INDOOR AIR QUALITY ASSESSMENTS IN SELECTED CHILD CARE INSTITUTIONS (NURSERIES & KINDERGARTEN) AT KUANTAN, PAHANG: THE IMPLICATION OF OCCUPANCY ON IAQ

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ABSTRACT

Children breath proportionately greater volumes of air compared to adults, thus they inhale more pollutants per pound of body weight. Higher occupancy may contribute to the higher level of indoor air pollutant. Besides, the age of the children determine their susceptibility towards diseases. Infants aged up to 1 year old are more susceptible compared to the toddler aged from 2 to 4 years old due to their growth which is still in the development process. This study was conducted to see the relationship of occupancy and the degree of exposure of airborne pollutants towards infants and toddler in child care institutions. These objectives can be achieved by determining the concentration of selected parameters such as physical (temperature and humidity), chemical (PM10) and biological (colony forming unit (CFUm-3) for bacteria and fungi. Following that, this study also aims to see the correlation of these IAQ parameters with occupancy factor based on types of sampling stations(control station for non-occupied) and (kindergarten for occupied station).The methodology for physical and chemical IAQ assessments were done using instruments known as DustMate Environmental Dust Detector and VelociCalc® Multi-Function Ventilation Meter 9565. Surface Air System Indoor Air Quality (SAS IAQ) was used to capture the bacteria and fungi. The data obtained were compared with the established standard reference known as the Industrial Code of Practice on Indoor Air Quality (ICOP 2010).This study shows that several IAQ parameters such as temperature, humidity and CFUm-3 for bacteria in the selected child care institutions were exceeding standard guideline by ICOP 2010. Moreover, there is high significant difference in IAQ parameters concentration in kindergarten station compare with control station in term of occupancy factor.

Keywords: IAQ; kindergarten; nursery; occupancy; bacteria CFUm-3

Introduction

Nearly, 1 millions of children under 5 years die every year due to exposure from indoor air pollutant (WHO, 2007). Besides, studies on human exposure stated that indoor level of pollutants may be about 2-5 times or higher than the ambient environment (United States Environmental Protection Agency, 1996). According to (Martin et al 2014), there is no clear threshold to define the level of exposure indoor air pollutant gave affect to children in child care institutions. It may due to less concern in term of indoor air quality in child care institution even though this is the most susceptible group to get diseases (USEPA,1996). Since, children have high vulnerability to any kind of diseases due to their premature development of their immune system, lungs and other organ. Therefore, children are more at risk to airborne exposure compared to adult.

The characteristic of good IAQ include the ranges from humidity, temperature, velocity of the air and chemicals substances (benzene, carbon monoxide, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) as well as particulates matters (PM) including dust and heavy metals (DOSH, 2010; WHO, 2010). The biological components such as bacteria and fungi are also important determinant of indoor air quality (WHO, 2009). Exceeding this range or limits of this control characteristic will cause adverse health effects toward the occupants. Besides, the facts that people spend most of their time indoors rather that outdoor become the risk to the occupants to be infected by indoor air contaminant was higher (California Air Resources Board, 2009).

Among major air pollutants, airborne particulate matter (PM) has become a main threat to humans' health due its high concentration in the atmosphere and toxicity for both indoor and outdoor(Afroz et al., 2003). Particulate matters are indoor air pollutants that will affect the quality of indoor air (Valavanidis and Vatista, 2006). Mixtures of organic and inorganic substances that remain suspended in the air are called respirable particulate matter (RPM) and generally inhalable if they are less than 10 μm (PM10) (Yau et al., 2012). Besides, many related studies found that PM has a strong association with increasing health problems and mortality cases especially related to respiratory system (Kampa & Castanas, 2008).

On top of that, the microbial contaminant will attach to the particulate matter and will be travel through the air. High humidity with low temperature encourages biological contaminants by the growth of mildew and other fungi on the building fabric and furnishings (Indoor Air Quality Management Group, 2003). In Malaysia, the studies on indoor air quality have been conducted but still lack and mostly only focus on a certain bases like haze episodes, vehicular emission, and industrialization processes (Afroz et al,2003).

As far as for this study concern, very limted number of study on IAQ has been conducted particularly in type of institutions. Moreover, there is no specific national guidelines available for indoors, the exposure to indoor particulate matter (PM10) and airborne biological contaminant that might increase the risk of respiratory symptoms especially for children. Besiedes, airborne pollutant also can reduce lung function among primary school children live in petrochemical industrial area (Ayuni et al,2014). In term of occupancy factor, there was also none of standard guideline that define outdoor air requirement (cfm/person) for children that meet the standard criteria for IAQ practice.

METHODS:

SAMPLING STATION

Pahang is an interesting area to be studied specifically for its air quality status. Other studies are mainly focused on the air quality of the urban areas such as Kuala Lumpur. Other than logistic and financial factors, Pahang especially in Kuantan is an interesting area to study because it has differentials background area such as urban, suburban, residential and rural areas so allowing air quality to be study in different type of background areas.

Thus, nurseries and kindergarten were chosen based on the background area of the institutions which were urban, sub-urban, residential and rural. Childcare institution for sub-urban was coded as CCE and has three station which are control (non-occupied), kindergarten and nursery. Childcare institution for residential area coded as CCI has three stations as CCE. CCBU for urban area consist of two stations only which were kindergarten and control same with rural childcare institution coded as CCJ. Walkthrough inspection was done before sampling to study the building characteristic of each childcare institution with number of occupancy.

IAQ PARAMETER SAMPLING

Physical and chemical IAQ assessments were done using instruments known as DustMate Environmental Dust Detector and VelociCalc® Multi-Function Ventilation Meter 9565. The data were recorded every 30 min for 8 hours. For microbial sampling, Surface Air System Indoor Air Quality (SAS IAQ) was used to capture the bacteria and fungi. The data obtained were compared with the established standard reference known as the Industrial Code of Practice on Indoor Air Quality (ICOP 2010) constructed by the Department of Occupational Safety and Health (DOSH), Malaysia.

The sampling time were divided into three sessions for 8 hourexposure according to child care schedule at the sampling point in selected station. The three sessions was divided into morning, afternoon and evening that represent 8 hour sampling time.

DATA ANALYSIS

The data will be analyzed by Statistical Package for Social Sciences (SPSS Version 23.0) and Microsoft Excel 2013. IAQ parameters which are temperature, humidity, PM10 and airborne microorganism concentrations were analyzed by descriptive statistic and presented in the form of mean or average while the correlation of IAQ parameters with occupancy factors was analyzed using paired T-test analysis.

RESULT AND DISCUSSION

This study was performed to approach the occupancy factor in IAQ parameter that influencing the concentration of indoor airborne pollutant in child care institution. In order to discuss the effect of occupancy towards indoor air environment, the building characteristic had been investigated to provide a framework of other potential factor that will influence the IAQ parameter inside the child care institution. The summarization of building characteristic was described in Table 1.

Table 1: Summarization of building characteristic in selected childcare institution

Sampling location	Sampling station	Building characteristics				
		Number of occupants	Size (volume)	Ventilation system	Number of doors	Number of windows
CCBU (Urban)	Control	0	31.5 m^3	Natural	1	1
	Kindergarten	25	206.7 m^3	Natural	2	2
CCJ (Rural)	Control	0	60.5 m^3	Mechanical	1	4
	Kindergarten	11	135.0 m^3	Natural	2	2
CCE (Sub Urban)	Control	0	106.67m^3	Mechanical	1	3
	Kindergarten	17	119.7 m^3	Mechanical	2	3
	Nursery	6	63.76 m^3	Natural	1	2
CCI (Residential)	Control	0	44 m^3	Natural	1	1
	Kindergarten	10	44 m^3	Natural	1	3
	Nursery	5	47.2 m^3	Natural	1	6

Table 1 shows the summarization of building characteristics at four selected childcare institutions. The table shows that each of the childcare institution represent type of the area such as CCBU located at urban area. This will become one of the contributing factor for IAQ parameter because area that are closed proximity to major roads will encounter the higher amount of chemicals release from vehicles.

As stated in the table, the sampling station defined as diferrent type of room which are control, kindergarten and nursery. This is the major contributing factor as the number of occupants was higher in kindergarten as compared to nursery and control that was non-occupied room. The volumes of selected sampling station were varied from each childcare institution. Mostly, kindergarten station was bigger than nursery and the control room as the occupancy was higher in kindergarten.

The ventilation system can be divided into two which are natural ventilation that used windows and fans or mechanical ventilation that used MVAC system. The table shows that 3 out of 10 sampling station was using mechanical ventilation. The relation between indoor air pollutant levels and ventilations system modes such as natural, or mechanical revealed that mechnical ventilation system caused a lower level of indoor air pollutants (Zuraimi et al, 2008)

IAQ PARAMETER CONCENTRATION AT FOUR SELECTED CHILDCARE INSTITUTION

PHYSICAL PARAMETER

Figure 1: Average temperature reading

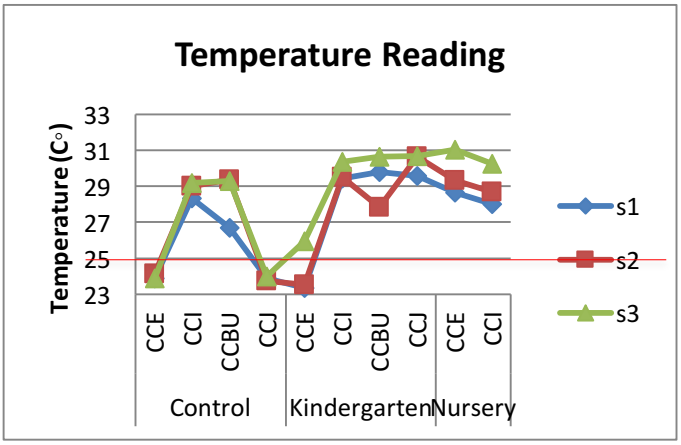

Figure 2: Average humidity reading

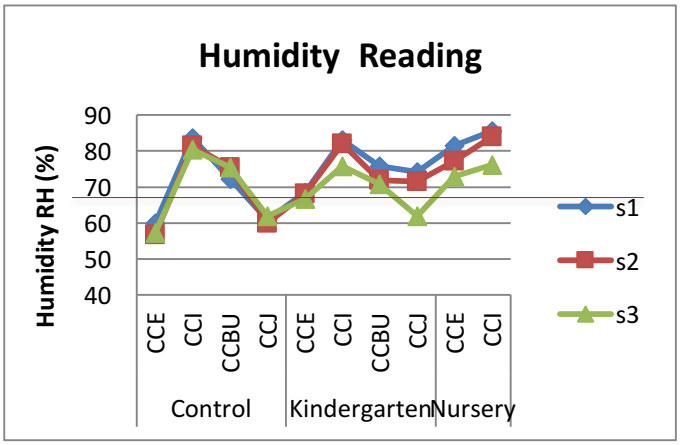

Figure 1 and 2 shows the IAQ physical parameter average for temperature and humidity reading by session. Figure 1 shows that all of the stations exceeded the ICOP guideline for temperature reading that should be between 23-26◦C except for control CCE, Control CCJ and Kindergarten CCE that was using mechanical ventilation.

In term of comfort, the temperature should be maintained in range of 23-26◦C. Exceeding this range will lead to discomfort, draught and dehydration espescially for children. As we can see from the result that all natural ventilated station exceeding guideline that means the children wherether in nursery and kindergarten were discomfort due to high temperature (WHO 2005). To ensure the temperature was in stipulated range MVAC system should be installed at natural ventilation station.

Figure 2 shows that most of the rooms exceeding the ICOP standard guideline which is 40-70% relative humidity except the mechanical ventilated station which are Control CCE and CCJ. Surprisingly, for CCJ during session 3 assessment the humidity reading was 60%. This is due to its location that was in rural area and occupancy factor which is only 3 children at CCJ on session 3.

Relative humidity refer to the amount of water vapour in the air (ICOP, 2003). Maintaining the relative humidity level is minimizes the growth of molds and other biological contaminant. The stations that were exceeding the relative humidity levels were because of their natural ventilation system. The fresh air enters through the windows without filter thus introduces the water vapour from ambient air into the indoor air inside the childcare institutions. High humidity is associated with fatigue and stuffiness of the occupants (Schwartz, J.2004)

CHEMICAL PARAMETER

Figure 3: Average PM10 concentration reading according to session for all sampling station

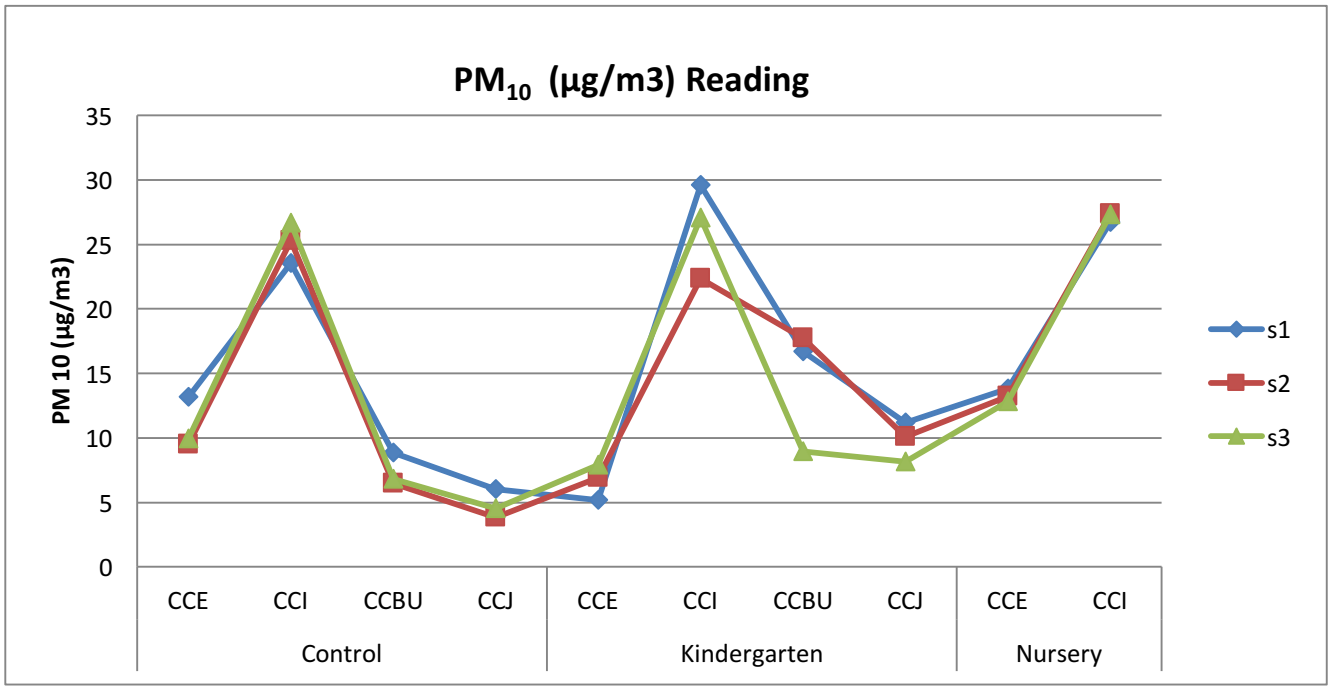

Figure 3 shows the IAQ chemical parameter which is PM10 concentration reading according to session for all sampling station. All of the sampling station met the standard concentration according to ICOP guideline which is 150µg. But, the highest reading was recorded at all sampling station in CCI. CCI was located in residential area that was closed to main road that have heavy traffic.

According to (WHO 2005), the coarse particle which is 2.5-10 µm will be deposited in the upper respiratory tract and large airways which is called as respirable particle or PM10. Children have lower body weight. Lower body weight, related to premature development of an organ thus also less lung surface area (Beatty, 2012). Thus exposure to PM10 will cause greater health adverse effect towards children. Heavy traffic espescially at CCI that was closed to main road will lead to emission of airborne chemical pollutants such as PM10 (Laden et.al, 2000). It was important to have mechanical ventilated system that have efficient filter in order to filter this PM10 from entering indoor air inside the childcare institutions.

BIOLOGICAL PARAMETER

Figure 4: Average CFU count for bacteria

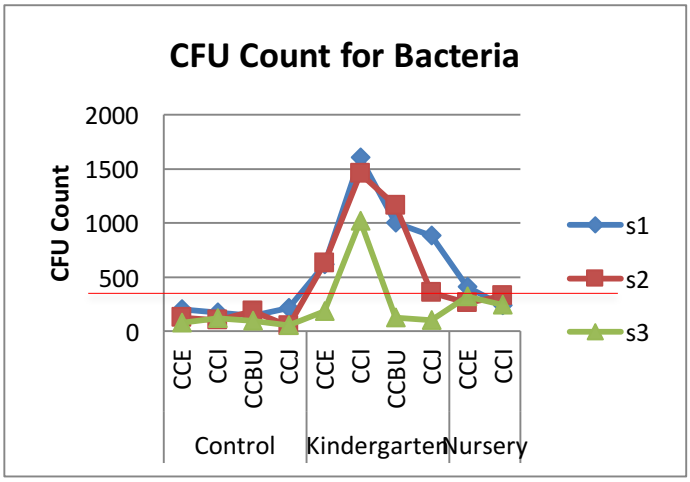

Figure 5: Average CFU count for fungi

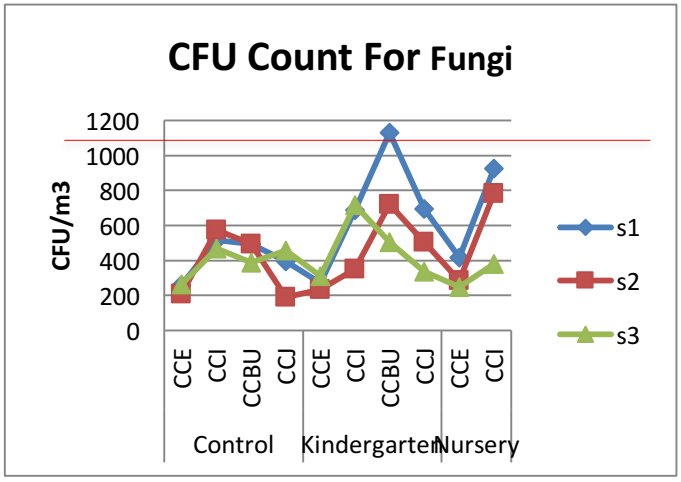

Figure 4 and 5 shows the average CFU count for IAQ biological parameter which are bacteria and fungi. Figure 4 shows that most of the bacteria CFU count at kindergartens station exceeding the ICOP guideline which is 500cfu.The highest reading recorded at CCI and CCBU kindergarten was due to occupancy factor. Eventhough CCI have less number of occupancy compare to CCE but the volume of CCI station was smaller than other kindergarten.

Figure 5 shows that all of the rooms was in between ICOP guideline which is 1000CFU except for kindergarten station at CCBU that exceeding the guideline. CCBU kindergarten has the highest number of occupancy thus contribute to higher CFU count for fungi.

In general, biological contaminat will be higher if the IAQ parameter does not meet standard guideline. A higher number of total bacteria could be associated with lower temperature and higher percentage of relative humidity. Moreover, higher humidity could cause the pathogenic bacteria to attach into droplets and discharged into the air, thus causing infections, which brought to respiratory diseases (Wang et al., 2005).

Poor ventilation system and absent of MVAC system that could result in high bacterial counts (Indoor Air Quality Management Group, 2003).Occupancy becomes the contributing factor because high number of occupancy lead to higher number of particulate matter and the spread of biological contaminant will become more contagious.These findings agree with (An,et al 2006) disputed high bacteria counts are associated with high occupancy, poor hygienic conditions of the occupants, and also inadequate ventilation (An.Hr.et.al,2006)

CORRELATION OF IAQ PARAMETERS WITH OCCUPANCY FACTOR

In general from the IAQ parameter data analysis shows that the concentration of IAQ parameter was higher in kindergarten compared to nursery and control station. To study the degree of this correlation between occupancy and IAQ parameters concentration, paired T-Test from SPSS was used to indicate the p-value.

Table 2: Paired samples T-test between sampling station control and kindergarten based on IAQ Parameter for all childcare institution.

Qualitative variables			
	Mean	T	P
PM10	2.64	1.36	0.018*
RH	-6.8	-2.59	0.014*
Temperature	-3.52	-6.425	0.001**
Bacteria CFU	-6.32	-6.5	0.001**
Fungi	-1.45	-2.03	0.027*

Each of the sampling station was compared between controls (non-occupied) with kindergartens (occupied) station to identify the p-value for each IAQ parameter. Control PM10 concentration was paired with kindergarten PM10 concentration and was repeating for another IAQ parameter. According to the paired t-test in Table 2 the data are highly significance at $**\alpha < 0.05$ which indicate 95% confident interval for all IAQ parameter reading. The analysis shows significant difference for all IAQ parameter reading in term of occupancy factor as the control station is non-occupied while kindergarten was occupied. In addition, the temperature and bacteria CFU reading indicates 99% confident interval shows a strong significant dfference in term of occupancy for this IAQ parameter.

IAQ parameter was related which one another. Higher number of occupancy resulting in increased of temperature reading as human release heat through the body. Moreover, for children their metabolism was higher than adult thus amount of air inhalation and their growing tissue and organ which together raise the possibility of higher exposure than adults (Schwartz,2004). The children metabolism was associated with by product which is sweat. Higher number of occupant also lead to increase in indoor air humidity percentage as the children sweating from time to time. When this IAQ physical parameter exceeding the standard guideline these indicate that chemical and biological parameter will also be affected.

Children need more oxygen relative to their small size of lung that has narrower airways than adults. This will result in proportionately greater airway obstruction if they exposed to polluted air (WHO, 2005). The statistical analysis prove that PM10 concentration was higher in occupied station which is kindergarten compared to control station. This is because, the PM10 will attach through the children body and travel together in indoor air environment resulting in higher concentration of PM10 inside the kindergarten. PM may cause acute effect as irritation on skin, eyes, nose and throat, as well as may contribute to the prevalence of chronic respiratory diseases like asthma (Zamani et al.2013).

Indoor air temperature, humidity and air movement must be maintained in favoured range as this will reduce the pollutants level and also prevent microbial growth according to (Mui et al., 2007). This study revealed that IAQ physical parameter reading in kindergarten was high and exceeding the standard guideline. Thus, it was the best condition for microbial growth and was proved by statistical analysis that microbial contaminant in kindergarten was higher compared to control station with 99% confident interval. Bacteria are one of the types of indoor air pollutant that will travel along with the dust. According to (Bouillard et al, 2005), the size of bacteria that are smaller than 10µm will attach to the particulate matter size 10µm in order to travel along the air.

Besides, higher humidity could cause the pathogenic bacteria to attach into droplets and discharged into the air, thus causing infections, which brought to respiratory diseases (Wang et al., 2005). It was also mentioned that bacterial counts in indoor environment were commonly higher in crowded places and did not necessarily emphasize that human infections would occur but served as screening tests for further investigation (Indoor Air Quality Management Group, 2003). Teachers and students respiratory fluid which may be emitted via talking, sneezing and coughing may contribute as the origin of airborne microbes in the schools. (Hospodky et al.2012). This is a prove when kindergarten have the highest number of occupancy and crowded as the space are not enough to support the occupant resulting crowded in the kindergarten stations.

According to (Yau et al. 2012) the researcher stated that pollutant concentration would be significantly low in a less crowded occupant inside the building. (Valavanidis and Vatista ,2006), stated that closed windows and occupants of more than 25 people can alter the air condition which can cause a higher risk of the transmission of infectious agents in indoor environment by airborne. Sufficient air-conditioning systems, less crowded buildings and enough number of air ventilation contribute in the reduction of indoor pollutants emission (Grisoli et al., 2012).

CONCLUSION

The increment of airborne exposure contaminants is believed to give affects towards children health status. From this study, all of the IAQ parameter was higher and some of the parameter was exceeding standard guideline by ICOP 2010 espescially in kindergarten due to occupancy factor. The consequences of this factor lead to respiratory symptoms among children cases that increased dramatically that was believe due to poor indoor quality (Choo et al,2015)

It was suggested for the childcare institution to improve their ventilation system. Nowadays, natural ventilation is not suitable for indoor air environments espescially in kindergarten. This is because pollutant from ambient air are dangerous and connot be introduce inside the childcare institution as the children body system was not fully develop. One of the way to control the IAQ parameter concentration, reduce number of occupant by relocate them into different room that meet the standard area or increase the area of the nursery for better IAQ practice. In addition, hygiene of the cildren should be managed properly to avoid any contagious diseases by giving them awareness. Health screening also is the best alternative to prevent any outbreak diseases from the source of IAQ parameters.

Currently, the references for standard guideline were ICOP 2010 which was design for industrial area. This study show that the IAQ parameters measured was exceeding standard guideline by ICOP 2010 which was design as references for adult. It was believed that children need special standard guideline as they was still in development process and their body system was more vulnerable than adult. Thus, new policy or standard guidelines need to be established for IAQ in children.

ETHICAL CONSIDERATIONS

Ethical approval and permission have been obtained from Jabatan Kebajikan Masyarakat, and IIUM Research Ethics Committee (IREC) prior to data collection. Other issues that may cause any misconducts or conflict of interest also been observed by the authors.

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