Assessment of indoor air quality of daycare centres in northern area of peninsular Malaysia: A case study in Perlis

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Abstract. Indoor air quality (IAQ) in day care centers (DCCs) is an emerging research topic nowadays. The paper presents both quantitative and qualitative assessment of IAQ in DCCs in Northern Peninsular Malaysia especially at Perlis. Indoor air pollutants such as total volatile organic compound, carbon monoxide, and ozone have been linked to many health effects in babies, toddlers and kids below 4 years old. The aim of this study was to investigate and quantify the exposure level of indoor air contaminants within the chosen DCCs at Perlis, Malaysia. IAQ monitoring was carried out at two DCCs located in different areas of Perlis which are Kangar and Pauh. The selected parameters measured were total volatile organic compound, carbon monoxide and ozone using the Department of Occupational Health and Safety analytical method. DCC at Kangar was exposed to high air pollutants compared to DCC at Pauh because it may enter their buildings from various adjacent sources as it is situated beside the busy roadside area. Anyway, the selected indoor air pollutants examined at both DCCs are not exceeding the acceptable level of standard guidelines, thereby the kids' health are not likely to affected by these selected indoor air pollutants.

1. Introduction

Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants and it can affect a person's health, comfort, and ability to work. According to a statistical survey funded by the U.S. Environmental Protection Agency (EPA) states that nearly 90% of people spent their time in indoor environment and exposing to poor IAQ will cause many health effects to the occupants [1]. Focusing, babies, toddlers and kids who are less than 4 years old are more vulnerable to any diseases and especially poor IAQ will affect their health thoroughly where they might get incurable chronic diseases in their later life.

Thus, this project is planned to be carried out only at daycare centres (DCC) and by referring to the Child Care Centre Act 1984, the child care centre/ daycare defined that any premises at which four or more children under the age of four years from more than one household are received to be looked after for reward [2]. Hygiene and the cleanliness of these places should be well maintained to ensure the well-being of the kids. Thus, the environment of the day care centres is assessed especially indoor environment mainly the air quality in such it is suitable for the kids to live in.

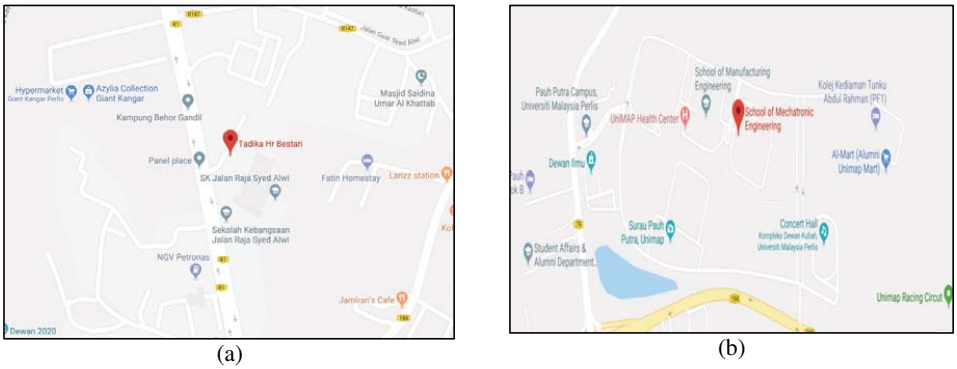
There are many researches which were conducted nationally and internationally which have proved that there are significant association between poor IAQ and the health problems in children. But there is no found researches done specifically in Northern Peninsular Malaysia especially at Perlis, thus, this project is the first research on examining the quantitative assessment on IAQ focussing on children who are raised in daycare centres respectively and it can be considered as the baseline study in future. The project is very beneficial to the nation as they can identify the contribution of indoor air quality to the health of the children who are raised in the daycare centres around Northern Peninsular Malaysia especially at Perlis.

2. Materials and Methods

2.1. Study location

This study was carried out at registered daycare centre (DCC) in Ulu Pauh and Kangar city in Perlis, selected wisely by referring to all criterion stated in Industry Code of Practice (ICOP) 2010 especially that the DCC should be fitted with mechanical ventilating air conditioning (MVAC) [3]. The daycare centres are Taska Pewaris UniMAP Pauh and Taska HR Bestari which were located at the latitude and longitude of (6.445398, 100.199138) and (6.461174, 100.353179) respectively.

Pauh DCC is located in the UniMAP campus and servicing for only UniMAP staffs while the Kangar DCC is located in the centre of the town area which is open to public. Pauh DCC is located exactly in the School of Mechatronic Engineering which is enclosed by buildings while Kangar DCC is located along the residential area and beside the roadside. The map in the Figure 1 shows both DCCs that were chosen as the study area prior to the IAQ monitoring. This project is planned to be carried out for two months period. The IAQ monitoring and health risk survey were conducted throughout the period.



(a) (b)

Figure 1. The location of (a) Taska HR Bestari, Kangar and (b) Taska Pewaris UniMAP, Pauh.

2.2. Instrumentation and procedure

IAQ monitoring was conducted in both Pauh and Kangar DCCs respectively on weekly basis for two months period starting from January until February. The trends of the IAQ pollutants for these two months period were recorded and analysed periodically. The areas of both DCCs are below 2000 m^2

and both of daycare centres were determined to have three sampling points depending on the usage of each points. The type of ventilation we used also majorly affect the level of indoor air pollutants inside the indoor area and thus the type of air ventilation systems at each monitoring location at each daycare centres wa also taken into account as shown in Table 1 below:-

Table 1. Type of air ventilation systems at each monitoring locations.

Pewaris Generasi Unimap Pauh DCC, Pauh Putra			**HR Bestari Daycare Centre, Kangar**		
Hall 1	Sleeping Room	Hall 2	Hall	Activity Room	Sleeping Room
Three centralised units of Air Conditioning	One split unit of Air Conditioning	One centralised units of Air Conditioning	Two fans	One split unit of Air Conditioning & One celling fan	One split unit of Air Conditioning & One celling fan

Moreover, only chemical contaminants such as total volatile organic compounds (TVOC), carbon monoxide (CO) and ozone (O_3) are monitored in this study. Real-time monitoring method was used for detection of contaminant sources and to provide information on the variation of contaminant levels throughout the day [3]. Integrated samples, normally obtained during the 8 working-hours for organization, can provide information on the total exposure level of a particular contaminant. Measurement of IAQ parameters was made on an 8-hour basis where intermittent measurement strategy of half an hour measurements per time slot for 4 interval times slot was adopted in this IAQ assessment. The time slot will be 8-10 am, 10-12 pm, 1-3pm and 3-5pm respectively. The four time-slots IAQ measurements were planned evenly over the office operating hours at the proposed sampling locations. Real-time monitor was used and at least one reading was taken every 5 minutes at each sampling point either with a data logging device or by properly recorded in a field data log sheet, regardless of whether the 8-hour continuous or surrogate measurement strategy is adopted. The equipment used for real time monitoring was Aeroqual series 500. The test parameters and the minimum and maximum setting is shown in Table 2.

Table 2. The test parameters and the minimum and maximum value for each parameter.

Instrument	**Test parameters**	**Minimum Value (ppm)**	**Maximum Value (ppm)**
Aeroqual Series 500 	Ozone (O_3)	0.0	3.0
	Total Volatile Organic Compounds (VOC)	0.0	10.0
	Carbon Monoxide (CO)	0.00	0.05

All data obtained from the monitoring were analysed after the monitoring work was done for two months period. The analysed data will be depicted in weekly boxplots and diurnal boxplots to determine the trend of the indoor air contaminants present in both daycare centres respectively. The association between the pollutants will be depicted in the Pearson Correlation while the p-value will be tested for both populations at DCCs using independent sample t-test.

3. Results and Discussion

3.1. Variations of indoor air pollutant concentration

Table 3 shows the weekly average values of IAQ pollutants at both DCC. Monitoring data shows that the Hall 1 at Pauh Daycare Centre and Activity Room at Kangar Daycare Centre are having high level of indoor air pollutants compared to other locations in the respective daycare centres. This is because the air ventilation system used in the Hall 1 of Pauh Daycare Centre are three centralised units of air conditioning and the Activity Room at Kangar Daycare Centre, one split unit of air conditioning and one ceiling fan. Poor maintenance and uncleaned air ventilation system at this respective Hall 1 and Activity room also cause this quite high level of indoor air pollutants especially TVOC, CO and O_3 in the respective areas.

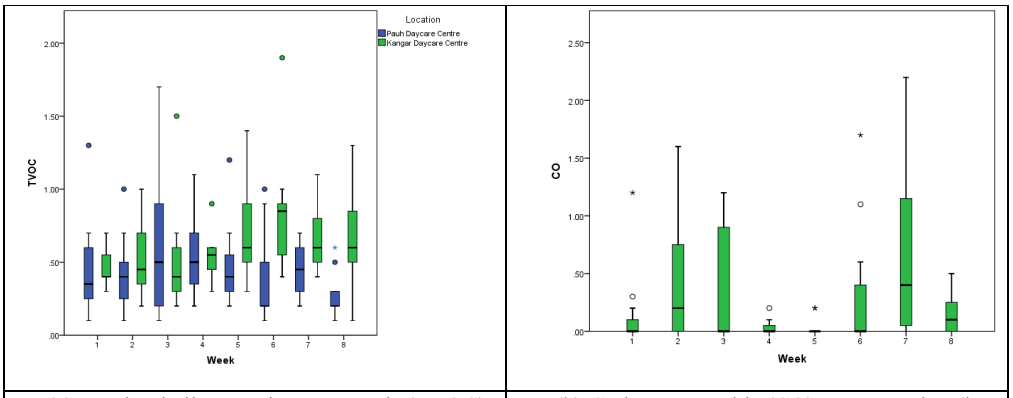
However, the trend of pollutants which are TVOC, O_3 and CO at Taska Pewaris Generasi UniMAP Pauh and Taska HR Bestari, Kangar were showing that the range of these pollutants were below the acceptable limits of ICOP 2010 introduced and enforced by Department of Occupational, Safety and Health under Ministry of Human Resources, Malaysia. TVOC, O_3 and CO were under control and had remained under 3.00 ppm, 0.05 ppm and 10.00 ppm respectively.

The average value of O_3 concentration were detected to be zero for both sampling locations in Pauh DCC and Kangar DCC. This concluded that the value of O_3 is too small to be detected which mostly lower than 0.0001 ppm. Only at certain days, the O_3 level is detected as below than 0.001 ppm. The equipment might also less sensitive to detect the small value of the O_3 concentration. Basically, ozone is created when there is a chemical reactions between oxides of nitrogen (NO_x) and TVOC in the presence of sunlight. Emissions from industrial facilities, electrical utilities, motor vehicle exhaust, and chemical solvents are major sources of NO_x and TVOC [4]. Earlier, IAQ monitoring reveals the average level of TVOC measured in both DCCs are relatively low which is less than 1.00 ppm but NO_x is not measured in this monitoring. Assuming low level of these both components are the main cause of extremely low level of ozone concentration which is less than 0.0001 ppm which is hardly to be detected by the equipment used.

Next, boxplots were plotted especially for TVOC and CO concentration as the values are significant to be observed and compared to the O_3 concentration. Values of O_3 concentration for both daycare centres are often recorded as 0.000 ppm. Figure 2 shows the average boxplots for weekly TVOC concentration for both daycare centres and carbon monoxide concentration in Kangar DCC. The level of TVOC in Kangar DCC is slightly higher compared to the Pauh DCC as the distribution of as asymmetrical tail expanding more towards positive values. This is due to the type of ventilation system at the two DCC. For CO concentration, it shows that the line connecting the maximum value to the box is slightly longer than that connecting the minimum value to the box. It indicated that there are positive skewness for every week at Kangar DCC shows the distribution of as asymmetrical tail expanding more towards positive values are more likely signifying the increase level of CO. The main source of CO is vehicle emission, hence, in week 4 and 5 very low concentration of CO was observed due to Chinese New Year holiday.

Table 3. Weekly average values of IAQ pollutants at both DCCs.

Location	Pewaris Generasi UniMAP, Pauh (Concentration in ppm)									HR Bestari Daycare Centre, Kangar (Concentration in ppm)								
Pollutants/ Week	Hall 1			Sleeping room			Hall 2			Hall			Activity room			Sleeping room		
	TVOC	O_3	CO	TVOC	O_3	CO	TVOC	O_3	CO	TVOC	O_3	CO	TVOC	O_3	CO	TVOC	O_3	CO
1	0.35	0.000	0.00	0.63	0.000	0.00	0.38	0.000	0.00	0.53	0.000	0.05	0.45	0.000	0.38	0.40	0.000	0.00
2	0.50	0.000	0.00	0.45	0.000	0.00	0.30	0.000	0.00	0.65	0.003	0.00	0.95	0.000	0.60	0.35	0.012	0.80
3	0.83	0.000	0.03	0.58	0.000	0.00	0.40	0.000	0.00	0.78	0.000	0.00	0.38	0.000	0.55	0.38	0.000	0.48
4	0.65	0.000	0.10	0.58	0.000	0.00	0.40	0.000	0.00	0.65	0.000	0.00	1.38	0.000	0.05	0.45	0.000	0.05
5	0.53	0.000	0.00	0.48	0.000	0.00	0.40	0.000	0.00	0.68	0.000	0.00	1.08	0.000	0.00	0.65	0.000	0.10
6	0.35	0.000	0.03	0.50	0.000	0.00	0.23	0.000	0.00	1.05	0.000	0.20	0.68	0.000	0.28	0.73	0.000	0.43
7	0.55	0.000	0.03	0.43	0.000	0.00	0.35	0.000	0.28	0.75	0.000	0.65	0.70	0.000	0.73	0.55	0.000	0.55
8	0.33	0.000	0.10	0.28	0.000	0.00	0.20	0.000	0.18	0.88	0.000	0.10	0.70	0.001	0.35	0.35	0.000	0.15
Average	**0.51**	**0.000**	**0.04**	**0.49**	**0.000**	**0.00**	**0.33**	**0.000**	**0.06**	**0.75**	**0.000**	**0.13**	**0.79**	**0.000**	**0.48**	**0.48**	**0.001**	**0.32**
ICOP 2010	3.00	0.050	10.00	3.00	0.050	10.00	3.00	0.050	10.00	3.00	0.050	10.00	3.00	0.050	10.00	3.00	0.050	10.00

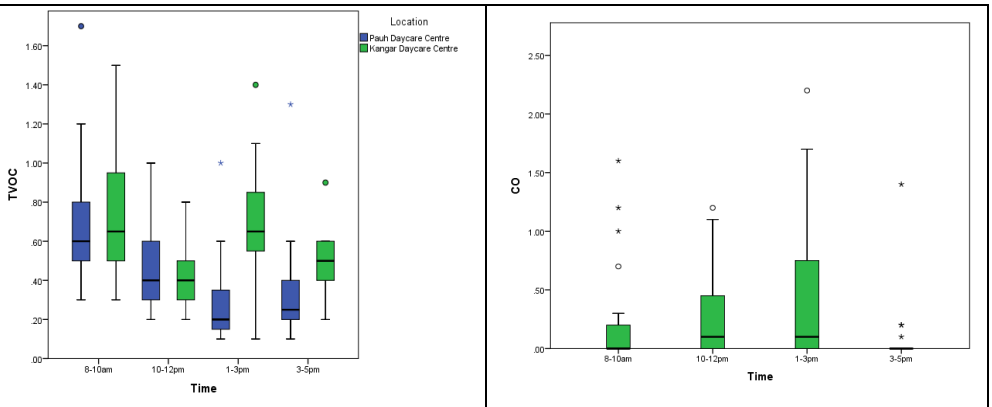


(a) Total volatile organic compounds (TVOC) concentration

(b) Carbon monoxide (CO) concentration (in ppm) for Kangar Daycare Centre

Figure 2. Average weekly boxplots of (a) Total volatile organic compounds (TVOC) concentration (in ppm) for both daycare centres and (b) Carbon monoxide concentration (in ppm) for Kangar Daycare Centre.

Figure 3 shows the boxplots for average diurnal TVOC concentration for both DCC and CO concentration in Kangar DCC. The monitoring data were recorded for 4 time slots per day on weekly basis. The boxplot shows that the line connecting the maximum value to the box is slightly longer than that connecting the minimum value to the box, indicating that there are positive skewness for every week at both daycare centres shows the distribution of as asymmetrical tail expanding more towards positive values are more likely signifying the increase level of TVOC. The level of TVOC in Kangar DCC is slightly higher compared to the Pauh DCC as the distribution of as asymmetrical tail expanding more towards positive values. Two peaks were observed at Kangar DCC (8-10 am, 1-3 pm) which might be due to the food preparation for the kids for lunch and tea break sessions that emitted fumes [5]. The CO concentration is plotted for Kangar Daycare Centre on hourly basis. At the peak hour especially at 1-3pm, there are more vehicles passing by the road and thus, the values reached its maximum level shown by the longer tail towards the maximum value to the box. In short, the level of pollutants are higher at Kangar DCC compared to Pauh DCC because it is situated nearby busy roadside in which incomplete combustion of automobile engine produces high amount of pollutants which enters the nearby housing areas including this DCC. While Pauh DCC is surrounded by building, there is less exposure to roadside pollutants.



(c) Total volatile organic compounds (TVOC) concentration

(d) Carbon monoxide (CO) concentration (in ppm) for Kangar Daycare Centre

Figure 3. Average diurnal boxplots for (a) Total volatile organic compounds (TVOC) concentration (in ppm) for both daycare centres on hourly basis and (b) Carbon monoxide (CO) concentration (in ppm) for both daycare centres on hourly basis.

Independent sample t-test is used to compare TVOC level at the two different daycare centres. In particularly, it compares the means of two independent groups in order to determine whether there is statistical evidence that the associated population means are significantly different. Levene's Test is also produced in this case for Equality of Variances. This is a test that determines if the two conditions have about the same or different amounts of variability between scores. TVOC is selected instead of CO and O_3 because of the significant and stable values recorded during the monitoring. Table 4 shows the independent samples test of TVOC at each DCC. From the table, Levene's Test shows that the significant value (p-value) of 0.846 which is a value more than 0.05 means that the variability in those two DCCs were different. As for the t-test for equality of mean, the p-value for the 2-tailed test was 0.014 which is less than 0.05. Thus, it can be concluded that there is no significant statistical difference between the TVOC concentration at the two different daycare centres which are located in different area of Perlis. This means that the TVOC concentration in the two studied DCC had their own factor that contributed to the variations of TVOC concentration and was not form the same factor or source.

Table 4. Independent samples test of TVOC at each DCC.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
TVOC	Equal variances assumed	0.039	0.846	-2.821	14.000	0.014	-0.235	0.08331	-0.4137	-0.05632
	Equal variances not assumed			-2.821	13.934	0.014	-0.235	0.08331	-0.4138	-0.05624

3.2. Associations between the IAQ pollutants (TVOC, CO and O_3)

Table 5 shows the Pearson correlation between the IAQ pollutants which are TVOC, CO and O_3 concentration. There was a positive correlation between CO-O_3 (r-value = 0.0219) while there is no correlation between TVOC-CO and also O_3 respectively. Tropospheric ozone is a secondary pollutant, which is not emitted directly into the ambient air, but, it is formed by photo chemistry in the atmosphere. It occurs especially during the summer, as a result of radiation of primary pollutants (such as NO_2) through ultraviolet radiation (UV).

Table 5. Pearson correlation matrix between the IAQ pollutants.

IAQ Pollutants	Pearson correlation (r-value)		
TVOC	1	0.029	-0.074
CO		1	0.0219**
O_3			1

Note:**Correlation is significant at the 0.01 level (2-tailed)

4. Conclusion

In short, this research has proven that the selected IAQ pollutants (TVOC, CO and O_3) were detected through the IAQ monitoring to be relatively low in average level and it were within the acceptable limits of Industry Code of Practice on Indoor Air Quality 2010. Thus, the impacts of it to the health of the kids is not at very hazardous level.

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