APPENDIX

APPENDIX A

A-1 Calculation of pollutant gases in passive samplers

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

$$C = \frac{Q * L}{A * t * D}$$

C = gas concentration ($\mu g/m^3$)

Q = quantity of gas transferred in sampling tube (μg)

L = length of diffusion tube (m)

A = cross-sectional area (m^2) = πr^2

t = sampling time (s)

D = diffusion coefficient ($m^2 s^{-1}$)

The diffusion coefficient of NO_2 and O_3 is $1.54 * 10^{-5}$ $m^2 s^{-1}$, while diffusion coefficient of SO_2 is $1.27*10^{-5}$ $m^2 s^{-1}$.

Please note that when using the sampling chemical in from of the solution, the diffusion length is measured from the surface area of the solution to the opened end of tube.

1. **Nitrogen dioxide (Determination by both ion chromatography and spectrophotometry)**

Q value of NO_2 determination was calculated by multiplication NO_2^- concentration obtained from calibration curve (ppm) with 4 (4 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.

Therefore

Q (μg) = NO_2^- concentration (ppm) * 4 ml

2. **Sulfur dioxide (Determination by both ion chromatography and spectrophotometry)**

Q value of SO_2 determination was calculated by multiplication SO_4^{2-} or SO_3^{2-} concentration (ppm) obtained from calibration curve of IC or spectrophotometry, respectively, with 4 (4 ml of extraction volume). The value was then multiplied with 64/96 or 64/80 to convert to SO_4^{2-} or SO_3^{2-}, respectively, to the total amount of SO_2 in passive sampler. In case of using the absorbing chemical in from of solution, use this volume instead the extraction volume.

Amount of SO_2 determination by IC

Q (μg) = SO_4^{2-} concentration (ppm) * 4 ml * 64/96

Amount of SO_2 determination by spectrophotometry

Q (μg) = SO_4^{2-} concentration (ppm) * 4 ml * 64/80

3. Ozone

3.1 Determination by ion chromatrography

Q value of O_3 determination was calculated by multiplication NO_3^- concentration obtained from calibration curve (ppm) with 4 (4 ml of extraction volume). The value was then multiplied by 48/62 to convert NO_3^- to O_3. The NO_3^- in ppm unit is converted to be the total amount of O_3 in passive sampler in μg unit

For example

Q (μg) = NO_3^- concentration (ppm) * 4 ml * 48/62

3.2 Determination by spectrophotometry

Q value of O_3 determination was calculated by multiplication O_3 concentration obtained from calibration curve (ppm) with 2 (2 ml of extraction volume). The O_3 in ppm unit is converted to be the total amount of O_3 in passive sampler in μg unit. . In case of using the absorbing chemical in from of solution, use this volume instead the extraction volume.

For example

Q (μg) = O_3 concentration (ppm) * 2 ml

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 dependent upon the temperature and pressure at the time of sampling, the pollutant concentration expressed in these units should, strictly speaking, specify the conditions at the time of sampling.

Volume mixing ratio: usually ppm - parts per million (10^{-6}); or ppb - parts per billion (10^{-9}); or ppt - parts per trillion (10^{-12}). This unit expressed the concentration of a pollutant as the ratio of its volume if segregated pure, to the volume of the air in which it is contained. Ideal gas behaviour is assumed and thus the concentration is not dependent upon temperature and pressure as these affect both the pollutant and the 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 per 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

$$\text{ppb} = \mu g\ m^{-3} * \frac{\text{molecular volume (litres)}}{\text{molecular weight}}$$

Where:

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

T = absolute temperature (K)

P = atmospheric pressure (kPa) (Remember that Celcius + 273 = Kelvin)

Similarly

$$\mu g\ m^{-3} = ppb^* \frac{\text{molecular weight}}{\text{molecular volume (litres)}}$$

Pollutant gases	From ppb to ug m^{-3}, multiply by:			From ug m^{-3} to ppb, multiply by:	
	Molecular weight	T = 0° C	T = 25° C	T = 0° C	T = 25° C
SO_2	64	2.855	2.617	0.350	0.382
NO_2	46	2.052	1.881	0.487	0.532
O_3	48	2.141	1.963	0.467	0.509

Sources:

Posch M., de Smet P.A.M., Hettelingh J.-P. and Downing R.J. [Eds.] (1999): Calculating and mapping of critical thresholds in Europe. Status Report 1999 - Coordination Center for Effects. Working Group on Effects of the Convention on Long-Range Transboundary Air Pollution. RIVM, Bilthoven, The Netherlands.

APPENDIX B

B.1 Calculation of detection limit

Detection limit was calculated from calibration curve with the help of equation 2.2.

$$Y = bX + a$$

Example of detection limit calculation for NO_2^-

Table B.1 Results of regression values for calculation detection limit

Conc.(ppm) [X_i]	Abs [Y_i]	$X_i-\overline{X}$	$Y_i-\overline{Y}$	$(X_i-\overline{X})^2$	$(Y_i-\overline{Y})^2$	$(X_i-\overline{X})(Y_i-\overline{Y})$
0.2	0.213	-0.400	-0.406	0.160	0.165	0.162
0.4	0.400	-0.200	-0.219	0.040	0.048	0.044
0.6	0.622	0.000	0.003	0.000	0.000	0.000
0.8	0.824	0.200	0.206	0.040	0.042	0.041
1.0	1.034	0.400	0.416	0.160	0.173	0.166
$\overline{X} = 0.6$	$\overline{Y} = 0.618$	$\Sigma = 0.000$	$\Sigma = 0.000$	$\Sigma = 0.400$	$\Sigma = 0.428$	$\Sigma = 0.414$

Where;

X_i = Response value from the instrument corresponding to the individual y value

$\overline{X}$ = Average value

Y_i = Response value from the instrument corresponding to the individual x value

$\overline{Y}$ = Average value

Correlation coefficient (r) = $$\frac{\sum\left[\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)\right]}{\left[\sum\left(X_I - \overline{X}\right)^2 \sum\left(Y_i - \overline{Y}\right)^2\right]^{1/2}}$$

= $$\frac{0.414}{\left(0.400 * 0.428\right)^{1/2}}$$

= 0.9997

Calculation of slope (b) = $$\frac{\sum\left[\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)\right]}{\sum\left(X_i - \overline{X}\right)^2}$$

b = $$\frac{0.414}{0.400}$$

b = 1.0339

Calculation of intercept of the Y-axis (a) = $\overline{Y} = b\overline{X}$

= 0.618 – (1.0339*0.6)

= -0.0018

Therefore

The equation for the regression line is Y = 1.0339X – 0.0018

Calculation of standard error on the slope ($S_{y/x}$) = $$\left[\frac{\sum\left(Y_i - Y_{pred}\right)^2}{\left(n-2\right)}\right]^{1/2}$$

Table B.2 Results of Y_{pred} values obtained from the regression line corresponding to the individual x values

X_i	Y_i	Ypred	$(Yi-Ypred)^2$
0.2	0.213	0.204	0.0000596
0.4	0.400	0.412	0.0001503
0.6	0.622	0.618	0.0000106
0.8	0.824	0.825	0.0000013
1.0	1.034	1.032	0.0000044
			$\sum = 0.0002262$

$$Sy/x = \left[\frac{0.0002262}{(5-2)}\right]^{1/2}$$

$$= 0.0086$$

$$\cong S_B$$

$$Y = Y_B + 3S_B$$

$$Y_B = a = -0.0018$$

$$Y = (-0.0018) + 3(0.0086)$$

$$= 0.024$$

$$0.024 = 1.0339X - 0.0018$$

$$X = 0.025$$

From the above calculation, the detection limit of NO_2^- determined by spectrophotometry was found 0.025 ppm

In case of calculation as follow the equation 2.3.

$$DL = [3*S_{y/x}]/b$$

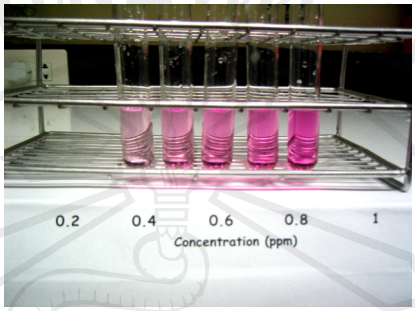
$$= [3*0.0086]/1.0339$$

$$= 0.025$$

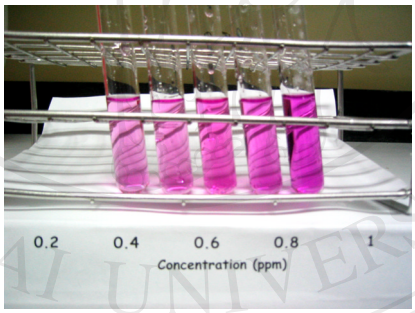
The detection limit of NO_2^- determined by spectrophotometry from this equation was 0.025 ppm, which equal to calculation by equation 2.3.

APPENDIX C

C.1 Color solutions of NO_2 determination by spectrophotometry



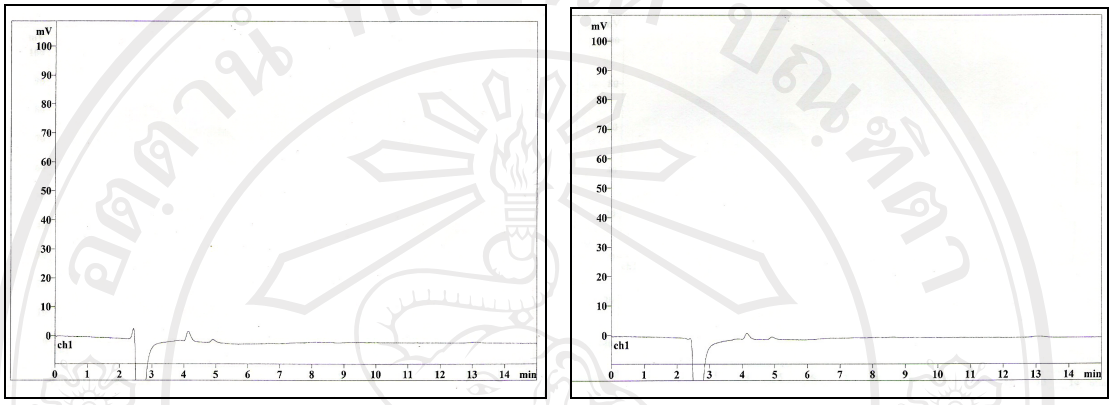
C.2 Color solutions of SO_2 determination by spectrophotometry



C.3 Color solutions of O_3 determination by spectrophotometry

APPENDIX D

Chromatograms



(a) (b)

Fig D.1 Chromatogram of Triethanolamine for determination of NO_2 and SO_2 (a) 20% Triethanolamine, (b) 12% of Triethanolamine / 4% glycerin

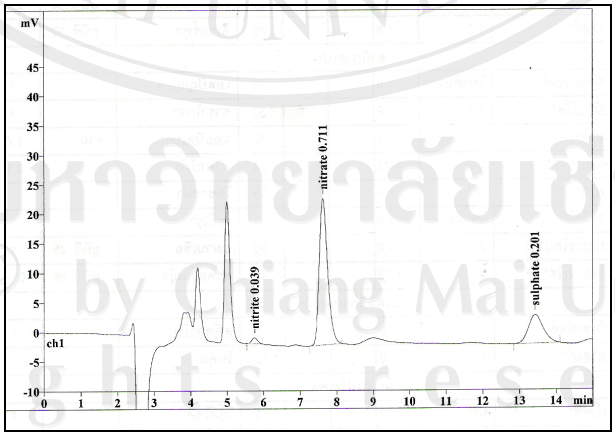
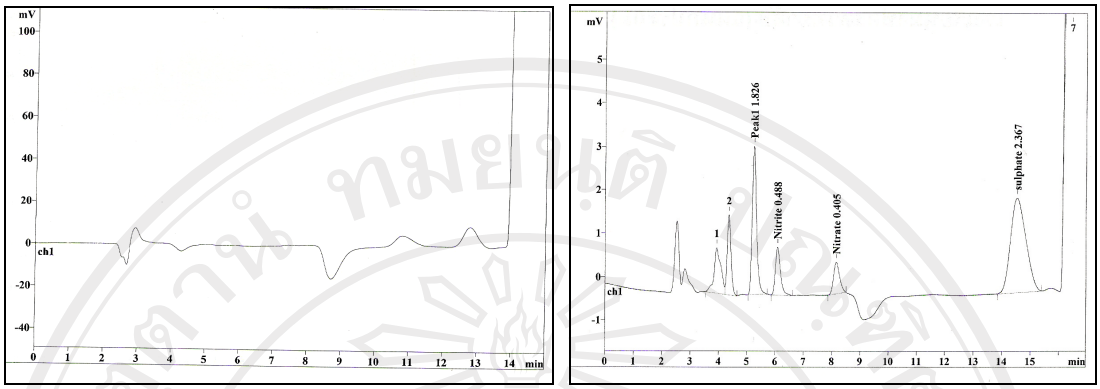
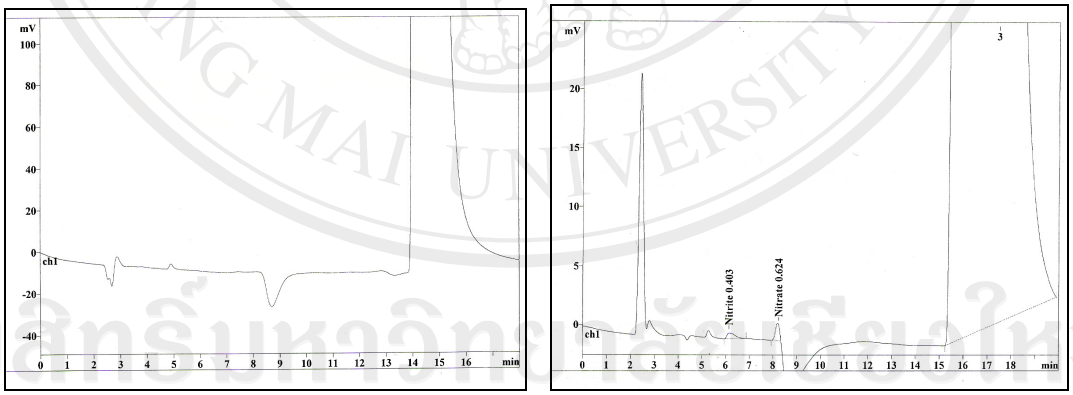


Fig D.2 Chromatogram of NO_2 and SO_2 using Triethanolamine as absorbing solution



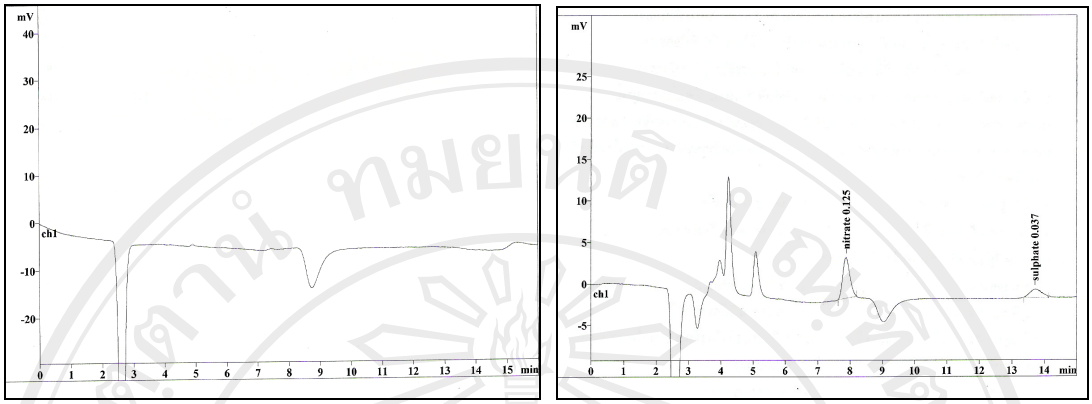
(a) (b)

Fig D.3 A mixed solution of KI / $NaAsO_2$ / ethylene glycol / MeOH for determination of NO_2 : (a) absorbing solution (b) sample



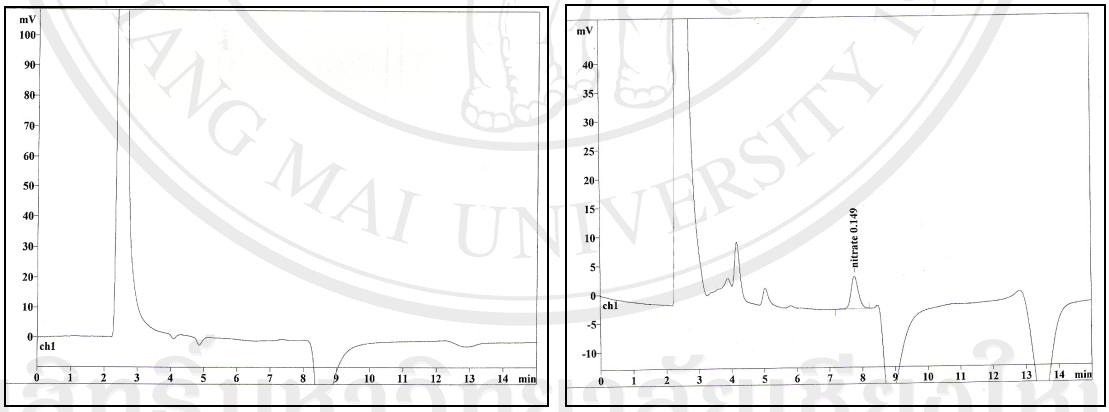
(a) (b)

Fig D.4 A mixed solution of NaI/ NaOH / MeOH for determination of NO_2 : (a) absorbing solurion, (b) sample



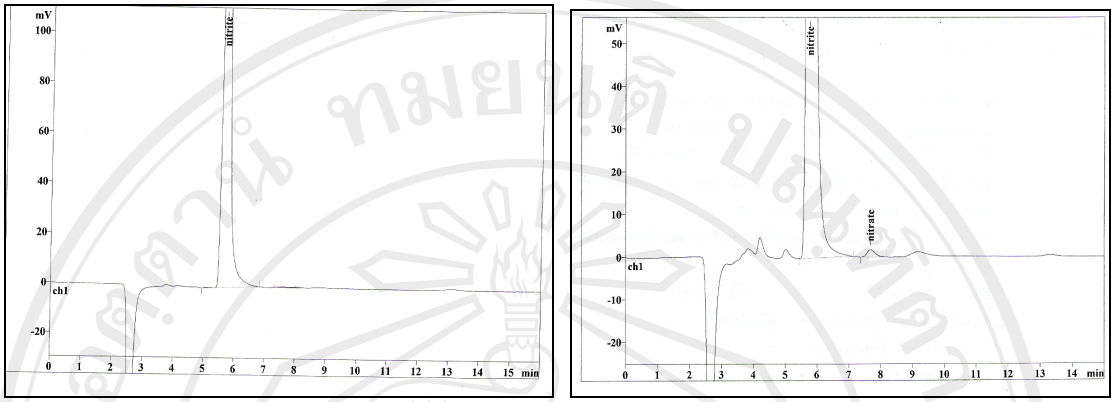
(a) (b)

Fig D.5 NaOH for determination of SO_2 : (a) absorbing solution, (b) sample



(a) (b)

Fig D.6 Na_2CO_3 for determination of SO_2 : (a) absorbing solution, (b) sample



(a) (b)

Fig D.7 $NaNO_2$ for determination of O_3 : (a) absorbing solution, (b) sample

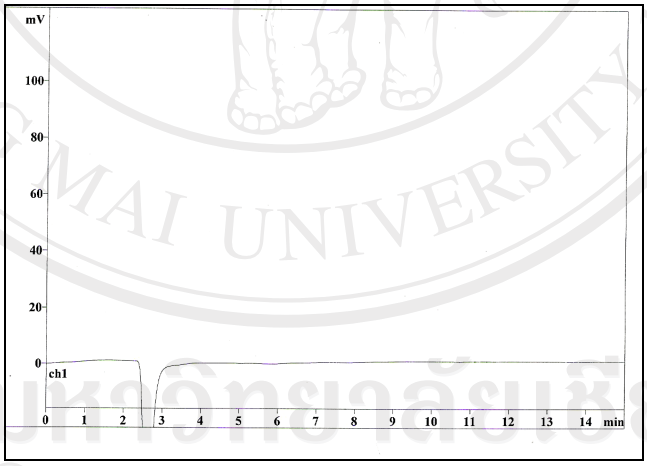


Fig D.8 Deionized water

Appendix E

Raw data

E-1 Selection of diffusion tube for passive sampler

Item	Polystylene tube						Polyethylene tube					
	NO_2^-		NO_3^-		SO_4^{2-}		NO_2^-		NO_3^-		SO_4^{2-}	
	Conc.(ppbv)	SD	Conc.(ppbv)	SD	Conc.(ppbv)	SD	Conc.(ppbv)	SD	Conc.(ppbv)	SD	Conc.(ppbv)	SD
Outdoor 1	3.291	0.28	13.336	2.38	3.037	0.88	4.156	0.42	15.399	1.50	4.442	0.34
Outdoor 2	3.436	0.27	14.256	2.53	3.596	0.71	4.248	0.43	15.759	1.53	4.520	0.37
Indoor 1	3.506	0.13	12.139	0.88	4.952	0.27	4.614	0.54	13.379	0.49	5.351	0.11
Indoor 2	3.674	0.11	16.023	0.89	4.569	0.27	4.852	0.56	19.240	0.45	5.851	0.15

E-2 Selection of sorbent for passive sampler

Sorbent	NO_2^- concentration (ppm)											SD
	blank1	blank2	blank3	Avr	sample1	sample2	sample3	sample4	sample5	Avr	Net conc.	
Whatman no.1	0.000	0.000	0.000	0.000	0.128	0.114	0.116	0.121	0.116	0.119	0.119	0.0057
Whatman no.6	0.000	0.000	0.000	0.000	0.127	0.122	0.128	0.125	0.128	0.126	0.126	0.0025
Whatman no.40	0.000	0.000	0.000	0.000	0.120	0.121	0.118	0.120	0.121	0.120	0.120	0.0012
GF/A	0.000	0.000	0.000	0.000	0.143	0.122	0.132	0.138	0.130	0.133	0.133	0.0080
Sorbent	SO_4^{2-} concentration (ppm)											
Whatman no.1	0.376	0.366	0.425	0.389	0.459	0.371	0.353	0.399	0.390	0.394	0.005	0.0402
Whatman no.6	0.252	0.268	0.297	0.272	0.244	0.316	0.312	0.300	0.283	0.291	0.019	0.0292
Whatman no.40	0.026	0.042	0.034	0.034	0.066	0.059	0.032	0.041	0.062	0.052	0.018	0.0147
GF/A	0.960	0.856	0.908	0.908	0.947	0.957	0.940	0.961	0.952	0.951	0.043	0.0083

E-3 Selection of absorbing solution

Gas	Absorbing solution	Ion chromatography			Spectrophotometry		
		Median (ppbv)	Max (ppbv)	Min (ppbv)	Median (ppbv)	Max (ppbv)	Min (ppbv)
NO_2	20% TEA / water	0.200	0.218	0.199	0.191	0.204	0.180
	12% TEA+4% glycerin / water	0.200	0.204	0.196	0.195	0.202	0.217
	KI+$NaAsO_2$+ethylene glycol / MeOH	0.244	0.252	0.280	0.208	0.221	0.209
	NaI/NaOH	0.244	0.258	0.285	0.198	0.204	0.194
SO_2	20%TEA	1.662	2.909	1.119	-		
	12%TEA/4%glycerin	1.598	1.758	1.374	-		
	2M Na_2CO_3	0.000	0.000	0.000	-		
	MeOH NaI/NaOH	0.192	0.224	0.160	-		
O_3	$NaNO_2$/Na_2CO_3/ethylene glycol	3.731	5.363	4.431	-		
	$NaNO_2$	3.498	5.820	2.449	-		
	DPE/MeOH	-			3.087	3.238	2.334
	DPE/glacial CH_3COOH	-			3.087	3.313	3.539

E-4 Recovery of extraction

Taget gas	Spiking standard	Extraction time (min)	Sonicate		Non sonicate	
			%Recovery	SD	%Recovery	SD
NO_2	NO_2^-	5	82.28	11.7	64.4	8.02
		10	86.02	10.90	65.40	11.26
		15	92.60	12.90	65.50	8.99
		20	86.50	9.10	66.00	5.20
SO_2	SO_4^{2-}	5	89.44	16.14	23.20	15.15
		10	102.99	11.61	65.40	6.77
		15	106.79	6.43	67.60	26.41
		20	86.50	3.13	29.60	21.89
	SO_3^{2-}	5	62.96	6.30	46.76	17.88
		10	97.37	10.36	60.93	5.90
		15	95.34	6.17	71.05	5.24
		20	81.17	8.98	77.13	11.61
O_3	NO_3^-	5	95.10	3.13	62.40	2.94
		10	98.10	7.36	70.70	1.34
		15	98.80	3.80	80.60	3.92
		20	97.00	2.70	83.60	1.86
	Pyridine-4-aldehyde	5	89.03	3.53	83.38	3.13
		10	94.69	8.36	84.26	5.34
		15	97.51	2.38	89.51	2.32
		20	97.24	1.27	95.21	4.86

E-5 Sampling period for NO_2 and SO_2 determination

Exposure period (days)	Item	Peak area		Conc (ppm)		Conc (ug/m^3)		Conc (ppbv)		Net conc (ppbv)*	
		NO_2^-	SO_4^{2-}	NO_2^-	SO_4^{2-}	NO_2	SO_2	NO_2	SO_2	NO_2	SO_2
1	blank	0.265	54.572	0.155	0.065	163.865	55.806	87.145	21.331	4.983	-13.278
		0.350	55.236	0.156	0.066	164.140	56.599	87.291	21.634		
		0.247	52.698	0.155	0.063	163.807	53.569	87.114	20.476		
	sample	2.793	20.164	0.163	0.017	172.053	14.722	91.499	5.627		
		4.096	27.414	0.167	0.027	176.273	23.379	93.744	8.936		
		3.158	25.480	0.164	0.025	173.235	21.070	92.128	8.054		
		3.521	23.568	0.165	0.022	174.411	18.787	92.753	7.181		
		2.680	26.530	0.163	0.026	171.687	22.323	91.305	8.533		
3	blank	0.000	25.138	0.000	0.024	0.000	6.887	0.000	2.633	4.810	2.248
		9.000	0.000	0.021	0.000	7.519	0.000	3.999	0.000		
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	sample	6.100	20.250	0.009	0.017	3.092	4.942	1.644	1.889		
		7.171	31.308	0.013	0.033	4.727	9.343	2.514	3.571		
		13.470	22.609	0.041	0.021	14.343	5.881	7.628	2.248		
		10.000	38.626	0.026	0.043	9.045	12.255	4.810	4.685		
		14.532	21.320	0.045	0.019	15.964	5.368	8.490	2.052		
5	blank	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.308	2.541
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	sample	10.866	35.672	0.030	0.039	6.220	6.648	3.308	2.541		
		10.973	37.570	0.030	0.042	6.318	7.101	3.360	2.714		
		6.156	30.590	0.009	0.032	1.906	5.434	1.014	2.077		
		5.807	39.485	0.008	0.044	1.587	7.558	0.844	2.889		
		14.622	31.655	0.046	0.033	9.661	5.689	5.138	2.174		
7	blank	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.834	2.752
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	sample	12.031	59.293	0.035	0.072	5.205	8.778	2.768	3.355		
		10.457	57.481	0.028	0.070	4.176	8.469	2.221	3.237		
		21.875	45.753	0.077	0.053	11.646	6.468	6.193	2.472		
		12.220	38.605	0.035	0.043	5.329	5.249	2.834	2.006		
		12.729	50.037	0.038	0.059	5.662	7.199	3.011	2.752		

* median value of sample-median value of blank

E-6 Effect of glycerin added in absorbing solution

Glycerin (%)	NO_2			SO_2		
	Conc. (ppbv)	Max (ppbv)	Min (ppbv)	Conc. (ppbv)	Max (ppbv)	Min (ppbv)
0	2.983	4.495	2.531	5.544	6.610	4.736
2	3.241	3.768	2.689	4.824	5.716	3.866
4	3.733	4.165	2.625	4.843	5.272	3.406
6	3.482	3.664	3.096	5.102	6.685	4.220
8	3.490	4.361	2.712	5.829	6.303	4.857
10	3.465	4.165	3.294	5.895	6.235	5.067

E-7 SO_2 determination

Conditions

Diffusion length (m) 0.054 m * , 0.038 m **

Radius (m) 0.007 m

Crossectional area (m^2) 0.000154 m^2

Diffusion coeff. (m^2/s) 0.0000127 m^2/s

Absorbing chemical	Analysis method	Sampling period	Date	Concentration (ppbv)		
				Median	Max	Min
50 µl 12% TEA/4% glycerin*	IC	1 day	22/9/2005	ND	-	-
			04/10/2005	ND	-	-
50 µl 4 M TCM*	Spectrophotometry	1 day	22/9/2005	ND	-	-
		3 day	4-6/10/05	1.376	1.834	0.423
		5 day	4-8/10/05	1.399	2.091	0.658
2 ml 4 MTCM**	Spectrophotometry	1 day	04/10/2005	ND	-	-
		3 day	4-6/10/05	1.635	2.764	0.659
		5 day	4-8/10/05	1.637	1.878	0.869

E-8 Outdoor ozone determination

Comparison of ozone determination in difference conditions

set	absorbing chemical	cover	type of tube	determination
1	$NaNO_2/Na_2CO_3$/ethylene glycol	original	wrap with foil	IC
2		new	wrap with foil	
3		new	No wraping	
4	DPE/MeOH	original	wrap with foil	spectrophotometry
5		new	wrap with foil	
6		new	No wraping	

set	Peak area / Abs								Net *	Conc. (ppm)	Conc. (ug/m^3)	Conc. (ppbv)
	blank1	blank2	blank3	sample1	sample2	sample3	sample4	sample5				
1	73.424	59.385	69.732	163.823	165.986	164.023	166.421	167.049	96.254	0.179	21.566	10.977
2	106.377	105.486	107.547	169.455	167.247	167.182	168.211	171.467	61.834	0.111	13.343	6.791
3	164.450	208.474	195.243	167.126	167.248	166.466	165.543	167.438	-28.117	-0.068	-8.149	-4.148
4	0.000	0.000	0.000	0.0225	0.023	0.0554	0.0516	0.0367	0.0367	0.008	0.623	0.317
5	0.000	0.000	0.000	0.0547	0.0796	0.0461	0.0661	0.0833	0.0661	0.023	1.797	0.915
6	0.034	0.033	0.029	0.0296	0.0213	0.0309	0.0378	0.0615	-0.0018	-0.012	-0.915	-0.465

* Median value of sample - Median value of blank

E-8 Outdoor ozone determination (continuous)

Conditions

Diffusion length (m) 0.054 m * , 0.038 m **

Radius (m) 0.007 m

Crossectional area (m^2) 0.000154 m^2

Diffusion coeff. (m^2/s) 0.0000154 m^2/s

Absorbing chemical	Analysis method	Sampling period	Date	Concentration (ppbv)		
				Median	Max	Min
50 µl 0.1% $NaNO_2$/ 0.1% $NaNO_2$/ 0.1% Na_2CO_3/ ethylene glycol*	IC	8 hr	22/9/2005	ND	-	-
		24 hr		15.757	18.667	10.127
50 µl DPE/MeOH*	Spectrophotometry	8 hr	22/9/2005	0.497	1.118	0.414
		24 hr		1.236	1.380	0.455
50 µl DPE/MeOH*		8 hr	04/10/2005	0.538	1.201	0.414
		24 hr		1.312	1.381	0.966
2 ml DPE/MeOH**	Spectrophotometry	8 hr	22/9/2005	2.634	3.390	2.334
		24 hr		11.179	11.910	10.578
2 ml DPE/MeOH**		8 hr	04/10/2005	8.631	14.629	8.371
		24 hr		12.207	14.555	10.296

E-9 Application of optimum passive sampler for NO_2 determination

NO_2 measurement on 11/10/05 (determined by ion chromatography)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.155	0.170	0.210	163.865	179.143	221.824	87.176	95.304	118.010												
blank	0.156	0.169	0.211	164.140	178.304	222.138	87.323	94.858	118.177	87.176	95.304	118.010	87.215	95.160	117.986	0.09	0.26	0.20	0.11	0.28	0.17
blank	0.155	0.170	0.210	163.807	179.169	221.374	87.145	95.318	117.771												
sample1	0.163	0.191	0.207	172.053	201.329	218.640	91.532	107.107	116.317												
sample2	0.164	0.193	0.224	173.034	203.560	235.884	92.054	108.294	125.490												
sample3	0.167	0.196	0.215	176.474	206.556	226.384	93.884	109.888	120.436	92.054	108.294	120.934	92.801	108.200	120.364	1.31	2.95	3.49	1.41	2.73	2.90
sample4	0.169	0.199	0.211	177.650	210.073	222.083	94.510	111.759	118.148												
sample5	0.164	0.185	0.217	172.982	195.395	228.253	92.027	103.950	121.431												
							Net Conc. (ppbv)			**4.878**	**12.990**	**2.923**	**5.587**	**13.040**	**2.378**						

NO_2 measurement on 12/10/05 (determined by ion chromatography)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.165	0.169	0.210	173.565	178.495	221.827	92.337	94.959	118.012												
blank	0.156	0.169	0.211	164.059	178.239	222.138	87.280	94.823	118.177	87.280	94.959	118.012	88.965	94.976	117.986	2.92	0.16	0.21	3.28	0.17	0.17
blank	0.156	0.170	0.210	164.056	178.845	221.371	87.278	95.145	117.769												
sample1	0.167	0.191	0.213	176.286	200.963	224.719	93.784	106.912	119.551												
sample2	0.166	0.201	0.215	175.486	212.039	227.149	93.359	112.805	120.843												
sample3	0.169	0.205	0.216	177.893	216.214	227.735	94.639	115.026	121.155	93.359	112.805	120.843	93.425	112.322	120.488	0.84	3.98	0.76	0.90	3.55	0.63
sample4	0.165	0.196	0.214	173.857	206.686	225.183	92.492	109.957	119.797												
sample5	0.166	0.208	0.216	174.537	219.758	227.621	92.854	116.911	121.095												
							Net Conc. (ppbv)			**6.079**	**17.846**	**2.831**	**4.461**	**17.346**	**2.502**						

Note; Length (L) = 0.054 m, Redius (R) = 0.007 m, Croossectional area (A)= 0.000154 m^2, Sampling period (t) = 86400 sec

E-9 Application of optimum passive sampler for NO_2 determination (continuous)

NO_2 measurement on 11/10/05 (determined by spectrophotometry)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.020	0.001	0.0076	20.794	1.369	8.043	11.062	0.728	4.279												
blank	-0.007	0.008	0.0093	-7.049	8.043	9.754	-3.750	4.279	5.189	8.062	1.184	4.279	5.125	2.064	4.370	7.83	1.93	0.78	0.00	93.62	17.80
blank	0.014	0.002	0.0065	15.155	2.225	6.845	8.062	1.184	3.642												
sample1	0.027	0.024	0.0156	28.547	24.813	16.428	15.187	13.201	8.740												
sample2	0.023	0.030	0.0086	24.318	32.001	9.070	12.937	17.024	4.825												
sample3	0.027	0.025	0.0119	28.547	26.525	12.492	15.187	14.111	6.646	12.937	14.111	7.056	13.237	16.150	6.919	1.90	4.14	1.64	14.36	25.65	23.71
sample4	0.021	0.041	0.0068	22.204	43.295	7.187	11.812	23.033	3.824												
sample5	0.020	0.024	0.0133	20.794	25.156	14.032	11.062	13.383	7.465												
							Net Conc. (ppbv)			4.875	12.928	2.777	8.112	14.087	2.549						

NO_2 measurement on 12/10/05 (determined by spectrophotometry)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.034	0.020	-0.0108	36.301	20.794	-11.415	19.312	7.943	-5.810												
blank	0.030	-0.007	-0.0124	32.072	-7.049	-13.021	17.062	-2.693	-6.628	17.250	4.443	-5.810	17.875	3.231	-5.931	1.25	5.42	0.64	6.98	167.76	-10.86
blank	0.031	0.011	-0.0100	32.424	11.630	-10.524	17.250	4.443	-5.356												
sample1	0.045	0.064	-0.0074	47.932	67.316	-7.848	25.500	25.715	-3.995												
sample2	0.043	0.043	-0.0044	45.817	45.817	-4.638	24.375	17.502	-2.360												
sample3	0.035	0.044	-0.0020	37.006	46.169	-2.140	19.687	17.637	-1.089	22.875	17.906	-2.360	22.162	20.841	-2.415	3.04	4.33	1.23	13.73	20.77	-51.11
sample4	0.041	0.044	-0.0061	42.997	46.874	-6.421	22.875	17.906	-3.268												
sample5	0.033	0.063	-0.0025	34.539	66.611	-2.675	18.375	25.445	-1.362												
							Net Conc. (ppbv)			**5.625**	**13.463**	**ND**	**4.287**	**17.610**	**ND**						

Note; Length (L) = 0.054 m, Redius (R) = 0.007 m, Croossectional area (A)= 0.000154 m^2, Sampling period (t) = 86400 sec

E-10 Application of optimum passive sampler for SO_2 determination

SO_2 measurement on 11-13/10/05 (determined by ion chromatography)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.202	0.041	0.051	57.286	11.771	14.372	21.883	4.496	5.490												
blank	0.201	0.043	0.051	57.042	12.181	14.373	21.790	4.653	5.490	21.790	4.653	5.490	21.818	4.665	5.481	0.06	0.18	0.02	0.26	3.75	0.30
blank	0.201	0.045	0.050	57.017	12.686	14.297	21.781	4.846	5.462												
sample1	0.234	0.078	0.064	66.461	22.298	18.121	25.388	8.518	6.922												
sample2	0.216	0.078	0.063	61.225	22.220	18.022	23.388	8.488	6.885												
sample3	0.226	0.079	0.064	64.223	22.334	18.223	24.533	8.532	6.961	24.533	8.518	6.914	24.436	8.519	6.917	0.72	0.03	0.03	2.96	0.32	0.41
sample4	0.223	0.078	0.064	63.444	22.255	18.100	24.236	8.501	6.914												
sample5	0.227	0.079	0.064	64.487	22.403	18.071	24.634	8.558	6.903												
							Net Conc. (ppbv)			**2.743**	**3.865**	**1.424**	**2.618**	**3.854**	**1.436**						

SO_2 measurement on 13-15/10/05 (determined by ion chromatography)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.042	0.024	0.053	11.992	6.815	14.953	4.581	2.603	5.712												
blank	0.044	0.027	0.052	12.401	7.722	14.784	4.737	2.950	5.647	4.581	2.603	5.712	4.596	2.708	5.780	0.13	0.21	0.18	2.91	7.74	3.05
blank	0.041	0.024	0.055	11.704	6.732	15.654	4.471	2.572	5.980												
sample1	0.064	0.076	0.059	18.296	21.608	16.632	6.989	8.254	6.354												
sample2	0.076	0.059	0.057	21.644	16.689	16.280	8.268	6.375	6.219												
sample3	0.086	0.060	0.059	24.406	17.036	16.789	9.323	6.508	6.413	8.268	6.508	6.241	8.169	6.854	6.283	0.88	0.80	0.10	10.77	11.66	1.53
sample4	0.079	0.059	0.058	22.398	16.666	16.337	8.556	6.366	6.241												
sample5	0.071	0.062	0.057	20.182	17.710	16.200	7.709	6.765	6.188												
							Net Conc. (ppbv)			**3.687**	**3.905**	**0.529**	**3.573**	**4.146**	**0.503**						

Note; Length (L) = 0.054 m, Redius (R) = 0.007 m, Croossectional area (A)= 0.000154 m^2, Sampling period (t) = 259200 sec

E-10 Application of optimum passive sampler for SO_2 determination (continuous)

SO_2 measurement on 11-13/10/05 (determined by spectrophotometry)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.005	0.0880	0.1308	0.586	10.557	15.688	0.224	4.033	5.993												
blank	0.004	0.0330	0.0697	0.440	3.959	8.357	0.168	1.512	3.192	0.224	4.033	5.993	0.243	5.769	5.806	0.09	5.34	2.53	35.25	92.58	43.50
blank	0.007	0.2567	0.1797	0.880	30.790	21.553	0.336	11.762	8.233												
sample1	0.020	0.1064	0.0856	2.346	12.756	10.263	0.896	4.873	3.921												
sample2	0.035	0.1467	0.0562	4.252	17.594	6.744	1.624	6.721	2.576												
sample3	0.042	0.1039	0.0709	4.985	12.463	8.504	1.904	4.761	3.248	1.512	5.993	3.248	1.490	5.892	3.349	0.37	1.06	0.85	24.74	18.02	25.43
sample4	0.033	0.1308	0.0550	3.959	15.688	6.598	1.512	5.993	2.520												
sample5	0.033	0.1553	0.0978	3.959	18.621	11.730	1.512	7.113	4.481												
							Net Conc. (ppbv)			**1.288**	**1.960**	**ND**	**1.247**	**0.123**	**ND**						

SO_2 measurement on 13-15/10/05 (determined by spectrophotometry)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.127	0.0000	0.0000	15.248	0.000	0.000	5.825	0.000	0.000												
blank	0.000	0.0000	0.1299	0.000	0.000	15.585	0.000	0.000	5.953	5.825	0.000	0.000	3.902	2.200	1.984	3.38	3.81	3.44	86.61	173.21	173.21
blank	0.128	0.1441	0.0000	15.395	17.279	0.000	5.881	6.600	0.000												
sample1	0.143	0.0240	-0.2542	17.154	2.880	-30.492	6.553	1.100	-11.648												
sample2	0.152	0.0339	-0.2034	18.181	4.066	-24.393	6.945	1.553	-9.318												
sample3	0.165	0.0113	-0.2090	19.794	1.355	-25.071	7.561	0.518	-9.577	6.945	1.424	-9.577	7.057	1.307	-9.927	0.54	0.53	0.97	7.61	40.88	-9.77
sample4	0.143	0.0424	-0.2062	17.154	5.082	-24.732	6.553	1.941	-9.448												
sample5	0.167	0.0311	-0.2105	20.087	3.727	-25.240	7.673	1.424	-9.642												
							Net Conc. (ppbv)			**1.120**	**1.424**	**ND**	**3.155**	**ND**	**ND**						

Note; Length (L) = 0.038 m, Redius (R) = 0.007 m, Croossectional area (A)= 0.000154 m^2, Sampling period (t) = 259200 sec

E-11 Application of optimum passive sampler for O_3 determination

O_3 measurement on 11/10/05 (determined by ion chromatography)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.033	0.061	0.078	26.646	49.398	63.454	13.563	25.143	32.298												
blank	0.032	0.058	0.063	26.474	47.034	51.379	13.475	23.940	26.152	13.563	25.143	31.449	13.574	24.832	29.966	0.10	0.78	3.33	0.77	3.16	11.11
blank	0.033	0.061	0.076	26.883	49.928	61.786	13.684	25.413	31.449												
sample1	0.060	0.096	0.097	48.811	78.712	79.330	24.845	40.064	40.379												
sample2	0.055	0.104	0.095	44.785	85.081	77.441	22.795	43.306	39.417												
sample3	0.067	0.099	0.077	54.708	81.037	62.740	27.846	41.248	31.935	24.845	42.146	39.898	25.309	43.135	36.700	1.88	3.44	5.69	7.41	7.98	15.51
sample4	0.063	0.118	0.071	51.555	96.092	57.717	26.241	48.911	29.378												
sample5	0.060	0.101	0.102	48.754	82.801	83.283	24.816	42.146	42.391												
							Net Conc. (ppbv)			**11.282**	**17.002**	**8.449**	**11.735**	**18.303**	**6.734**						

O_3 measurement on 12/10/05 (determined by ion chromatography)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.051	0.059	0.049	41.727	47.907	39.822	21.239	24.385	20.269												
blank	0.051	0.058	0.052	41.763	47.195	42.644	21.257	24.023	21.706	21.239	24.385	21.099	21.111	24.634	21.025	0.24	0.77	0.72	1.12	3.12	3.43
blank	0.050	0.061	0.051	40.938	50.090	41.452	20.837	25.496	21.099												
sample1	0.080	0.091	0.060	65.247	74.102	48.633	33.211	37.718	24.754												
sample2	0.080	0.107	0.057	65.503	87.668	46.128	33.341	44.623	23.479												
sample3	0.081	0.097	0.067	66.415	79.535	54.795	33.805	40.483	27.891	33.347	40.483	25.336	33.473	40.721	25.373	0.25	2.52	1.61	0.74	6.18	6.33
sample4	0.080	0.099	0.061	65.516	80.618	49.776	33.347	41.035	25.336												
sample5	0.081	0.096	0.061	66.127	78.087	49.912	33.659	39.746	25.405												
							Net Conc. (ppbv)			**12.108**	**16.098**	**4.237**	**12.361**	**16.087**	**4.348**						

Note; Length (L) = 0.054 m, Redius (R) = 0.007 m, Croossectional area (A)= 0.000154 m^2, Sampling period (t) = 86400 sec

E-11 Application of optimum passive sampler for O_3 determination (continuous)

O_3 measurement on 11/10/05 (determined by spectrophotometry)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.020	0.050	0.0224	7.234	18.628	8.306	3.682	9.482	4.228												
blank	0.015	0.050	0.0170	5.516	18.601	6.320	2.808	9.468	3.217	3.352	9.468	4.228	3.280	9.438	4.136	0.44	0.06	0.88	13.46	0.68	21.20
blank	0.018	0.050	0.0263	6.585	18.399	9.751	3.352	9.365	4.963												
sample1	0.077	0.111	0.0351	28.477	41.207	13.001	14.495	20.974	6.618												
sample2	0.080	0.136	0.0477	29.660	50.559	17.696	15.097	25.735	9.007												
sample3	0.077	0.122	0.0229	28.629	45.406	8.487	14.572	23.112	4.320	14.522	23.112	6.618	14.533	23.345	6.691	0.40	1.72	1.67	2.72	7.35	25.02
sample4	0.074	0.127	0.0341	27.465	46.933	12.640	13.980	23.889	6.434												
sample5	0.077	0.122	0.0375	28.530	45.215	13.904	14.522	23.014	7.077												
							Net Conc. (ppbv)			**11.170**	**13.644**	**2.390**	**11.253**	**13.906**	**2.555**						

O_3 measurement on 12/10/05 (determined by spectrophotometry)

Item	conc. (ppm)			conc. (ug/m^3)			conc. (ppbv)			median conc. (ppbv)			Avr conc. (ppbv)			SD			%RSD		
	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C	site A	site B	site C
blank	0.025	0.0000	0.0031	9.333	0.000	1.160	4.751	0.000	0.590												
blank	0.020	0.0000	0.0000	7.425	0.000	0.000	3.779	0.000	0.000	4.751	0.000	0.590	5.398	0.000	2.187	2.02	0.00	3.29	0.00	0.00	150.43
blank	0.041	0.0000	0.0316	15.059	0.000	11.728	7.665	0.000	5.969												
sample1	0.054	0.0549	0.0073	20.021	20.365	2.706	10.191	10.366	1.378												
sample2	0.069	0.0542	0.0268	25.747	20.117	9.923	13.105	10.239	5.051												
sample3	0.070	0.0550	0.0288	26.129	20.403	10.697	13.300	10.385	5.445	13.105	10.366	4.920	12.581	10.344	4.362	1.35	0.06	1.49	10.72	0.58	34.15
sample4	0.068	0.0549	0.0115	25.366	20.346	4.253	12.911	10.356	2.165												
sample5	0.071	0.0550	0.0254	26.320	20.384	9.408	13.397	10.375	4.789												
							Net Conc. (ppbv)			**8.355**	**10.366**	**4.329**	**7.183**	**10.344**	**2.176**						

Note; Length (L) = 0.038 m, Redius (R) = 0.007 m, Croossectional area (A)= 0.000154 m^2, Sampling period (t) = 86400 sec

E-12 PM_{10} (ug/m^3) in Chiang Mai ambient air in 2004-2005

Yupparaj Wittayalai School							Chiang Mai Governmental Office Center							
Month	Concentration			Month	Concentration			Month	Concentration			Month	Concentration		
	max	avr	min		max	avr	min		max	avr	min		max	avr	min
Jan-04	117.0	86.7	55.4	Jan-05	106.8	78.0	46.6	Jan-04	168.8	115.9	67.9	Jan-05	131.3	81.6	50.2
Feb-04	203.7	115.8	62.3	Feb-05	206.9	127.8	63.3	Feb-04	291.0	159.5	65.6	Feb-05	198.8	120.8	56.0
Mar-04	178.2	142.4	98.1	Mar-05	148.6	92.4	39.0	Mar-04	249.3	204.8	143.7	Mar-05	156.5	99.1	41.2
Apr-04	156.2	72.6	26.5	Apr-05	167.7	62.7	22.3	Apr-04	224.3	114.6	39.8	Apr-05	157.4	70.3	36.1
May-04	31.2	18.8	11.5	May-05	69.2	37.8	14.8	May-04	56.6	34.9	21.0	May-05	66.5	43.0	17.4
Jun-04	33.6	19.8	11.3	Jun-05	38.3	24.5	17.1	Jun-04	63.5	41.1	27.8	Jun-05	45.1	26.9	16.6
Jul-04	29.5	20.7	11.0	Jul-05	45.2	31.0	19.5	Jul-04	25.6	17.2	13.6	Jul-05	34.1	22.1	12.0
Aug-04	39.6	23.1	13.8	Aug-05	59.4	38.5	19.2	Aug-04	55.9	28.8	17.7	Aug-05	34.0	24.0	13.8
Sep-04	57.9	34.3	17.5	Sep-05	69.3	35.5	15.7	Sep-04	53.7	26.1	14.0	Sep-05	47.2	23.4	14.1
Oct-04	103.0	63.5	24.1	Oct-05	69.7	47.5	21.6	Oct-04	96.0	60.9	30.7	Oct-05	58.8	35.5	15.8
Nov-04	61.8	45.7	17.4	Nov-05	62.8	45.6	31.6	Nov-04	72.2	45.1	20.3	Nov-05	46.7	29.2	22.0
Dec-04	105.6	68.6	25.7	Dec-05	112.2	57.4	26.0	Dec-04	84.9	62.6	23.7	Dec-05	87.7	42.4	16.1

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