APPENDIX A

A-1 Calculation of pollutant gases in passive sampler

According to Fick's low, the concentration of gases in passive sampler in $\mu g/m^3$ unit is calculated as follow:

$$C = \left[\frac{Q * L}{A * t * D}\right]$$

Where:

C = concentration measured by passive sampling tube ($\mu g/m^3$)

Q = quantity of absorption products present in the sampler (μg)

L = diffusion length (m)

A = cross-sectional area (m^2) = πr^2

t = sampling time (s)

D = diffusion coefficient (m^2/s)

The diffusion coefficient of nitrogen dioxide in air must be corrected to average ambient temperature (K) during sampling period, according to equation:

$$D_T = D_{298}(T)^{1.75} \times (298.15)^{-1.75}$$

Where:

D_T = diffusion coefficient (cm^2s^{-1}) of NO_2 through air at T (K)

D_{298} = is the diffusion coefficient of NO_2 through air at 298.15 K (0.154 cm^2s^{-1})

T = temperature (K)

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A-2 Quantity of absorption products in the sampler (Q)

Q value of NO_2 determination was calculated by multiplication NO_2^- concentration obtained from calibration curve (ppm) with 2 (2 ml of extraction volume). The NO_2^- in ppm unit was converted to the total amount of NO_2 in passive sampler in µg unit.

$$Q\ (\mu g) = NO_2^-\ \text{concentration (ppm)} * 2\ ml$$

A-3 Determination of total air resistance

The total air resistance can be calculated by summing all resistances that influence diffusive transport of the gas to the sampling filter. The Teflon filter over the inlet prevents turbulent diffusion inside the sampler.

$$\text{Total air resistance } (m^{-1}) = \left[\frac{LR}{AR} + \frac{LF}{AF} + \frac{LN}{AN} + \frac{LBL}{AR} \right]$$

AR = area of tube 1.33×10^{-4} (m^2)

AF = total pore area of Teflon filter

AN = total pore area of steel mesh

LF = thickness of Teflon filter

LR = length of tube 5.3×10^{-2} (m)

LN = thickness of steel mesh) (m)

LBL* = laminar boundary layer depth 1.5×10^{-3}(m).

*Ferm 1991, cited by Ayera *et al*, 1998

A, is the total area of all pores in the filter. If only Teflon filter is used the member *LN/AN* from equation must to be dropped out.

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Total air resistance (m^{-1}) = $\left[\frac{LR}{AR}+\frac{LF}{AF}+\frac{LBL}{AR}\right]$

$$= \left[\frac{5.3*10^{-2}}{1.33*10^{-4}}+\frac{LF}{AF}+\frac{1.5*10^{-3}}{1.33*10^{-4}}\right]$$

$$= 409.77\ m^{-1}$$

Comparison between enclosed membrane and without membrane exposed can be determining LF/AF value from the experimental for evaluated air resistance by calculated performed as following.

Mass of without membrane equal 0.072 µg total air resistance is 409.77 m^{-1}

Mass of membrane equal 0.071 µg then, total air resistance is 404.07 m^{-1}

Then,

$$C\ (\mu g/m^3) = \frac{X\ (\mu g) \times 404.07\ m^{-1}}{D\ (m^2 s^{-1}) \times t\ (s)}$$

A-4 Unit conversions

Mass per unit volume: usually µg/m^3. The mass of pollutant is expressed as a ratio to the volume of air. Since the volume of a given parcel of air is depended upon the temperature and pressure at the time sampling, the pollutant concentration expressed in these units, should, strictly speaking, specify the conditions at the time of sampling.

Volume mixing ratio: usually ppm-part per million (10^{-6}); or ppb–part per billion (10^{-9}). This unit expressed the concentration of a pollutant as ratio of its volume if segregated pure, to the volume of the air in which it is contained. Ideal gas behavior is assumed thus the concentration is not depended on temperature and pressure as these

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affect both the pollutant and air to the same extent. As a consequence of the gas laws, a gas present at a volume mixing ratio of 1 ppm is not only 1 $cm^3/10^6$ cm^3 of polluted air, it is also 1 molecule per 10^{-6} molecules and has a partial pressure of one millionth of the atmospheric pressure.

Conversion factors

$$ppbv = \mu g/m^3 * \frac{\text{molecular volume (liters)}}{\text{molecular weight}}$$

Where:

$$\text{molecular volume} = 22.41 * \frac{T}{273} * \frac{101.3}{P}$$

T = absolute temperature (K) (Remember that Celcius+273 = Kelvin)

P = atmospheric pressure (kPa) (Remember that 1 atm = 760 mmHg, 1 atm = 101.3 kPa and 1 torr = 133.322 Pa)

Similarly

$$\mu g/m^3 = ppbv \ X \ \frac{\text{molecular weigh}}{\text{molecular volume (liters)}}$$

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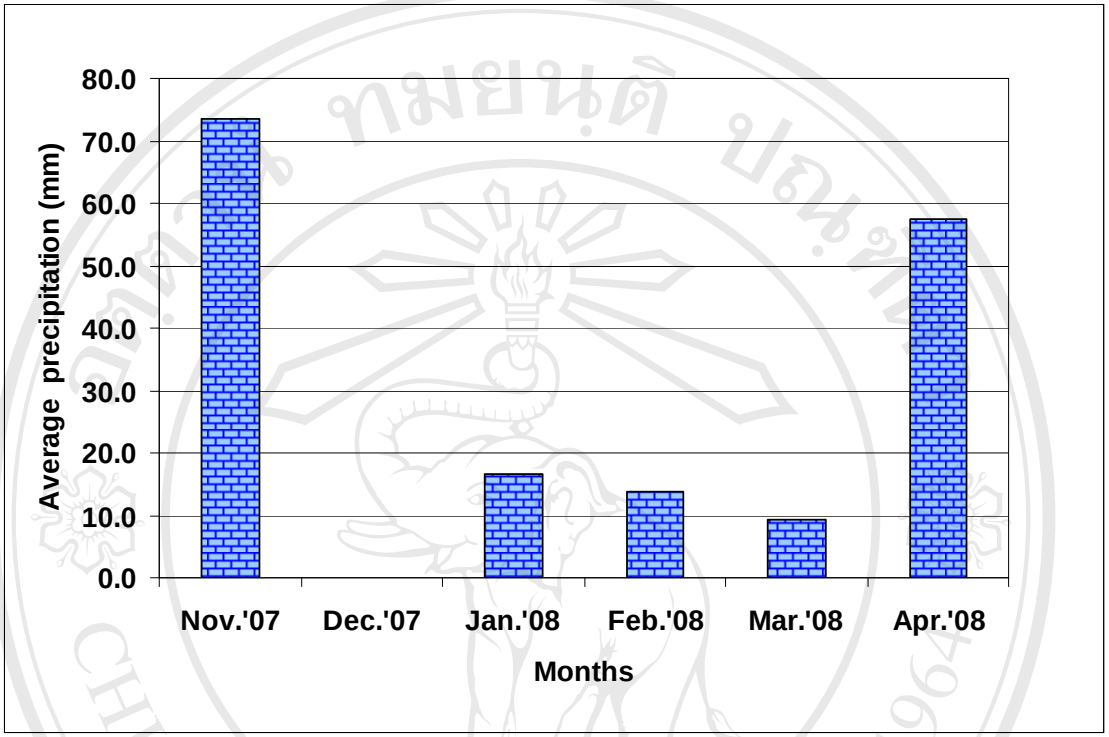
APPENDIX B



Sources: Chiang Mai Meteorologocal Station, 2007-2008

Figure B1 Total of precipitation during November 2007 to April 2008 in Chiang Mai Province

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APPENDIX C

Correlations

Correlations

		Spectrophometry	Test kit
Spectrophotometry	Pearson Correlation	1	.899(**)
	Sig. (2-tailed)		.000
	N	347	345
Test kit	Pearson Correlation	.899(**)	1
	Sig. (2-tailed)	.000	
	N	345	345

** Correlation is significant at the 0.01 level (2-tailed).

Areas of Chiang Mai Province

One-way

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.472	2	334	.624

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ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	20.069	2	10.034	232.023	.000
Within Groups	14.445	334	.043		
Total	34.514	336			

Homogeneous Subsets

	Areas	N	Subset for alpha = .05		
			1	2	3
Tukey HSD(a,b)	**Rural**	105	.6070		
	Sub-urban	99		1.0135	
	Urban	133			1.1847
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a Uses Harmonic Mean Sample Size = 110.523.

b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

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Month

One-way

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.333	5	335	.250

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.310	5	.462	4.797	.000
Within Groups	32.267	335	.096		
Total	34.577	340			

Homogeneous Subsets

	month	N	Subset for alpha = .05	
			1	2
Tukey HSD(a,b)	Nov.	45	.7712	
	Aprl.	58	.9301	.9301
	Mar.	60		.9404
	Feb.	60		.9877
	Jan.	58		1.0252
	Dec.	60		1.0357
	Sig.		.075	.464

Means for groups in homogeneous subsets are displayed.

a Uses Harmonic Mean Sample Size = 56.230.

b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Comparison of urban NO_2 concentrations from spectrophotometry and chemiluminescence

One-way

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
2.318	8	43	.036

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ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3824.129	8	478.016	30.053	.000
Within Groups	683.959	43	15.906		
Total	4508.088	51			

Homogeneous Subsets

	Month	N	Subset for alpha = .05			
			1	2	3	4
Tukey HSD(a,b)	U8	6	10.1000			
	U6	6	10.3000			
	U7	6	12.1333			
	U5	6	13.6833	13.6833		
	U4	5	15.9600	15.9600		
	U2	6	16.3000	16.3000		
	U1	5		20.9600	20.9600	
	Active	6			24.5000	
	U3	6				38.1667
	Sig.		.203	.076	.847	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 5.745.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

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APPENDIX D

Table D1 Before of classification of NO_2 concentrations

Code	Mean NO_2 concentration (ppbv, N=3)											
	November 2007		December 2007		January 2008		February 2008		March 2008		April 2008	
	Data	Colors	Data	Colors	Data	Colors	Data	Colors	Data	Colors	Data	Colors
U1	FS		22.5	Yellow	28.2	Orange	20.2	Yellow	17.6	Green	16.3	Green
U2	11.1	Lightblue	22.0	Yellow	21.5	Yellow	16.0	Green	14.0	Lightblue	13.0	Lightblue
U3	28.1	Orange	42.5	Red	45.1	Red	36.5	Red	39.4	Red	37.4	Red
U4	FS		18.8	Green	17.2	Green	17.6	Green	11.2	Lightblue	15.0	Lightblue
U5	11.7	Lightblue	16.9	Green	11.3	Lightblue	11.1	Lightblue	11.7	Lightblue	10.1	Lightblue
U6	9.0	Blue	6.4	Blue	11.6	Lightblue	11.9	Lightblue	10.5	Lightblue	12.4	Lightblue
U7	12.7	Lightblue	15.6	Green	11.6	Lightblue	13.1	Lightblue	16.4	Green	12.7	Lightblue
U8	8.4	Blue	10.1	Lightblue	13.8	Lightblue	9.4	Blue	6.3	Blue	12.6	Lightblue
SU1	FS		15.4	Green	16.4	Green	18.4	Green	19.1	Green	17.1	Green
SU2	5.4	Blue	9.3	Blue	13.4	Lightblue	6.8	Blue	5.1	Blue	5.5	Blue
SU3	FS		13.1	Lightblue	16.1	Green	13.6	Lightblue	13.3	Lightblue	14.0	Lightblue
SU4	FS		14.1	Lightblue	7.3	Blue	9.1	Blue	9.9	Lightblue	10.7	Lightblue
SU5	10.3	Lightblue	11.0	Lightblue	12.0	Lightblue	8.0	Blue	9.0	Blue	6.3	Blue
SU6	5.4	Blue	8.9	Blue	17.9	Green	7.6	Blue	13.6	Lightblue	6.9	Blue
R1	2.9	Blue	7.9	Blue	3.9	Blue	6.5	Blue	7.1	Blue	5.7	Blue
R2	1.6	Blue	5.4	Blue	6.9	Blue	2.9	Blue	4.0	Blue	4.8	Blue
R3	3.0	Blue	6.1	Blue	4.7	Blue	5.7	Blue	4.6	Blue	2.9	Blue
R4	4.2	Blue	8.7	Blue	3.9	Blue	6.9	Blue	7.2	Blue	5.2	Blue
R5	2.2	Blue	3.4	Blue	3.8	Blue	4.3	Blue	2.2	Blue	2.7	Blue
R6	3.1	Blue	4.5	Blue	3.1	Blue	4.2	Blue	2.9	Blue	3.1	Blue

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APPENDIX E

Table E1 The concentrations of NO_2 measured by NO_2 test kit and spectrophotometry

Site area	Code	Concentration of NO_2 (ppbv)					
		11-13 Nov 07			16-18 Dec 07		
		Spectrophotometry	Test kit		Spectrophotometry	Test kit	
		(N=3)	Read value	Average of range	(N=3)	Read value	Average of range
Urban	**U1**	FS	FS	FS	22.5	10.62-42.47	26.5
	U2	11.0	6.4-10.6	8.5	22.0	10.62-42.47	26.5
	U3	28.1	10.62-42.47	26.5	42.5	42.47	42.5
	U4	FS	FS	FS	18.8	10.62-42.47	26.5
	U5	11.7	10.62	10.6	16.9	10.62-42.47	26.5
	U6	9.0	6.37	6.4	6.4	7.43	7.4
	U7	12.7	10.62	10.6	15.6	10.62-42.47	26.5
	U8	8.4	3.19-6.37	4.8	10.1	6.37-10.62	8.5
Sub-urban	**SU1**	FS	FS	FS	15.4	10.62-42.47	26.5
	SU2	5.4	3.19-6.37	4.8	9.3	6.37	6.4
	SU3	FS	FS	FS	13.1	10.62	10.6
	SU4	FS	FS	FS	14.1	6.37-10.62	8.5
	SU5	10.3	6.37	6.4	11.0	10.62	10.6

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Site area	Code	Concentration of NO_2 (ppbv)					
		11-13 Nov 07			16-18 Dec 07		
		Spectrophotometry	Test kit		Spectrophotometry	Test kit	
		(N=3)	Read value	Average of range	(N=3)	Read value	Average of range
Rural	SU6	5.0	6.37	6.4	8.9	6.37	6.4
	R1	2.9	3.19	3.2	7.9	3.19-6.37	4.8
	R2	1.6	3.19	3.2	5.4	3.19-6.38	5.8
	R3	3.0	3.19	3.2	6.1	3.19	3.2
	R4	4.2	3.19	3.2	8.7	10.62	10.6
	R5	2.2	3.19	3.2	3.4	3.19	3.2
	R6	3.1	3.19	3.2	4.5	3.19	3.2

Note; FS – failed sampling (e.g., diffusion tube was broken and lost)

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Table E1 (continued)

Site area	Code	Concentration of NO_2 (ppbv)					
		13-15 Jan 08			10-12 Feb 08		
		Spectrophotometry	Test kit		Spectrophotometry	Test kit	
		(N=3)	Read value	Average of range	(N=3)	Read value	Average of range
Urban	**U1**	28.2	10.62-42.47	26.5	20.2	10.62-42.47	26.5
	U2	21.5	10.62-42.47	26.5	16.0	10.62-42.47	26.5
	U3	45.1	42.47	42.5	36.5	42.47	42.5
	U4	17.2	10.62-42.47	26.5	17.6	10.62-42.47	26.5
	U5	11.3	10.62	10.6	11.1	10.62-42.47	26.5
	U6	11.6	10.62	10.6	11.9	10.62	10.6
	U7	11.6	10.62-42.47	26.5	13.1	10.62	10.6
	U8	13.8	10.62-42.47	26.5	9.4	10.62	10.6
Sub-urban	**SU1**	16.4	10.62-42.47	26.5	18.4	10.62-42.47	26.5
	SU2	13.4	10.62	10.6	6.8	6.37-10.62	8.5
	SU3	16.1	10.62-42.47	26.5	13.6	10.62-42.47	26.5
	SU4	7.3	6.37-10.62	8.5	9.1	10.62	10.6
	SU5	12.0	10.62	10.6	8.0	10.62	10.6

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Site area	Code	Concentration of NO_2 (ppbv)					
		13-15 Jan 08			10-12 Feb 08		
		Spectrophotometry	Test kit		Spectrophotometry	Test kit	
		(N=3)	Read value	Average of range	(N=3)	Read value	Average of range
Rural	SU6	17.9	10.62-42.47	26.5	7.6	6.37-10.62	8.5
	R1	3.9	3.19-6.37	4.8	6.5	6.37-10.62	8.5
	R2	6.9	6.37	6.4	2.9	3.19-6.37	4.8
	R3	4.7	6.37	6.4	5.7	6.37-10.62	8.5
	R4	3.9	3.19	3.2	6.9	6.37-10.62	8.5
	R5	3.8	3.19-6.37	4.8	4.3	6.37	6.4
	R6	3.1	3.19-6.37	4.8	4.2	3.19	3.2

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Table E1 (continued)

Site area	Code	Concentration of NO_2 (ppbv)					
		9-11 Mar 08			7-9 Apr 08		
		Spectrophotometry	Test kit		Spectrophotometry	Test kit	
		(N=3)	Read value	Average of range	(N=3)	Read value	Average of range
Urban	**U1**	17.6	10.62-42.47	26.5	16.3	10.62-42.47	26.5
	U2	13.8	10.62	10.6	13.1	10.62	10.6
	U3	39.4	42.47	42.5	37.4	42.47	42.5
	U4	11.2	10.62	10.6	15.0	10.62	10.6
	U5	11.7	6.37-10.62	8.5	10.1	6.37-10.62	8.5
	U6	10.5	6.37	6.4	12.4	10.62	10.6
	U7	16.4	10.62	10.6	12.7	10.62	10.6
	U8	6.3	6.37-10.62	8.5	12.6	10.62	10.6
Sub-urban	**SU1**	19.1	10.62	10.6	17.1	10.62-42.47	26.5
	SU2	5.1	6.37	6.4	5.5	3.19-6.37	4.8
	SU3	13.3	10.62	10.6	14.0	10.62	10.6
	SU4	9.9	10.62	10.6	10.7	10.62	10.6
	SU5	9.0	10.62	10.6	6.3	3.19-6.37	4.8

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Site area	Code	Concentration of NO_2 (ppbv)					
		9-11 Mar 08			7-9 Apr 08		
		Spectrophotometry	Test kit		Spectrophotometry	Test kit	
		(N=3)	Read value	Average of range	(N=3)	Read value	Average of range
Rural	SU6	13.6	10.62	10.6	6.9	3.19-6.37	4.8
	R1	7.1	6.37-10.62	8.5	5.7	3.19-6.37	4.8
	R2	4.0	3.19	3.2	4.8	3.19	3.2
	R3	4.6	6.37-10.62	3.2	2.9	3.19	3.2
	R4	7.2	6.37-10.62	8.5	5.2	3.19-6.37	4.8
	R5	2.2	3.19	3.2	2.7	3.19	3.2
	R6	2.9	3.19	3.2	3.1	3.19	3.2

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List of Publication

1. Bootdee, S. and Chantara, S. Spatial and Temperal Variation of Nitrogen Dioxide in Chiang Mai City based on Passive Sampling Technique, Student/ Faculty Meeting 2008 at the Convention Center Chulabhorn Research Institute, Bangkok, Thailand.
2. Bootdee, S. and Chantara, S. Field Application of Nitrogen Dioxide Test Kit in Comparison with Spectrophotometry: Case Study Chiang Mai City, Thailand, 12th International Conference on Integrated Diffuse Pollution Management (IWA DIPCON 2008), Research Center for Environmental and Hazardous Substance Management (EHSM), Khon Kaen University, Thailand.

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