Indoor And Outdoor Relationships Of Size Fractionated Particulate Matters In Urban Residential Houses In Vietnam And Deposited Dose Estimation

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The indoor air pollution has been a major global health concern because people spend much more time (over 90%) in enclosed sites than in outdoor areas.

A population living in the tight buildings contracted upper respiratory diseases was at rates 46 to 50% higher than group living in better ventilated houses.

Particulate matter was the fifth-ranking mortality risk factor in 2016 and has been known as leading cause of global burden of disease.

Household air pollution was ranked as the 10th greatest risk factor for mortality in 2019 and responsible for 2.7% of global burden of disease (GBD, 2020), which caused about 4 million premature deaths (approximately 7.7% of the global mortality).

In 2019: $\text{PM}_{2.5}$ exposure in 56,808 deaths in VN (9.9% of natural deaths); In 2009, more than 3000 extra deaths by related $\text{PM}_{10}$ in VN.
1. What is PM?

- **PM**: Particulate Matter
- **PM10**: Particles up to 10 μm in diameter
- **PM2.5**: Particles up to 2.5 μm in diameter
- **PM0.1**: Particles up to 0.1 μm in diameter

### Types and effects of particulate matter

- **Fine particulate inhalable**
  - Street dust, abrasion
  - Respiratory ailment
  - Decrease of pulmonary function

- **Fine particulate respirable**
  - Industrial dust, exhaust
  - Dermatologic diseases
  - Increased risk of lung cancer

- **Ultra fine particles**
  - Soot (diesel, residential burning), exhaust
  - Increased risk of heart attacks
  - Increased risk of cancer

### Introduction

- **Cheng, Y.S.**, 2014
- **Source**: DUH

- Hanoi: 10 μg/m³ increase in PM10, PM2.5 and PM1: 1.4, 2.2 and 2.5% for 5 year children for Hospital admission

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Hanoi: 10 μg/m³ increase in PM10, PM2.5 and PM1: 1.4, 2.2 and 2.5% for 5 year children for Hospital admission

Cheng, Y.S., 2014
2. PM source

- **Outdoor environment** that has infiltrated into the indoor environment

- **Indoor actives**
  - Cooking, smoking, burning of coal, candles and incenses
  - Painting, domestic compliances (fax, printer, photocopy), construction materials, cleaning ...

- **Moving**
Current Indoor PM pollution status

- PM10 (μg/m³)
- PM2.5 (μg/m³)
- PM0.1 (μg/m³)
1. Sampling strategy

- Winter and Summer
- (2 weeks/sites)
- Principles: Gravity method

1320 samples

- Flow rate: 40 L/min
- Paper: Quartz, D= 55mm.
- Height: 1.5m
- Duration: 24h
- In/Out
- PM$_{0.1}$; PM$_{0.1-0.5}$, PM$_{0.5-1}$, PM$_{1-2.5}$; PM$_{2.5-10}$, PM$_{>10}$

CHAPTER 4
Methodology
2. Indoor-outdoor relationship

1. Ratio of I/O

\[ I/O = \frac{C_{in}}{C_{out}} \]

- I/O ≥ 1.2 or I/O ≤ 0.8, the possible indoor or outdoor sources was dominant,
- 0.8 < I/O < 1.2: Equivalence between indoor and outdoor sources

2. Infiltration factor

\[ C_{in} = F_{INF} \cdot C_{out} + C_{ig} \]

- \( C_{in}, C_{out} \): Indoor and Outdoor PM concentration
- \( C_{ig} \): PM indoor generated in indoor source
- \( F_{INF} \): infiltration factor
3. Input for HIA US.EPA (2011)

<table>
<thead>
<tr>
<th>Age categories</th>
<th>0-1y</th>
<th>1-3y</th>
<th>3-6y</th>
<th>6-11y</th>
<th>11-&lt;21</th>
<th>21- &lt;60</th>
<th>&gt;60y</th>
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</thead>
<tbody>
<tr>
<td>Parameter</td>
<td></td>
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<tr>
<td>IRA</td>
<td>US.EPA 2011</td>
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<tr>
<td>AT</td>
<td>US.EPA 2011</td>
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<td></td>
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<tr>
<td>C(pollutants)</td>
<td>Sampling</td>
<td></td>
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<tr>
<td>ET</td>
<td>Questionnaire</td>
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<tr>
<td>ED</td>
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</tr>
</tbody>
</table>

300 offline + 200 online questionnaires

Parameter | Resources
--- | ---
PM characteristics | Sampling
Respiratory physiological parameters (TV, BF, FRC and exposed subject characteristics) | (ICRP, 1994),
Activity pattern | Questionnaires

MPPD model to estimate deposition fraction
Mass concentrations of indoor and outdoor PM at different fractions

Indoor-summer
Indoor-winter
Outdoor-Summer
Outdoor-Winter

WHO 15 µg/m³
WHO 45 µg/m³
## Chapter 4
### Results and discussions

<table>
<thead>
<tr>
<th></th>
<th>Indoor</th>
<th>Outdoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM(_{0.1})</td>
<td>-0.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>PM(_{0.5})</td>
<td>-0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>PM(_{1})</td>
<td>-0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>PM(_{2.5})</td>
<td>-0.1</td>
<td>0.2*</td>
</tr>
<tr>
<td>PM(_{10})</td>
<td>-0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>TSP</td>
<td>-0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

* Intercorrelation between PM and meteorological parameters:
  - PM\(_{10}\):
    - PM\(_{2.5}\):
      - PM\(_{1}\):
        - PM\(_{0.1}\):
          - PM\(_{0.5}\):

** Intercorrelation between PM and meteorological parameters:
  - PM\(_{10}\):
    - PM\(_{2.5}\):
      - PM\(_{1}\):
        - PM\(_{0.1}\):
          - PM\(_{0.5}\):

*: 0.05 level
**: 0.01 level
The contribution proportions of PM fractions were relatively similar in two seasons.

- PM_{0.5-1} and PM_{1-2.5} contributed larger proportions to PM_{2.5} and PM_{10} than PM_{0.1}.
- Indoor PM_{0.1}/PM_{2.5} and PM_{0.1}/PM_{10} > outdoor ratios; indoor PM_{2.5-10}/PM_{10} < outdoor ratio.
Chapter 4
Results and discussions

Indoor and outdoor ratios (I/O)

- PM_{0.1} contributed lower proportions than other fractions to PM_{10}
- Indoor PM_{0.1}/PM_{2.5} and PM_{0.1}/PM_{10} > outdoor ratios; indoor PM_{2.5-10}/PM_{10} < outdoor ratio

PM_{0.1} I/O\geq1: influence of indoor sources
PM_{2.5-10} and PM_{>10}: I/O <1 influence of outdoor sources
### Infiltration factors and indoor generated PM

<table>
<thead>
<tr>
<th></th>
<th>$F_{\text{inf}}$</th>
<th>$R^2$</th>
<th>Cig/Cin (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{0.1}$</td>
<td>0.8 (0.5-1.1)</td>
<td>0.7-0.9</td>
<td>33.5 (16.1-63.3)</td>
</tr>
<tr>
<td>PM$_{0.1-0.5}$</td>
<td>0.8 (0.4-1.1)</td>
<td>0.7-0.9</td>
<td>20.4 (5.1-63)</td>
</tr>
<tr>
<td>PM$_{0.5-1}$</td>
<td>0.8 (0.6-1)</td>
<td>0.8-0.9</td>
<td>22.7 (5.8-48.7)</td>
</tr>
<tr>
<td>PM$_{1-2.5}$</td>
<td>0.7 (0.6-0.9)</td>
<td>0.7-0.9</td>
<td>20.7 (3.9-32.1)</td>
</tr>
<tr>
<td>PM$_{2.5-10}$</td>
<td>0.3 (0.2-0.5)</td>
<td>0.8-0.95</td>
<td>15 (8.8-18.8)</td>
</tr>
</tbody>
</table>

1. $F_{\text{inf}}$: fraction of outdoor particles that penetrates indoors
2. Cig/Cin (%): % indoor PM generated from indoor sources

Easier to penetrate smaller sizes than bigger sizes

Majority indoor PM derived from outdoor sources
Chapter 4
Results and discussions

Deposited doses of PM in the HRT

<table>
<thead>
<tr>
<th>PM mass</th>
<th>HA (%)</th>
<th>TB (%)</th>
<th>AL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM0.1</td>
<td>8.3-25.5</td>
<td>13.3-23.4</td>
<td>66.9 - 84</td>
</tr>
<tr>
<td>PM0.5</td>
<td>21.5 - 56.9</td>
<td>8.6 - 12.2</td>
<td>33 - 61.1</td>
</tr>
<tr>
<td>PM1</td>
<td>36.1 - 59.5</td>
<td>7.1 - 11.1</td>
<td>31.3 - 52.7</td>
</tr>
<tr>
<td>PM2.5</td>
<td>35.7 - 53.7</td>
<td>6.1 - 18.7</td>
<td>40.1 - 45.5</td>
</tr>
<tr>
<td>PM10</td>
<td>55 - 94.9</td>
<td>4.2 - 44.3</td>
<td>0.6 - 8.4</td>
</tr>
</tbody>
</table>

The highest PM10 in HA; Majority of PM0.1 was deposited in AL

Manojkumar et al.(2019): PM10 HA (73%) and TB (23%) AL region (4%); PM2.5 HA (45%); TB (9%); and AL (45%); PM1 HA (50%); TB (9%); and 40% in AL
### Chapter 4
Results and discussions

#### Deposited doses of PM in the Lobe region

<table>
<thead>
<tr>
<th>PM Size</th>
<th>LU (%)</th>
<th>LL (%)</th>
<th>RU (%)</th>
<th>RM (%)</th>
<th>RL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM0.1</td>
<td>8.9-21.9</td>
<td>25.6-30.5</td>
<td>7.5-17.4</td>
<td>5.4-7.2</td>
<td>21.2-35.5</td>
</tr>
<tr>
<td>PM0.5</td>
<td>5.5-10.9</td>
<td>13.9-29</td>
<td>4.8-10</td>
<td>2.1-6</td>
<td>11.7-20.4</td>
</tr>
<tr>
<td>PM1</td>
<td>5-9</td>
<td>13-23.8</td>
<td>3.9-9.8</td>
<td>2-4.9</td>
<td>10.9-18.6</td>
</tr>
<tr>
<td>PM2.5</td>
<td>6.1-11.6</td>
<td>16.9-26.7</td>
<td>5.2-15.8</td>
<td>2.7-5.4</td>
<td>14.2-25.4</td>
</tr>
<tr>
<td>PM10</td>
<td>0.7-6.2</td>
<td>1.8-13.8</td>
<td>0.6-6.8</td>
<td>0.4-2.5</td>
<td>0.1-10.7</td>
</tr>
</tbody>
</table>

**PM0.1**: Highest in Lobes, **PM10**: Lowest

% EDIs: Lower lobe > Upper lobe > Right middle lobe
1. High concentrations of PM$_{0.1}$, PM$_{0.5}$, PM$_1$, PM$_{2.5}$ and PM$_{10}$ are found in both seasons.
   - PM$_{2.5}$ and PM$_{10}$ exceed WHO recommended values.

2. Smaller size has better infiltration than bigger sizer.
   - NP influenced by indoor sources.
   - Coarse particles strongly influenced by outdoor sources.

3. EDI distribution
   - PM$_{10}$ highest in HA; PM$_{0.1}$ highest in AL.
   - PM$_{0.1}$: highest in Lobes, PM$_{10}$: Lowest.
   - Lower lobe > Upper lobe > Right middle lobe for all particle sizes.
Thank you for your attention