APPENDICES

Appendix A

STATISTICAL TABLE

Table A1 One-way analysis of bark pH between mango trees and bullet wood trees

	pH1
Mann-Whitney U	60.000
Wilcoxon W	165.000
Z	-1.965
Asymp. Sig. (2-tailed)	.049
Exact Sig. [2*(1-tailed Sig.)]	.051[a]

a. Not corrected for ties. b. Grouping Variable: treat

Appendix B

STATISTICAL TABLE

Table B1 Test of homogeneity of variances of bark pH

Levene Statistic	df1	df2	Sig.
2.600	3	68	.059

Table B2 One-way analysis of variences (ANOVA) of bark pH

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.023	4	.256	3.551	.011
Within Groups	4.899	68	.072		
Total	5.923	72			

Table B3 Test of homogeneity of variances of NO_2 and AQC

Levene Statistic	df1	df2	Sig.
2.212[a]	3	14	.132

Table B4

Correlations

		AQC	AQI	NO2	pH	Month	Nitrogen	Class
AQC	Pearson Correlation	1	.966**	-.525*	.093	.[a]	-.752**	1.000**
	N	19	19	19	19	19	17	19
AQI	Pearson Correlation	.966**	1	-.473*	.030	.[a]	-.687**	.966**
	N	19	19	19	19	19	17	19
NO_2	Pearson Correlation	-.525*	-.473*	1	-.022	.[a]	.940**	-.525*
	N	19	19	19	19	19	17	19
pH	Pearson Correlation	.093	.030	-.022	1	.[a]	.062	.093
	N	19	19	19	19	19	17	19
Month	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	1	-.110	.000
	N	19	19	19	19	76	73	76
Nitrogen	Pearson Correlation	-.752**	-.687**	.940**	.062	-.110	1	-.388**
	N	17	17	17	17	73	73	73
Class	Pearson Correlation	1.000**	.966**	-.525*	.093	.000	-.388**	1
	N	19	19	19	19	76	73	76

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

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

Appendix C

Table C1 Sum of lichen frequencies on 6 Mango or Bullet wood trees in sampling site, standard deviation (SD) and sum of all squared deviation.

Examined unit	Sums of lichen frequencies on individual tree						Sum	AQI	SD						Sum-SD
j	T1	T2	T3	T4	T5	T6			S1	S2	S3	S4	S5	S6	
1A	16	29	19	2	17	18	101	16.83	0.69	148.03	4.69	220.03	0.03	1.36	374.83
2A	8	15	5	3	11	-	42	8.40	0.16	43.56	11.56	29.16	6.76	-	91.20
3A	4	6	7	13	-	-	30	7.50	12.25	2.25	0.25	30.25	-	-	45.00
4A	10	5	10	10	22	22	79	13.17	10.03	66.69	10.03	10.03	78.03	78.03	252.83
5A	40	17	18	27	14	8	124	20.67	373.78	13.44	7.11	40.11	44.44	160.44	639.33
6A	39	35	49	17	10	48	198	33.00	36.00	4.00	256.00	256.00	529.00	225.00	1306.00
7A	10	10	2	3	16	14	55	9.17	0.69	0.69	51.36	38.03	46.69	23.36	160.83
8A	4	3	10	3	6	3	29	4.83	0.69	3.36	26.69	3.36	1.36	3.36	38.83
9A	4	8	11	11	12	13	59	9.83	34.03	3.36	1.36	1.36	4.69	10.03	54.83
10A	13	12	2	6	13	12	58	9.67	11.11	5.44	58.78	13.44	11.11	5.44	105.33
11A	2	2	6	13	7	4	34	5.67	13.44	13.44	0.11	53.78	1.78	2.78	85.33
12A	24	23	23	20	14	22	126	21.00	9.00	4.00	4.00	1.00	49.00	1.00	68.00
13A	10	6	22	22	13	41	114	19.00	81.00	169.00	9.00	9.00	36.00	484.00	788.00
14A	19	23	19	8	4	9	82	13.67	28.44	87.11	28.44	32.11	93.44	21.78	291.33
15A	22	15	5	15	14	18	89	14.83	51.36	0.03	96.69	0.03	0.69	10.03	158.83

*Note: - mean no suitable tree in this unit

Table C (Continue)

Examined unit	Sums of lichen frequencies on individual tree						Sum	AQI	SD						Sum-SD
j	T1	T2	T3	T4	T5	T6			S1	S2	S3	S4	S5	S6	
16A	3	5	2	8	3	5	26	4.33	1.78	0.44	5.44	13.44	1.78	0.44	23.33
17A	10	18	8	20	19	12	87	14.50	20.25	12.25	42.25	30.25	20.25	6.25	131.50
18A	10	5	1	2	1	8	27	4.50	30.25	0.25	12.25	6.25	12.25	12.25	73.50
19A	20	20	9	16	13	22	100	16.67	11.11	11.11	58.78	0.44	13.44	28.44	123.33
20A	6	12	27	19	11	33	108	18.00	144.00	36.00	81.00	1.00	49.00	225.00	536.00
21A	12	21	13	16	10	10	82	13.67	2.78	53.78	0.44	5.44	13.44	13.44	89.33
22A	15	19	17	11	12	13	87	14.50	0.25	20.25	6.25	12.25	6.25	2.25	47.50
23A	33	20	14	-	-	-	67	22.33	113.78	5.44	69.44	-	-	-	188.67
24A	6	16	3	10	11	2	48	8.00	4.00	64.00	25.00	4.00	9.00	36.00	142.00
25A	22	11	6	21	37	42	139	23.17	1.36	148.03	294.69	4.69	191.36	354.69	994.83
26A	32	13	9	37	7	23	121	20.17	140.03	51.36	124.69	283.36	173.36	8.03	780.83
27A	13	13	16	19	10	14	85	14.17	1.36	1.36	3.36	23.36	17.36	0.03	46.83
28A	21	10	23	16	10	10	90	15.00	36.00	25.00	64.00	1.00	25.00	25.00	176.00
29A	21	25	10	2	6	10	74	12.33	75.11	160.44	5.44	106.78	40.11	5.44	393.33
30A	10	15	10	10	11	-	56	11.20	1.44	14.44	1.44	1.44	0.04	-	18.80
31A	6	12	5	6	6	10	45	7.50	2.25	20.25	6.25	2.25	2.25	6.25	39.50
32A	13	14	9	15	5	10	66	11.00	4.00	9.00	4.00	16.00	36.00	1.00	70.00
33A	23	25	20	14	18	9	109	18.17	23.36	46.69	3.36	17.36	0.03	84.03	174.83
34A	15	10	7	9	11	10	62	10.33	21.78	0.11	11.11	1.78	0.44	0.11	35.33
35A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36A	4	10	11	10	8	11	54	9.00	25.00	1.00	4.00	1.00	1.00	4.00	36.00

*Note: - mean no suitable tree in this unit

Table C (Continue)

Examined unit	Sums of lichen frequencies on individual tree						Sum	AQI	SD						Sum-SD
j	T1	T2	T3	T4	T5	T6			S1	S2	S3	S4	S5	S6	
1B	18	30	24	5	46	15	138	23.00	25.00	49.00	1.00	324.00	529.00	64.00	992.00
2B	40	66	20	60	25	34	245	40.83	0.69	633.36	434.03	367.36	250.69	46.69	1732.83
3B	38	43	55	14	12	8	170	28.33	93.44	215.11	711.11	205.44	266.78	413.44	1905.33
4B	17	12	11	28	14	12	94	15.67	1.78	13.44	21.78	152.11	2.78	13.44	205.33
5B	23	26	10	26	29	31	145	24.17	1.36	3.36	200.69	3.36	23.36	46.69	278.83
6B	11	12	11	28	10	25	97	16.17	26.69	17.36	26.69	140.03	38.03	78.03	326.83
7B	30	42	25	32	35	42	206	34.33	18.78	58.78	87.11	5.44	0.44	58.78	229.33
8B	20	11	2	51	12	34	130	21.67	2.78	113.78	386.78	860.44	93.44	152.11	1609.33
9B	11	32	16	24	23	16	122	20.33	87.11	136.11	18.78	13.44	7.11	18.78	281.33
10B	11	12	13	22	14	35	107	17.83	46.69	34.03	23.36	17.36	14.69	294.69	430.83
11B	4	10	4	5	3	11	37	6.17	4.69	14.69	4.69	1.36	10.03	23.36	58.83
12B	13	11	27	7	10	10	78	13.00	0.00	4.00	196.00	36.00	9.00	9.00	254.00
13B	5	9	10	8	10	9	51	8.50	12.25	0.25	2.25	0.25	2.25	0.25	17.50
14B	8	23	24	6	43	5	109	18.17	103.36	23.36	34.03	148.03	616.69	173.36	1098.83
15B	5	10	13	8	17	17	70	11.67	44.44	2.78	1.78	13.44	28.44	28.44	119.33
16B	5	35	28	29	20	21	138	23.00	324.00	144.00	25.00	36.00	9.00	4.00	542.00
17B	30	22	12	18	23	37	142	23.67	40.11	2.78	136.11	32.11	0.44	177.78	389.33
18B	11	10	20	26	28	15	110	18.33	53.78	69.44	2.78	58.78	93.44	11.11	289.33
19B	10	30	4	15	10	16	85	14.17	17.36	250.69	103.36	0.69	17.36	3.36	392.83
20B	23	10	30	5	2	6	76	12.67	106.78	7.11	300.44	58.78	113.78	44.44	631.33
21B	12	2	18	18	10	17	77	12.83	0.69	117.36	26.69	26.69	8.03	17.36	196.83
22B	11	19	18	20	10	33	111	18.50	56.25	0.25	0.25	2.25	72.25	210.25	341.50
23B	12	3	7	15	11	2	50	8.33	13.44	28.44	1.78	44.44	7.11	40.11	135.33
24B	15	9	24	1	5	5	59	9.83	26.69	0.69	200.69	78.03	23.36	23.36	352.83

*Note: - mean no suitable tree in this unit

Table C (Continue)

Examined unit	Sums of lichen frequencies on individual tree						Sum	AQI	SD						Sum-SD
j	T1	T2	T3	T4	T5	T6			S1	S2	S3	S4	S5	S6	
25B	23	14	7	31	-	-	75	18.75	18.06	22.56	138.06	150.06	-	-	328.75
26B	24	33	44	24	26	18	169	28.17	17.36	23.36	250.69	17.36	4.69	103.36	416.83
27B	22	1	15	20	10	22	90	15.00	49.00	196.00	0.00	25.00	25.00	49.00	344.00
28B	10	19	16	6	3	23	77	12.83	8.03	38.03	10.03	46.69	96.69	103.36	302.83
29B	11	22	5	5	11	10	64	10.67	0.11	128.44	32.11	32.11	0.11	0.44	193.33
30B	10	4	5	16	6	29	70	11.67	2.78	58.78	44.44	18.78	32.11	300.44	457.33
31B	2	23	14	12	11	7	69	11.50	90.25	132.25	6.25	0.25	0.25	20.25	249.50
32B	28	20	28	14	25	15	130	21.67	40.11	2.78	40.11	58.78	11.11	44.44	197.33
33B	10	6	11	17	19	31	94	15.67	32.11	93.44	21.78	1.78	11.11	235.11	395.33
34B	20	18	6	6	21	44	115	19.17	0.69	1.36	173.36	173.36	3.36	616.69	968.83
35B	43	46	16	15	22	41	183	30.50	156.25	240.25	210.25	240.25	72.25	110.25	982.00
36B	21	2	1	29	5	6	64	10.67	106.78	75.11	93.44	336.11	32.11	21.78	665.33
37B	10	2	20	20	10	15	77	12.83	8.03	117.36	51.36	51.36	8.03	4.69	240.83
38B	19	38	1	13	22	17	110	18.33	0.44	386.78	300.44	28.44	13.44	1.78	731.33
														Sum of all squared deviation	**27867.42**

Sum of all squared deviation	27,867.42
Mean number of trees per grid squared (n_p)	5.88
Mean standard deviation of all examined grid squared (Sp)	8.8
Width of air quality classes	9.1

*Note: - mean no suitable tree in this unit

Appendix D

D 1 Preparation of solutions for NO_2 sampling and analysis (Bootdee, 2009)

1.1 Absorbing solution (20% v/v of Triethanolamine, TEA)

A 20 ml of TEA was accurately pipette into 100 ml volumetric flask and adjusted to volume with de- ionized water.

1.2 Sulfanilamide solution

A 10.75 g of sulfanilamide was weighed and dissolved in 28 ml of phosphoric acid and adjusted volume to 500 ml with de- ionized water in a volumetric flask.

1.3 N- (1Napthyl) ethylenediamine dihydrochloride (NEDA) solution

A 0.1520 g of N- (1Napthyl) ethylenediamine dihydrochloride was dissolved in de- ionized water and adjusted to 100 ml in a volumetric flask.

1.4 Saltzmann reagent

Sulfanilamide solution and NEDA solution were mixed in a ratio of 10:1. This reagent must be refrigerated and protected from light.

1.5 Nitrite strand stock solution (1,000 mg/L)

A 0.150 g of sodium nitrite ($NaNO_2$) was dissolved in de- ionized water and adjusted to 100 ml in a volumetric flask.

D 2 Analytical characteristics

2.1 Linear dynamic range

The linear dynamic range was investigated by varying concentrations of nitrite (NO_2^-) in a range from 0.01 – 10 mg/L. It was then determinate by plotting absorbance versus concentrations of nitrite standard solution.

2.2 Calibration curve

A calibration curve was constructed by plotting concentrations of nitrite standard solution versus absorbance obtained from spectrophotometry. Nitrite solution were prepared from 1,000 mg/L stock standard solution and diluted in a range from 0.01- 1.0 mg/L. After 2 ml of Salzmann reagent were added. Standard solutions were measured by spectrophotometry by using reagent as blank.

2.3 Limit of Detection (LOD) and Limit of Quantitation (LOQ)

In analytical chemistry, the LOD is the lowest concentration of the

analyte that can detected with a given degree of confidence. LOQ is a parameter for quantitative assays for low levels of compounds in the sample matrices and used particularly for determination products or low levels of active constituent in a product (Christian, 2001 cited by Bootdee, 2009). The limits of detection and quantitative were calculated as follow:

$$LOD = 3 \times SD$$

$$LOQ = 10 \times SD$$

Where:

SD is a standard deviation from 10 times measurement of the lowest concentration of nitrite standard solution used in calibration curve.

2.4 Repeatability and reproducibility

Repeatability is the results of standard deviation of measurements repeated by the same analyze on the same instrument within a short time period. The repeatability in this work was checked by 10 times continuously measurement of absorbance of the 0.2 mg/L nitrite standard solution by spectrophotometer at 540 nm.

Reproducibility is the closeness of agreement between independent result obtained with the same method on identical test material but under different conditions (different operators, different apparatus, different laboratories and after intervals of time). The reproducibility in this work was

pursued by preparing 10 flasks of 0.2 mg/L nitrite standard solutions followed by analysis in the same manner. The results were estimated by standard deviation (SD) and the percent relative standard deviation (%RSD).

Appendix E

E1 Location of passive sampling site

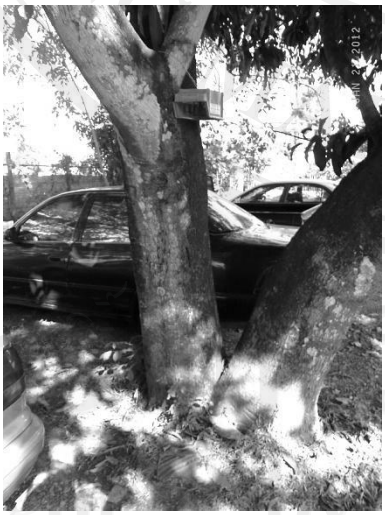
Urban area

16A Phan-ohn Temple
(วัดพันอ้น)

33 A Nuntaram Temple
(วัดนันทาราม)

36A Charoen Prathet alley 12
(ริมถนนเจริญประเทศ ซอย 12)

Suburban area (North)



5B Lanna Polytechnic Technology College Chiang Mai car park
(ที่จอดรถวิทยาลัยเทคโนโลยีโปลิเทคนิคลานนาเชียงใหม่)

11B Changpuak crematory
(สุสานช้างเผือก)

12B Institute of physical education
(สถาบันการพลศึกษาเชียงใหม่)

Suburban area (East)

14B Brownie Steak & Bakery
(ร้าน บราวนี่บุฟเฟ่ต์สเต็ก)

23B Chiang Mai- Lamphun Roadside
(ริมถนนเชียงใหม่ ลำพูน)

24B Industrial Promotion Centre Region 1 Department of Industrial Promotion
(ศูนย์ส่งเสริมอุตสาหกรรมภาคที่ 1 กรมส่งเสริมอุตสาหกรรม)

Suburban area (South)

32B Chiang Mai Land Village
(หมู่บ้านเชียงใหม่แลนด์)

36B Wang Tan Villa 2nd Exit, Padad
(หน้าทางเข้าออกที่ 2หมู่บ้านวังตาล ป่าแดด)

Suburban area (West)

18B Maharaj Nakorn Chiang Mai Hospital
(โรงพยาบาลมหาราช เชียงใหม่)

21B Chiang Mai Provincial Public Health Office
(สำนักงานสาธารณสุข จังหวัดเชียงใหม่)

AQI Class 4

6A Scorpion tailed pier
(ท่าเรือหางแมงป่อง)

3B Trees Market for Welfare, 33rdMilitary circle
(ตลาดต้นไม้เพื่อสวัสดิการ มณฑล ทหารบกที่ 33)

7B Lankga Temple
(วัดลังกา)

AQI Class 4 (Continued)

26B Wing 41
(กองบิน 41)

35B Ban North Padad alley 5
(บ้านป่าแดดเหนือ ซอย 5)

AQI Class 5

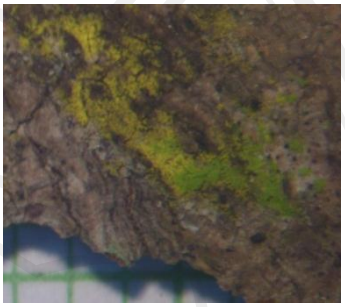
2B 700 years Roadside
(ริมถนนสมโภช 700 ปี)

Appendix F

F1 Crustose lichen

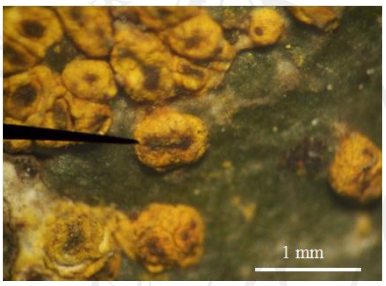
Arthonia sp.

Bacidia connexula

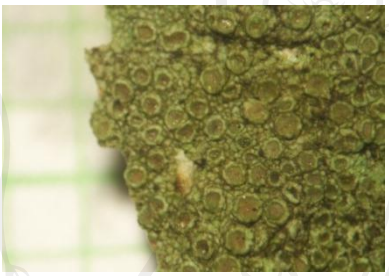


Chrysothrix xanthina

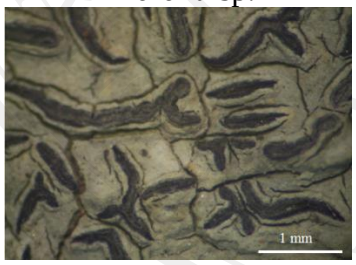
Dimerella sp.



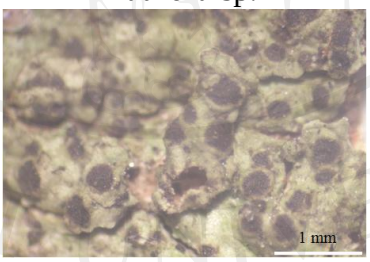
Laurera sp.



Lecanora spp.

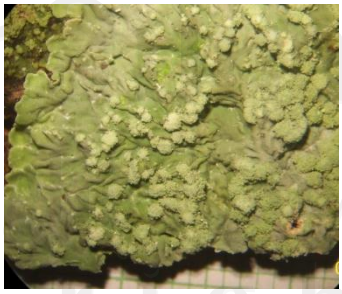


Opegrapha spp.



Rinodina roboris

F2 Foliose lichen



Dirinaria picta

Phyllopeltula cf. corticola

Pyxine cocoes

Appendix G

Recording Form

Date:……..

Grid Square……Tree no.……

General Data

Altitude above sea level_____m

GPS coordinate: _____

Light intensity: _____ Temperature: _____ Wet tem. _____ Dry tem. _____

Relative Humidity (%) : _____

Tree species ☐ Mango Tree ☐ Pigul Tree

Circumference of tree trunk _____ cm (@ 150 cm above ground level)

Aspects : ☐ N ☐ S ☐ W ☐ E ☐ NE ☐ SE ☐ NW ☐ SW

Bark Type : ☐ Smooth ☐ Superficial Cracked ☐ Deep Cracked

Bark pH :_____ Tree description: ☐ exposed ☐ sheltered ☐ unshaded ☐ shaded

Site Land Use :

____ No statement	____ Urban area	____ Rural area	____ Village
____ Industrial area	____ Park / grassy plot	____ Memorial park	____ Roadside
____ Backyard	____ Private garden	____ Fallow land	____ Grassland
____ Pasture	____ Farmland	____ Riparian vegetation	____ Commercial area
____ Temple	____ Graveyard	____ Car park	____ Official place

Influence by traffic :

__ dirty road __ asphalt road / low traffic __ main road/highway

Distance to the road :

____ < 2 m ____ < 5 m ____ < 10 m ____ > 10 m

Other emission sources :

____ domestic heating	____ chemical industry	____ power plant (fossil fuelled)	____ coking plant
____ incinerator	____ landfill	____ crematory	____ sewerage purification plant
____ intensive agriculture	____ vehicle	____ other emission sources	

Lichen Diversity

Grid Square……Tree no.……

No.	Lichen Type		Lichen species	Frequency	remarks
	Crustose	Foliose			

Note

_____
_____
_____
_____
_____

CURRICULUM VITAE

Name	Ms. Nattakarn Sransupphasirigul
Date of Birth	23 Nov. 1986
Education	Bachelor degree of Science (Biology), Chiang Mai University (2009)
	Master degree of Science (Environmental Science), Chiang Mai University (2013)
	Apprentice at The Queen Sirigit Botanical Garden Organization, Chiang Mai, 2008
	Participation and Completion in the workshop of "Teaching Assistance Training for Graduate Students" from May 2009, at Department of Biology, Faculty of Science, Chiang Mai University
Scholarship	The scholarship from Environmental Health and Toxicology (EHT) (former: The Center of Excellence on Environmental Health, Toxicology and Management of Chemicals (ETM)), Faculty of Science, Mahidol University during 2009- 2012
	Teaching Assistance in Biology Department between 2009- 2012
Working Experience	Staff at Science camp (Biology part), Science and Technology Service Center, Faculty of Science, Chiang Mai University (STSC- CMU)
	Staff at 5th Junior Science Camp during 21- 22 March 2013, STSC- CMU
Publication	Sransupphasirigul, N., Saipunkaew, W. and Chantara, S. 2012. Air quality mapping of Chiang Mai City using lichens as indicator. Proceeding of the First Asean Plus Three Graduate Research Congress. 152- 157.
	Sransupphasirigul, N. and Saipunkaew, W. 2011. Distribution of some selected lichen species in urban and suburban areas of Chiang Mai. Proceeding of the

Conference on Perspectives in Environmental Health Research. 73- 77.

Presentation/ Poster

Sransupphasirigul, N. 2012. Air quality mapping of Chiang Mai City using lichens as indicator. The First Asean Plus Three Graduate Research Congress (AGRC). Chiang Mai. March 1st-2nd, 2012.

Sransupphasirigul, N. 2011. Distribution of some selected lichen species in urban and suburban areas of Chiang Mai. Center of Excellence on Enivironmental Health, Toxicology and Management of Chemicals (ETM). Bangkok. August 21st, 2011.

Sransupphasirigul, N. 2011. Air quality mapping of Chiang Mai City using lichens as indicators. Environmental Science Seminar, Bangkok. January 25th, 2012.

Sransupphasirigul, N. 2009. Lichen diversity survey and air quality mapping using lichen as indicator. Environmental Science Seminar, Chiang Mai. February 8th, 2010.