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MINISTRY OF HUMAN RESOURCES

NIOSH

# Protecting the future by reconstructing past exposure history: A case study of occupational lifetime chrysotile exposure and lung cancer risk among mechanics


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# OUTLINE

- Study background
- Importance of exposure assessment
- Role of exposure modelling
- Estimating occupational lifetime chrysotile exposure
- Predicting lung cancer risk

# STUDY BACKGROUND

**25% - 65% chrysotile can be found in brake pad, brake lining, gasket and clutch lining[1, 2]**

**What is chrysotile?**

- **Aka 'White Asbestos '**
- **Belongs to Serpentine family**
- **Commonly used in friction product**

**<u>Advantages</u>:**
- **Flexible**
- **Heat resistant (up to 500 °C)**
- **Non-flammable**
- **Good for insulator**


[1]Dement, J.M. et al. 2008, *Occup Environ Med, 65, 605-12.*
[2]Richter, R.O., et al., 2008, *J Exp Sci Environ Epidemiol,* 10, 36-43.

# STUDY BACKGROUND

**Generally, brake lining will be repaired or changed after every 2400 KM[3]**

**Mechanics in auto repair workshop are at higher risk to asbestos exposure and asbestos-related diseases[4]**

**Higher incidence of lung cancer and mesothelioma among these workers compared to the general population[5]**

[3]Gilles, T. 2005, Thomson Delmar Learning, A Division of Thomson Learning, Inc, USA.
[4]Finkelsten, M.M., 2008, *Annals of occupational hygiene*, *52*(6), 455-461
[5]Langer AM, McCaughey WTE. 1982. *Lancet* 8307, 1101-103.

# Chrysotile fibre detection using PLM

Our previous article: Zahaba, M. et al. (2023) Identification of chrysotile in brake pads and linings from Malaysian vehicles and heavy vehicles by using Polarized Light Microscope (PLM). Jurnal Teknologi, 85 (3). pp. 125-134. ISSN 0127-9696 E-ISSN 2180-3722

## Extinction Angle

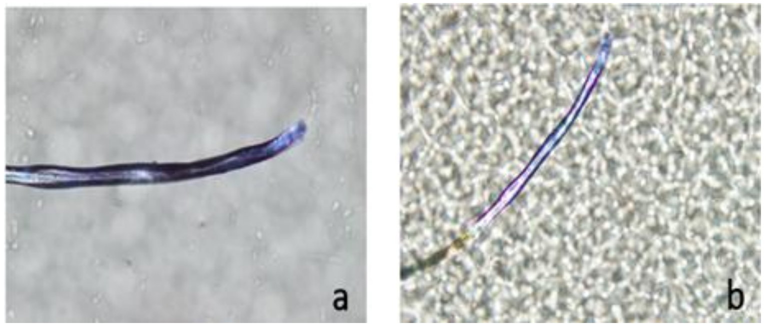



Figure 1
(a) Aligned parallel to 0° angle polariser
(b) Aligned at 45° orientation to the polariser

## Dispersion Staining using a darkfield view technique

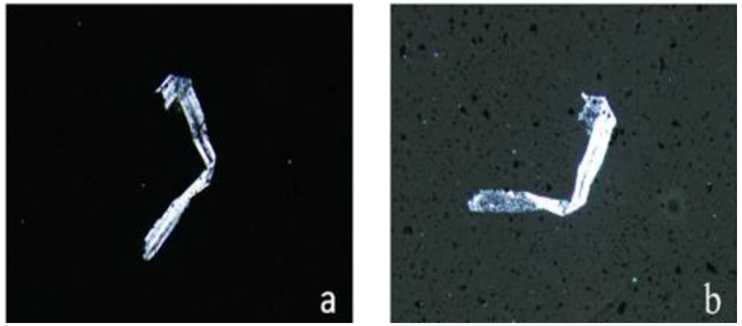



Figure 2
(a) sample rotated at 45° angle
(b) sample rotated at 0° angle

## The sign of the elongation using first order compensator

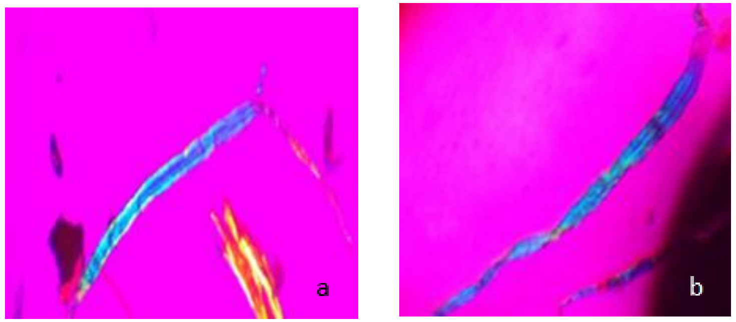



Figure 3
(a & b) showed blue colour fibres at the NE-SW orientation. Meanwhile, (a) the fibres present at the NW-SE orientation appeared in yellow form.

# Chrysotile fibre detection using PLM

## Anisotropic Characteristic of Chrysotile fibre

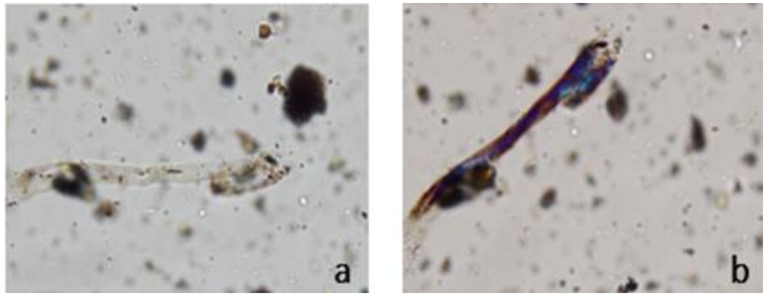



Figure 4
(a) Fibre was aligned at parallel orientation
(b) Fibre was aligned at 45° orientation

## Colour and morphology

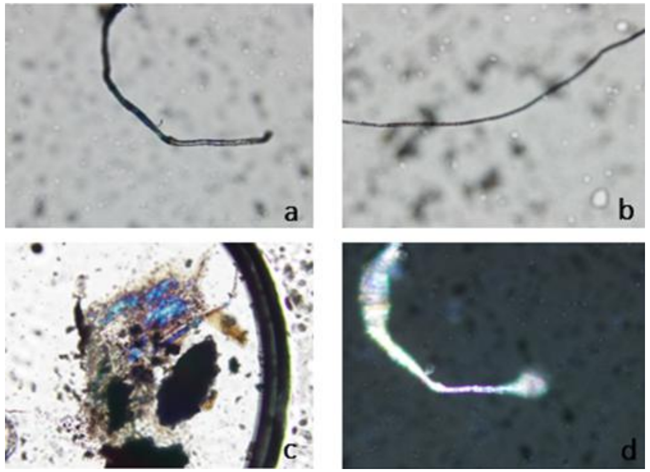



Figure 5
(a) A fibre was aligned at parallel orientation,
(b) A fibre was aligned at parallel orientation
(c) A fibre was aligned at 45° orientation. Fully crossed polarisation image of chrysotile detected under RI 1.550 using 20X magnification
(d) A fibre in the darkfield view

## Pleochroism

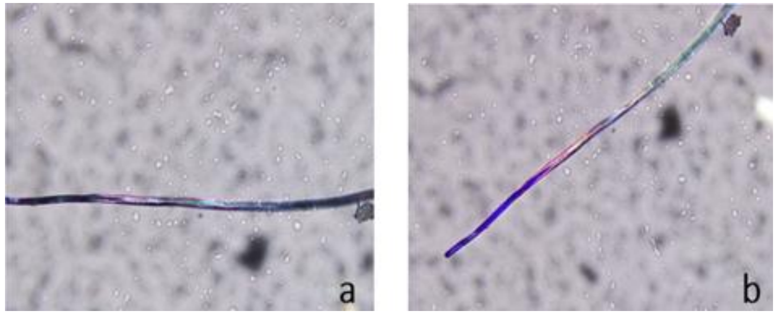
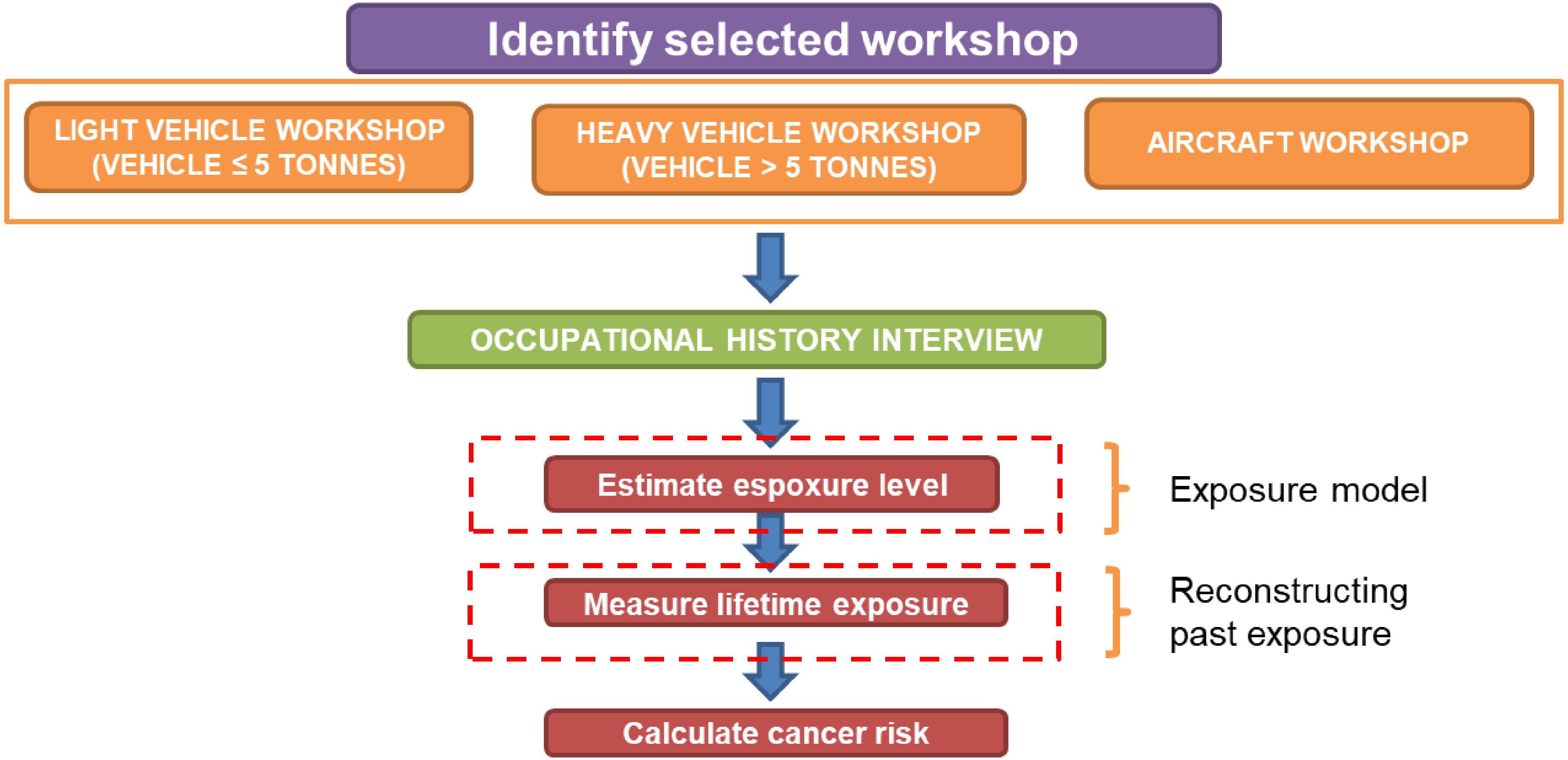



Figure 6
(a) Aligned parallel to 0° angle polariser
(b) Aligned at 45° orientation to the polariser

# A CASE STUDY: OCCUPATIONAL LIFETIME CHRYSOTILE EXPOSURE & LUNG CANCER RISK AMONG MECHANICS

- Aims:
  - To estimate chrysotile inhalation exposure level for each job tasks
  - To estimate lifetime chrysotile occupational exposure of the workers
  - To calculate lung cancer risk

# METHODOLOGY



# EXPOSURE ASSESSMENT METHOD

## Direct method

**Air sampling – area or personal**

- Expensive
- Labour extensive
- Snap-shot of exposure

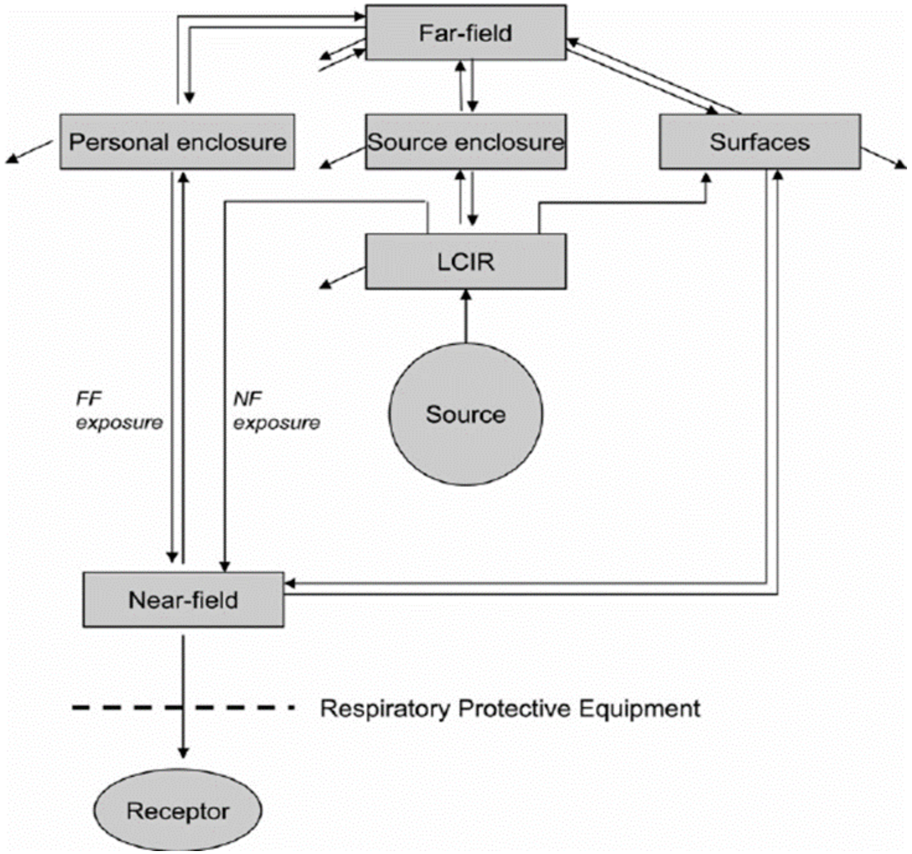

## Indirect method

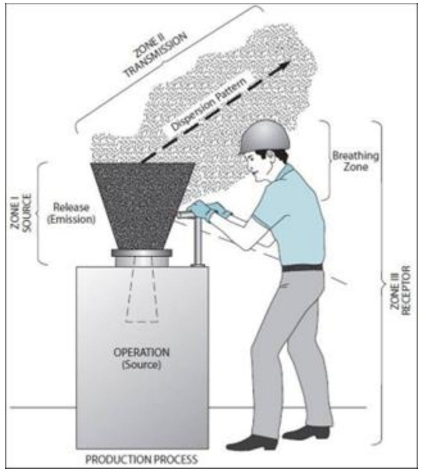
**Exposure modelling / Control Banding**

- Absence of measured data
- Predict exposure / control
- Act as compliment to measured data

# EXPOSURE MODELLING

**Can be used in epidemiological research & regulatory risk assessment**



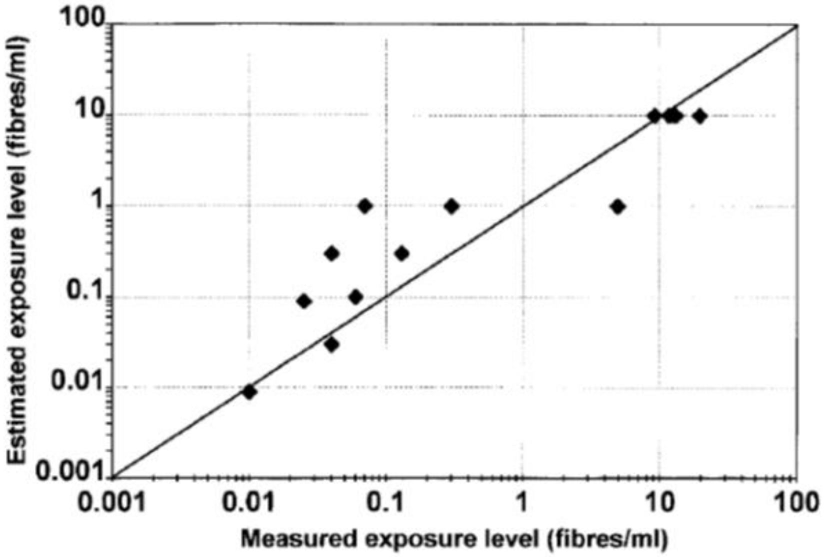




Fig. 5. Comparison of measured and estimated exposure levels for asbestos (Assessor 1).

(correlation coefficient 0.93)

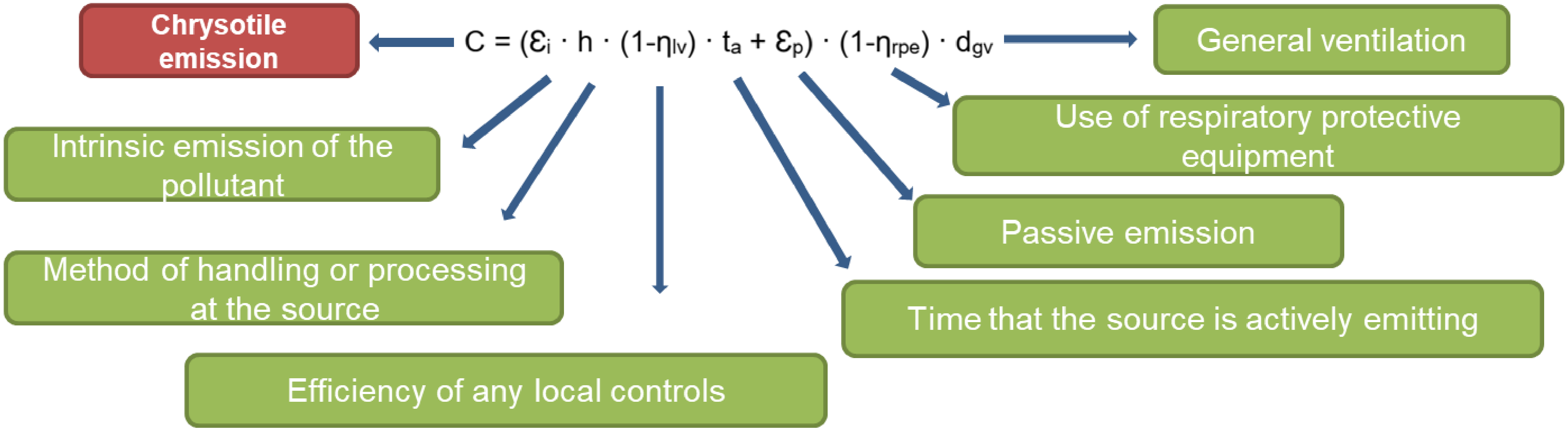
**Based on source-receptor modelling approach**

**Validated in number of various situation**

[6]Tielemans, E., Schneider, T., Goede, H., Tischer, M., Warren, N., Kromhout, H., ... & Cherrie, J. W. (2008). Conceptual model for assessment of inhalation exposure: defining modifying factors. *Annals of occupational hygiene*, *52*(7), 577-586.

[7]Cherrie, J. W., & Schneider, T. (1999). Validation of a new method for structured subjective assessment of past concentrations. Annals of occupational hygiene, 43(4), 235-245.

# MODEL PARAMETERS




- The intrinsic and passive emissions in fibres/ml
- The other parameters in these equations are dimensionless
- All parameters are assumed to be independent of each other
- They are combined in a multiplicative form to estimate the exposure level.
- Except, the passive emission term (act as an additive factor unrelated to the active source).

# MODEL PARAMETERS GUIDANCE

- To reconstruct exposure levels, the assessor must assign numeric values to each of the parameters.

- Selection of these parameters should be based on descriptive information for the process and work activities
  - ✓ may need to use their judgement, e.g. when details about the duration of the dust generating activity are unavailable or the task description is unclear.

- To aid consistency while coding exposure level it is recommend that assessors are trained and use the chrysotile-specific guidance

- Exposures can be independently reconstructed by two or three assessors if there is a need for greater reliability, but there is little value in having more than three independent assessments

# MODEL PARAMETERS GUIDANCE

Table 1: Guidance materials for asbestos inhalation exposure modelling

| Symbol | Definition | Value | Unit |
|---|---|---|---|
| $\varepsilon_i$ | • Aircraft and truck (16 -23%) | 1.5 | f/ml |
| | • Automobiles such as car; and train (40 – 70%) | 2.25 | f/ml |
| h | Machining | | |
| | • Bevelling new or used brake linings/pads | 10 | Dimensionless |
| | • Grinding new or used brake linings/pads | 10 | Dimensionless |
| | • Grinding brake linings/pads on wheels | 10 | Dimensionless |
| | • Sanding brake linings/pads | 10 | Dimensionless |
| | • Rivet installation | 1 | Dimensionless |
| | • Rivet removal | 1 | Dimensionless |
| | • Preparation of brake shoes before riveting new linings | 0.3 | Dimensionless |
| | • Turning brake drums / brake discs | 0.3 | Dimensionless |
| | • Opening / changing / assembly / disassembly of drum brakes/discs | 0.3 | Dimensionless |
| | • Bevelling new or used brake linings/pads | 0.3 | Dimensionless |
| | Cleaning | | |
| | • Cleaning discs/drum brake assembly with compressed air / water* | 10 | Dimensionless |
| | • Cleaning discs/drum brake assembly with compressed air /brush/ dry clot/ vacuum* | 3 | Dimensionless |
| | *cleaning using solvent, vacuum or water are treated in the local control section. | | |
| $1-\eta_{lv}$ | No local control | 1 | Dimensionless |
| | Local ventilation (i.e. LEV) | | |
| | • Well-designed and maintained captor ventilation | 0.1 | Dimensionless |
| | • Less carefully designed or maintained captor hoods | 0.3 | Dimensionless |
| | Enclosure | | |
| | • Partial enclosure (i.e. fume cupboard) without air ventilation | 0.05 | Dimensionless |
| | • Partial enclosure with air ventilation | 0.01 | Dimensionless |
| | • Total enclosure | 0.01 | Dimensionless |
| | Cleaning | | |
| | • Cleaning with water, compressed air, dry cloth, and vacuum. | 0.3 | Dimensionless |
| | • Cleaning with solvent, damp cloth and wet brush | 0.1 | Dimensionless |
| $\varepsilon_p$ | Good housekeeping | 0 | f/ml |
| | Poor housekeeping (but the situation is generally controlled) | 0.1 | f/ml |
| | Very poor housekeeping (i.e. very dusty) | 0.3 | f/ml |
| $d_{gv}$ | The general ventilation parameter can be determined by using the information on room volume and air changes per hour | Please refer # | Dimensionless |
| $1-\eta_{rpe}$ | • No RPE use | 1 | Dimensionless |
| | • Limited RPE use | 0.5 | Dimensionless |
| | • Improved RPE use | 0.3 | Dimensionless |
| | • Effective RPE use | 0.01 | Dimensionless |

Note:

$\varepsilon_i$ = Intrinsic emission (f/ml); h = Handling; $1-\eta_{lv}$ = Local control; $t_a$ = the time that the source is actively emitting (%); $\varepsilon_p$ = passive emission (f/ml); $d_{gv}$ = General ventilation; $1-\eta_{rpe}$ = Respiratory Protective Equipment;

#Guidance value for general ventilation[1]

| Room volume | 0.3 air changes per hour | 1 air changes per hour | 3 air changes per hour | 10 air changes per hour |
|---|---|---|---|---|
| *Near-Field Multipliers* | | | | |
| 30 $m^3$ | 37 | 18 | 7 | 3 |
| 100 $m^3$ | 13 | 6 | 2.9 | 1.6 |
| 300 $m^3$ | 5.1 | 2.7 | 1.6 | 1.2 |
| 1000 $m^3$ | 2.2 | 1.5 | 1.2 | 1 |
| 3000 $m^3$ | 1.4 | 1.2 | 1.1 | 0.5 |
| *Far Field Multipliers* | | | | |
| 30 $m^3$ | 37 | 17 | 6 | 2 |
| 100 $m^3$ | 12 | 5 | 2 | 0.6 |
| 300 $m^3$ | 4.1 | 1.7 | 0.6 | 0.2 |
| 1000 $m^3$ | 1.2 | 0.5 | 0.2 | 0.07 |
| 3000 $m^3$ | 0.4 | 0.2 | 0.1 | 0.05 |

Note:

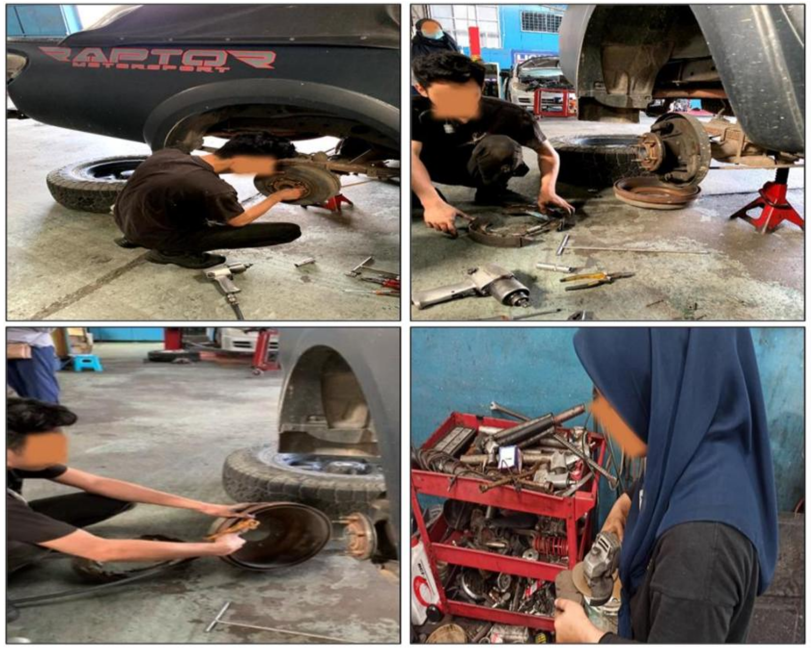
Near-field: a volume around the worker whose exposure is being investigated

Far-field: the remainder of the work environment.

[1] Cherrie et al (2011). Annals of occupational hygiene, 55(9), 1006-1015.

# FINDINGS & DISCUSSION

## AUTOMOBILE WORKSHOP



## TRUCK WORKSHOP

## AIRCRAFT WORKSHOP

| Type of workshop | Automobile | Truck | Aircraft |
|---|---|---|---|
| **Number of workers** | 10 | 18 | 10 |
| **Chrysotile-related task duration** | 5 minutes/shift | 25 minutes/shift | 6.25 hours/shift |
| **Number of chrysotile-related tasks** | 2 | 5 | 3 |
| **Housekeeping** | Poor housekeeping (but the situation is generally controlled) | Poor housekeeping (but the situation is generally controlled) | Poor housekeeping (but the situation is generally controlled) |
| **Ventilation** | No adequate | Not adequate | Not adequate |
| **Estimated room volume** | 3000 $m^3$ (3 ACH) | 3000 $m^3$ (10 ACH) | 3000 $m^3$ (0.3 ACH) |
| **RPEs program** | Limited RPE use | Limited RPE use | Improved RPE use |

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# Estimated chrysotile emissions

| Workshop | Task | | $\mathcal{E}_i$ | h | $1\text{-}\eta_{lv}$ | $t_a$ | $\mathcal{E}_p$ | $1\text{-}\eta_{rpe}$ | $d_{gv}$ | C |
|---|---|---|---|---|---|---|---|---|---|---|
| Automobile | 1 | Opening / changing / assembly brake linings / pad / disc | 2.25 | 0.3 | 1 | 0.01 | 0.1 | 0.5 | 1.1 | 0.06 |
| | 2 | Cleaning brake disc / drum with compressed air | 2.25 | 10 | 0.3 | 0.01 | 0.1 | 0.5 | 1.1 | 0.09 |
| | | | Total exposure (f/ml): | | | | | | | 0.15 |
| Truck | 1 | Rivet removal | 1.5 | 1 | 1 | 0.01 | 0.1 | 0.5 | 0.5 | 0.03 |
| | 2 | Preparation of Brake Shoes before riveting new linings | 1.5 | 0.3 | 1 | 0.01 | 0.1 | 0.5 | 0.5 | 0.03 |
| | 3 | Rivet installation | 1.5 | 1 | 1 | 0.01 | 0.1 | 0.5 | 0.5 | 0.03 |
| | 4 | Opening / changing / assembly brake linings / pad / disc | 1.5 | 0.3 | 1 | 0.01 | 0.1 | 0.5 | 0.5 | 0.03 |
| | 5 | Cleaning brake disc / drum with compressed air | 1.5 | 10 | 0.3 | 0.01 | 0.1 | 0.5 | 0.5 | 0.04 |
| | | | Total exposure (f/ml): | | | | | | | 0.16 |
| Aircraft | 1 | Disassembly of carbon brake | 1.5 | 0.3 | 1 | 0.375 | 0.1 | 0.3 | 1.1 | 0.09 |
| | 2 | Assembly of carbon brake | 1.5 | 0.3 | 1 | 0.375 | 0.1 | 0.3 | 1.1 | 0.09 |
| | 3 | Cleaning carbon brake assembly with dry cloth / brush | 1.5 | 3 | 0.1 | 0.03 | 0.1 | 0.3 | 1.1 | 0.04 |
| | | | Total exposure (f/ml): | | | | | | | 0.22 |

Note:
$\mathcal{E}_i$ = Intrinsic emission (f/ml); h = Handling; $1\text{-}\eta_{lv}$ = Local control; $t_a$ = the time that the source is actively emitting (%); $\mathcal{E}_p$ = passive emission (f/ml); $d_{gv}$ = General ventilation; $1 - \eta_{rpe}$ = Respiratory Protective Equipment; C = Total exposure (f/ml)

# OCCUPATIONAL LIFETIME CHRYSOTILE EXPOSURE

Occupational lifetime chrysotile exposure

= (Estimated chrysotile exposure level * total occupational exposure period (hours/year x number of years))/2000#

**Example:**

**(Aircraft workshop worker, ID No: 25)**

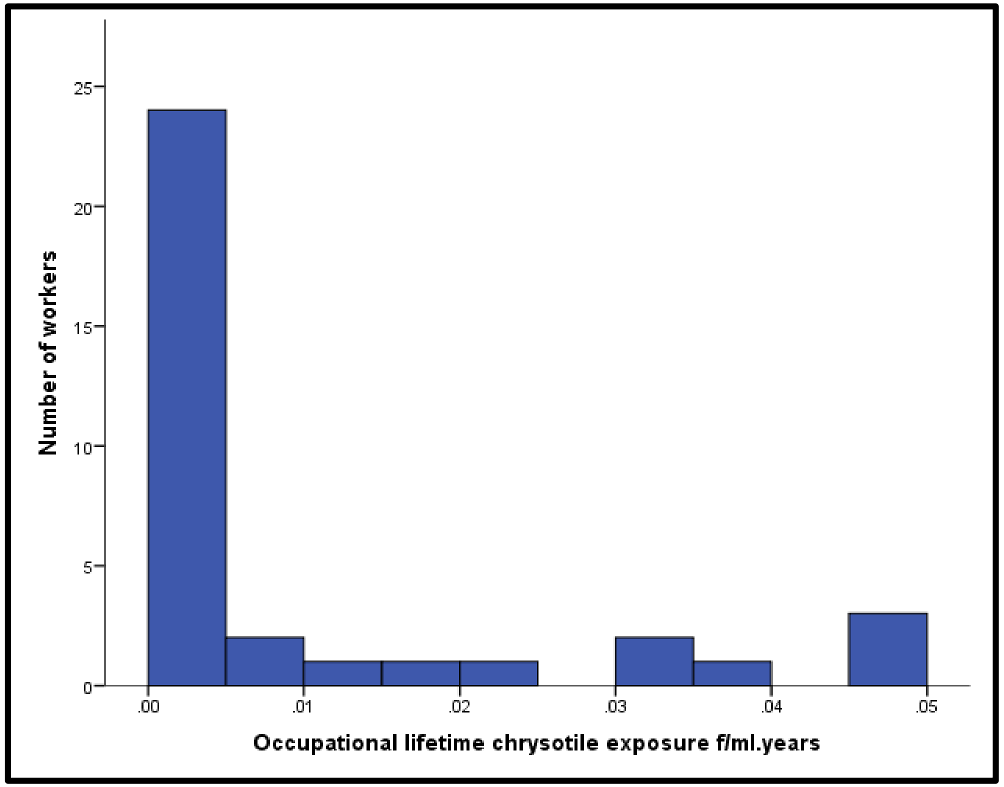
**Hours/year = 14.6;Number of years = 26**

Estimated asbestos Lifetime exposure

= (0.22 f/ml * 438.8 hours) / 2000

= 0.04 f/ml.years

#based on "occupational" years (40hrs x 48 weeks ~ 2000hrs)




Estimated occupational lifetime chrysotile exposure among mechanics

0.0001 – 0.0486 f/ml.years, median (IQR) = 0.0018 (0.009)

# LUNG CANCER RISK

$$\text{Relative risk (RR)} = \alpha * (1.00 + K_L * (CE_{10}))$$

- $\alpha$: statistical uncertainty (≤2)
- $K_L$: lung cancer potency factor $(f/ml.years)^{-1}$
- $CE_{10}$: cumulative exposure (lagged by 10 years (f/ml.years))

Due to long latency of lung cancer, the mortality rate can be estimated by 10 years lagged of exposure

Example:

$$RR = 1 * (1 * 0.0061\ (f/ml.years)^{-1} * 0.005\ f/ml.years = 1.00003$$

It appears that the additional contribution of exposure to lung cancer risk in our study is low (0.00003%).



[8]US EPA Model: Nicholson, W.J. (1986). Airborne asbestos health assessment update. Report 600/884003F. Washington, DC: U.S. Environmental Protection Agency.

# LIMITATION

- Small sample size among exposed workers, but:
  - recruited from 3 different categories of workshops (represent the different chrysotile-related tasks)
  - minimize the exposure misclassification bias (extensive occupational history interview)

- Subjective exposure model might overestimate the exposure compared to the measured exposure, but it is common.
  - Overestimate: costly or unnecessary control action
  - Underestimate: jeopardize the workers' health

# CONCLUSION

- Exposure modelling can be used to reconstruct past exposure.
- A task-based approach can estimate lifetime occupational chrysotile exposure in the absence of historical sampling data.
- The cancer risk in mechanics is low, most likely due to lower cumulative exposure of the workers.

# ACKNOWLEDGEMENT

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National Institute Of Occupational Safety And Health

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LEADING THE WORLD
AN INTERNATIONAL AWARD-WINNING INSTITUTION FOR SUSTAINABILITY

# THANK YOU