Indoor-Outdoor Air Quality Assessment in Nurseries

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Abstract. Poor Indoor Air Quality (IAQ) can adversely affect children’s health, comfort and school performance. This study mainly aimed to assess indoor and outdoor air quality status in terms of physical and chemical aspects at nurseries of two higher public institutions. The monitored parameters are temperature (T), relative humidity (RH), air movement (AM), particulate matter (PM), carbon dioxide (CO₂) and carbon monoxide (CO) by using Climomaster (RH, T, AM), Dust Trax™ (RSP ) and Kanomax IAQ (CO, CO₂). The measurement was taken continuously in a period of three days at two nurseries of public institutions. Results show all chemicals contaminants at two nurseries did not exceed the standard except CO₂ for indoor concentration. Indoor-Outdoor (I/O) ratio stated that PM₁₀ concentrations were influenced by the outdoor contaminant for both study areas. In conclusion, this study provides useful information for engineers, policy makers and planners to make decision on managing and improving the environment in terms of air quality.

1. Introduction

Air pollution is the most interesting environmental issue in the world including Malaysia because of their rapid development which becomes a major concern. This is because it could be harmful to the health, comfort of humans and other living things as air contains dust, fumes or odour in harmful amount [1]. There are two major contributions to air pollution which is indoor and outdoor air pollution. In previous year, outdoor air pollutants have remained a prime environmental risk to human because in urbanization and industrialisation development, the concentrations of outdoor air quality far exceeded the limit stated by World Health Organization guideline [2]. Currently, Indoor Air Quality (IAQ) has received a great attention from people all around the world since previous research has located around 90 percent of humans spend near 22 hours indoor each day [3]. People think that, indoor air is safe and protective to live more than 8 hours, but indoor air pollution is actually dangerous than outdoor air pollution. Indoor pollution in dust and air are frequently generated from various sources including environmental tobacco smoke, building materials, fixtures, cleaning and...
hygiene products, air fresheners, computers, printers, cooking and other indoor activities, and from humans themselves [1, 2, 3]. IAQ can lead to decreased productivity and absenteeism. Other than that, in 2016, indoor and outdoor air pollution contributed to respiratory tract infection that lead to the death of 543,000 children younger than 5 years [4]. The common sources of outdoor air quality are emissions due to combustion strategies from motor automobiles, stable fuel burning and industry, smoke from bushfires, windblown dirt, and biogenic emissions from plants [5]. Outdoor or ambient air is polluted with a dynamic mixture of pollutants from both natural and man-made sources [6] that can enter the building and affect the IAQ. Schools located in urban areas and cities with high traffic levels that exposed to air pollution give influence of outdoor sources on classroom indoor air quality [7]. Thus, good air quality towards children’s is important to avoid short- and long-term health effects such as respiratory infections, allergies, and asthma [1]. Therefore, maintaining good air quality in the nurseries is essential to children because they are one of vulnerable group.

2. Experimental

2.1. Site selection
The study areas covered the District of Kuala Nerus, Terengganu State. Taska Permata Keluarga UMT (S1) and UniSZA (S2) were chosen in this study. Taska Permata Keluarga UMT is a nursery located in University Malaysia Terengganu while Taska Permata Keluarga UniSZA located in University Sultan Zainal Abidin. Both nurseries have the same surrounding activities, located inside the institutional area. The sampling location was shown in figure 1.

![Figure 1. Study area.](image)

2.2. Data analysis
Measurements of indoor and outdoor air quality were conducted to assess the level of indoor and outdoor air pollutant in both nurseries. The assessments of IAQ at the both nurseries were conducted according to the Industry Code of Practice (ICOP) (2010) by Department of Safety and Health while New Malaysia Ambient Air Quality Standard (NMAAQS) was used for outdoor air quality. Chemical and physical parameters were measured in this study. Physical parameters that been measured including relative humidity (RH), temperature (T) and wind speed (WS) while chemical parameters were carbon dioxide (CO₂), carbon monoxide (CO) and particulate matter with diameter 10μg/m³ (PM₁₀). Kanomax IAQ model 2211 was used to measure carbon dioxide and carbon monoxide and Dust Trax™ Aerosol Monitor 8534 was used to measure the particulate matter. Kanomax Climomaster used to measure the physical parameters for indoor and outdoor air quality. The data were collected for 3 days during school days for all nurseries. Sampling duration for each nursery is eight hours starting from 0800 hours to 1700 hours. The reading was taken every five minutes in interval of one hour.

Descriptive analysis and I/O ratio were used to determine relationship between indoor and outdoor relationship in two nurseries by using Microsoft Excel and Statistical Package for the Social Sciences (SPSS®) version 22.0. I/O ratio directly represents the relationship between indoor and outdoor
particle concentrations, which is very easy to understand and widely used. Thus, I/O ratio data were summarized in order to provide a general impression on the relationship between indoor and outdoor particles.

3. Results and discussions

The descriptive statistics for all parameters was conducted using SPSS® as shown in table 1, used to summarizes the main statistical parameters which are minimum, maximum and median of the hourly mean values of indoor and outdoor parameters for each selected point in the nurseries. Median was used in this study due to the data set was not normally distributed due to the skewness and kurtosis showing abnormality. All the data sets have skewness ranged from 5.685 to 11.461 and kurtosis ranged -0.546 to 131.571. Normally data distributed must have skewness near zero and kurtosis near 3 and data sets in this study were different from this statement due to different activities such as sweeping and movement of the children in the nurseries [8]. All parameters, except outdoors temperature show the data were not normally distributed because the significant value (p-value) was less than 0.05 via Kolmogorov-Smirnov and Shapiro-Wilk [9]. The abnormality data were due to uncontrolled factors inside the nurseries and outdoors activities such as number of vehicles around both nurseries, number of people that walk around the nurseries and cleaning activities performed inside and outsides the nurseries.

The level of indoor PM_{10} was higher during 10 am in the morning because of activities inside the building such as sweeping and cooking while the window is closed which shown in figure 2.a). Previous study stated that cooking and cleaning activities were found to contribute significantly to higher PM concentration and corresponding to elevated levels of PM in the building [6]. The outdoor concentration was higher due to heavy traffic and was highly polluted with activities such as sending children to the nurseries using cars and motorcycles. The major sources of outdoor PM_{10} were secondary pollution (41%) and motor vehicles (26%) [10]. Trends of the chemical parameters were shown in Figure 2. Figure 2(c) and 2(d) show the concentration of CO_{2} in two different nurseries with ranged from 603.50 – 1155.50 ppm especially in S2 for indoor concentration which is not all time is complied with ICOP-IAQ (2010). This incompliance was due to all occupants gather in a small room for having breakfast without open the windows around 9am besides the high number of occupants at S2. The indoor CO_{2} concentration in nurseries usually used as an alternative to describe the ventilation rate. Previous study reported the monitored rate of indoor CO_{2} concentration in the nurseries and most of those previous studies concluded that insufficient ventilation rate was a common problem associated with participating space [2]. Figure 2(e) and 2(f) show the level of CO concentration at two different nurseries. Compliance of CO with standard was important because high concentration of CO can cause headache, dizziness, nausea, sickness, coma and long lasting neurological effects especially towards children [11]. CO concentration started to increase in the morning and decrease at the evening, influenced by cooking activities in the nurseries. Household appliances such as gas fires, boilers, cookers, and open fires which use gas may be possible sources of CO gas [12] while for outdoor CO concentration was increase due to motor vehicles running engine can produce amounts of CO within 10 minutes [13].
Table 1. Descriptive Statistics of IAQ parameters at study areas.

| Study Area | Parameters | Med     | Min     | Max     | IAQ  | Med     | Min     | Max     | NAAQS |
|------------|------------|---------|---------|---------|------|---------|---------|---------|-------|
|            | Indoor TPK UMT |         |         |         |      | Outdoor TPK UMT |         |         |       |
| PM₁₀ (mg/m³) | 0.0360     | 0.0300  | 0.0615  | 0.15   | 0.0358 | 0.0290  | 0.0475  | 0.1    |
| CO (ppm)   | 0.2500     | 0.1000  | 0.8000  | 10     | 0.3000 | 0.1000  | 0.6500  | 30     |
| CO₂ (ppm)  | 646.50     | 603.50  | 1762.50 | 1000   | 597.00 | 544.50  | 708.00  |        |
| T (ºC)     | 28.650     | 27.450  | 29.100  | 23-26  | 28.700 | 27.250  | 29.700  |        |
| RH (%)     | 74.900     | 72.850  | 77.000  | 40-70  | 74.350 | 72.050  | 79.450  |        |
| WS (m/s)   | 0.1900     | 0.0500  | 0.9400  | 0.15-1.50 | 0.2475 | 0.0650  | 0.7100  |        |
|            | Indoor TPK Unisza |         |         |         |      | Outdoor TPK Unisza |         |         |       |
| PM₁₀ (mg/m³) | 0.0305     | 0.0220  | 0.0695  | 0.15   | 0.0315 | 0.0195  | 0.0475  | 0.1    |
| CO (ppm)   | 2.2250     | 1.8500  | 3.0000  | 10     | 2.4500 | 1.3500  | 3.3500  | 30     |
| CO₂ (ppm)  | 901.25     | 800.50  | 1155.5  | 1000   | 824.00 | 778.50  | 919.50  |        |
| T (ºC)     | 28.950     | 25.300  | 30.550  | 23-26  | 29.450 | 25.250  | 33.850  |        |
| RH (%)     | 74.925     | 59.800  | 87.500  | 40-70  | 74.950 | 64.400  | 91.400  |        |
| WS (m/s)   | 0.2300     | 0.1100  | 0.9450  | 0.15-1.50 | 0.1950 | 0.0650  | 0.6550  |        |

Figure 2. a) Indoor PM₁₀ concentration. b) Outdoor PM₁₀ concentration. c) Indoor CO₂ concentration. d) Outdoor CO₂ concentration. e) Indoor CO concentration. f) Outdoor CO concentration.

Indoor-outdoor ratio or I/O ratio was used to determine the relationship between indoor and outdoor pollutants to exhibit considerable variation. The result of I/O > 1, indoor concentration is higher than the outdoors and could be due to indoor sources, 0.9 < I/O < 1, indoor concentration is equilibrating with outdoor concentration and I/O < 0.9 indoor concentration is lower than the outdoor which is illustrating possible outdoor influence [4,11]. Table 2 shows the summary of indoor-outdoor ratio of all parameter’s concentration. PM₁₀ concentration in S1 is higher than S2 where the I/O ratio of S1 is 1.00 and S2 I/O ratio was 0.97 which is indoor equilibrium by the outdoor contaminant. Indoor-outdoor ratio at the selected areas was less than 1 except carbon monoxide for both area and wind.
speed at S2 which proved that both indoor air quality in the kindergartens was equilibrium or has possibility influenced by outdoor activities due the nursery is located besides of the roadside where the motor vehicles passed by. Most likely, the relationships between indoor levels caused infiltration of outdoor pollutants towards indoors affected in indoor level of air pollution and occurred in most chemical parameters in this study [15,16]. Exposure of IAQ occurs caused by human activities, natural environment and both strength of their correlation varies between sites. CO₂ in this study generated from indoor sources which influenced by crowded of children without proper ventilation [15]. In addition outdoor levels of different air pollutants vary between studies area due to differences in factor, e.g. climate, building characteristics, human activity, ventilation and heating systems.

Table 2. Summary of indoor-outdoor ratio parameters concentration.

| Param. | Med ± Std (Indoor) | Med ± Std (Outdoor) | I/O Ratio | Med ± Std (Indoor) | Med ± Std (Outdoor) | I/O Ratio |
|--------|-------------------|-------------------|-----------|-------------------|-------------------|-----------|
|        | Sampling Site 1 (S1) | Sampling Site 2 (S2) |           |                   |                   |           |
| PM₁₀ (µg/m³) | 0.036±0.004 | 0.036±0.004 | 1 | 0.031±0.011 | 0.032±0.007 | 0.97 |
| CO (ppm) | 0.250±0.198 | 0.300±0.134 | 0.83 | 2.225±0.276 | 2.450±0.375 | 0.91 |
| CO₂ (ppm) | 646.5±41.61 | 597.0±32.87 | 1.08 | 901.2±69.26 | 824.5±34.49 | 1.09 |
| RH (%) | 74.90±0.81 | 74.35±1.08 | 1.01 | 75.15±6.64 | 74.95±6.614 | 1 |
| Temp (°C) | 28.62±0.326 | 28.70±0.325 | 0.99 | 28.95±1.078 | 29.45±2.071 | 0.98 |
| WS (m/s) | 0.175±0.176 | 0.248±0.159 | 0.71 | 0.230±0.193 | 0.195±0.150 | 1.18 |

4. Conclusions
Trend of indoor-outdoor chemical and physical parameters at both study areas have been summarize using descriptive statistics and boxplot analysis which showed that, all chemicals contaminant at two nurseries did not exceed the standard approved by ICOP-IAQ (2010) except for CO₂ (603.50 – 1155.50 ppm) for indoor concentration. The I/O ratios were applied to obtain the relationship between two parameters. For I/O ratio showed those PM₁₀ concentrations and all others chemical parameters at both study areas were influenced by the outdoor contaminants.

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