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Preschools’ indoor air quality and respiratory health symptoms among preschoolers in Selangor

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Abstract

Poor indoor air quality (IAQ) has been linked to increased respiratory symptoms among children. The aim of this study was to assess current IAQ status of preschools (urban, suburban and rural areas) in Selangor and its association with preschooler’s respiratory health. There was a significant difference between the indoor concentration of carbon monoxide (CO), particulate matter (PM10 & PM2.5) and Volatile Organic compounds (VOCs) (p = 0.001; p = 0.005; p = 0.005; p = 0.006) among the preschools. Urban area preschools (UAP) recorded highest concentration of CO, PM10 and PM2.5. The prevalence of cough ($\chi^2 = 25.462, p = 0.001$) and wheezing ($\chi^2 = 27.299, p = 0.001$) were significantly higher among preschoolers from UAP. Statistical results showed that there was a significant association between cough and indoor CO, PM10 and PM2.5. The findings concluded that exposures to poor IAQ might increase the risk of getting respiratory symptoms among preschoolers.

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Keywords: Preschool children; indoor air quality; respiratory symptoms

1. Introduction

Most Malaysian children, aged between 4 to 6 years old, begin their early childhood education by attending preschool established by government or private agencies. The quality of air inside schools is an essential determinant

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of healthy life and people’s well-being [1]. A significant influence from indoor environmental quality can affect and influences student’s attendance and performance [2]. It is important to recognize the association between wellness and student learning ability and the importance of providing healthy learning environments for children. Poor IAQ including inadequate ventilation, contaminated air and extreme temperature is one factor that if not adequately addressed, may contribute to absenteeism and reduced students’ performance.

Classroom’s IAQ is of special concern since children are more susceptible to poor IAQ and indoor air problems can be subtle and do not always produce easily recognizable impacts on health and wellbeing [3]. According to WHO [1], 19% of deaths in children under the age of 5 is due to acute respiratory infection, which is the impact of indoor air pollution. The aim of this research was to investigate the IAQ of preschools in Selangor (urban, suburban and rural area). The IAQ parameters such as CO, CO₂, PM₁₀, PM₂.₅, VOCs, air velocity (AV), relative humidity (RH), temperature and ventilation rates were assessed in this study. The chronic respiratory symptoms and home exposure data were collected by using the modified ISAAC and ATS questionnaire. This study is important to evaluate current IAQ of preschools in urban, suburban and rural area located in Selangor, Malaysia. The results obtained may be useful for the preschool management to initiate short and long term control measures such as to maintain the preschool environment in ways to minimize and control sources of pollution in the future.

2. Methodology

2.1 Study location and study design

This study is a cross sectional study where a complete assessment of IAQ and respiratory symptoms were conducted among children from urban area preschools (UAP), suburban area preschools (SAP) and rural area preschools (RAP) in Selangor.

2.2 Study population

A total of 630 preschoolers aged 4-6 years old were recruited from 39 preschools located in Selangor, Malaysia. Study samples were selected among male and female preschoolers who attended UAP, SUP and RAP in Selangor. Respondents who fulfilled the inclusion criteria (preschoolers aged 4 to 6, healthy, enrolled in the preschool for not less than 6 months, full enrollment (45 hours/week) and free from any respiratory illness) were selected randomly to participate in this study.

2.3 Instruments and procedures

Questionnaires adopted from The American Thoracic Society [4], ‘Questionnaire ATS-DLD-C WHO (1982)’ were used and pre-tested with 10% of the total respondents from the sample size. Air sampling for at least 3 to 4 hours period during preschool normal activities were carried out. Q-Trak Plus Model 8554 Monitor were used to measure CO₂, CO, temperature and RH; DustTrak DRX Monitor Aerosol for PM₂.₅ and PM₁₀; PbbRAE Portable VOC Monitor (pbbRAE 3000) for VOCs; and TSI Velocicale Plus Model 8386 for air velocity. Instruments for PM₂.₅, PM₁₀ and VOCs were placed at a height of about 0.6 to 1.5 meters above the floor (children’s breathing zone). Instruments were placed at the back of the classroom to avoid any sound disturbance and attraction from children during class session. Measurements of CO₂, CO, temperature, RH and air velocity were taken periodically and the sampling points were taken from different areas in the preschool to ensure that they were evenly distributed.

2.4 Data analysis

Data collected was analyzed using ‘Statistical Package for Science Version 21. Kolmogrov Smirnov, skewness and kurtosis values were used to determine normality of continuous variables. One-way ANOVA test and Chi square test were used to study the association and differences between indoor air pollutants (IAPs) concentrations and the respiratory symptoms of the preschoolers. Multiple Logistic regressions test was performed to determine the association of the main variables that influenced the respiratory symptoms among the preschoolers.
### 3. Results

**Table 1** Comparison of preschool’s IAQ among study areas

| Variables     | Urban Area (n=13) | Suburban Area (n=13) | Rural Area (n=13) | F     | p-value |
|---------------|-------------------|----------------------|-------------------|-------|---------|
| **Temperature (°C)** | 29.55 ± 1.50      | 29.65 ± 0.97         | 29.42 ± 1.05      | 0.129 | 0.879   |
| **RH (%)**    | 68.42 ± 10.87     | 72.01 ± 7.35         | 76.25 ± 4.53      | 3.101 | 0.057   |
| **Air Velocity (m/s)** | 0.16 ± 0.13      | 0.36 ± 0.47          | 0.30 ± 0.48       | 0.858 | 0.433   |
| **CO₂ (ppm)** | 695.31 ± 386.63   | 546.62 ± 85.42       | 596.98 ± 327.25   | 0.845 | 0.438   |
| **CO (ppm)**  | 4.48 ± 1.12       | 3.38 ± 0.38          | 3.04 ± 0.39       | 14.393| 0.001*  |
| **PM₂.₅ (μg/m³)** | 112.62 ± 32.82   | 109.31 ± 43.30       | 71.77 ± 17.28     | 6.176 | 0.005*  |
| **PM₁₀ (μg/m³)** | 121.85 ± 33.45   | 119.46 ± 43.10       | 80.46 ± 24.35     | 6.034 | 0.005*  |
| **VOC (ppb)** | 29.64 ± 23.77     | 33.45 ± 11.53        | 13.52 ± 6.29      | 5.832 | 0.006*  |

*Significant at p < 0.05; N = 39

**Table 2** Prevalence of respiratory symptoms among respondents

| Variables | Urban Area (n=210) | Suburban Area (n=208) | Rural Area (n=212) | χ² | p-value |
|-----------|--------------------|-----------------------|-------------------|----|---------|
| Cough     |                    |                       |                   |    |         |
| Yes       | 76 (36.2 %)        | 68 (32.7 %)           | 33 (15.6 %)       | 25.462 | 0.001* |
| No        | 134 (63.8 %)       | 140 (67.3 %)          | 179 (84.4 %)      |     |         |

Wheezing

| Yes       | 24 (11.4 %)        | 55 (26.4 %)           | 20 (9.4 %)        | 27.299 | 0.001* |
| No        | 186 (88.6 %)       | 153 (73.6 %)          | 192 (90.6 %)      |     |         |

*Significant at p<0.05, N = 630

**Table 3** Association between preschool’s indoor CO with respiratory symptoms among study respondents

| Variables | Indoor CO | χ² | p-value | PR  | 95% CI     |
|-----------|-----------|----|---------|-----|------------|
| Cough     | High (≥3.6 ppm) | 7.074 | 0.008* | 1.612 | 1.132 – 2.294 |
| No        | Low (<3.6 ppm) |       |         |     |            |

Wheezing

| Yes       | 95 (24.4 %)        | 82 (34.2 %)           | 15.413 | 0.001* | 2.378 | 1.531 – 3.694 |
| No        | 295 (75.6 %)       | 158 (65.8 %)          |       |         |     |            |

*Significant at p<0.05, N = 630

**Table 4** Association between preschool’s indoor air velocity with respiratory symptoms among study respondents

| Variables | Indoor Air Velocity | χ² | p-value | PR  | 95% CI     |
|-----------|--------------------|----|---------|-----|------------|
| Wheezing  | High (≥0.14 m/s)   | 15.413 | 0.001* | 2.378 | 1.531 – 3.694 |
| No        | Low (<0.14 m/s)    |       |         |     |            |

Chest tightness

| Yes       | 38 (10.7 %)        | 61 (22.2 %)           | 4.087 | 0.043* | 0.394 | 0.155 – 1.001 |
| No        | 317 (89.3 %)       | 214 (77.8 %)          |       |         |     |            |

*Significant at p<0.05, N = 630

**Table 5** Association between preschool’s indoor PM₁₀ with respiratory symptoms among study respondents

| Variables | Indoor PM₁₀ | χ² | p-value | PR  | 95% CI     |
|-----------|-------------|----|---------|-----|------------|
| Cough     | High (≥0.91 mg/m³) | 7.074 | 0.008* | 1.612 | 1.132 – 2.294 |
| No        | Low (<0.91 mg/m³) |       |         |     |            |

Wheezing

| Yes       | 95 (24.4 %)        | 82 (34.2 %)           | 29.972 | 0.001* | 3.323 | 2.129 – 5.187 |
| No        | 295 (75.6 %)       | 158 (65.8 %)          |       |         |     |            |

*Significant at p<0.05, N = 630
Table 6 Association between preschool’s indoor PM\textsubscript{2.5} with respiratory symptoms among study respondents

| Variables | Indoor PM\textsubscript{2.5} | χ\textsuperscript{2} | p value | PR | 95% CI |
|-----------|-----------------------------|----------------|--------|----|-------|
| | High (≥0.84 mg/m\textsuperscript{3}) | Low (<0.84 mg/m\textsuperscript{3}) |
| Cough | | | | | |
| Yes | 70 (24.4 %) | 82 (34.2 %) | 7.074 | 0.008* | 1.612 – 2.294 |
| No | 295 (75.6 %) | 158 (65.8 %) | | | |
| Wheezing | | | | | |
| Yes | 37 (9.5 %) | 62 (25.8 %) | 29.972 | 0.001* | 3.323 – 5.187 |
| No | 353 (90.5 %) | 178 (74.2 %) | | | |

*Significant at p<0.05, N = 630

Table 7 Association between preschool’s indoor VOCs with respiratory symptoms among study respondents

| Variables | Indoor VOCs | χ\textsuperscript{2} | p value | PR | 95% CI |
|-----------|-------------|----------------|--------|----|-------|
| | High (≥20.5 ppb) | Low (<20.5 ppb) |
| Cough | | | | | |
| Yes | 56 (20.5 %) | 121 (33.9 %) | 13.711 | 0.001* | 1.987 – 2.866 |
| No | 217 (79.5 %) | 236 (66.1 %) | | | |
| Wheezing | | | | | |
| Yes | 8 (2.9 %) | 91 (25.5 %) | 59.445 | 0.001* | 1.332 – 23.812 |
| No | 265 (97.1 %) | 266 (74.5 %) | | | |

*Significant at p<0.05, N = 630

Table 8 Factors influenced cough among study respondents after controlling all confounders

| Independent Variables | β | S.E | p-value | PR | 95% CI |
|-----------------------|---|-----|---------|----|-------|
| Constant | 0.931 | 0.089 | 0.001 |
| CO\textsubscript{2} | 0.992 | 0.349 | < 0.001** | 0.049 | 0.0018 – 0.128 |
| Temperature | -3.260 | 0.483 | < 0.001** | 0.015 | 0.009 |
| Humidity | -3.343 | 0.802 | < 0.001** | 0.035 | 0.007 – 0.170 |
| CO | -3.026 | 0.496 | < 0.001** | 2.696 | 1.360 – 5.341 |
| Air velocity | -2.496 | 0.578 | < 0.001** | 0.082 | 0.027 – 0.256 |
| PM\textsubscript{10} | -0.760 | 0.914 | < 0.001** | 1.454 | 0.827 – 2.557 |
| PM\textsubscript{2.5} | 1.083 | 0.642 | 0.047* | 2.954 | 0.840 – 10.387 |
| VOC | -1.926 | 0.588 | 0.406 | 0.468 | 0.078 – 2.804 |
| Indoor smoking | 0.208 | 0.236 | 0.379 | 1.231 | 0.775 – 1.954 |
| Hairy pets in the house | -0.201 | 0.291 | 0.490 | 0.818 | 0.462 – 1.448 |
| Cooking fuel | 0.454 | 0.550 | 0.409 | 1.574 | 0.536 – 4.622 |
| Carpet in the house | -0.125 | 0.232 | 0.592 | 0.883 | 0.560 – 1.392 |
| Mosquito repellants | 0.375 | 0.288 | 0.193 | 1.231 | 0.560 – 6.461 |

N = 630; 95% CI = 95% Confidence Interval; β = Regression Coefficient; S.E = Standard Error; Nagelkerke R Square = 0.330; **Significant at p < 0.001; *Significant at p<0.05

4. Discussion

Statistical analysis results showed that the indoor concentrations of CO, PM\textsubscript{2.5}, PM\textsubscript{10} and VOCs in RAP were significantly lower as compared to UAP and SAP. UAP recorded the highest mean concentrations of CO, PM\textsubscript{2.5}, PM\textsubscript{10} and VOCs. These could be explained by more polluted environment in this area. The average concentration of CO was highest in UAP (4.48 ± 1.12) ppm. High volume of road traffic and industrial activities within the vicinity might lead to higher indoor concentration of CO in UAP. Similar results were reported by Marzuki et al. [5] where outdoor combustion generated activities such as automobile exhaust from nearby roads or parking areas were believed to be the main sources of indoor CO. They reported that there was a significant difference (p< 0.05) between the means indoor CO where commercial area reported the highest value and suburban area has the lowest indoor CO. Building-related illness has been associated with the volatile chemicals in school’s cleaning agent used, chemicals off-gassing from newly installed floors or carpets, improper maintained exhaust and air intake systems. Statistical analysis has shown that there was a significant difference between indoor VOCs level between UAP, SAP and RAP (F = 5.832; p = 0.006). Indoor VOCs concentration levels were highest in UAP. It is suggested that this might be due to high VOCs emitting materials being used inside preschool building. According to our observation, most of the preschool furniture like chairs, tables and bookshelves were made of pressed woods (most pressed wood products contain urea-formaldehyde) may have cause the released of formaldehyde gases over a substantial period.
of time. These conditions were more pronounced among preschool with new furniture products. High indoor temperature and humidity in the preschools may contribute to the increased release of formaldehyde from these products. Respiratory health effects due to chemical emissions from new building materials such as paint, have been reported in Europe [11], but there was limited similar studies in Malaysia.

This study found that there were significant differences of indoor PM10 and PM2.5 among the UAP, SAP and RAP (p = 0.005; p = 0.005). UAP have the highest concentration of indoor PM10 and PM2.5, followed by SAP and RAP. The allowable standard for indoor PM10 concentrations were 150 μg/m³ [6] and the allowable standard for indoor PM2.5 is 65 μg/m³ [3]. All the UAP, SAP and RAP were having mean indoor PM10 below the recommended standard, (121.85 ± 33.45) μg/m³; (119.46 ± 43.10) μg/m³ and (80.46 ± 24.35) μg/m³ for UAP, SAP and RAP respectively. However, the mean indoor PM2.5 for UAP, SAP and RAP were above the recommended standard. Road traffic and emissions from the industrial activities nearby was considered to be the main source of PM10 and PM2.5 for UAP. Construction work such as the repair of roads and highway present in the urban area might also be one of the contributing factors to high level of PM10 and PM2.5 in UAP. It is also suggested that the high concentration of PM10 was rooted from the shelf areas and ceiling fans from the classes itself. Ismail et al. [7] concluded that indoor concentrations of pollutants released were influenced by surrounding human activities [7].

The age of the building, types of flooring, presence of curtains, shelf area, dust from blackboard and fans were the major sources of school indoor PM10. Yahaya et al. [8] reported that the indoor PM10 among homes located in the urban area (71.47 μg/m³) were significantly higher (p < 0.001) as compared to the homes located in rural areas (47.06 μg/m³). Salleh et al. [2] reported that the mean values of PM10 for six naturally ventilated classrooms were beyond the Malaysian Code of Practice [6]. They suggested that the outdoor particles were the main source of indoor PM10 in the schools involved in their study. Study conducted by Nurul Anis et al. [9] showed that the indoor PM2.5 concentration was significantly difference between exposed and comparative groups with (t=−2.496, p=0.014).

According to Nur Aida et al. [10], the median (interquartile range) concentration of PM2.5 (63.0 (32) μg/m³) and PM10 (68.2 (31) μg/m³) in preschools from urban area were slightly higher compared to the preschools in rural area (PM2.5 = 55(37) μg/m³; PM10 = 62 (35) μg/m³). It was suggested that preschool children in urban area are highly exposed to indoor air particles compared to those from the rural area.

Statistical results from the Chi-square test showed that there were significant difference between cough and wheezing among respondents with (χ² = 25.462, p = 0.001) and (χ² = 27.299, p = 0.001) respectively. Results showed that children from UAP have higher prevalence of cough (36.2%) as compared to SAP (32.7%) and RAP (15.6%). Meanwhile, children from the SAP reported highest prevalence of wheezing (26.4%) as compared to children from an UAP (11.4%) and children from RAP (9.4%). Multiple Logistic Regressions were conducted to assess the factors influenced the respiratory symptoms among pre-schoolers involved in this study. Results showed that cough symptoms among preschoolers were significantly associated with the preschool indoor concentration of CO (OR = 2.696; 95% CI = 1.60–5.341), PM10 (OR = 1.454; 95% CI = 0.827–2.557) and PM2.5 (OR = 2.954; 95% CI = 0.840-10.387) after controlling for all the confounders (parents’ income, parental education, home indoor exposure). Several local studies found an association between the presence of acute respiratory symptoms and short term reduction of pulmonary function with exposure to particulate matter [12]. Study done by Nazariah et al. [13] showed a significant association between indoor PM10 and reported respiratory symptoms in an urban area for cough (OR=1.81, CI 95%=1.18-2.79), phlegm (OR=2.45, CI 95%=1.42-4.24) and wheezing (OR=5.43, CI 95%=2.21-13.37). Similar results were obtained by Nur Azwani et al. [14], where their study revealed that the prevalence of respiratory symptoms was higher among studied children for cough (OR = 3.23, 95% CI = 1.24–8.40) and wheezing (OR = 2.56, 95% CI = 1.02–6.47). Her findings concluded that exposures to poor IAQ might increase the risk of getting respiratory problems among study respondents.

5. Conclusion

In summary, indoor concentrations of CO, PM10, PM2.5 and VOCs were significantly higher among the UAP. This could be explained by preschools’ location (UAP) which were close to main traffic ways and industrialized areas (higher air pollution areas) were linked to higher concentrations of IAPs among the preschools involved in this study. Findings from this study indicated that the exposures to poor IAQ and increasing levels of IAPs were the risk factors that had caused an increasing report of respiratory symptoms among the study respondents. Cough symptoms...
among preschoolers were significantly associated with the preschool indoor concentration of CO, PM_{10} and PM_{2.5}. Preschool IAQ may have not been widely recognized as a major health issue among preschoolers in Malaysia, it is important that we acknowledge the potential problems to exist. There is a need to develop a more definite evidence base to examine the relationship between IAQ parameters exposure and other health outcomes in order to inform considerations on public policy and clinical care for preschoolers.

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