1.57
4.00	1.24

Where Q_{ind} = rotameter indicated flow rate, L/min

ΔH = transfer standard pressure, inches of water

1. Calculation of actual flow rate (Q_{act})

$$Q_{act} = \left(m_{flo} \times \sqrt{\frac{\Delta H \times T_{act}}{P_{act}}} \right) + b_{flo}$$

Q_{ind} = 5 L/min, ΔH = 1.99; $$Q_{act} = \left(5.7013 \times \sqrt{\frac{1.99 \times 305.15}{727}} \right) - 0.0548$$

$$= 5.156 \text{ L/min}$$

Where Q_{act} = actual flow rate, L/min

ΔH = transfer standard pressure, inches of water

m_{flo} = slope of linear regression of sampler calibration (5.7013)

b_{flo} = intercept of linear regression of sampler calibration (-0.0548)

T_{act} = ambient temperature, K (305.15 K)

P_{act} = ambient barometric pressure, mmHg (727 mmHg)

2. Calculation of standard correction flow rate ($Q_{@std}$)

$$Q_{@std} = Q_{act} \times \sqrt{\frac{T_{std} \times P_{act}}{T_{act} \times P_{std}}}$$

Q_{ind} = 5 L/min, ΔH = 1.99; $$Q_{@std} = \left(5.156 \times \sqrt{\frac{298.15 \times 727}{305.15 \times 760}} \right)$$

$$= 4.985 \text{ L/min}$$

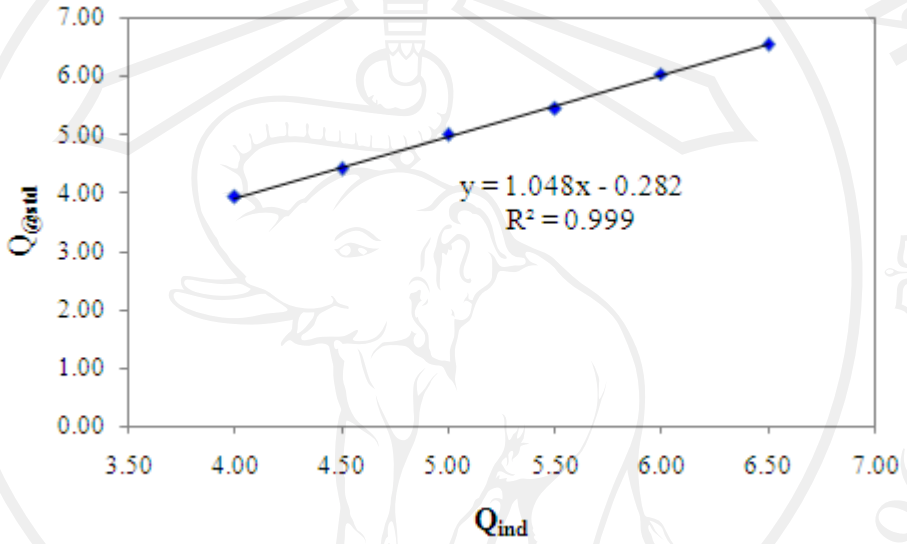
Where $Q_{@std}$ = standard correction flow rate, L/min

T_{std} = standard temperature, K (298.15 K)

P_{std} = standard pressure, mmHg (760 mmHg)

3. Calculation of sampler flow rate from the linear regression (Q_{calc})

Calculate Q_{calc} (L/min) from linear regression of calibration curve, which constructed by plotting the different Q_{ind} of sampler flow rate versus $Q_{@std}$ obtained from calculation



Example calculation for Q_{ind} = 5.00 L/min

Y = 1.048X - 0.282

= 1.048(5.00) - 0.282

= 4.958 L/min

Q_{ind} (L/min)	ΔH (inches of water)	Q_{act} (L/min)	$Q_{@std}$ (L/min)	Q_{calc} (L/min)	Difference (%)
6.50	3.40	6.754	6.530	6.533	0.05
6.00	2.91	6.245	6.037	6.009	-0.47
5.50	2.37	5.630	5.443	5.485	0.77
5.00	**1.99**	**5.155**	**4.983**	**4.961**	**-0.45**
4.50	1.57	4.572	4.420	4.436	0.36
4.00	1.24	4.057	3.922	3.912	-0.26

A-2 Calculation of PM10 concentration (µg/m^3)

To calculate the PM10 concentration for a sample taken with the mini volume air sampler, the volume of air that passed through the filter at ambient conditions must be calculated.

1. Calculation of the volume of air that passed through the filter during the sampling period at actual ambient conditions, V_{act} (m^3)

$$V_{act} = \frac{60_{min/hrs} \times Q_{calc} \times t_{hrs}}{1000_{L/m^3}}$$

$$= \frac{60_{min/hrs} \times 4.961 \times 24}{1000_{L/m^3}}$$

$$= 7.144 \text{ m}^3$$

Where t_{hrs} = sampling period, hours

2. Calculation of the mass concentration of PM10, divide the net mass gain of the filter by the volume of air that passed through the filter

$$PM_{act} = \frac{M_{PM}}{V_{act}}$$

Where PM_{act} = PM10 concentration, µg/m^3

M_{PM} = mass of PM10 collected on the filter, µg

M_{PM} = Post-exposure weight - Pre-exposure weight

Example calculation for M_{PM} = 203µg;

$$PM_{act} = \frac{203}{7.144}$$

$$= 28.4 \text{ µg/m}^3$$

APPENDIX B

PM10 in Chiang Mai ambient air

B-1 Concentrations of PM10 in ambient air obtained from SCB1-CMU, CH and YP stations in dry and wet season 2010

Date	PM10 (µg/m^3)			Date	PM10 (µg/m^3)			Date	PM10 (µg/m^3)			Date	PM10 (µg/m^3)		
	SCB1-CMU	CH	YP		SCB1-CMU	CH	YP		SCB1-CMU	CH	YP		SCB1-CMU	CH	YP
					Dry season (n = 51)								Wet season (n = 7)		
27/2/2010	96.2	106.1	119.4	16/3/2010	249.1	268.4	279.9	2/4/2010	113.7	118.2	126.8	15/7/2010	28.5	21.2	27.5
28/2/2010	73.8	70.0	89.7	17/3/2010	175.7	179.1	187.0	3/4/2010	128.4	129.8	140.0	18/7/2010	22.6	15.5	20.3
1/3/2010	82.4	93.2	97.3	18/3/2010	100.0	88.7	86.2	4/4/2010	140.8	140.6	153.2	22/7/2010	15.6	21.2	30.9
2/3/2010	98.2	101.6	105.3	19/3/2010	75.9	57.8	65.5	5/4/2010	133.2	133.5	143.2	25/7/2010	21.9	18.6	26.4
3/3/2010	92.0	89.8	94.8	20/3/2010	88.2	73.5	84.0	6/4/2010	155.4	150.0	164.8	29/7/2010	14.3	15.8	18.0
4/3/2010	104.5	92.3	96.8	21/3/2010	105.8	84.2	104.4	7/4/2010	139.7	155.2	167.6	1/8/2010	32.2	22.1	28.0
5/3/2010	104.0	101.7	95.0	22/3/2010	80.7	82.6	96.3	8/4/2010	144.3	163.8	192.0	8/8/2010	12.0	21.1	24.8
6/3/2010	124.5	112.8	123.9	23/3/2010	99.4	96.3	106.2	9/4/2010	92.9	115.1	123.4				
7/3/2010	121.7	106.5	114.9	24/3/2010	126.9	123.2	145.3	10/4/2010	111.7	113.4	117.6				
8/3/2010	119.9	132.3	153.4	25/3/2010	172.8	179.8	197.6	11/4/2010	115.9	131.5	142.6				
9/3/2010	141.7	162.2	146.2	26/3/2010	125.7	107.2	115.0	12/4/2010	114.1	133.1	145.3				
10/3/2010	118.3	83.1	95.4	27/3/2010	77.5	66.4	70.0	13/4/2010	119.3	127.7	141.9				
11/3/2010	105.3	95.2	100.3	28/3/2010	88.0	72.2	75.9	14/4/2010	83.3	95.4	102.3				
12/3/2010	83.6	80.4	84.1	29/3/2010	78.2	62.9	68.0	15/4/2010	82.8	95.7	113.3				
13/3/2010	127.3	124.9	148.9	30/3/2010	79.5	77.8	84.5	16/4/2010	79.1	102.4	81.8				
14/3/2010	149.1	167.8	176.7	31/3/2010	104.1	106.5	106.6	17/4/2010	74.1	77.5	69.6				
15/3/2010	200.9	220.5	227.5	1/4/2010	103.6	97.9	109.9	19/4/2010	87.9	89.8	85.8				

B-2 Values of PM10 concentrations, EC and pH in ambient air at SCB1-CMU station during dry and wet season 2010

Date	PM10 ($\mu g/m^3$)	EC (mS/m)	pH	Date	PM10 ($\mu g/m^3$)	EC (mS/m)	pH	Date	PM10 ($\mu g/m^3$)	EC (mS/m)	pH	Date	PM10 ($\mu g/m^3$)	EC (mS/m)	pH
Dry season (n = 51)												Wet season (n = 7)			
27/2/2010	96.2	0.55	6.68	16/3/2010	249.1	1.08	6.48	2/4/2010	113.7	0.73	6.47	15/7/2010	28.5	0.33	6.67
28/2/2010	73.8	0.50	6.77	17/3/2010	175.7	0.88	6.68	3/4/2010	128.4	0.77	6.38	18/7/2010	22.6	0.28	6.70
1/3/2010	82.4	0.41	6.67	18/3/2010	100.0	0.73	6.48	4/4/2010	140.8	0.74	6.69	22/7/2010	15.6	0.34	6.94
2/3/2010	98.2	0.54	6.82	19/3/2010	75.9	0.51	6.58	5/4/2010	133.2	0.71	6.45	25/7/2010	21.9	0.28	6.95
3/3/2010	92.0	0.43	6.29	20/3/2010	88.2	0.61	6.92	6/4/2010	155.4	0.76	6.39	29/7/2010	14.3	0.30	7.26
4/3/2010	104.5	0.71	6.31	21/3/2010	105.8	0.70	6.68	7/4/2010	139.7	0.72	6.17	1/8/2010	32.2	0.31	6.75
5/3/2010	104.0	0.67	6.19	22/3/2010	80.7	0.62	6.55	8/4/2010	144.3	0.70	6.26	8/8/2010	12.0	0.29	7.09
6/3/2010	124.5	0.75	6.39	23/3/2010	99.4	0.68	6.87	9/4/2010	92.9	0.54	6.61				
7/3/2010	121.7	0.70	6.25	24/3/2010	126.9	0.73	6.58	10/4/2010	111.7	0.59	6.40				
8/3/2010	119.9	0.60	6.43	25/3/2010	172.8	0.87	6.70	11/4/2010	115.9	0.56	6.43				
9/3/2010	141.7	0.67	6.46	26/3/2010	125.7	0.69	6.83	12/4/2010	114.1	0.54	6.44				
10/3/2010	118.3	0.63	6.33	27/3/2010	77.5	0.59	6.54	13/4/2010	119.3	0.56	6.52				
11/3/2010	105.3	0.63	6.30	28/3/2010	88.0	0.61	6.65	14/4/2010	83.3	0.48	6.47				
12/3/2010	83.6	0.55	6.51	29/3/2010	78.2	0.34	7.25	15/4/2010	82.8	0.47	6.83				
13/3/2010	127.3	0.68	6.32	30/3/2010	79.5	0.52	6.68	16/4/2010	79.1	0.42	6.63				
14/3/2010	149.1	0.86	6.08	31/3/2010	104.1	0.61	6.49	17/4/2010	74.1	0.48	6.60				
15/3/2010	200.9	0.84	6.68	1/4/2010	103.6	0.64	6.63	19/4/2010	87.9	0.40	6.66				

B-3 Ion concentrations from PM10 in ambient air during dry season 2010

Date	Ion concentrations ($\mu g/m^3$)											
	CH_3COO^-	$HCOO^-$	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Total ions
27/2/2010	0.00	0.00	0.00	1.89	0.00	2.78	0.00	0.71	1.18	0.25	0.04	6.86
28/2/2010	0.00	0.23	0.14	1.52	0.00	2.33	0.00	0.76	0.72	0.00	0.00	5.71
1/3/2010	0.00	0.00	0.00	1.77	0.00	2.10	0.00	0.43	0.68	0.12	0.00	5.09
2/3/2010	0.00	0.00	2.17	2.40	0.00	2.86	0.00	0.59	1.01	0.21	0.05	9.30
3/3/2010	0.00	0.00	2.12	2.01	0.00	3.00	0.00	0.36	0.56	0.12	0.06	8.24
4/3/2010	0.00	0.23	0.81	2.54	0.00	6.22	0.00	0.97	0.86	0.52	0.05	12.21
5/3/2010	0.00	0.00	1.71	2.25	0.00	5.61	0.00	1.10	0.84	0.37	0.00	11.87
6/3/2010	0.00	0.23	1.74	2.74	0.00	6.63	0.00	1.42	1.08	0.46	0.05	14.34
7/3/2010	0.00	0.26	0.85	2.64	0.00	5.97	0.00	1.20	1.06	0.62	0.08	12.67
8/3/2010	0.00	0.00	1.61	2.77	0.00	4.06	0.00	0.83	0.99	0.60	0.08	10.94
9/3/2010	0.00	0.31	1.71	3.24	0.00	4.00	0.00	1.06	1.20	0.48	0.06	12.06
10/3/2010	0.00	0.00	1.62	2.88	0.00	3.32	0.00	0.81	1.42	0.30	0.06	10.41
11/3/2010	0.00	0.60	0.94	2.36	0.00	3.83	0.00	1.09	1.12	0.22	0.06	10.21
12/3/2010	0.00	0.23	0.85	1.91	0.00	3.77	0.00	0.43	0.87	0.15	0.06	8.26
13/3/2010	0.00	0.25	0.10	3.22	0.00	4.11	0.00	1.10	1.31	0.25	0.05	10.40
14/3/2010	0.00	0.47	1.21	3.66	0.00	5.52	0.00	1.58	1.56	0.38	0.07	14.45
15/3/2010	0.00	0.27	0.00	4.83	0.00	4.63	0.00	2.17	1.30	0.37	0.07	13.64
16/3/2010	0.00	0.33	0.12	5.58	0.00	4.88	0.00	3.01	1.95	0.88	0.06	16.82

B-3 (Continued)

Date	Ion concentrations ($\mu g/m^3$)											
	CH_3COO^-	$HCOO^-$	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Total ions
17/3/2010	0.00	0.27	0.16	3.99	0.00	4.63	0.00	2.23	1.75	0.56	0.09	13.66
18/3/2010	0.00	0.26	0.14	3.19	0.00	3.66	0.00	1.75	1.02	0.25	0.05	10.32
19/3/2010	0.00	0.00	0.00	2.24	0.00	2.50	0.00	0.98	0.81	0.08	0.06	6.67
20/3/2010	0.00	0.32	0.23	2.27	0.00	3.09	0.00	1.24	0.93	0.27	0.07	8.41
21/3/2010	0.00	0.25	0.12	2.52	0.00	4.04	0.97	1.63	0.96	0.19	0.00	10.69
22/3/2010	0.00	0.00	0.09	2.21	0.00	4.17	0.00	1.42	0.91	0.27	0.06	9.14
23/3/2010	0.00	0.26	2.42	2.68	0.00	4.12	0.00	1.91	0.79	0.18	0.00	12.36
24/3/2010	0.00	0.00	0.05	2.67	0.00	4.43	0.00	1.84	1.19	0.41	0.07	10.65
25/3/2010	0.00	0.26	0.07	3.80	0.00	5.67	0.00	2.52	1.60	0.79	0.08	14.79
26/3/2010	0.87	0.00	0.00	2.98	0.00	3.85	0.00	1.56	0.89	0.43	0.07	10.65
27/3/2010	0.00	0.00	0.08	2.48	0.00	3.14	0.00	1.14	0.61	0.21	0.05	7.71
28/3/2010	0.81	0.00	0.00	2.32	0.00	3.62	0.00	1.07	0.75	0.29	0.05	8.91
29/3/2010	0.00	0.00	0.00	2.18	0.00	3.02	0.00	0.62	0.87	0.00	0.00	6.69
30/3/2010	1.30	0.00	0.00	1.72	0.00	3.06	0.00	1.06	0.83	0.13	0.00	8.11
31/3/2010	0.93	0.00	0.00	2.25	0.00	3.60	0.00	1.82	1.12	0.08	0.00	9.79
1/4/2010	0.00	0.00	0.00	2.44	0.00	3.82	0.00	1.61	0.96	0.37	0.08	9.29
2/4/2010	1.11	0.25	0.00	2.92	0.00	5.39	0.00	2.95	1.08	0.65	0.12	14.47

B-3 (Continued)

Date	Ion concentrations ($\mu g/m^3$)											
	CH_3COO^-	$HCOO^-$	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Total ions
3/4/2010	1.39	0.31	0.00	2.71	0.00	5.34	0.00	2.05	1.11	0.14	0.00	13.05
4/4/2010	1.28	0.00	0.00	2.67	0.00	4.86	0.00	2.03	1.47	0.23	0.05	12.58
5/4/2010	0.00	0.31	0.00	2.63	0.00	4.47	0.00	1.78	1.13	0.18	0.06	10.57
6/4/2010	0.93	0.27	0.00	2.89	0.00	4.39	0.00	2.30	1.44	0.37	0.07	12.65
7/4/2010	0.00	0.30	1.41	2.88	0.00	4.13	0.00	1.55	0.97	0.37	0.07	11.68
8/4/2010	0.00	0.25	0.00	2.93	0.00	4.55	0.00	1.49	0.95	0.57	0.10	10.83
9/4/2010	0.00	0.00	0.00	2.17	0.00	3.55	0.00	1.02	0.68	0.24	0.06	7.72
10/4/2010	0.00	0.24	0.00	2.39	0.00	4.42	0.00	1.20	0.54	0.19	0.07	9.05
11/4/2010	0.00	0.00	0.00	1.89	0.00	3.50	0.00	1.03	0.67	0.33	0.09	7.50
12/4/2010	0.00	0.25	0.00	2.32	0.00	3.97	0.00	0.74	0.45	0.26	0.07	8.06
13/4/2010	0.00	0.00	0.00	2.24	0.00	3.93	0.00	1.30	0.49	0.17	0.07	8.21
14/4/2010	0.00	0.00	0.00	1.67	0.00	3.19	0.00	1.16	0.41	0.00	0.05	6.48
15/4/2010	0.00	0.00	0.00	1.85	0.00	2.40	0.00	1.87	0.42	0.00	0.08	6.61
16/4/2010	0.00	0.00	0.00	1.62	0.00	2.17	0.00	1.87	0.32	0.00	0.05	6.04
17/4/2010	0.00	0.00	0.00	1.81	0.00	3.77	0.00	1.53	0.33	0.07	0.07	7.58
19/4/2010	0.00	0.00	0.00	0.53	0.00	0.71	0.00	1.39	0.46	0.00	0.00	3.09
Average	**0.17**	**0.14**	**0.44**	**2.55**	**0.00**	**3.94**	**0.02**	**1.40**	**0.95**	**0.29**	**0.05**	**9.95**
SD	**0.40**	**0.16**	**0.72**	**0.82**	**0.00**	**1.14**	**0.14**	**0.61**	**0.36**	**0.21**	**0.03**	**2.89**

B-4 Ion concentrations from PM10 in ambient air during wet season 2010

Date	Ion concentrations ($\mu g/m^3$)											
	CH_3COO^-	$HCOO^-$	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Total ions
15/7/2010	0.00	0.00	0.00	0.51	0.00	1.30	0.00	0.00	0.15	0.00	0.04	2.00
18/7/2010	0.00	0.00	0.10	0.33	0.00	0.89	0.00	0.00	0.19	0.00	0.00	1.52
22/7/2010	0.00	0.00	0.00	0.61	0.00	1.04	0.00	0.00	0.37	0.00	0.00	2.03
25/7/2010	0.00	0.00	0.00	0.36	0.00	1.06	0.00	0.00	0.16	0.00	0.00	1.59
29/7/2010	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00	0.22	0.00	0.00	1.10
1/8/2010	0.00	0.00	0.00	0.56	0.00	0.93	0.00	0.00	0.39	0.00	0.00	1.87
8/8/2010	0.00	0.00	0.00	0.37	0.00	1.29	0.00	0.00	0.15	0.00	0.00	1.81
Average	**0.00**	**0.00**	**0.01**	**0.39**	**0.00**	**1.06**	**0.00**	**0.00**	**0.23**	**0.00**	**0.01**	**1.70**
SD	**0.00**	**0.00**	**0.04**	**0.20**	**0.00**	**0.18**	**0.00**	**0.00**	**0.10**	**0.00**	**0.02**	**0.33**

APPENDIX C

C Carbon (C), hydrogen (H) and nitrogen (N) contents of biomass samples

Biomass types	No.	Concentration (%)		
		C	H	N
R-MR	1	36.88	5.36	0.27
	2	36.57	5.15	0.26
	3	36.36	5.03	0.29
	Average	**36.60**	**5.18**	**0.27**
	SD	**0.26**	**0.17**	**0.02**
R-DK	1	37.09	5.00	0.33
	2	36.89	5.18	0.40
	3	37.46	4.94	0.24
	Average	**37.15**	**5.04**	**0.32**
	SD	**0.29**	**0.12**	**0.08**
R-CD	1	34.70	5.17	1.05
	2	34.90	5.43	1.11
	3	34.85	5.28	0.97
	Average	**34.82**	**5.29**	**1.04**
	SD	**0.10**	**0.13**	**0.07**
M-MR	1	38.86	4.98	2.15
	2	39.17	5.12	1.88
	3	39.56	4.99	1.9
	Average	**39.20**	**5.03**	**1.98**
	SD	**0.35**	**0.08**	**0.15**
M-MC	1	39.68	6.20	1.32
	2	39.51	5.83	1.27
	3	39.43	5.99	1.15
	Average	**39.54**	**6.01**	**1.25**
	SD	**0.13**	**0.19**	**0.09**
M-CD	1	42.98	6.06	1.12
	2	42.68	5.91	1.09
	3	42.71	5.93	0.79
	Average	**42.79**	**5.97**	**1.00**
	SD	**0.17**	**0.08**	**0.18**

C (Continued)

Biomass types	No.	Concentration (%)		
		C	H	N
L-MR	1	46.23	5.88	0.52
	2	46.00	5.56	0.51
	3	45.78	5.84	0.62
	Average	**46.00**	**5.76**	**0.55**
	SD	**0.23**	**0.17**	**0.06**
L-DK	1	48.80	6.01	0.50
	2	48.57	6.11	0.63
	3	48.49	6.03	0.82
	Average	**48.62**	**6.05**	**0.65**
	SD	**0.16**	**0.05**	**0.16**
L-CD	1	44.97	5.71	0.24
	2	44.75	5.85	0.2
	3	44.31	5.59	0.18
	Average	**44.68**	**5.72**	**0.21**
	SD	**0.34**	**0.13**	**0.03**

APPENDIX D

PM10 samples from biomass burning in the combustion chamber

D-1 Gas concentrations emitted from biomass burning for collecting PM10 samples

Biomass types	No.	Gas concentrations							
		ppm				EFs (g/kg)			
		CO	NO	NO_2	SO_2	CO	NO	NO_2	SO_2
R-MR	1	705.0	7.0	10.6	0.0	48.2	0.5	1.2	0.0
	2	746.6	6.6	7.3	1.9	51.2	0.5	0.8	0.3
	3	840.8	11.0	10.7	0.0	58.0	0.8	1.2	0.0
R-DK	1	2757.7	9.7	12.0	9.7	188.0	0.7	1.3	1.5
	2	1053.4	10.5	14.5	0.0	72.0	0.8	1.6	0.0
	3	920.1	10.2	15.4	7.0	63.7	0.8	1.8	1.1
R-CD	1	564.5	15.1	15.6	1.9	37.9	1.1	1.7	0.3
	2	792.6	8.3	22.4	0.0	55.2	0.6	2.6	0.0
	3	524.5	15.6	13.4	0.0	36.4	1.2	1.5	0.0
M-MR	1	309.9	8.1	12.6	0.0	42.7	1.2	2.8	0.0
	2	235.2	12.5	6.9	0.0	32.1	1.8	1.5	0.0
	3	305.3	9.3	7.7	0.0	42.2	1.4	1.8	0.0
M-MC	1	295.4	13.2	15.0	0.0	39.5	1.9	3.3	0.0
	2	178.2	16.0	10.5	0.0	24.7	2.4	2.4	0.0
	3	246.7	20.6	10.8	0.0	34.4	3.1	2.5	0.0
M-CD	1	408.3	5.5	12.4	0.0	56.4	0.8	2.8	0.0
	2	350.9	12.1	7.1	0.0	48.0	1.8	1.6	0.0
	3	354.6	14.5	9.2	0.0	47.5	2.1	2.0	0.0
L-MR	1	325.7	8.8	15.0	0.0	43.6	1.3	3.3	0.0
	2	314.0	13.0	12.9	0.0	41.5	1.8	2.8	0.0
	3	477.6	11.0	12.6	2.5	63.6	1.6	2.7	0.8
L-DK	1	603.8	11.4	5.1	0.0	82.8	1.7	1.2	0.0
	2	481.9	14.2	12.2	0.0	66.3	2.1	2.8	0.0
	3	466.4	10.0	12.9	0.0	64.5	1.5	2.9	0.0
L-CD	1	273.3	10.9	13.2	0.3	37.0	1.6	2.9	0.1
	2	298.4	16.1	10.1	0.0	41.2	2.4	2.3	0.0
	3	338.8	11.9	13.4	2.6	45.4	1.7	3.0	0.8

D-2 EC and pH values of PM10 samples

Biomass types	No.	EC (mS/m)	pH	Biomass types	No.	EC (mS/m)	pH	Biomass types	No.	EC (mS/m)	pH
	1	7.42	5.1		1	3.18	5.3		1	2.81	5.2
	2	5.70	5.0		2	3.11	5.7		2	2.50	5.1
R-MR	3	9.94	5.0	M-MR	3	4.31	5.2	L-MR	3	2.92	4.7
	Average	**7.69**	**5.0**		**Average**	**3.53**	**5.4**		**Average**	**2.74**	**5.0**
	SD	**2.13**	**0.0**		**SD**	**0.67**	**0.3**		**SD**	**0.22**	**0.3**
	1	6.38	4.7		1	3.64	5.5		1	3.95	4.9
	2	3.42	5.1		2	4.84	5.7		2	2.48	4.8
R-DK	3	7.87	5.0	M-MC	3	6.26	5.4	L-DK	3	3.19	5.1
	Average	**5.89**	**4.9**		**Average**	**4.91**	**5.5**		**Average**	**3.21**	**4.9**
	SD	**2.27**	**0.2**		**SD**	**1.31**	**0.1**		**SD**	**0.74**	**0.1**
	1	9.32	5.0		1	7.83	5.2		1	1.42	5.2
	2	6.06	5.1		2	6.42	5.6		2	2.75	5.0
R-CD	3	7.47	4.9	M-CD	3	10.79	5.5	L-CD	3	1.90	4.8
	Average	**7.62**	**5.0**		**Average**	**8.35**	**5.4**		**Average**	**2.03**	**5.0**
	SD	**1.64**	**0.1**		**SD**	**2.23**	**0.2**		**SD**	**0.68**	**0.2**

D-3 EFs of PM10 and ions species from biomass burning

Biomass types	No.	PM10	EFs of ions (mg/kg)											
		(g/kg)	CH_3COO^-	$HCOO^-$	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Total ions
R-MR	1	0.7	0.00	0.20	49.32	10.88	0.26	18.27	0.67	5.19	52.69	0.13	0.00	137.60
	2	0.9	0.00	0.30	36.25	6.64	0.08	12.31	0.34	7.97	40.42	0.00	0.00	104.31
	3	0.9	0.00	0.29	75.56	9.90	1.16	16.90	0.27	10.08	81.71	0.00	0.00	195.87
R-DK	1	0.9	0.00	0.36	37.84	7.40	3.55	17.66	1.85	10.74	33.83	0.21	0.04	113.47
	2	0.2	0.00	0.14	22.33	3.99	0.14	9.62	0.12	5.47	24.92	0.02	0.01	66.77
	3	0.7	0.00	0.31	51.13	10.46	3.35	19.23	2.41	11.10	56.06	0.17	0.05	154.26
R-CD	1	0.7	0.00	0.33	60.20	10.04	1.02	27.49	0.93	19.40	52.98	0.00	0.00	172.39
	2	0.5	0.00	0.14	38.60	9.88	0.42	18.13	0.08	11.80	38.68	0.00	0.00	117.74
	3	0.8	0.00	0.32	41.23	9.38	0.84	24.02	0.34	13.77	40.54	0.07	0.00	130.50
	Average	**0.69**	**0.00**	**0.26**	**45.83**	**8.73**	**1.20**	**18.18**	**0.78**	**10.61**	**46.87**	**0.07**	**0.01**	**132.54**
	SD	**0.23**	**0.00**	**0.08**	**15.46**	**2.26**	**1.33**	**5.38**	**0.82**	**4.36**	**16.47**	**0.08**	**0.02**	**38.42**
M-MR	1	0.7	0.00	0.24	39.09	14.09	0.00	14.89	0.89	8.15	52.57	0.00	0.00	129.92
	2	0.4	0.00	0.22	44.52	7.24	0.00	13.87	0.23	8.31	50.84	0.49	0.00	125.73
	3	0.9	0.00	0.28	60.44	10.43	0.00	18.84	0.10	11.14	72.94	0.00	0.00	174.17
M-MC	1	1.3	0.00	0.53	36.37	14.60	0.12	28.75	0.23	17.89	34.45	0.00	0.00	132.93
	2	0.9	0.00	0.23	55.86	10.13	0.13	44.90	0.00	30.60	36.32	0.00	0.05	178.22
	3	1.4	0.00	0.26	84.81	11.12	0.00	46.19	0.00	26.08	78.86	0.00	0.00	247.32
M-CD	1	0.8	0.00	0.42	100.00	20.37	0.08	46.84	0.47	17.51	117.29	0.00	0.00	302.99
	2	0.8	0.00	0.29	99.94	10.56	0.00	20.36	0.74	7.10	132.70	0.00	0.00	271.69
	3	0.9	0.00	3.01	191.93	14.26	1.59	47.84	0.87	31.35	194.12	0.00	0.00	484.98
	Average	**0.90**	**0.00**	**0.61**	**79.22**	**12.53**	**0.21**	**31.39**	**0.39**	**17.57**	**85.56**	**0.05**	**0.01**	**227.55**
	SD	**0.31**	**0.00**	**0.91**	**48.92**	**3.79**	**0.52**	**14.90**	**0.36**	**9.73**	**53.09**	**0.16**	**0.02**	**116.42**

D-3 (Continued)

Biomass types	No.	PM10 (g/kg)	EFs of ions (mg/kg)											
			CH_3COO^-	$HCOO^-$	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Total ions
L-MR	1	2.0	0.00	0.66	6.89	22.01	0.00	30.40	1.30	13.40	20.77	0.13	0.06	95.61
	2	1.5	0.00	0.48	11.52	11.92	0.00	21.21	0.70	13.30	13.56	0.00	0.03	72.72
	3	1.4	0.00	0.42	14.27	18.65	0.00	17.75	0.95	10.20	19.38	0.00	0.05	81.68
L-DK	1	3.0	0.00	0.40	37.62	8.84	0.00	23.65	0.13	28.24	9.26	0.00	0.07	108.21
	2	1.4	0.00	0.75	13.75	10.96	0.00	16.08	0.00	9.27	17.76	0.00	0.10	68.67
	3	1.2	0.00	0.66	26.64	15.99	0.00	23.21	0.36	13.64	37.95	0.00	0.00	118.45
L-CD	1	0.7	0.00	0.31	3.83	13.34	0.00	10.83	1.03	6.33	8.90	0.05	0.00	44.61
	2	1.1	0.00	0.46	12.22	18.14	0.00	26.11	0.00	8.69	32.53	0.00	0.00	98.14
	3	1.4	0.00	0.48	3.14	15.34	0.00	14.51	0.00	8.86	5.58	0.00	0.03	47.94
	Average	**1.52**	**0.00**	**0.51**	**14.43**	**15.02**	**0.00**	**20.42**	**0.50**	**12.44**	**18.41**	**0.02**	**0.04**	**81.78**
	SD	**0.65**	**0.00**	**0.14**	**11.17**	**4.18**	**0.00**	**6.16**	**0.51**	**6.44**	**10.90**	**0.04**	**0.03**	**25.70**

APPENDIX E

Water-soluble samples from biomass burning in the combustion chamber

E-1 Gas concentrations emitted from biomass burning for collecting water-soluble samples

Biomass types	No.	Gas concentrations							
		ppm				EFs (g/kg)			
		CO	NO	NO_2	SO_2	CO	NO	NO_2	SO_2
R-MR	1	1079.5	6.3	14.6	0.0	75.4	0.5	1.7	0.0
	2	791.7	9.0	5.3	0.0	55.2	0.7	0.6	0.0
	3	521.8	13.9	11.1	0.0	36.4	1.0	1.3	0.0
R-DK	1	667.4	12.7	9.9	0.0	46.2	0.9	1.1	0.0
	2	1261.6	13.6	15.8	0.0	87.8	1.0	1.8	0.0
	3	691.0	8.9	15.7	0.0	48.4	0.7	1.8	0.0
R-CD	1	880.0	11.5	18.8	0.0	61.2	0.9	2.2	0.0
	2	413.1	10.5	20.3	0.0	28.6	0.8	2.3	0.0
	3	592.9	20.1	14.6	0.0	40.3	1.5	1.6	0.0
M-MR	1	467.3	6.4	14.5	0.0	62.1	0.9	3.2	0.0
	2	476.1	7.0	15.8	0.0	64.7	1.0	3.5	0.0
	3	387.0	10.0	13.4	0.0	53.7	1.5	3.1	0.0
M-MC	1	410.7	15.0	14.8	0.0	56.2	2.2	3.3	0.0
	2	365.9	7.7	18.6	0.0	48.7	1.1	4.1	0.0
	3	295.4	6.3	17.1	0.0	40.5	0.9	3.8	0.0
M-CD	1	297.0	5.0	16.4	0.0	41.3	0.8	3.7	0.0
	2	376.4	8.2	16.7	0.0	51.7	1.2	3.8	0.0
L-MR	1	271.9	10.3	10.2	0.0	37.1	1.5	2.3	0.0
	2	369.3	9.2	17.3	0.0	51.3	1.4	4.0	0.0
	3	312.6	14.7	13.8	0.0	43.4	2.2	3.2	0.0
L-DK	1	483.3	10.5	16.8	0.0	67.5	1.6	3.8	0.0
	2	408.9	10.9	15.6	0.0	55.2	1.6	3.5	0.0
	3	427.6	6.2	13.3	0.0	58.8	0.9	3.0	0.0
L-CD	1	427.6	6.2	13.3	0.0	59.7	0.9	3.0	0.0
	2	293.6	3.2	20.3	0.0	40.4	0.5	4.6	0.0
	3	245.2	10.6	17.9	0.0	33.9	1.6	4.1	0.0

E-2 EC and pH values of water-soluble samples

Biomass types	No.	EC (mS/m)	pH	Biomass types	No.	EC (mS/m)	pH	Biomass types	No.	EC (mS/m)	pH
	1	1.44	4.6		1	0.71	5.2		1	0.96	4.8
	2	0.88	5.1		2	1.12	4.9		2	1.08	4.8
R-MR	3	0.96	5.0	M-MR	3	1.04	4.8	L-MR	3	1.04	4.8
	Average	**1.09**	**4.9**		**Average**	**0.96**	**4.9**		**Average**	**1.03**	**4.8**
	SD	**0.31**	**0.2**		**SD**	**0.22**	**0.2**		**SD**	**0.06**	**0.0**
	1	1.46	5.0		1	1.46	4.7		1	1.21	4.7
	2	1.60	4.8		2	1.20	4.7		2	1.15	4.6
R-DK	3	1.29	4.7	M-MC	3	1.23	4.7	L-DK	3	1.11	4.7
	Average	**1.45**	**4.8**		**Average**	**1.30**	**4.7**		**Average**	**1.16**	**4.7**
	SD	**0.16**	**0.1**		**SD**	**0.14**	**0.0**		**SD**	**0.05**	**0.0**
	1	1.41	4.7		1	1.01	4.9		1	1.24	4.7
	2	1.44	4.7		2	1.07	4.7		2	1.11	4.8
R-CD	3	1.38	4.7	M-CD	3	1.04	4.8	L-CD	3	1.14	4.7
	Average	**1.41**	**4.7**		**Average**	**1.04**	**4.8**		**Average**	**1.16**	**4.7**
	SD	**0.03**	**0.0**		**SD**	**0.03**	**0.1**		**SD**	**0.07**	**0.0**

E-3 EFs of ions species from biomass burning

Biomass types	No.	EFs of ions (mg/kg)												
		CH_3COO^-	$HCOO^-$	Cl^-	NO_2^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Total ions
R-MR	1	201.3	25.2	50.1	70.9	25.2	0.0	15.4	21.1	33.4	45.4	35.9	1.9	525.8
	2	287.1	51.0	67.1	138.5	6.6	0.0	8.9	47.3	15.5	79.5	68.3	3.6	773.5
	3	96.9	39.7	38.0	51.4	13.2	0.0	17.0	0.0	19.6	49.0	0.0	1.8	326.6
R-DK	1	323.5	81.3	10.3	56.2	16.0	0.0	8.6	0.0	18.0	8.7	3.3	0.0	525.9
	2	204.2	59.3	24.3	9.3	18.1	0.0	10.8	1.8	24.0	18.4	24.7	0.0	394.9
	3	199.7	54.2	17.6	61.5	16.0	0.0	7.2	0.0	15.8	15.9	5.9	0.0	393.7
R-CD	1	326.2	75.7	13.7	116.3	17.8	0.0	7.0	4.4	33.2	16.3	41.1	0.7	652.3
	2	227.4	63.3	13.8	128.0	20.8	0.0	10.5	22.1	19.0	69.0	12.7	0.0	586.6
	3	248.7	61.0	9.7	123.0	13.3	0.0	19.3	15.0	27.4	51.1	15.8	0.0	584.2
M-MR	1	146.5	28.7	55.9	260.8	12.7	0.0	14.8	26.7	10.4	115.8	56.4	1.2	729.6
	2	219.6	106.0	60.6	144.1	33.9	0.0	29.1	0.0	30.7	135.1	8.1	0.0	767.2
	3	80.9	46.6	69.5	228.7	25.2	0.0	41.1	1.7	39.2	142.1	0.0	0.0	675.1
M-MC	1	549.5	129.3	48.3	146.4	37.4	0.0	74.3	0.0	87.4	148.6	13.6	22.6	1257.2
	2	111.1	74.9	20.9	115.6	40.8	0.0	28.2	0.0	37.5	18.2	0.0	0.0	447.2
	3	121.1	86.6	30.5	164.8	47.9	0.0	83.5	19.8	37.9	136.3	14.4	4.8	747.5
M-CD	1	205.7	90.6	46.0	227.8	32.3	0.0	36.6	17.7	30.5	132.9	27.4	1.5	849.1
	2	160.5	65.1	28.5	245.2	26.1	0.0	13.7	9.4	19.2	114.6	0.0	0.0	682.3
	3	240.8	91.2	95.4	201.6	22.7	0.0	19.3	9.7	30.9	80.3	45.8	0.0	837.7

E-3 (Continued)

Biomass types	No.	EFs of ions (mg/kg)												
		CH_3COO^-	$HCOO^-$	Cl^-	NO_2^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Total ions
L-MR	1	273.1	105.1	1.4	155.6	13.8	0.0	20.7	13.9	13.5	87.9	17.6	0.0	702.6
	2	272.0	103.7	98.8	331.0	56.1	0.0	11.6	54.2	24.6	121.6	98.4	2.6	1174.5
	3	312.3	101.0	51.1	142.8	42.4	0.0	14.5	0.0	22.2	65.6	21.7	0.0	773.6
L-DK	1	320.7	99.0	12.1	250.1	35.9	0.0	22.5	20.6	26.0	105.0	18.6	0.0	910.5
	2	324.1	85.3	0.0	189.7	21.6	0.0	25.0	0.0	30.6	49.0	0.0	0.0	725.4
	3	354.2	110.6	8.2	226.0	30.0	0.0	18.5	23.4	36.4	67.7	0.0	0.0	875.0
L-CD	1	540.3	117.1	0.0	96.6	9.3	0.0	16.0	0.0	19.9	46.1	0.0	0.0	845.2
	2	117.6	62.9	23.2	252.2	46.6	0.0	7.9	32.6	12.0	94.9	56.9	1.3	708.1
	3	203.3	91.5	68.0	232.7	1753.3	0.0	45.1	9.5	143.7	36.5	575.0	6.1	3164.7

CURRICULUM VITAE

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Graduated Seminars	Sillapapiromsuk, S., 2008. Chemical composition of acid precipitation in Asia. Graduated Seminar I, SCB 1-720, Science Complex Building I, Faculty of Science, Chiang Mai University.
	Sillapapiromsuk, S., 2009. Effect of biomass burning on atmospheric acid deposition in Chiang Mai-Lamphun intermontane basin. Graduated Seminar II, SCB 1-720, Science Complex Building I, Faculty of Science, Chiang Mai University.
Oral presentation	Sillapapiromsuk, S., Chantara, S., 2009. Chemical Composition and Seasonal Variation of Acid Deposition in Chiang Mai, Thailand. 13th International Conference on Integrated Diffuse Pollution Management (IWA DIPCON 2009), Seoul, Korea, 11-15 October 2009.
Poster presentation	Sillapapiromsuk, S., Chantara, S., 2009. Seasonal Variation and Source Estimation of Atmospheric Dry Deposition in Chiang Mai, Year 2008. Center for Environmental Health, Toxicology and Management of Chemical (ETM), Thailand, 27-28 June 2009.

Publications

Chantara, S., Sillapapiromsuk, S., Wiriya, W., 2012. Atmospheric pollutants in Chiang Mai (Thailand) over a five-year period (2005-2009), their possible sources and relation to air mass movement. Atmospheric Environment 60, 88-98.

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Fellowship

EANET Research Fellowship Program 2010 entitled "Assessment of haze episodes on long-range transport contribution to ambient air pollution levels in northern Thailand using Trajectory model" at Asia Center for Air Pollution Research (ACAP), Niigata, Japan, 18 October-10 December 2010.