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CO_2 FIELD EVALUATION OF NATURAL VENTILATION CLASSROOM IN REFURBISHED PRESCHOOL

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Abstract

Private preschools in Malaysia have shown significant inclination throughout years however recent studies for Indoor Air Quality (IAQ) targeting more on school rather than preschool building. It is contradicting as preschool students are susceptible to unhealthy environment as they often spend time indoors plus their metabolism level is different than an adult. Therefore, this study emphasises IAQ in the classroom of two refurbished preschool buildings. Besides, their correlation with the space of classroom and number of children are also being determined. The case study is conducted in Penang Island based on the type of building (double storey house) with natural ventilation system. Parameter such as carbon dioxide (CO_2) is measured and analysed to compare with the existing standard and regulation which are i) Industrial Code of Practice (ICOP), ii) American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and iii) Uniform Building by Law (UBBL). Findings indicate the maximum concentration of indoor CO_2 reached more than 1000 ppm for classroom that exceeds the 15 person/classroom limit, which did not comply to ASHRAE and ICOP standards. The excessive of CO_2 caused from several factors such as openings of door and window, space of the classroom and the number of pupils in the classroom.

Keywords: Preschool, carbon dioxide, ventilation, classroom.

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1. Introduction

Studies on air quality in terms of CO_2 concentration level in educational buildings have been conducted in other countries. Some of them reported that the CO_2 concentration level exceeds 1000 ppm (Lee & Chang, 2014; Mainka & Zajusz-zubek, 2015; Vilčeková, Kapalo, Meciarova, Burdova, & Imreczeova, 2017; Persson, Wang, & Hagberg, 2018). However, it is known that the indoor CO_2 concentration level should not exceeds 1000 ppm as compliance with ASHRAE and ICOP (ICOP, 2010; Salleh, Kamaruzzaman, Riley, Zawawi, & Sulaiman, 2015).

Lazovic, Stevanovic, and Zivkovic, (2015) mentioned that the CO_2 concentration acts as an indicator in IAQ. Besides, the CO_2 concentration distribution is affected by the type of ventilation strategy (Mahyuddin & Awbi, 2012). According to UBBL Part 111 Section 39(3), a total area of each class should be < 20% of the clear floor area of the room should be equipped with natural ventilation through of one or more windows that allow continuous airflow of not less than 10% of floor area (UBBL, 2016). Moreover, Mahyuddin and Awbi (2012) mentioned that human exhalation is a significant source of indoor CO_2 concentration. In correlation to this, the average range of CO_2 concentration exhaled by a human is 4.0% to 5.2% (Cichowicz, Sabiniak, & Wielgosiński, 2015). Therefore, the number of occupancies (pupils) plays a greater impact on the increased level of CO_2 concentration.

The number of private preschool is higher than public preschool (56% of private preschool, Jabatan Kemajuan Masyarakat KEMAS (22%), Malaysia Of Education (MOE) (18%) and JPNIN (4%)) (MOE, 2018). As stated by Salleh et al. (2015), double storey house which converted into classrooms of private preschool obtained the highest percentage. At least space allocation of $2m^2$ per person and $40m^2$ per 20 persons is required for classroom (UBBL, 2016). Depending on the area of the classroom, MOE mentioned that the number of occupants in the classroom required should not be more than 15 persons Salleh, Agus Salim, Kamaruzzaman, & Mahyuddin, 2016). Hence, the number of occupants (pupils) in the classroom influences the CO_2 concentration whereby it affects pupils' health and learning performance such as drowsiness, tiredness, and lethargy in the classroom (Mahyuddin & Awbi, 2012).

2. Problem Statement

Most people spend about 90-95% indoors rather than outdoors (Vilčeková et al., 2017) where children spend 7 to 11 hours per weekday at school (Pegas et al., 2010). Pupils spending most of their daytime in the classroom are exposed to health problems which are frequently triggered by inadequate ventilation (Salleh, Kamaruzzaman, & Mahyuddin, 2013). Children's respiratory and immune systems are weaker than adult which made them more sensitive to environmental exposure (Oliveira, Slezakova, Delerue-Matos, Pereira, & Morais, 2016). There are several sources that influence the CO_2 concentration such as equipment of ventilation, furniture, human factors (breathing) and activities (number of pupils in the classroom, class duration, break time) (Lazovic, Stevanovic, & Zivkovic, 2015). Nevertheless, when the classroom experiences full occupancy, the carbon dioxide concentration often exceeds 1500 ppm (Cichowicz et al., 2015). Consequently, inadequate ventilation is likely to be caused by increasing CO_2 concentration level (Shaughnessy, Haverinen-Shaughnessy, Nevalainen, & Moschandres, 2006).

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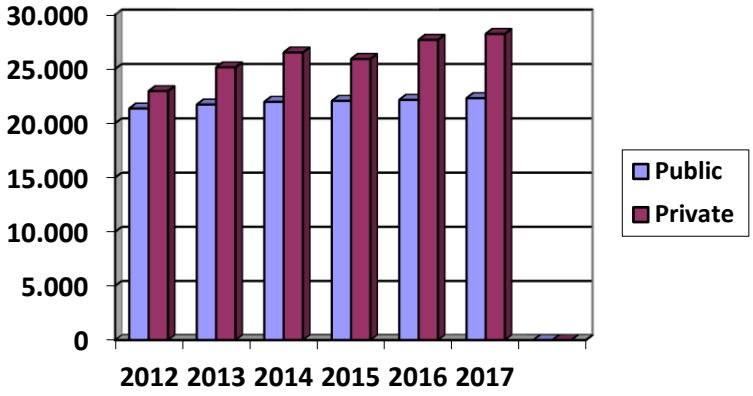

Figure 01. Total number of public and private preschools. Source: (MOE, 2018)

Figure 1 illustrates the number of enrolments in private preschools throughout the years from 2012 until 2017. The actual total space per room is set at 9 m² to 23 m² for about 15 to 20 pupils in the refurbished preschool's classroom (Salleh et al., 2015). Thus, inclination in the number of refurbished private preschool throughout the years (except for 2015) proven the essentiality of providing comfortable space for pupils in preschool classroom.

3. Research Questions

The research questions for this study are:

- Do refurbished private preschool classroom area appropriate for pupils?
- What is the correlation between classroom, carbon dioxide and ventilation mode in refurbished preschool building?

4. Purpose of the Study

The research aims to determine the carbon dioxide concentration distribution in the classroom following with the existing standard and regulation provided such as ICOP and ASHRAE and its association with space and pupils.

- To determine the variation of carbon dioxide (CO_2) in the existing private preschool classroom in natural ventilation mode;
- To define the CO_2 concentration and its relation to classroom area, ventilation strategies and number of children.

5. Research Methods

Two private preschool buildings were selected as a case study which located in Penang Island area only. The selection of the case study is based on the type of preschool premise building, location of preschool which situated in a residential area, and the physical activity in the preschool. The selection of

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preschool building based on the list of registration preschool by Malaysian of Education (MOE). Figure 2 shows the location of P1 and P2 located in residential areas.

Figure 02. Location of case study. Source: (Google earth, 2019).

Table 1 shows the case study labelling for each preschool building. Each case study was labelled differently (P1 indicates the first preschool, whereas P2 indicates the second preschool building). This was done to facilitate for analysing and collecting data.

Table 01. Case study labelling

Location	Preschool	Classroom
Teluk Kumbar	P1	P1-C1
		P1-C2
Bayan Lepas	P2	P2-C1
		P2-C2

5.1. The measurement instrument and procedure

The measurement focused on natural ventilation mode in the classrooms. Parameter of carbon dioxide was measured by using the TSI model 7525 with accuracy of±3.0% of reading or ±50 ppm. Both preschools data collection was carried out for three days. Table 2 illustrates the characteristic of each preschool classroom based on a different aspect which are type of ventilation, construction activity, number of pupils per classroom, and the classrooms' areas. Each class had a different type of classroom area and various number of students.

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Table 02. Characteristic of preschool classroom

Case characteristic	Preschool 1(P1)		Preschool 2 (P2)	
	C1	C2	C3	C4
Type of Ventilation	Natural Ventilation			
Construction Activity	No			
Number of Ceiling fan	1	1	1	1
Classroom Area (m^2)	14.00	22.10	22.11	17.08
Maximum student capacity per classroom	20	16	13	13

Measurements for all selected preschools were performed during working days only (Monday until Friday). The measurement was collected in the classroom at a specific point which was allocated at 1m apart from the wall and recorded every 1 minute for 8 hours from 7:30 am until 1:30 am. To ensure the accuracy of every data, the data was collected for every 1-minute interval. Initial reading was taken before pupils entered the classroom to obtain neutral reading that can acted as base reading for further comparison. The measurement was done for three days in each classroom (each point) to develop the mean, maximum and minimum value. The instrument was placed on the tripod. Data collected was then analysed by using Microsoft Excel.

6. Findings

Figure 3 and 4 illustrate the concentration of CO_2 based on the two selected preschool building which being measured during weekday.

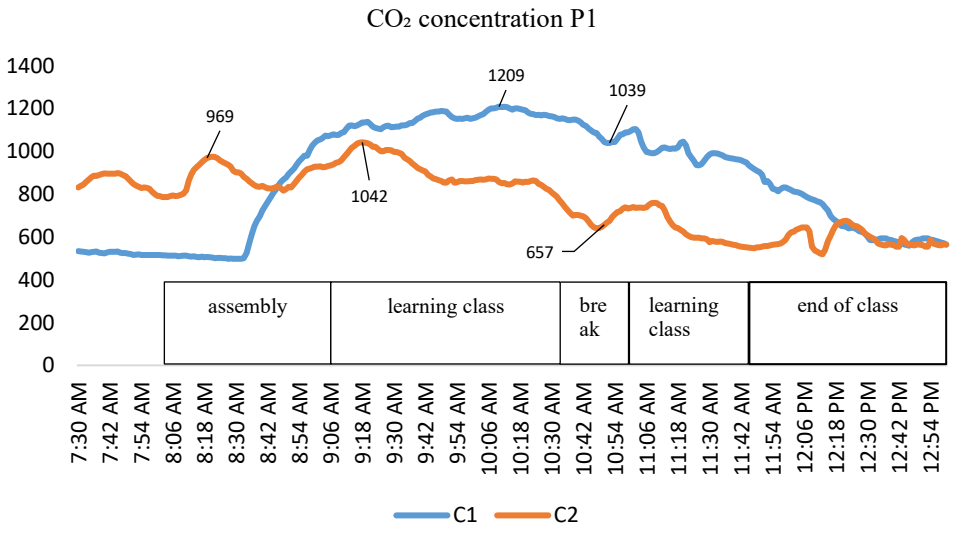

Figure 03. The CO_2 concentration of P1-C1 and P1-C2

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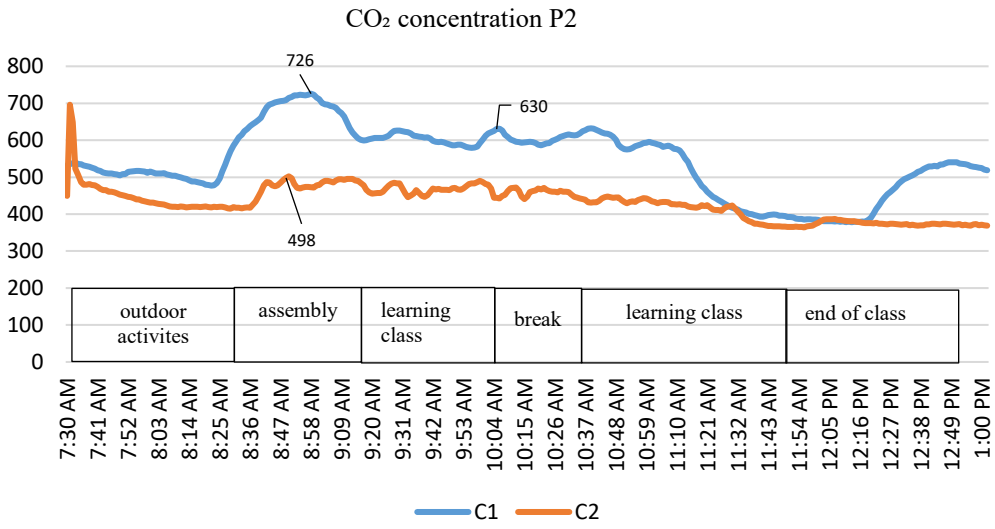

Figure 04. The CO_2 concentration of P2-C1 and P2-C2

In preschool P1, the concentration obtained was the lowest before class started (7:30 am to 8.30 am), during break time (10:45 am) and at the end of the class (noon). However, during learning class, the value of CO_2 concentration exceeds 1000 ppm at 10.19 am for P1-C1 and 9:40 am for P1-C2. In P1 preschool, the CO_2 concentration was low until 8:30 am in every classroom as the room was empty and pupils gathered in another room. Noted that only a few students entered it to place their bag in the class for a short while. The increasing CO_2 level caused by the number of pupils in the classroom, which exceed 15-16pupils classroom and the number of students did not comply with the area of class $2m^2$/ person. Moreover, the windows were slightly opened causing insufficient outdoor air entered into the classroom.

In preschool P2, the concentration was the lowest before class started at 8:18 am, during break time at 9:80 a.m. and when the classroom was unoccupied at 11:18 a.m. The concentration of CO_2 rose during learning class at 8:42 a.m. Although the value of CO_2 concentration increased during the learning class, it did not exceed the standard limitation of 1000 ppm. It was proven that the ventilation in preschool P2 was good. The classroom abled to occupy 15 pupils/classroom, but there were only 13 pupils in it. Furthermore, all its windows and door functioned well, and there was maintenance for ceiling fan and stand fan. Thus, airflow in the class can be circulated well.

Table 03. Average, Minimum(min), Maximum(max), Mean and Standard Deviation (SD) value of CO_2 concentration of preschool classroom

	Preschool Classroom			
	P1-C1	**P1-C2**	**P2-C1**	**P2-C2**
Min	498	519	391	363
Max	1209	1042	921	490
SD	256.0	148.0	92.4	45.0
Mean	870.8	771.1	620.9	405.44

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Table 3 illustrates the minimum, maximum, standard deviation (SD) and mean of CO_2 concentration for P1 and P2. Based on table 3, the average value of CO_2 concentration complied with ASHRAE and ICOP standard and regulation, which it did not exceed 1000 ppm. However, the maximum value of CO_2 for P1-C1 and P1-C2 surpassed the 1000 ppm limit. The results for SD of CO_2 concentration for P1 were P1-C1(256.0), P1-C2(148.0), whereas for P2, P2-C1(92.4) and P2-C2(45.0). The minimum value indicating the situation of where there were no pupils in the class (before class start, during break time, and at the end of class) read lower than 1000 ppm.

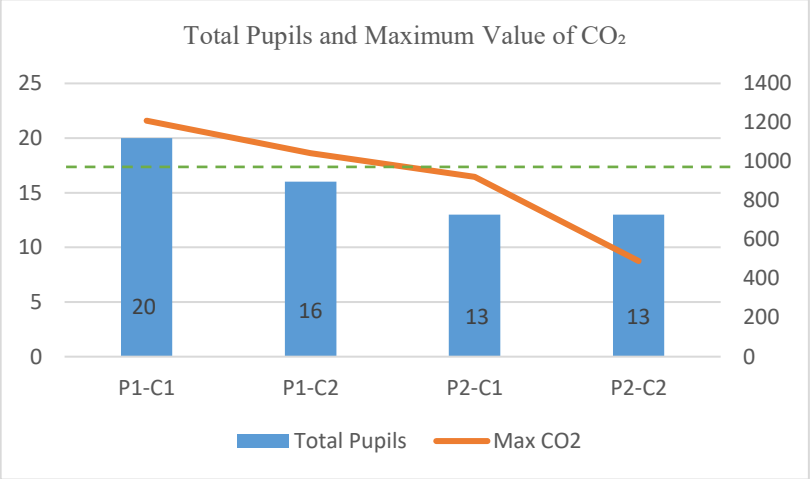

Figure 05. Total pupils and maximum value of CO_2 for each classroom.

Based on Figure 5, the level of CO_2 concentration was affected by the ventilation strategies and the number of occupants in the classroom. P1-C1 class with 20 pupils achieved the highest CO_2 concentration (1209 ppm), followed by P1-C2 consisting of 16 pupils (1042 ppm), while P2-C1 with 13 pupils (921 ppm) and P2-C2 with 13 pupils obtained the lowest of CO_2 level of 490 ppm. By referring to the formula specified by MOE (Salleh, Agus Salim, Kamaruzzaman, Mahyuddin, & Darus, 2016), P1-C1 did not comply with the guideline.

7. Conclusion

Children often spend time indoors thus they were susceptible to the unhealthy environment and their metabolism level different than an adult. The data was measured and analysed to compare with the existing standard and regulation such as ICOP and ASHRAE. It showed that during learning class, P1 achieved the maximum concentration of indoor CO_2 which exceeded the standard limit provided by ASHRAE and ICOP (<1000ppm). Excessive concentration of indoor CO_2 was caused by several factors which were door and window openings, space of the classroom and the number of pupils in the classroom. Aforementioned, inclination for the indoor CO_2 concentration occurred during learning class. Noted that the indoor CO_2 concentration during break time was slightly different from learning class as it was in short duration and most of the pupils remained inside the classroom. Hence, it was justified that the indoor CO_2 concentration will increase when there is any physical activity conducted by the children inside the class.

Also, space per children in the classroom contributed to the rising of indoor CO_2 concentration. For this study, the existing allocation of space was checked of its compliance with UBBL (2m² per person) and MOE (15-16 pupils/classroom) regulations. Noted that P2 had only 13 pupils per classroom (<15 pupils per classroom) which resulting on the CO_2 reading not exceeding 1000 ppm limit. The movement of pupils which closed to each other in occupied space tends to raise the CO_2 concentration level. They will experience such discomfort, health problem (dizziness, sweat) and these could affect their learning performance as they tend to lose focus during learning class. This proven that P2 had a good ventilation system. In conclusion, further investigation needed to be conducted to study on the management strategies of pupils per classroom and the ventilation system which monitored the CO_2 concentration level in the preschool classroom.

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