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Evaluation and measurement of indoor air quality in the preschool building

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Evaluation and measurement of indoor air quality in the preschool building

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Abstract. Under the principle that a suitable temperature and air quality are key to guarantee optimal conditions of learning and growth to students, this study has evaluated the comfort of the classrooms from the data extracted after analyzing the temperatures, the interior of each building, as well as the relative humidity of the classroom environment. In addition, to measure the quality of the indoor air, six chemical contaminants of Carbon Dioxide (CO_2), Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Formaldehyde (HCHO), Volatile Organic Compound (VOC) and Particulate Matter (PM) in the classroom were measured. The results indicate that the physical parameters of each building were in good condition. Meanwhile, on the chemical contaminants, the measurement shows that the concentration of CO_2, PM and VOC for most buildings exceeds the acceptable exposure limits. In the end, the recommendations for a good quality of the indoor environment in the classroom have been suggested through an emphasis on good design, construction and renovation of buildings as well as continuous maintenance practices.

1. Introduction

Nowadays, people pay more attention to the indoor environment than ever before. This tendency has been demonstrated by the increasingly strict regulations that affect the products used in construction [1] and the widespread use of certification systems and eco-friendly construction labels [2]. Taking into account that people spend most of their time in indoor spaces, it is worth paying attention to indoor air quality. This has an impact on our health.

Children are more vulnerable than adults to the effects of air pollution, since they breathe a greater volume of air in relation to their body weight, and their immune system is not yet mature [3] [4] [5]. Poor indoor air quality can affect children's health, growth or school performance [6]. Asthmatic children are exceptionally sensitive to the effects of poor air quality [7].

2. Indoor Air Quality (IAQ)

2.1 Definition and terminology of IAQ

Indoor Air Quality (IAQ) is broadly defined in various forms. IAQ is a term referring to the air quality in the building and around the buildings related to the health and comfort of building occupants [8]. According to [9], IAQ is a term, which refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.

The definition by the National Health and Medical Research Council [10] state that the indoor air as air within a building used for at least one hour by occupants of varying states of health. The American Society of Heating, Refrigerating and Air-Conditioning Engineers or ASHRAE [11] has determined the IAQ is acceptable when 80 percent of the residents in the building feel comfortable and do not suffer from health problems while in the building.

From the above-mentioned definitions, it can be summarized that good air quality is very important in making the occupants feel comfortable and to avoid any health implications while they are in the building.

2.2 Problem associated with IAQ in the classroom

In Malaysia, children spend more than 90% of their time in indoor environments; much of that time is in their schools. In the case of day and evening schooling, it is usually up to 33% of the day in closed environments. Parents or guardians expect the school and classrooms to be healthy and sustainable, maximizing each child's learning potential. In reality, comprehensive and effective learning requires classrooms with sustainable environments including good indoor air [12].

Currently, the innumerable benefits of good indoor air quality in schools are recognized throughout the world. Good quality of air inside a building, showed a positive effect on the reduction of absenteeism, improved the welfare of the occupants and the learning of the children. Studies conducted in the USA show that the grades and scores of students increase when indoor air quality is improved [13]. Other studies show that more than half of the academic staff considered not working at their best due to poor indoor air quality, high moisture, leaks, fungi, low thermal comfort and poor ventilation as the main problem [14].

As a result of poor indoor air quality in schools; discomfort, irritation, short-term and long-term health problems may occur [15], existing health problems such as asthma and allergies may worsen [16], infectious diseases may spread, and productivity of students [17] and teachers may be reduced as well as increased absenteeism [18].

2.3 Source of IAQ pollution in the classroom

Indoor air pollutants can be produced in different ways. Outdoor sources can be traffic and emissions from factories and pollen from flowers [19]. Different activities can also cause pollution, such as smoking, burning incense and candles, air fresheners, cleaning products and perfumes [20].

Figure 1 below explains how major pollutants penetrate preschool building.

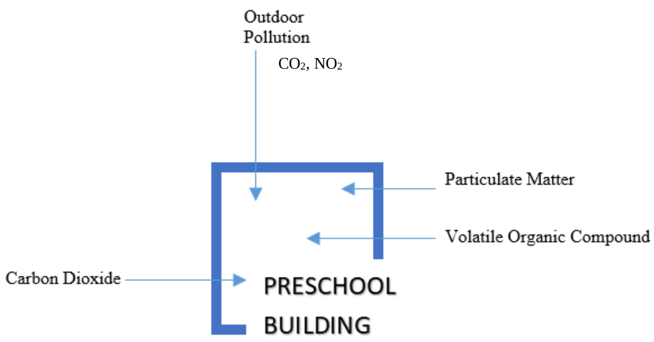

Figure 1. Major source of indoor air pollution

The main sources of air pollution in schools are building and decoration materials, furniture, substances related to the activities developed in these environments (such as cleaning products, paints, glues) and the generation of humidity (RH) and carbon dioxide (CO_2) [21] [22] [23]. In addition, the outside air, with industrial pollution or traffic, which cause high concentrations of carbon monoxide (CO), is an important factor that contributes to deteriorating the quality of indoor air [24] [25].

Common indoor contaminants in schools are particulate matter (PM), nitrogen dioxide (NO2), volatile organic compounds (VOC), formaldehyde (HCHO), biological agents such as allergens from mites, cockroaches and fungi, molds, viruses and bacteria [26] [27] [28] [29] [30]. These air pollutants can be found in the classes, sometimes in high concentrations, and often higher than outside [31].

Table 1 shows the common source of indoor contaminants in the preschool classroom [32].

Table 1. A potential source of indoor contaminants [32]

Compound	Potential Source
T	HVAC, climate control, outdoor
RH	Plumbing, roof/ window leaks, flooding, condensation, pipe sweating, drain pans, poorly-vented kitchenettes
CO_2	Carbon combustion, biological respiration, overcrowding coupled with poor ventilation
NO_2	Burning fuel, emissions from vehicles/ off-road equipment
CO	Leaking vented combustion appliances, vehicle exhaust, parking garages, furnace
PM	Dust, soot, smoke, wood stoves, unpaved roads, agricultural practices
VOC	Paints, cleaning supplies, pesticides, building materials and finishes, copiers, printers, glues, adhesives, permanent markers, candles, cologne
HCHO	Insulation, combustion devices, wood products, furniture

3. Method & Materials

The objectives of this research are to evaluate the comfortable of the preschool classroom as well as to measure the quality of the indoor air inside. Therefore, the physical parameter, which focuses on evaluation of temperature (˚C) and humidity (RH), is used for the research methods. Meanwhile, the indoor air quality is determined by measuring the levels of chemical parameter that exist inside the classroom. This includes CO_2, CO, NO_2, HCHO, PM and VOC.

Three preschool buildings were selected as case studies based on the location of the preschool buildings, which were located along the main road, 1 kilometer from main road and 2 kilometers from main road. Walkthrough inspection was done in order to study the characteristics of selected preschool. Figure 2 below shows the exact distance of the preschool from the main road.

Station A Station B Station C

Figure 2. Location of Station A, Station B and Station C from main road

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The evaluation and measurements of physical and chemical parameter were done using Kanomax IAQ Monitor Model 2212, Graywolf Formaldehyde Multimode Monitor Model FM801 and Graywolf Toxic Gas Model TG502. The data were recorded every 30 minutes for 8 hours in 10 school days.

The data obtained were compared with the Industrial Code of Practice on Indoor Air Quality (ICOP 2010) established by the Department of Occupational Safety and Health (DOSH), Malaysia [32]. The overall research framework from this study can be generalized as in Figure 3.

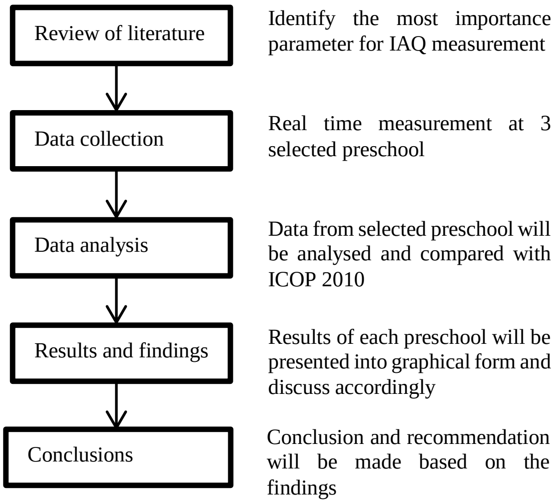

Figure 3. Overall research framework

4. Result & Discussions

The walkthrough inspection of the preschool has indicated the distance of the building from the main road, number of occupants, type of ventilation system and number of doors. Table 2 shows the building characteristics of each preschool.

Table 2. Building Characteristics

Station	*Distance from main road*	*No. of occupants*	*Ventilation system*	*No of doors*
A	0 km	19	Natural and Mechanical	2
B	1 km	24	Natural and Mechanical	2
C	2 km	16	Natural and Mechanical	2

4.1 Physical parameters

Figure 4 and Figure 5 shows the data on the evaluation of indoor temperature and relative humidity at every preschool classroom

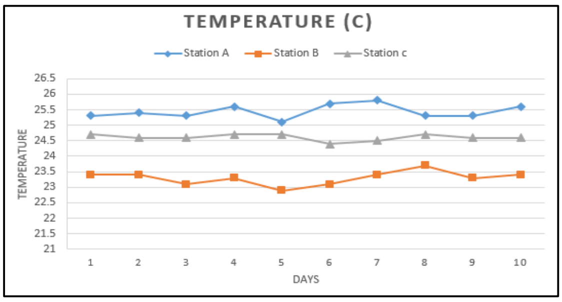

Figure 4. Average temperature reading

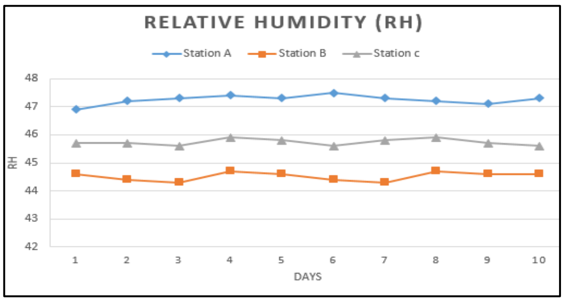

Figure 5. Average relative humidity reading

As shown in Figure 4, it can be seen that temperature for all stations are between the ranges of 22.9 to 25.5 degree Celsius and not exceed the ICOP-2010 guideline, which recommended 23 – 26 degree Celsius. This is due to the mechanically ventilated classroom in each preschool building.

From Figure 5, it can be seen that all stations show low percentage of relative humidity with ranges between 44.3 to 47.5 percent. This percentage can consider as good because high humidity optimizes the growth of mold and other biological contaminants. The recommended percentage of relative humidity by ICOP-2010 is between 30 – 70 percent.

4.2 Chemical parameters

Figure 6 to Figure 11 indicate the average reading for six chemical parameters measured for indoor air at every station.

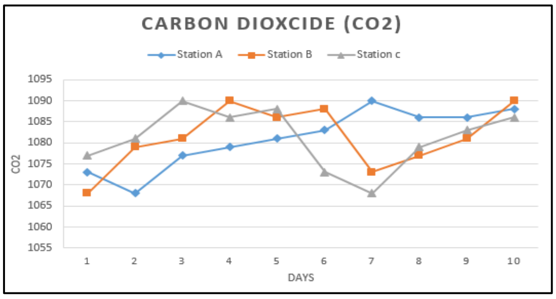

Figure 6. Average CO_2 reading

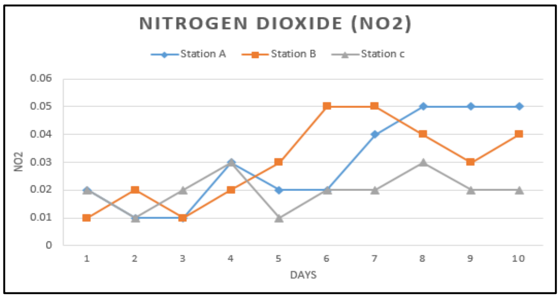

Figure 7. Average NO_2 reading

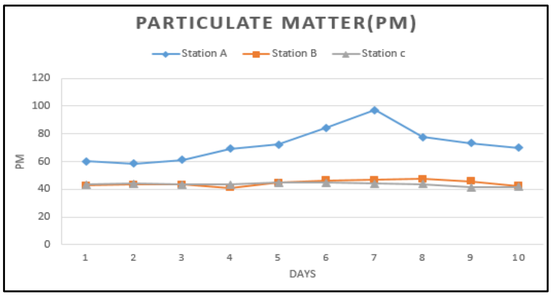

Figure 8. Average PM reading

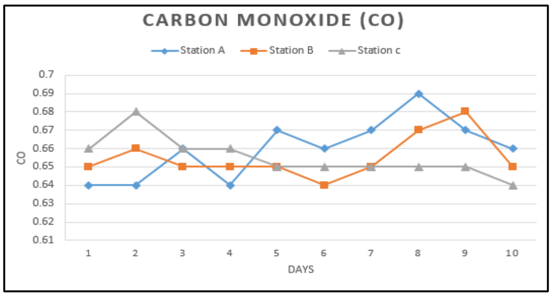

Figure 9. Average CO reading

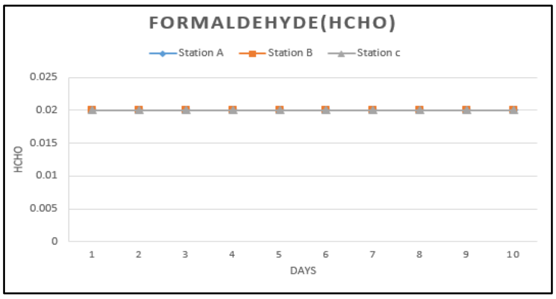

Figure 10. Average formaldehyde reading

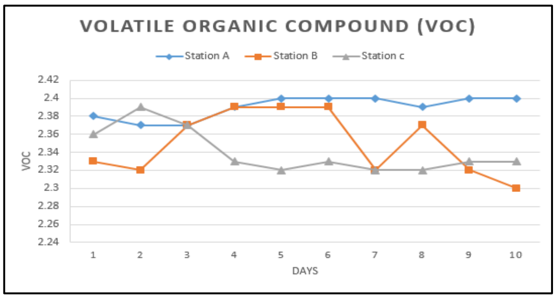

Figure 11. Average VOC reading

According to Figure 6, the average carbon dioxide (CO_2) concentration at all stations were quite similar, between the ranges of 1068 to 1090. However, the ranges exceeded the ICOP-2010 guidelines for CO_2 concentrations that should be lower than 1000ppm. While Figure 7 above indicates the average nitrogen dioxide (NO_2) concentration at all stations. The results show that NO_2 concentration is acceptable as it is below the ICOP-2010 guidelines, which set the permissible exposure limit at 0.1 ppm.

Figure 8 shows the data on the measurement of particulate matter (PM) at all sampling stations. From the figure, it can be seen that PM for station A has exceeded the limit permissible by ICOP-2010 which should be below 50 ppm. This is due to the location of station A which is located along the main road. PM for both station B and C were at acceptable standard.

Figure 9 shows the average concentration of carbon monoxide (CO) for all sampling stations. Results indicate that all station recorded the CO concentration within the recommended guideline by ICOP-2010 which should be below 3 ppm. Figure 10 shows that all of the stations were in between ICOP-2010 guideline for formaldehyde (HCHO) concentration which should not exceed 0.05 ppm.

Figure 11 records the IAQ chemical parameter which is a volatile organic compound (VOC) concentration reading according to session for all sampling station. All of the sampling stations exceed the standard concentration according to ICOP-2010 guideline which is 1 ppm.

4.3 Discussion

In all, the results in Table 3 summarized that the physical parameters of each building were in good condition. Meanwhile, on the chemical contaminants, the measurement shows that the concentration of CO_2, PM and VOC for most buildings exceeds the acceptable exposure limits.

As a positive finding, it can be concluded that the levels of pollutants in most schools are below the maximum levels recommended by the ICOP-2010. However, certain pollutants sometimes exceed the recommended levels and can negatively affect the children.

Table 3. Summary of results

Station	Parameters							
	°C	RH	CO_2	NO_2	PM	CO	HCHO	VOC
A	√	√	×	√	×	√	√	×
B	√	√	×	√	√	√	√	×
C	√	√	×	√	√	√	√	×

5. Recommendations for future improvements

Poor IAQ can cause impaired health of students and teachers and will cause discomfort during the process of teaching and learning. Thus, the effect of IAQ is one of the most important aspects of teaching and learning environment that should be given serious attention. Several strategies have been recognizing as the steps to overcome and improve the indoor air quality in learning environment. Among the strategies and recommendations are [33] [34] [35] [36]:

i. Open the window at least three times every day to 'dilute' the contaminated air.
ii. Make sure the furniture layout promotes ventilation.
iii. Maintain and clean the mechanical ventilation regularly
iv. Check the air quality of their premises regularly and periodically.
v. Use the natural or environmentally friendly cleaner and fragrances. The use of cleaning agents or non-chemical alternatives is very good for removing stains and reduces chemical pollution.
vi. Use the tools that can trap and kill bacteria, fungi and microorganisms and clinically proven.
vii. Use Local Exhaust Ventilation with air filter High-Efficiency Particulate Arrestance (HEPA)

6. Conclusion

This study has evidently shown that CO_2 and VOC for all selected classroom did not comply the minimum ICOP-2010 guidelines. This may cause adverse health effects towards the children as they breathe almost twice as much air as adults, so they expel more CO_2. VOC may be emitted by wide array of products available in the classroom and elevated concentrations can last longer persist in the air.

Meanwhile, station A records the highest PM concentrations which had exceeds the permitted level. This is probably due to the distance of a station that is very close to the main road.

As a reflection of this study, the quality of indoor air in schools classroom must reach the optimum levels dictated by the DOSH standard, otherwise, the legislation is violated and affects the comfort of children, who spend many hours a day inside the classrooms.

Children are very vulnerable to pollutants that spread through the air, which is why they are more affected by infectious diseases, lungs, allergies or headaches than the rest of the population. Consequently, their health and school performance would decrease.

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