#### **APPENDIX A**

#### A-1 Calculation of pollutant gases in passive samplers

The formaldehyde gas concentration can be calculated from Fick's First Law.

$$\mathbf{C}_{o} = \mathbf{Q} \left( \frac{\mathbf{LR}}{\mathbf{AR}} + \frac{\mathbf{LF}}{\mathbf{AF}} + \frac{\mathbf{LN}}{\mathbf{AN}} + \frac{\mathbf{LBL}}{\mathbf{AR}} \right)$$

Co = HCHO gas concentration in air (mg/m3)

 $Q = mass of gas collected (\mu g)$ 

T = time exposure (sec)

D = diffusion coefficient of HCHO (m<sup>2</sup>/s)

#### A-2 Mass of gas collected (Q)

Q value of formaldehyde determination was calculated by multiplication formaldehyde concentration obtained from calibration curve ( $\mu$ g/ml) with 3 ml (3 ml of extraction volume). The formaldehyde in  $\mu$ g/ml unit was converted to the mass amount of formaldehyde in passive sampler in  $\mu$ g unit.

Therefore

Q ( $\mu$ g) = HCHO gas concentration ( $\mu$ g/ml) × 3 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. Equation 2.3 is used to calculate total air resistance calculate total air resistance

Total air resistance (m<sup>-1</sup>) = 
$$\frac{LR}{AR} + \frac{LF}{AF} + \frac{LN}{AN} + \frac{LBL}{AR}$$

 $AR = area of ring 1.32 \times 10^{-4} (m^2)$ 

 $\mathbf{AF} =$ total pore area of Teflon filter

AN = total pore area of steel mesh

**LF** = thickness of Teflon filter

 $LR = length of ring 5 \times 10^{-2} (m)$ 

LN = thickness of steel mesh) (m)

**LBL** = laminar boundary layer depth 5 x  $10^{-3}$ (m).

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.

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

 $= \frac{5 \times 10^{-2} (m) + LF + 5 \times 10^{-3} (m)}{1.32 \times 10^{-4} (m^2) + AF + 1.32 \times 10^{-4} (m^2)}$ 

#### $= 416 \text{ m}^{-1}$

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 8.7  $\mu$ g total air resistance is 416 m<sup>-1</sup>

Mass of membrane equal 8.0  $\mu$ g then, total air resistance is **382.3** m<sup>-1</sup>

Then,

$$C (mg/m^{3}) = X (\mu g) \times 382.3 m^{-1}$$
  
D (m<sup>2</sup>s<sup>-1</sup>) × t (s)

#### A-4 Determination of analyte concentration in the chamber

The passive samplers were placed inside the chamber in order to test their efficiency of formaldehyde absorbing by determination % recovery of each parameter. The concentration in the chamber can be determined by calculation of mass of gas delivery rate ( $\mu$ g/min) (using gas collector) per flow rate of gas HCHO (L/min).

$$C(mg/m^{3}) = \frac{R(\mu g/min)}{F(L/min)}$$
2.1

- $C (mg/m^{3}) = Theoretical$  solvent concentration in chamber
- *R*  $(\mu g/min) = mass of HCHO gas$
- F (L/min) = flow rate of air the chamber

#### A-5 Determination of mass formaldehyde gas

Molecular of formaldehyde gas was collected under 20 ml DI water (four sets) of in continuously gas collector. Then, formaldehyde solution was transferred 2 ml to developed color with CTA method and measure by spectrophotometry.

Calculation of mass formaldehyde gas

mass of HCHO gas ( $\mu$ g) = ppm ( $\mu$ g/ml) x 20/2 x 20 ml

#### A-6 Unit conversions

Mass per unit volume: usually mg m<sup>-1</sup>. 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 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- part per million  $(10^{-6})$ . This unit expressed the concentration of a pollutant as a ratio of its volume if segregated pure, 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 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<sup>3</sup> per 10<sup>-6</sup> cm<sup>3</sup> 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

 $ppm = \frac{mg/m^3 \times molecular volume (litres)}{molecular weight}$ 

Where:

Molecular volume =  $\frac{22.41 \times T \times 101.3}{273 P}$ 

T = absolute temperature (K)

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

Similarly mg/m<sup>3</sup> = ppm × <u>molecular weigh</u> molecular volume (litres) A lights reserved

### **APPENDIX B**



Optimization of impregnated filter papers



**Optimization of diffusion tube** 

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Study site



**Reverse Diffusion** 



Wind speed and Temperature effect





**Relative humidity effect** 





Sampling duration



รียงใหม่ University erved

Orientation



### APPENDIX C

#### **3M COMPANY**

# OCCUPATIONAL HEALTH AND ENVIRONMENTAL SAFETY DIVISION DETERMINATION OF FORMALDEHYDE VAPORS IN AIR

#### **USING 3M 3721 FORMALDEHYDE MONITORS**

May, 2002

#### **1. SCOPE**

This procedure covers the method of collecting and analyzing samples to determine the amount of formaldehyde present in the air using the 3M 3721 Formaldehyde Monitor. The calibration curve covers the 0-15 microgram range.

#### 2. SUMMARY OF THE METHOD

In the monitor, formaldehyde vapors are adsorbed on bisulfite impregnated paper and desorbed with formaldehyde-free distilled water. Aliquots are reacted with chromotropic acid in the presence of sulfuric acid to form a purple monocationic chromogen.1 The absorbance of the colored solution is read in a spectrophotometer at 580 nanometers (nm) and is proportional to the amount of formaldehyde in the solution.

#### **3. REAGENTS/SUPPLIES**

The following or equivalent reagents and supplies are used: 3M 3721 Formaldehyde Monitor

#### **3.1 Chromotropic Acid Solutions**

Dissolve 0.25 g of 4,5-dihydroxy-2,7-naphthalenedisulfonic acid disodium salt dihydrate (Aldrich 21,327-6 or equivalent) in 25 mL of formaldehyde-free distilled

water. Make solution fresh each day. Previously used Acros 40525-0100, formerly Kodak 230, is no longer available, but existing supplies may be used.

3.2 Sulfuric Acid: Concentrated, reagent grade.

3.3 Distilled Water: Formaldehyde-free.

**3.4 1% Sodium Bisulfite Solution**: Dissolve 2.5 g of sodium bisulfite (Baker 3556-01 or equivalent) in 250 mL of distilled water.

#### 3.5 Standard Formaldehyde Solution:

25 uL of 37% formaldehyde (Aldrich 25,254-9 or equivalent) is diluted to 10 mL with 1% sodium bisulfite solution. This solution is used to prepare the calibration curve - each microliter is equivalent to one microgram of formaldehyde. Formaldehyde Analytical Method

#### 4. SAMPLE ANALYSIS

#### 4.1 Elution

Both ports of the elution cap are opened and 3 mL of formaldehyde-free distilled water is added to each monitor through the center port using a repipet or syringe. The ports are immediately resealed and each monitor allowed to elute for 30 minutes with occasional gentle agitation. Transfer a 2 mL aliquot of the eluate to a test tube or vial for color development. (The amount of the aliquot may be varied to be sure that each sample absorbance will be within the calibration curve. Dilute the aliquot to 2 mL with 1% sodium bisulfite solution.)

#### 4.2 Color Development

Add 1.0 mL of chromotropic acid solution to each sample and mix well. Carefully add 5 mL of concentrated sulfuric acid slowly with mixing. CAUTION: Take proper safety precautions such as goggles, gloves and apron when handling **concentrated sulfuric acid.** Allow the samples to cool to room temperature and measure the absorbance at 580 nm (medium sensitivity setting) using 1 cm cells or 1 in test tube cuvettes. Use distilled water in the reference cell. A reagent blank is carried through all the steps of the sample analysis. Subtract the absorbance of the reagent blank from that of the standards and samples and refer to the calibration curve to determine the micrograms of formaldehyde present.

#### **5. CALIBRATION CURVE**

#### Formaldehyde Analytical Method

To a series of test tubes or vials, carefully add 1.0, 3.0, 5.0, 10.0 and 15.0 microliters of standard formaldehyde solution equivalent to 1.0, 3.0, 5.0, 10.0, and 15.0 micrograms of formaldehyde. Adjust the volumes to 2 mL with 1% sodium bisulfite solution. Develop the color and measure the absorbance as described above. Carry a reagent blank through all the steps and subtract its absorbance from all the standards as well as the samples. Prepare a calibration curve by plotting the corrected absorbance (x axis) vs. micrograms of formaldehyde (y axis). Determine the slope and intercept for the calibration curve.

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### **APPENDIX D**

### The Table of Multiple Comparisons (RCB test)

1.1	Desor	ption	efficiency	and	number	of	filter	laye	er
-----	-------	-------	------------	-----	--------	----	--------	------	----

	(I) type	(J) type	Sig.
Tukey HSD	1.00	2.00	1.000
		3.00	0.946
		4.00	0.976
		5.00	0.487
	2.00	1.00	1.000
		3.00	0.959
		4.00	0.984
		5.00	0.519
	3.00	1.00	0.946
		2.00	0.959
		4.00	1.000
		5.00	0.884
	4.00	1.00	0.976
		2.00	0.984
		3.00	1.000
		5.00	0.816
	5.00	1.00	0.487
		2.00	0.519
		3.00	0.884
		4.00	0.816
Tamhane	1.00	2.00	1.000
		3.00	0.918
		4.00	0.992
		5.00	0.949
	2.00	1.00	1.000
		3.00	0.949
		4.00	0.997
		5.00	0.958
	3.00	1.00	0.918
		2.00	0.949
		Chia4.00 Mai U	Jnvers1.000
		5.00	0.999
	4.00		0.992
		2.00	0.997
		3.00	1.000
	5.00	5.00	0.998
	5.00	1.00	0.949
		2.00	0.958
		3.00	0.999
		4.00	0.998

	(I) type	(J) type	Sig.
Tukey HSD	Whatman No 1	2.00	0 990
randy mod	() Hudrinari i (ö.i	3.00	0.001
		4.00	0.203
		5.00	0.990
		6.00	1.000
	Whatman No.6	1.00	0.990
		3.00	0.005
		4.00	0.067
		5.00	0.831
		6.00	0.990
	Whatman No.1	1.00	0.001
		2.00	0.005
		4.00	0.000
		5.00	0.000
		6.00	0.001
	GF	1.00	0.203
		2.00	0.067
		3.00	0.000
		5.00	0.487
		6.00	0.203
	GFA	1.00	0.990
		2.00	0.831
		3.00	0.000
		4.00	0.487
		6.00	0.990
	GFC	1.00	1.000
		2.00	0.990
		3.00	0.001
		4.00	0.203
		5.00	0.990
Tamhane	Whatman No.1	2.00	0.985
		3.00	0.153
		4.00	0.697
		2 5.00	0.999
		6.00	1.000
	Whatman No.6	1.00	0.985
		3.00	0.229
		4.00	0.449
		5.00	0.846
		6.00	1.000
	Whatman No.1	1.00	0.153
		2.00	0.229
		4.00	0.022
		5.00	0.077

### 1.2 Optimization of Filter paper

		6.00	0.148
	(I) type	(J) type	Sig.
	GF	1.00	0.697
		2.00	0.449
		3.00	0.022
		5.00	0.939
		6.00	0.832
	GFA	1.00	0.999
		2.00	0.846
		3.00	0.077
		4.00	0.939
		6.00	1.000
	GFC	1.00	1.000
		2.00	1.000
		3.00	0.148
		4.00	0.832
		5.00	1.000
* 11 1.00	· · · · · · · · · · · · · · · · · · ·	0.051 1	A

\* The mean difference is significant at the 0.05 level.

### 1.3 Storage stability of sampler

	(I) type	(I) type	Sig
Tukey HSD	1.00  day	2.00	0.012
Tuney 115D	1.00 duy	3.00	0.012
		4 00	0.000
		5.00	0.000
		6.00	0.000
		0.00	0.013
		7.00	0.002
	2.00	1.00	0.012
		3.00	0.685
		4.00	0.617
		5.00	0.774
		6.00	1.000
		7.00	0.983
	3.00	1.00	
		2.00	0.685
		<b>4.00 A S</b>	<b>– – 1.000</b>
		5.00	1.000
		6.00	0.672
		7.00	0.983
	4 00	1.00	0.000
	T.UU	2 00	0.617
	(I) type	(J) type	Sig.

		3.00	1 000
		5.00	1 000
		6.00	0.603
		7.00	0.967
		1.00	0.907
	5.00	1.00	0.000
		2.00	0.774
		3.00	1.000
		4.00	1.000
		6.00	0.762
		7.00	0.994
	6.00	1.00	0.013
		2.00	1.000
		3.00	0.672
		4 00	0.603
		5.00	0.762
		7.00	0.762
		1.00	0.980
	7.00	1.00	0.002
	/.00	1.00	0.002
		2.00	0.983
		3.00	0.983
		4.00	0.967
		5.00	0.994
		6.00	0.980
Tamhane	1.00	2.00	0.173
		3.00	0.002
		4 00	0.038
		1 5 00	0.001
		6.00	0.010
		7.00	0.080
		7.00	0.000
	2.00	1.00	0.173
			0.983
			0.995
		5.00	0.993
		7.00	1.000
	3.00	<b>3</b> 1.00 <b>C 3</b>	0.002
		2.00	0.983
		4.00	1.000
		5.00	1.000
		6.00	0.729
		7.00	1.000
	4.00	1.00	0.038



<sup>5</sup> The mean difference is significant at the 0.05 level.

1.4 Optimization of tube type	

	(I) type	(J) type	Sig.
Tukey HSD	PP	PE	0.011
C <sup>7</sup>		PS	0.005
	PE	PP	0.011
		PS	0.831
	PS	PP	0.005
		no PE	0.831
Tamhane	PP	PE	0.093
		PS	0.000
	PE	PP S C	0.093
		PS	0.963
	PS	PP	0.000
		PE	0.963

\* The mean difference is significant at the 0.05 level.

**1.5 Reverse diffusion (Paired Samples Test)** 

		t	df	Sig. (2-tailed)
Pair 1	Expose 4hrs – Expose zero air	0.127	4	0.905

#### 1.6 Orientation

	0		
	(I) type	(J) type	Sig.
Tukey HSD	1.00	2.00	0.617
		3.00	0.835
	2.00	1.00	0.617
		3.00	0.922
	3.00	1.00	0.835
		2.00	0.922
Tamhane	1.00	2.00	0.960
		3.00	0.990
	2.00	1.00	0.960
		3.00	0.993
	3.00	1.00	0.990
		2.00	0.993
1.8 Sampling pe	riod		65

### 1.8 Sampling period

	(I) type	(J) type	Sig.
		6.62	
Tukey HSD	1.00	2.00	0.170
		3.00	0.001
		4.00	0.000
		5.00	0.000
		6.00	0.000
		7.00	0.000
	2.00	1.00	0.170
		3.00	0.210
		4.00	0.000
		5.00	Univers <u>0.000</u>
		6.00	0.000
		ts <sup>7.0</sup> res	$\mathbf{e} \mathbf{r} \mathbf{v} \mathbf{e}^{0.000}$
	3.00	1.00	0.001
		2.00	0.210
		4.00	0.059
		5.00	0.001
		6.00	0.000
		7.00	0.001

	4.00	1.00	0.000
		2.00	0.000
		3.00	0.059
		5.00	0.511
		6.00	0.173
		7.00	0.442
		91	
	5.00	1.00	0.000
		2.00	0.000
		3.00	0.001
		4.00	0.511
		6.00	0.990
		7.00	1.000
	6.00	1.00	0.000
		2.00	0.000
		3.00	0.000
		4.00	0.173
		5.00	0.990
		7.00	0.996
	7.00	1.00	0.000
		2.00	0.000
	(I) type	(J) type	Sig.
	7.00	3.00	0.001
		4.00	0.442
		5.00	1.000
		6.00	0.996
Tamhane	1.00	2.00	0.834
		3.00	0.148
		4.00	0.012
		5.00	0.007
		6.00	0.002
		7.00	0.007
		histor Mai	
	2.00	1.00	0.834
		5.00	0.525
		S 4.00 e S	
		6.00	0.000
		7.00	0.001
		/.00	0.000
	3.00	1.00	0.148
		2.00	0.523
		2.00	
		4.00	0.520
		4.00 5.00	0.520 0.031

	6.00	0.016
	7.00	0.027
4.00	1.00	0.012
	2.00	0.039
	3.00	0.520
	5.00	0.925
	6.00	0.709
	7.00	0.891
5.00	1.00	0.007
	2.00	0.000
	3.00	0.031
	4.00	0.925
	6.00	1.000
	7.00	1.000
6.00	1.00	0.002
	2.00	0.001
	3.00	0.016
	4.00	0.709
	5.00	1.000
	7.00	1.000
7.00	1.00	0.007
	2.00	0.000
(I) type	(J) type	Sig.
	3.00	0.027
	4.00	0.891
	5.00	1.000
	6.00	1.000

\* The mean difference is significant at the0 .05 level.

#### VITA

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December 3, 1980

Bachelor degree of Science (chemistry) Rajabhat Phuket Institute, 2002

Center for Innovation in Chemistry Postgraduate Education and Research Program in Chemistry, PERCH-CIC, Ministry of University Affairs (Nov 2004 - Oct 2006)

Development of Passive Sampling Devices and exposure Chamber for Determination of Formaldehyde Indoors, 32<sup>th</sup> Congress on Science and Technology of Thailand, 2006, Bangkok

Validation of Passive Samplers in the Formaldehyde Exposure Chamber, the PERCH-CIC Annual Scientific Conference (PERCH-CIC V), 2007, Chonburi

Diffusive Passive Sampler and Exposure Chamber for Determination of Indoor Formaldehyde, the 2<sup>nd</sup> Academic conference of CMU, 2006, Chiang Mai

## Name

Date of birth

Education

Scholarship

#### List of conference

Poster presentation

in conferences