

APPENDIX A

RECORDING FORM

Information on the locality of the examined tree

Date:.....

Surveyor:.....

General Data

Altitude above sea level.....m

GPS coordinates.....

Circumference of tree trunk.....cm. (at 150 cm above ground level)

Tree species.....

Age of lichens

- 1 young and mature thalli together
- 2 predominantly young thalli
- 3 predominantly mature thalli

Lichen vitality

- 1 predominantly healthy thalli
- 2 healthy and degraded thalli
- 3 predominantly degraded thalli

Tree description

- 1 exposed 2 sheltered
- 1 unshaded 2 shaded

Bark cracks:

- 1 superficial 3 deep
- 2 moderately deep

Type of terrain

- 00 no statement 04 slope
- 01 flat 05 hill top
- 02 valley 06 gap
- 03 depression 07 mountain

(if not flat) Aspect

- 0 no statement
- 1 S 3 N
- 2 W 4 E

Site Land use

- 00 no statement 08 backyard
- 01 urban area 09 private garden
- 02 rural area 10 fallow land
- 03 village 11 grassland
- 04 industrial area 12 pasture
- 05 commercial area 13 farmland
- 06 park/grassy plot 14 forest
- 07 memorial park 15 riparian vegetation

Influence by traffic

- 1 dirty road
- 2 asphalt road, low traffic
- 3 main road/highway

Distance to the road

- 1 < 2 m 3 < 10 m
- 2 < 5 m 4 > 10 m

Other emission sources

- 01 domestic heating
- 02 chemical industry
- 03 power plant (fossil fuelled)
- 04 metallurgical plant
- 05 coking plant
- 11 Other emission sources
- 06 incinerator
- 07 landfill
- 08 sewerage purification plant
- 09 intensive agriculture
- 10 lime emitting plant

Grid No.....Tree No:.....

No.	Lichen species	Frequency			
		N	E	S	W
Sum of Frequencies (SF)					

APPENDIX B

CALCULATION

B1 The calculation of LDVs and width of lichen diversity class

The frequency of lichen species was noted as the number occurred in surveying quadrat (1-5). The sums of frequencies (SF) were calculated as the following scheme;

Table B1 Sampling unit 1

Tree no.	1	2	3	4	5	6
Aspect	N E S W	N E S W	N E S W	N E S W	N E S W	N E S W
Lichen species 1	0 5 4 2	0 0 - 2	- 5 5 4	0 5 5 5	3 2 1 1	- 2 2 1
Lichen species 2	1 3 3 2	1 2 - 0	- 4 2 1	0 3 1 4	4 1 0 1	- 3 3 4
Lichen species 3	0 0 0 0	0 0 - 0	- 2 3 3	1 0 0 0	0 0 0 1	- 0 2 3
Lichen species 4	0 1 4 0	1 5 - 4	- 0 0 2	0 3 5 3	4 3 0 2	- 3 3 4
Lichen species 5	0 1 0 5	0 2 - 1	- 4 0 3	1 4 4 4	4 4 2 1	- 5 4 1
SF	1 10 11 9	2 9 - 7	- 15 10 13	2 15 15 16	15 10 3 6	- 13 14 13

*Symbols: –, data were omitted due to unsuitable aspect for sampling

Table B2 Sampling unit 2

Tree	1	2	3	4	5	6
Aspect	N E S W	N E S W	N E S W	N E S W	N E S W	N E S W
Lichen species 1	5 2 3 4	0 0 1 2	0 2 4 5	5 5 0 4	3 2 2 2	0 - 1 4
Lichen species 2	0 3 3 4	0 1 0 2	3 2 0 0	5 3 5 0	3 1 2 2	0 - 1 0
Lichen species 3	0 5 3 4	2 1 0 2	3 2 0 4	5 4 4 0	3 2 2 2	0 - 1 0
Lichen species 4	5 5 5 1	2 1 0 2	3 2 0 5	5 5 3 5	3 1 2 2	5 - 1 2
Lichen species 5	5 2 4 1	3 1 0 0	3 2 3 5	3 0 5 5	3 3 0 2	5 - 2 2
SF	15 17 18 14	7 4 1 8	12 10 7 19	23 17 17 14	15 9 8 10	10 - 6 8

* See Table B1 for explanation of symbols

Table B3 Sampling unit 3

Tree	1	2	3	4	5	6
Aspect	N E S W	N E S W	N E S W	N E S W	N E S W	N E S W
Lichen species 1	1 2 3 1	1 5 1 3	0 2 1 2	2 3 0 3	3 4 2 0	3 3 0 2
Lichen species 2	0 0 1 0	1 0 0 0	3 2 1 2	2 3 0 3	3 4 0 0	3 0 0 2
Lichen species 3	0 2 1 0	1 0 0 3	3 0 1 2	2 3 0 3	3 4 0 0	3 3 0 2
Lichen species 4	1 0 2 0	1 5 5 3	3 3 1 2	2 5 0 3	2 2 5 0	3 0 0 2
Lichen species 5	2 1 0 1	1 3 5 3	3 0 1 0	2 0 0 3	0 0 5 0	2 3 0 0
SF	4 5 7 2	5 13 11 12	12 7 5 8	10 14 0 15	11 14 12 0	14 9 0 8

* See Table B1 for explanation of symbols

The LDV and the width of lichen diversity class for sampling unit 1-3 were then calculated as following;

Sampling Unit	Aspect	Sum of frequencies (SF)						MSF	SD
		Tree1	Tree2	Tree3	Tree4	Tree5	Tree6		
1	N	1	2	-	2	15	-	5.00	6.68
1	E	10	9	15	15	10	13	12.00	2.68
1	S	11	-	10	15	3	14	10.60	4.72
1	W	9	7	13	16	6	13	10.67	3.93
2	N	15	7	12	23	15	10	13.67	5.50
2	E	17	4	10	17	9	-	11.40	5.59
2	S	18	1	7	17	8	6	9.50	6.66
2	W	14	8	19	14	10	8	12.17	4.31
3	N	4	5	12	10	11	14	9.33	3.98
3	E	5	13	7	14	14	9	10.33	3.88
3	S	7	11	5	0	12	0	5.83	5.19
3	W	2	12	8	15	0	8	7.50	5.72

Table B4 MSF and SD of each sampling unit

For sampling unit 1

$$\begin{aligned} \text{Lichen diversity values (LDV)} &= \text{MSF}_{\text{N1}} + \text{MSF}_{\text{E1}} + \text{MSF}_{\text{S1}} + \text{MSF}_{\text{W1}} \\ &= 5.00 + 12.00 + 10.60 + 10.67 \\ &= 38.27 \end{aligned}$$

$$\begin{aligned} \text{Average standard deviation} &= 6.68 + 2.68 + 4.72 + 3.93 \\ &= 4.51 \end{aligned}$$

$$\begin{aligned} \text{Standard error (SE)} &= \text{SD} / \sqrt{(n-1)} \\ &= 4.51 / \sqrt{5} \\ &= 2.02 \end{aligned}$$

The calculations for unit 2 and 3 were carried out in the same way. After SE of each sampling unit was calculated, the median of SE was then determined and the width of lichen diversity class was calculated as following;

$$\begin{aligned} \text{The width of lichen diversity class} &= 3 \times \text{median of SE (unit 1-3)} \\ &= 3 \times 13.14 \\ &= 39.43 \end{aligned}$$

B 2 The calculation of NO₂ and SO₂ concentration

The concentration of NO₂ (µg/ m³) in the ambient air for 2 weeks exposure was calculated as follows

Table B5 Calculation of NO₂ concentration

site	Peak area	NO ₂ ⁻ (µg/ml) (y)	Q(NO ₂ ⁻) µg	t (sec)	NO ₂ Conc. (µg/ m ³)	NO ₂ (ppb)
18	9.79	0.30	1.20	1211220	26.56	14.12

Linearity equation obtained from calibration curve; $y = 0.0322x - 0.0132$

$$\begin{aligned}\text{Amount of NO}_2^- (y) &= (0.0322 \times 9.79) - 0.0132 \\ &= 0.30 \text{ µg/ml}\end{aligned}$$

Recalling equation 2.6;

$$\begin{aligned}Q\text{NO}_2 &= m \text{ NO}_2^- \\ &= 0.30 \times 4 \text{ µg}\end{aligned}$$

(Multiplied by 4 as 4 ml was the volume used to extract the sample)

Therefore, the corresponding quantities of NO₂ = 1.20 µg

Recalling equation 2.5;

$$\begin{aligned}C &= \frac{Q \times z}{(\pi r^2) \times t \times D} \\ &= \frac{1.20 \times 0.054}{(3.14 \times 4.22 \times 10^{-5}) \times 1195800 \times (0.154 \times 10^{-4})}\end{aligned}$$

Therefore, the concentration of NO₂ = 26.56 µg/m³

Unit conversion

$$\text{ppb} = \mu\text{g}/\text{m}^3 \times \frac{\text{molecular volume}}{\text{molecular weight}}$$

$$\text{Molecular volume} = 22.41 \times \frac{T}{273} \times \frac{1013}{P}$$

Where;

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

P = atmospheric pressure (hPa)

Therefore, at an ambient pressure of 1 atm and temperature 25 °C,

Molecular weight of NO₂ = 46

$$\begin{aligned} \text{Molecular volume} &= 22.41 \times \frac{273+25}{273} \times \frac{1013}{1013} \\ &= 24.46 \end{aligned}$$

Therefore;

$$\begin{aligned} \text{NO}_2 (\text{ppb}) &= 26.56 \times \frac{24.46}{46} \\ &= 14.12 \end{aligned}$$

The concentration of SO₂ (μg/m³) was calculated in the same way by using equation 2.5 and 2.7 from chapter 2

APPENDIX C

Table C1 Sum of frequencies (SF) of lichen species on 6 Mango tree in sampling units, Mean of sum of frequencies (MSF) and standard deviation (SD)

Sampling Unit	Cardinal point	SF						MSF	SD
		Tree1	Tree2	Tree3	Tree4	Tree5	Tree6		
1	N	13	4	-	2	5	10	6.80	4.55
	E	12	5	6	6	5	13	7.83	3.66
	S	12	-	5	-	7	9	8.25	2.99
	W	12	4	10	5	5	-	7.20	3.56
2	N	15	7	12	23	15	10	13.67	5.50
	E	17	4	10	17	9	-	11.40	5.59
	S	18	1	7	17	8	6	9.50	6.66
	W	14	8	19	14	10	8	12.17	4.31
3	N	4	27	12	10	11	14	13.00	7.64
	E	5	13	7	14	14	9	10.33	3.88
	S	7	11	5	0	12	0	5.83	5.19
	W	2	12	8	15	0	8	7.50	5.72
4	N	4	-	5	12	2	3	5.20	3.96
	E	3	5	-	8	0	-	4.00	3.37
	S	1	2	5	5	0	3	2.67	2.07
	W	-	-	5	-	0	3	2.67	2.52
5	N	11	6	8	8	5	6	7.33	2.16
	E	14	2	6	11	5	9	7.83	4.36
	S	-	2	3	-	4	6	3.75	1.71
	W	8	2	20	9	5	3	7.83	6.55
6	N	6	6	10	-	6	8	7.20	1.79
	E	7	12	10	11	1	2	7.17	4.71
	S	-	-	-	12	8	4	8.00	4.00
	W	2	2	7	11	3	10	5.83	4.07
7	N	6	9	13	3	8	5	7.33	3.50
	E	-	10	3	8	8	6	7.00	2.65
	S	11	4	-	5	5	10	7.00	3.24
	W	13	6	10	-	1	5	7.00	4.64

Symbols: -, data were omitted due to unsuitable cardinal point for sampling

Table C1 (Continued)

Sampling Unit	Cardinal point	SF						MSF	SD
		Tree1	Tree2	Tree3	Tree4	Tree5	Tree6		
8	N	5	14	5	3	0	9	6.00	4.90
	E	3	10	-	-	5	-	6.00	3.61
	S	-	-	4	2	0	7	3.25	2.99
	W	-	1	5	5	2	7	4.00	2.45
9	N	19	7	0	4	20	18	11.33	8.71
	E	15	-	5	0	7	8	7.00	5.43
	S	3	7	0	1	-	10	4.20	4.21
	W	12	8	2	5	4	14	7.50	4.72
10	N	12	9	26	16	14	7	14.00	6.72
	E	11	-	25	13	18	7	14.80	6.94
	S	13	-	13	-	24	5	13.75	7.80
	W	11	1	6	6	7	8	6.50	3.27
11	N	21	-	15	-	5	2	10.75	8.81
	E	15	20	15	-	5	6	12.20	6.46
	S	-	6	10	-	-	5	7.00	2.65
	W	11	11	10	-	1	3	7.20	4.82
12	N	-	15	11	11	17	12	13.20	2.68
	E	3	6	9	3	13	9	7.17	3.92
	S	5	13	-	9	17	7	10.20	4.82
	W	11	6	4	12	14	-	9.40	4.22
13	N	12	8	9	3	1	13	7.67	4.80
	E	8	12	2	2	4	9	6.17	4.12
	S	2	5	7	2	3	-	3.80	2.17
	W	4	3	5	3	3	12	5.00	3.52
14	N	14	1	3	5	1	15	6.50	6.38
	E	10	-	2	8	2	10	6.40	4.10
	S	16	4	-	2	-	8	7.50	6.19
	W	12	3	2	7	1	12	6.17	4.96
15	N	6	5	10	0	0	13	5.67	5.24
	E	2	1	10	0	2	11	4.33	4.84
	S	4	4	0	0	0	10	3.00	3.95
	W	4	0	9	0	0	15	4.67	6.19

Symbols: —, data were omitted due to unsuitable cardinal point for sampling

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Table C1 (Continued)

Sampling Unit	Cardinal point	SF						MSF	SD
		Tree1	Tree2	Tree3	Tree4	Tree5	Tree6		
16	N	7	4	12	0	5	0	4.67	4.55
	E	5	0	4	0	2	0	1.83	2.23
	S	5	3	11	0	2	0	3.50	4.14
	W	3	6	12	0	5	0	4.33	4.50
17	N	4	4	0	0	16	11	5.83	6.40
	E	3	0	0	0	8	4	2.50	3.21
	S	6	0	0	0	10	4	3.33	4.13
	W	0	0	0	0	0	1	0.17	0.41
18	N	-	-	8	11	7	12	9.50	2.38
	E	11	10	1	-	1	2	5.00	5.05
	S	1	7	9	2	1	10	5.00	4.15
	W	1	6	8	11	3	4	5.50	3.62
19	N	7	15	8	7	1	12	8.33	4.80
	E	6	-	6	9	0	14	7.00	5.10
	S	-	7	3	16	0	11	7.40	6.35
	W	9	5	2	15	1	8	6.67	5.16
20	N	6	10	9	3	6	6	6.67	2.50
	E	8	6	19	-	13	-	11.50	5.80
	S	4	10	9	8	8	5	7.33	2.34
	W	8	11	9	6	11	5	8.33	2.50
21	N	3	10	2	6	1	8	5.00	3.58
	E	-	3	3	5	1	7	3.80	2.28
	S	4	1	4	-	-	4	3.25	1.50
	W	6	5	1	5	1	8	4.33	2.80
22	N	4	1	4	8	9	6	5.33	2.94
	E	6	0	2	4	9	-	4.20	3.49
	S	5	2	-	-	6	4	4.25	1.71
	W	1	3	1	10	7	3	4.17	3.60
23	N	10	10	5	0	3	5	5.50	3.94
	E	7	7	5	2	0	4	4.17	2.79
	S	5	3	0	-	0	5	2.60	2.51
	W	0	1	0	-	0	4	1.00	1.73

Symbols: —, data were omitted due to unsuitable cardinal point for sampling

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Table C1 (Continued)

Sampling Unit	Cardinal point	SF						MSF	SD
		Tree1	Tree2	Tree3	Tree4	Tree5	Tree6		
24	N	-	0	4	0	5	0	1.80	2.49
	E	11	5	1	0	10	0	4.50	5.01
	S	14	3	0	0	-	0	3.40	6.07
	W	9	3	4	0	-	0	3.20	3.70
25	N	13	15	0	0	8	15	8.50	7.06
	E	-	11	3	0	7	9	6.00	4.47
	S	10	8	3	1	4	0	4.33	3.93
	W	11	15	0	0	5	6	6.17	5.98
26	N	13	15	9	-	2	5	8.80	5.40
	E	12	11	-	-	3	2	7.00	5.23
	S	0	10	-	1	4	-	3.75	4.50
	W	12	9	1	1	3	12	6.33	5.28
27	N	4	8	1	11	4	5	5.50	3.51
	E	7	6	4	3	7	8	5.83	1.94
	S	9	3	9	2	3	6	5.33	3.14
	W	4	2	7	4	8	10	5.83	2.99
28	N	17	10	25	20	-	5	15.40	7.96
	E	6	8	22	6	7	14	10.50	6.38
	S	8	1	18	8	13	-	9.60	6.35
	W	9	12	11	10	3	8	8.83	3.19
29	N	3	5	3	3	7	4	4.17	1.60
	E	4	8	2	6	7	2	4.83	2.56
	S	5	1	1	7	6	5	4.17	2.56
	W	0	-	5	5	7	5	4.40	2.61
30	N	-	3	14	6	19	6	9.60	6.66
	E	3	5	13	7	17	3	8.00	5.76
	S	5	4	10	1	16	5	6.83	5.34
	W	4	6	7	-	14	4	7.00	4.12
31	N	7	9	13	21	9	2	10.17	6.40
	E	4	5	18	-	3	10	8.00	6.20
	S	5	1	11	8	4	4	5.50	3.51
	W	9	2	0	5	-	-	4.00	3.92

Symbols: —, data were omitted due to unsuitable cardinal point for sampling

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Table C1 (Continued)

Sampling Unit	Cardinal point	SF						MSF	SD
		Tree1	Tree2	Tree3	Tree4	Tree5	Tree6		
32	N	5	6	2	6	4	13	6.00	3.74
	E	5	-	0	1	-	13	4.75	5.91
	S	4	11	0	8	5	5	5.50	3.73
	W	6	12	6	6	1	7	6.33	3.50
33	N	4	12	7	6	4	11	7.33	3.44
	E	4	11	3	10	1	2	5.17	4.26
	S	1	9	9	7	0	2	4.67	4.13
	W	3	10	6	4	9	-	6.40	3.05
34	N	12	10	12	8	5	4	8.50	3.45
	E	5	9	5	4	5	-	5.60	1.95
	S	9	5	3	5	5	4	5.17	2.04
	W	7	5	5	9	-	5	6.20	1.79
35	N	5	6	6	3	7	1	4.67	2.25
	E	5	7	-	3	8	8	6.20	2.17
	S	3	-	1	2	11	7	4.80	4.15
	W	-	2	1	2	7	0	2.40	2.70
36	N	7	23	14	9	12	22	14.50	6.66
	E	7	17	8	6	10	9	9.50	3.94
	S	3	5	5	3	14	9	6.50	4.28
	W	3	-	-	9	7	14	8.25	4.57
37	N	4	6	9	6	5	7	6.17	1.72
	E	4	2	8	13	5	9	6.83	3.97
	S	1	7	1	9	4	3	4.17	3.25
	W	5	3	0	8	6	4	4.33	2.73
38	N	7	4	6	15	14	1	7.83	5.56
	E	16	7	4	13	14	-	10.80	5.07
	S	5	6	-	12	10	2	7.00	4.00
	W	3	4	5	12	11	3	6.33	4.08
39	N	22	9	10	10	17	6	12.33	5.96
	E	19	16	11	12	13	11	13.67	3.20
	S	-	20	-	11	20	-	17.00	5.20
	W	16	11	8	15	5	7	10.33	4.46

Symbols: —, data were omitted due to unsuitable cardinal point for sampling

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APPENDIX D

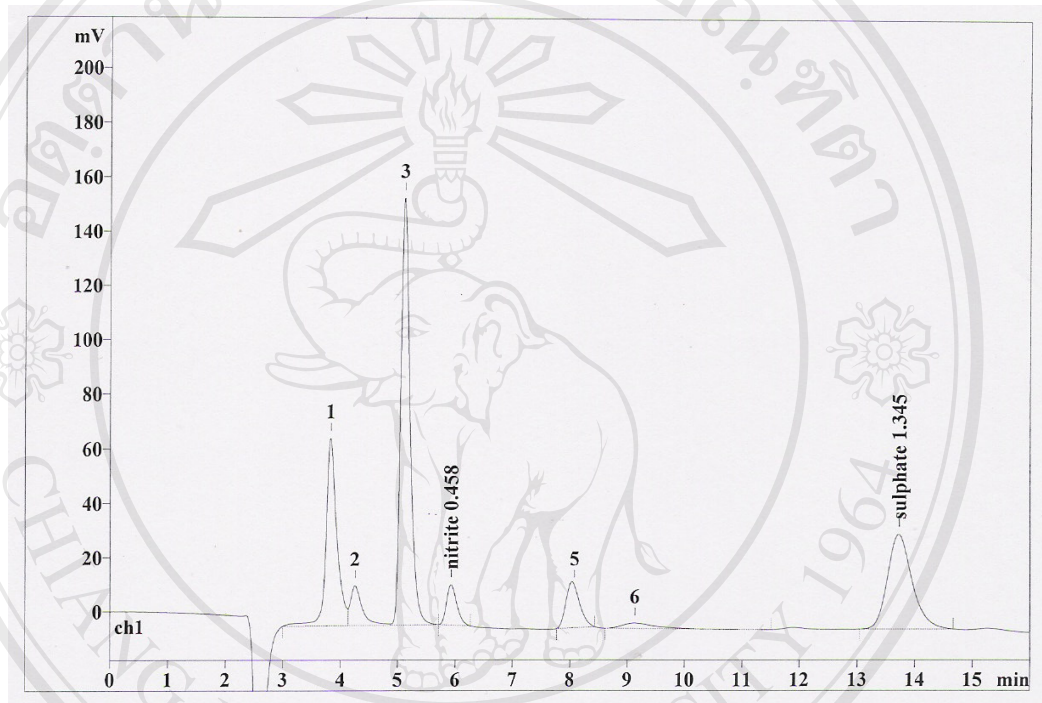


Figure D1 Chromatogram of extracted sample at sampling site no. 18,
for two week exposure

APPENDIX E
STATISTICAL TABLE

Table E1 Test of homogeneity of variances of bark pH

Levene Statistic	df1	df2	Sig.
1.980	7	31	.090

Table E2 One-way analysis of variances (ANOVA) of bark pH

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.983	7	.140	1.027 ^{ns}	.432
Within Groups	4.238	31	.137		
Total	5.222	38			

ns means non significant

Table E3 Test of homogeneity of variances of NO₂

Levene Statistic	df1	df2	Sig.
1.264	7	31	.300

Table E4 One-way analysis of variances (ANOVA) of NO₂

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	140.911	7	20.130	5.455*	.000
Within Groups	114.395	31	3.690		
Total	255.307	38			

* means significant at the 0.05 level

Table E5 Test of homogeneity of variances of SO₂

Levene Statistic	df1	df2	Sig.
1.184	7	31	.340

Table E6 One-way analysis of variances (ANOVA) of SO₂

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	90.417	7	12.917	1.599 ^{ns}	0.173
Within Groups	250.405	31	8.078		
Total	340.822	38			

ns means non significant

Table E7 Correlations between LDV and NO₂

NO ₂	Pearson Correlation Sig. (2-tailed)	NO ₂	LDV
		1.000	-.614**
		.	.000
LDV	Pearson Correlation Sig. (2-tailed)	-.614**	1.000
		.000	.
	N	39	39

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

Table E8 Correlations between LDV and SO₂

LDV	Pearson Correlation Sig. (2-tailed)	LDV	SO ₂
		1.000	-.119
		.	.437
SO ₂	Pearson Correlation Sig. (2-tailed)	-.119	1.000
		.437	.
	N	39	39

APPENDIX F

F1 Crustose lichen

F 1.1 *Arthonia* spp.

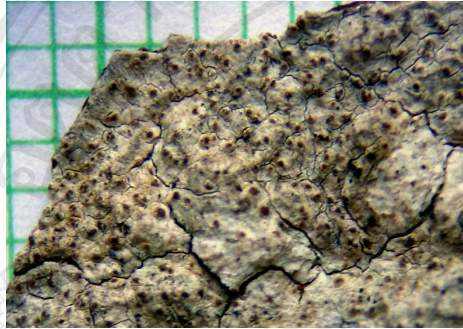


Figure 1 *Arthonia antillarum*

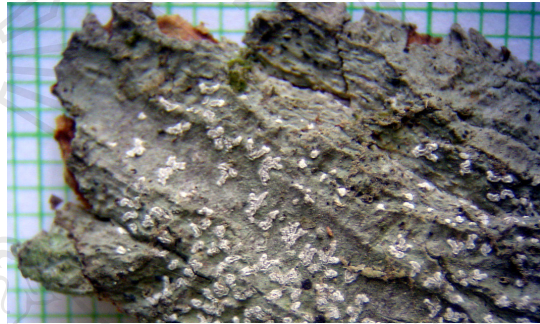


Figure 2 *Arthonia* species 1

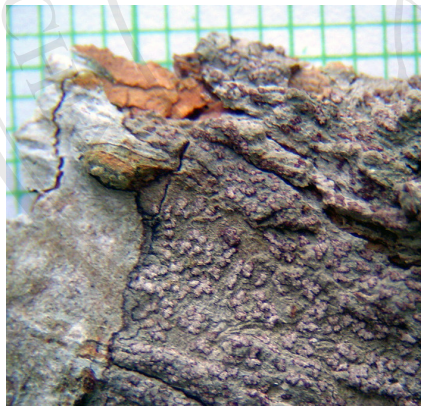


Figure 3 *Arthonia* species 2

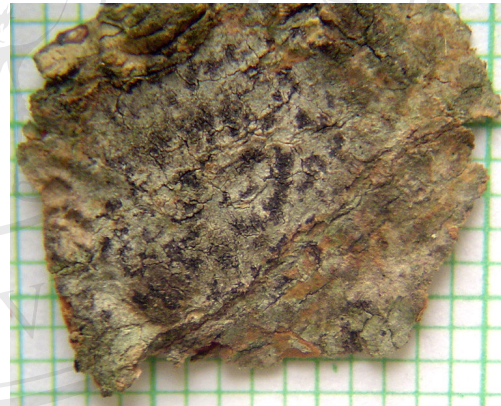


Figure 4 *Arthonia* species 3

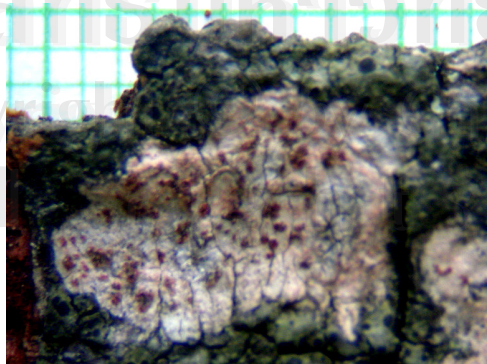


Figure 5 *Arthonia* species 4

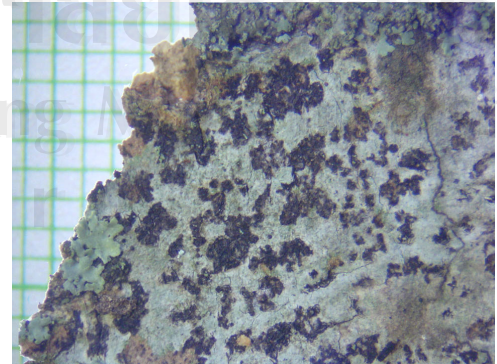


Figure 6 *Arthonia* species 5

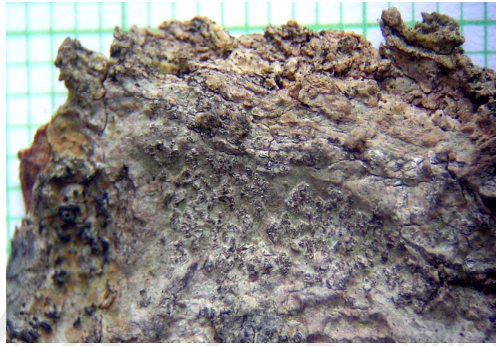


Figure 7 *Arthonia* species 6

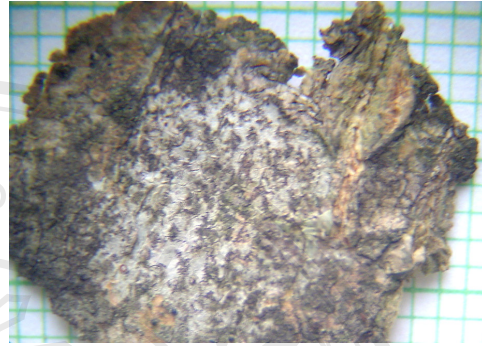


Figure 8 *Arthonia* species 7

F 1.2 Graphidaceae

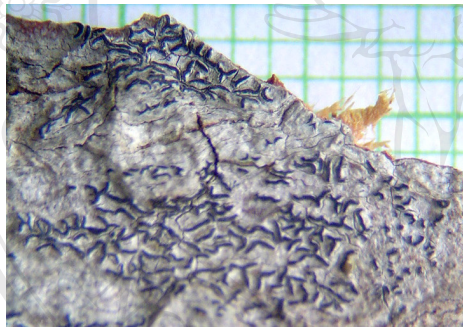


Figure 9 Graphidaceae species 1

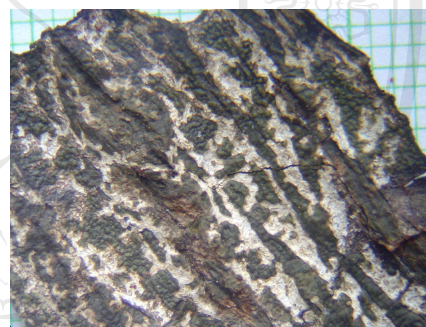


Figure 10 Graphidaceae species 2

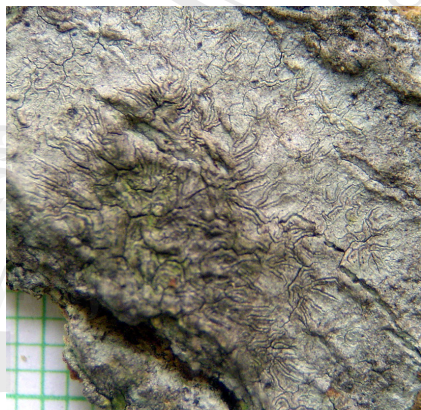


Figure 11 Graphidaceae species 3

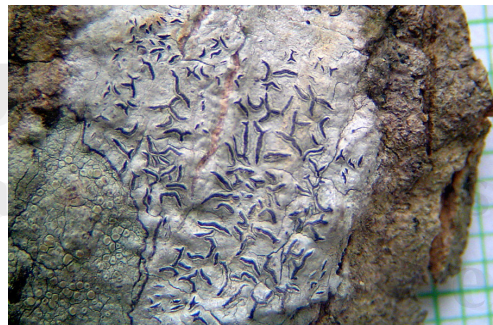


Figure 12 Graphidaceae species 4

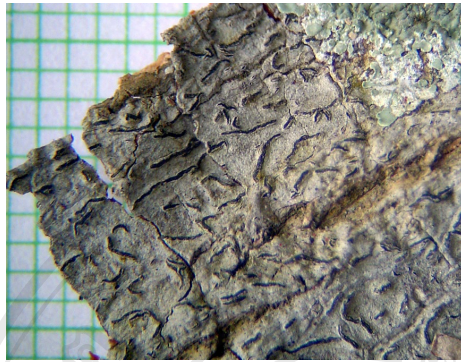


Figure 13 Graphidaceae species 5

F 1.3 *Lecanora* spp.

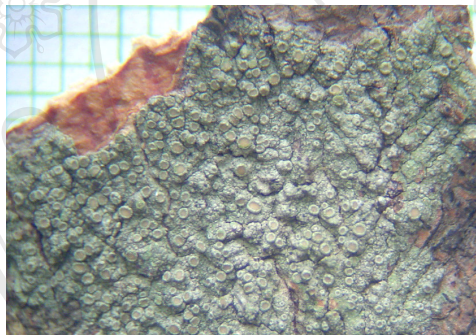


Figure 14 *Lecanora* species 1

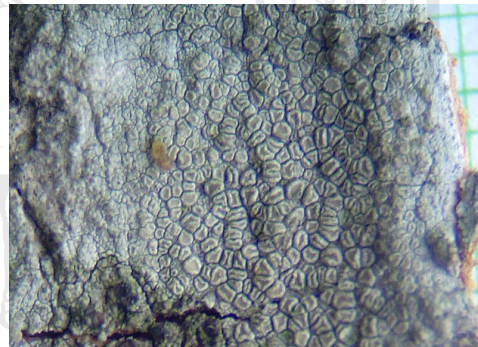


Figure 15 *Lecanora* species 2

F 1.4 *Laurera* spp.

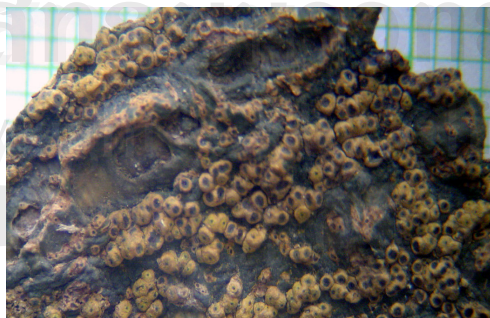


Figure 16 *Laurera* species 1



Figure 17 *Laurera* species 2

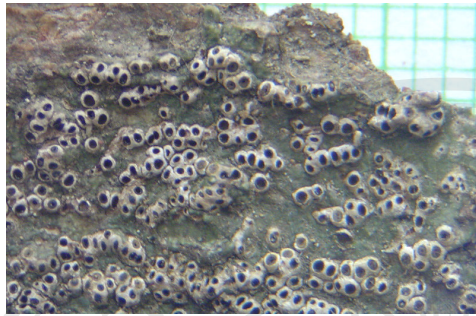


Figure 18 *Laurera* species 3

F 1.5 *Trypethelium* spp.

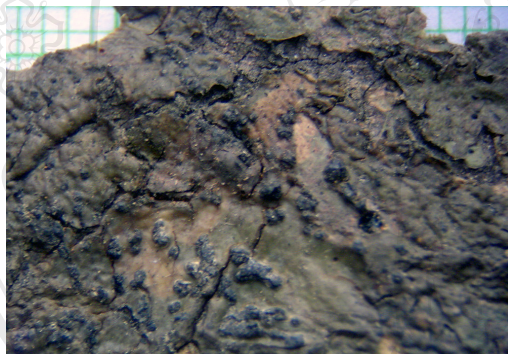


Figure 19 *Trypethelium* species 1

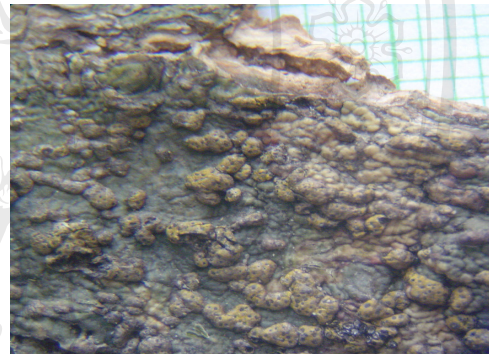


Figure 20 *Trypethelium* species 2

F 1.6

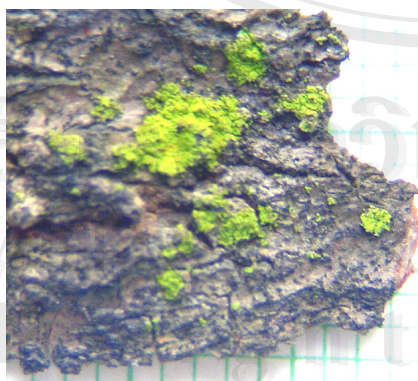


Figure 21 *Chrysothrix xanthina*

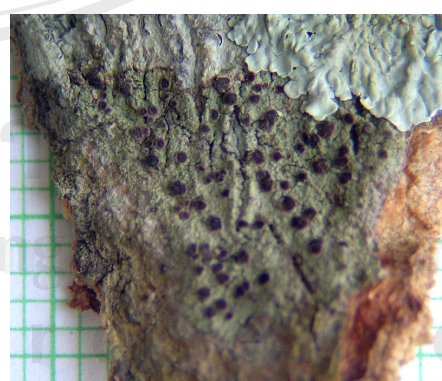


Figure 22 *Caloplaca* sp.

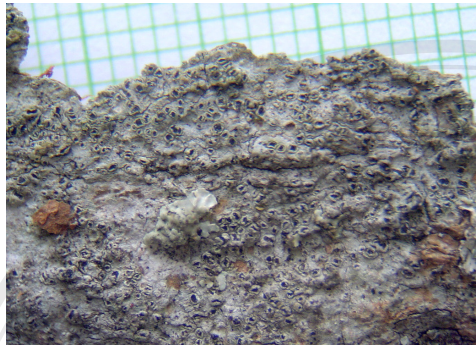


Figure 23 cf. *Leconographa*



Figure 24 *Rinodina* sp.



Figure 25 *Pyrenula* sp.

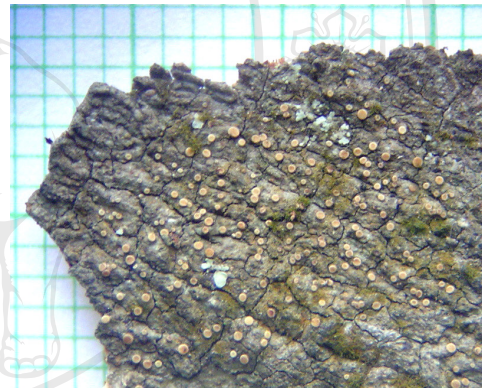


Figure 26 *Bacidia* sp.

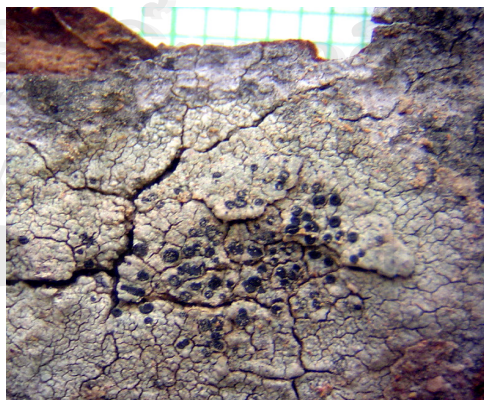


Figure 27 *Buellia* sp.

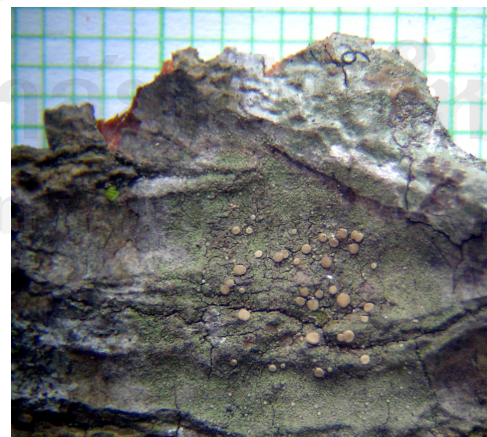


Figure 28 *Dimerella* sp.

F2 Foliose lichen

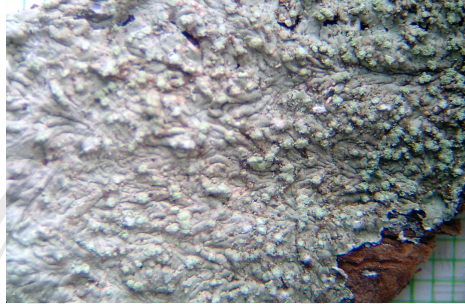


Figure 29 *Dirinaria picta*

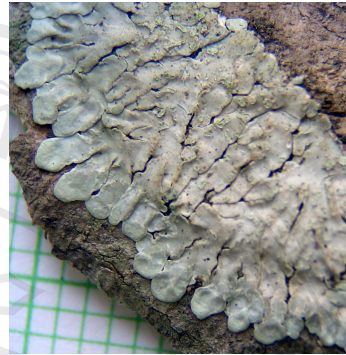


Figure 30 *Pyxine cocoes*

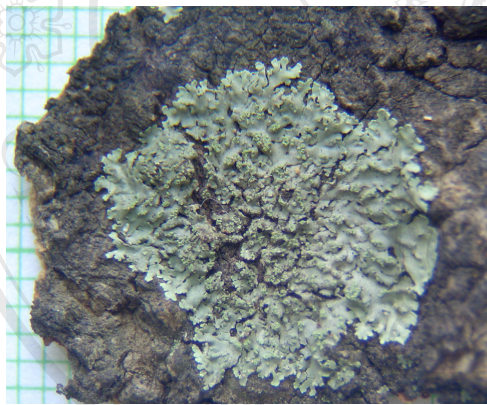


Figure 31 *Hyperphyscia adglutinata*

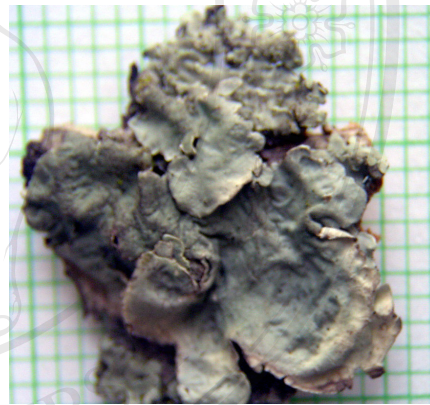


Figure 32 *Parmotrema praesorediosum*

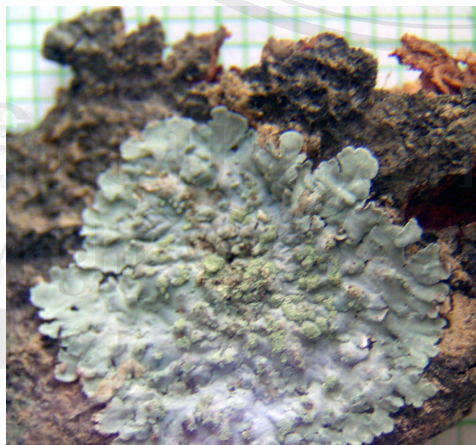
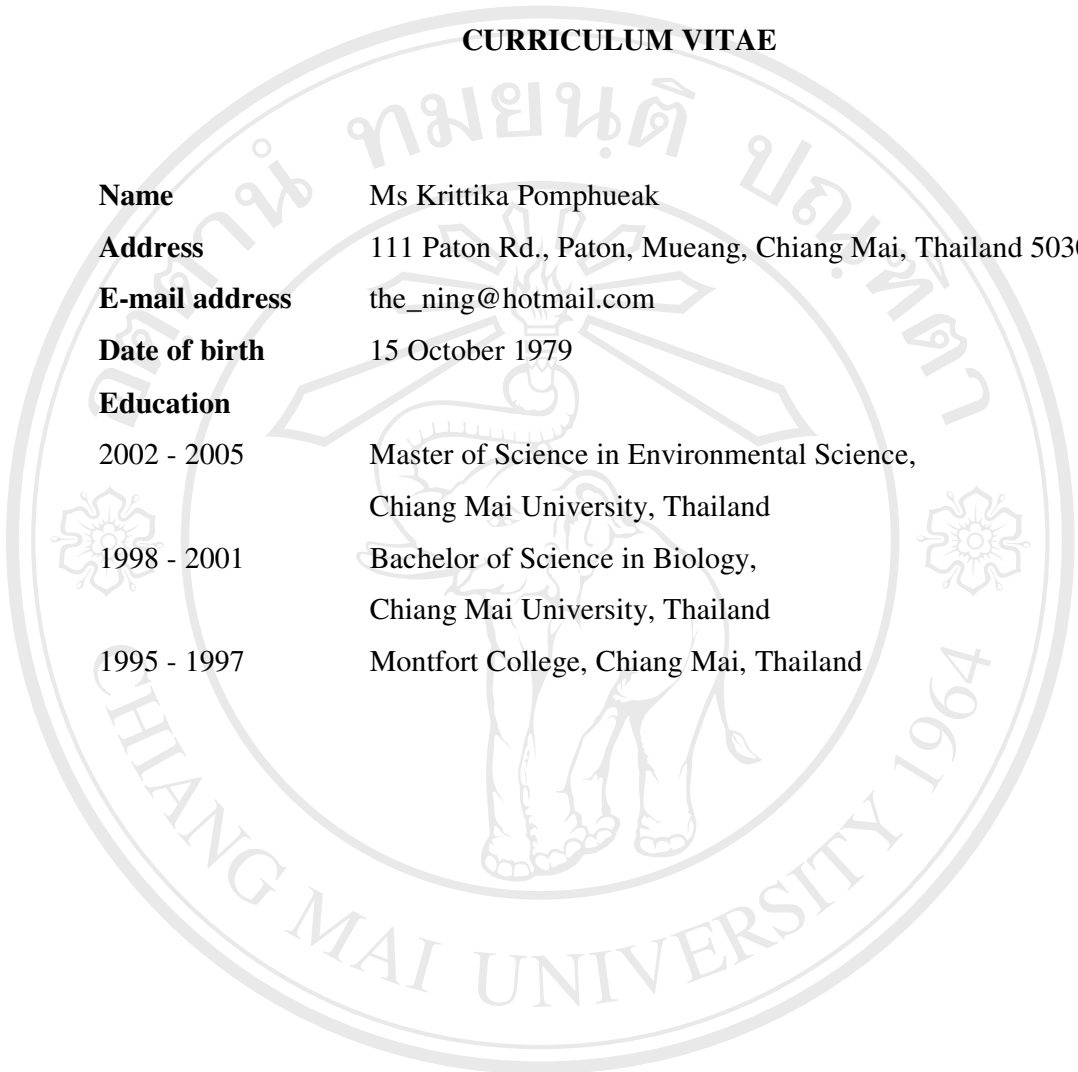


Figure 33 *Physcia poncinsii*

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ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่

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