Evaluation and Measurement of Indoor Air in Preschool Building

M.A.A. Rahman, M. Awang, N. Saji, K.A.M. Sari, M.K. Musa and M.Z.M. Najib
Dept. of Civil Engineering Technology
Faculty of Engineering Technology, UTHM
84600 Pagoh, Muar, Johor.

A.I. Che Ani
Department of Architecture
Faculty of Engineering and Built Environment, UKM
43600 Bangi, Selangor.

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 will evaluate the comfort of the classrooms from the data extracted after analyzing the temperatures outside, 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 (CO2), Carbon Monoxide (CO), Nitrogen Dioxide (NO2), 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 CO2, PM and VOC for most buildings exceeds the acceptable exposure limits. In the end, the recommendations for a good quality of 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.

Keywords—indoor air; preschool buildings; contaminants

I. 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].

II. INDOOR AIR QUALITY

A. Definition and terminology

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. ASHRAE [11] has determine 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.

B. Problem associated with IAQ in 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, a 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. A good quality of air inside a building, showed a positive effect in 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 increase absenteeism [18].

C. Source of IAQ pollution in 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].

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 (CO2) [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 deteriorate 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].

III. Method and Materials

The objectives of this research is to evaluate the comfortable of the preschool classroom as well as to measure the quality of the indoor air inside. Therefore, physical parameter, which focuses on evaluation of temperature (˚C) and humidity (RH), are used for the research methods. Meanwhile, the indoor air quality is determine by measuring the contents of chemical parameter that exist inside the classroom. This includes of CO2, CO, NO2, HCHO, PM and VOC.

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

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 Industrial Code of Practice on Indoor Air Quality (ICOP 2010) established by the Department of Occupational Safety and Health (DOSH), Malaysia.

IV. Result and Findings

The walkthrough inspection of the preschool has indicate the buildings distance from the main road, number of occupants, type of ventilation system and number of doors. Table 1 show the building characteristics of each preschool.

TABLE I. Building Characteristics

Station	Distance	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

A. Physical parameters

Figure 1 and Figure 2 shows the data on evaluation of indoor temperature and relative humidity at every preschool classroom.

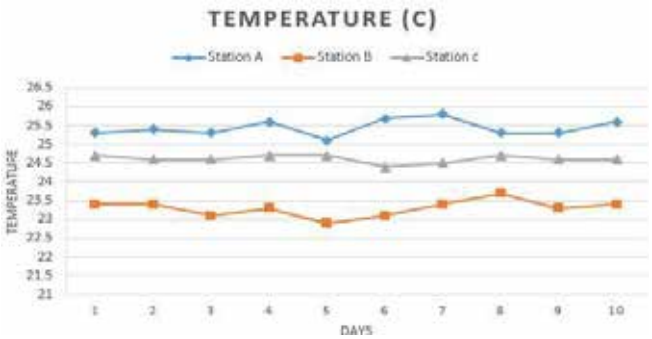

Figure 1: Average temperature reading

From the Figure 1, 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.

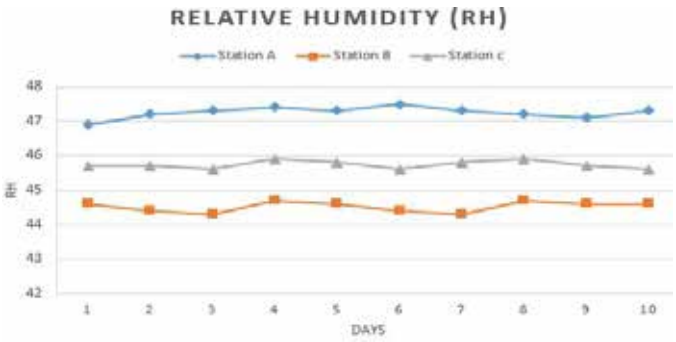

Figure 2: Average relative humidity reading

From the Figure 2, 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 optimize the growth of mold and other biological contaminants. The recommended percentage of relative humidity by ICOP-2010 is between 30 – 70 percent.

B. Chemical parameters

Figure 3 to Figure 8 indicates the average reading for six chemical parameters measured for indoor air at every station.

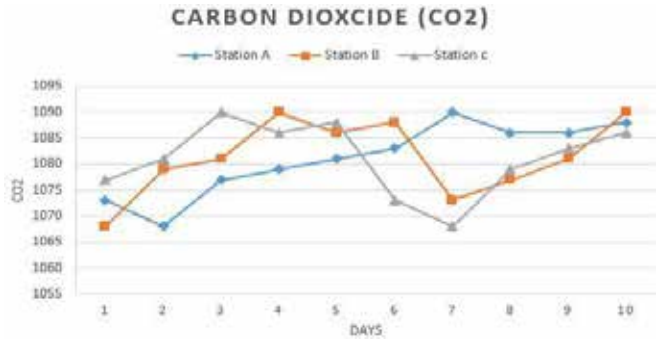

Figure 3: Average carbon dioxide reading

According to Figure 3, the average carbon dioxide (CO2) concentration at all stations were quite similar, between the ranges of 1068 to 1090. However, the ranges exceeded the ICOP-2010 guidelines for CO2 concentrations that should be lower than 1000 ppm.

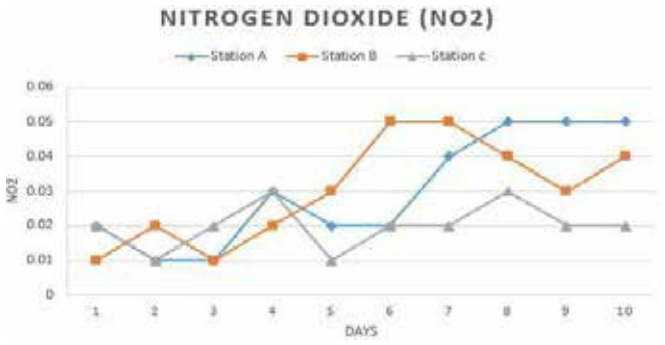

Figure 4: Average nitrogen dioxide reading

Figure 4 above indicates the average nitrogen dioxide (NO2) concentration at all stations. The results show that NO2 concentration are acceptable as it is below the ICOP-2010 guidelines, which set the permissible exposure limit at 0.1 ppm.

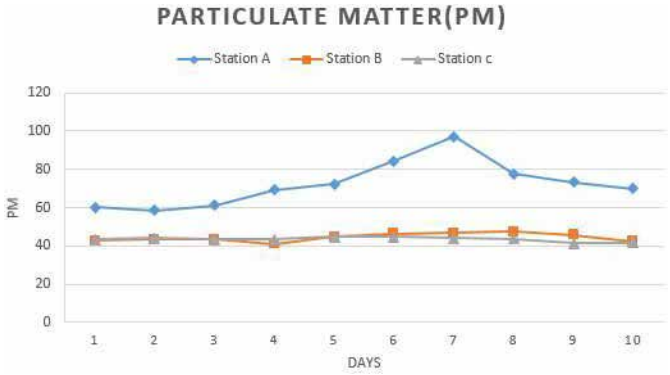

Figure 5: Average particulate matter reading

Figure 5 shows the data on measurement of particulate matter (PM) at all sampling stations. From the figure, it can be seen that PM for station A has exceed 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.

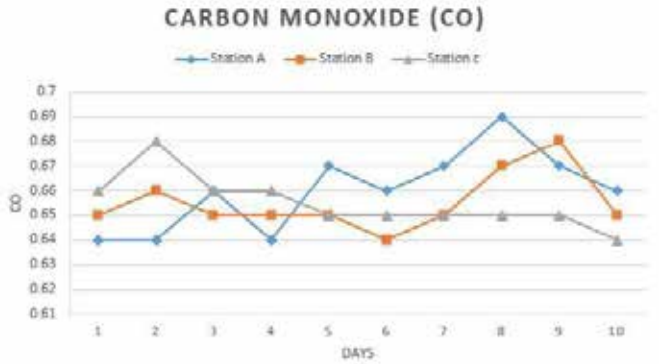

Figure 6: Average carbon monoxide reading

Figure 6 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.

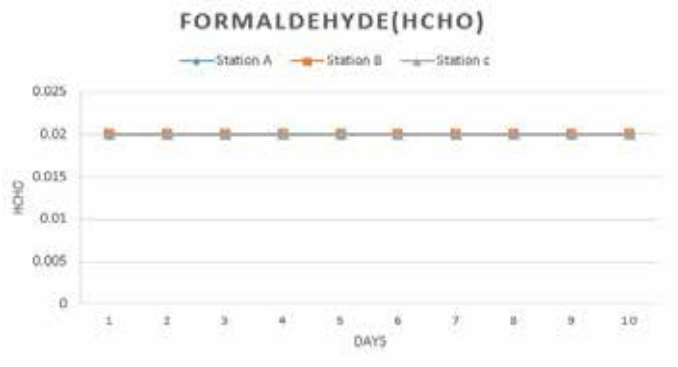

Figure 7: Average formaldehyde reading

Figure 7 shows that all of the stations was in between ICOP-2010 guideline for formaldehyde (HCHO) concentration which should not exceed 0.05 ppm.

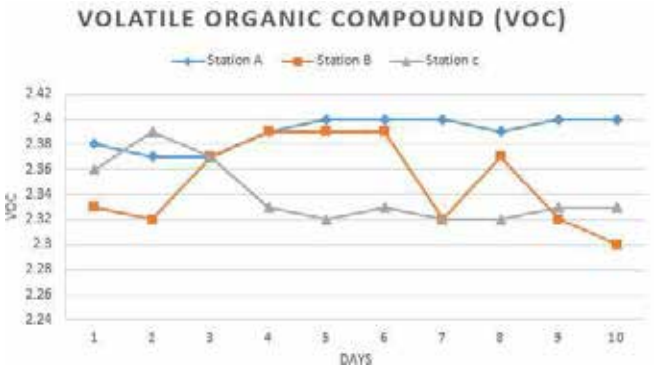

Figure 8: Average volatile organic compound reading

Figure 8 shows the IAQ chemical parameter which is volatile organic compound (VOC) concentration reading according to session for all sampling station. All of the sampling station exceed the standard concentration according to ICOP-2010 guideline which is 1 ppm.

In all, the results (Table II) summarized that the physical parameters of each building were in good condition. Meanwhile, on the chemical contaminants, the measurement shows that the concentration of CO2, PM and VOC for most buildings exceeds the acceptable exposure limits.

TABLE II. SUMMARY OF RESULTS

Station	Parameters							
	°C	RH	CO^2	NO^2	PM	CO	HCHO	VOC
A	☐	☐	×	☐	×	☐	☐	×
B	☐	☐	×	☐	☐	☐	☐	×
C	☐	☐	×	☐	☐	☐	☐	×

☐= Complied × = Did not comply

As a positive finding, it can be concluded that the levels of indoor air pollution 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.

V. Recommendations for 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 in 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 [32] [33] [34] [35]:

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 cleaning 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)

VI. Conclusions

This study has evidently shows that CO2 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 CO2. VOC may 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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