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RESEARCH PAPER

Indoor Particulate Matter ($PM_{2.5}$) and Comfort Parameters in a University Building

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Abstract

This study aims to determine the particulate matter ($PM_{2.5}$) mass concentrations and the comfort parameters (total bacterial counts (TBC), total fungal counts (TFC), relative humidity and temperature) in a university building. The samplings were carried out in three different indoor areas, including lecture hall, laboratory and lecturer office. $PM_{2.5}$ samples were collected over a period of 8 h sampling using a low volume sampler (LVS). The anemometer Model Kestrel 0855YEL was used to measure relative humidity and temperature parameters. The sampling of airborne microorganisms was conducted by using microbial sampler at 350 L air sampled volume. The results showed that the highest average of $PM_{2.5}$ was at lecture hall (88.54 ± 26.21 μgm^{-3}) followed by lecturer office (69.79 ± 19.06 μgm^{-3}) and laboratory (47.92 ± 24.88 μgm^{-3}). The mean of TBC and TFC readings recorded as follow; 32.71 ± 5.91 cfu m^{-3} and 76.71 ± 21.5 cfu m^{-3} for laboratory, 112.1 ± 29.06 cfu m^{-3} and 124.67 ± 23.35 cfu m^{-3} for lecturer office, 121.74 ± 19.33 cfu m^{-3} and 115.33 ± 8.08 cfu m^{-3} for lecture hall. The average of all comfort parameter was within the prescribed standard by Industry Code of Practice on Indoor Air Quality 2010 for all sampling sites. Therefore, all occupants of the building can work in a conducive and comfortable environment. This study is in line with the objectives of National Policy on the Environment (DASN), which focusing on achieving a clean, safe, healthy and productive environment for present and future generations.

Keywords: Particulate matter ($PM_{2.5}$); Indoor air quality; Relative humidity; Temperature; Airborne microorganism

Abstrak

Kajian ini bertujuan untuk menentukan kepekatan bahan zarahan terampai ($PM_{2.5}$) dan parameter keselesaan, (jumlah bakteria (TBC), jumlah fungi (TFC), kelembapan relatif dan suhu) di bangunan universiti. Persampelan telah dijalankan di tiga ruang dalaman yang berbeza termasuk dewan kuliah, makmal dan pejabat pensyarah. Sampel $PM_{2.5}$ dikumpulkan dalam tempoh 8 jam persampelan menggunakan Persampel Udara Berisipadu Rendah (LVS). Model anemometer Kestrel 0855YEL digunakan untuk mengukur parameter kelembapan relatif dan suhu. Pengambilan mikroorganisma bawaan udara dilakukan dengan menggunakan pensampel mikrob pada isipadu udara 350 L. Keputusan menunjukkan purata tertinggi $PM_{2.5}$ berada di dewan kuliah (88.54 ± 26.21 μgm^{-3}) diikuti oleh pejabat pensyarah (69.79 ± 19.06 μgm^{-3}) dan makmal (47.92 ± 24.88 μgm^{-3}). Purata bacaan bagi TBC dan TFC yang dicatatkan adalah seperti berikut; 32.71±5.91 cfu m^{-3} dan 76.71±21.5 cfu m^{-3} bagi makmal, 112.1±29.06 cfu m^{-3} dan 124.67±23.35 cfu m^{-3} bagi bilik pensyarah, 121.74±19.33 cfu m^{-3} dan 115.33±8.08 cfu m^{-3} bagi bilik kuliah. Purata semua parameter keselesaan menepati piawaian yang ditetapkan oleh Kod Amalan Industri Kualiti Udara Tertutup 2010 untuk semua tapak persampelan. Oleh itu, semua penghuni di dalam bangunan dapat bekerja dalam keadaan persekitaran yang kondusif dan selesa. Kajian ini selari dengan objektif Dasar Kebangsaan Mengenai Alam Sekitar (DASN) yang memberi tumpuan untuk mencapai persekitaran yang bersih, selamat, sihat dan produktif untuk generasi sekarang dan akan datang.

Kata kunci: Bahan zarahan terampai ($PM_{2.5}$); Kualiti udara dalaman; Kelembapan relatif; Suhu; Mikroorganisma bawaan udara

INTRODUCTION

Indoor air quality (IAQ) is one of the essential components in a workplace environment that will be important for international codes of practice (NIOSH, 2015). Each IAQ parameter shall be ensured to comply with acceptable limits in order to maintain a good IAQ. The selected indoor air quality parameters and their acceptable limits are proposed by the Industrial Code of Practise on Indoor Air Quality (ICOP) (2010) that was published by the Department of Occupational Safety and Health, Malaysia (DOSH). Particulate matter poses more danger to human health than other common air pollutants (such as formaldehyde, carbon monoxide and ozone). The main pollutant in the airborne particle is fine particulate matter ($PM_{2.5}$), which has an aerodynamic diameter of less than 2.5μm and may penetrate deep into human lungs (WHO 2013). $PM_{2.5}$ can also run a variety of components such as heavy metals, bacteria, viruses, and volatile organic compounds, due to its high penetration capability (Cao et al., 2011). In addition, $PM_{2.5}$ can result in greater harmfulness due to its smaller size (Huang et al., 2012).

School and university students will stay longer in internal environments compared with individuals at work (Ashmore & Dimitroulopoulou, 2009; Chithra & Shiva Nagendra, 2012; Raysoni et al., 2013). The previous study in Malaysia indicated that poor IAQ in a university building could affect productivity as well as the health problems to occupants (Zhong et al., 2014) and correlates with student's performance as well (Mohai et al., 2011). However, not much study has been conducted to clarify the microbial population in a university building. Thus, this study illustrates the need for indoor air quality studies in Malaysia higher learning institutions. This study may increase the knowledge on indoor particulate matter and provide a better understanding to the authorities to come out with effective indoor air quality management strategies.

MATERIALS AND METHOD

Description of Sampling Sites

The samples were collected from the Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris (UPSI), which was situated in Sultan Azlan Shah Campus in Proton City, Tanjung Malim, Perak (3.7211 ºN, 101.5263 ºE) (Figure 1). UPSI location was in a suburban district of Perak, which was situated about 80 km or 45 minutes from the capital city of Kuala Lumpur. Tanjung Malim was known for its tranquillity and splendid natural views of the Titiwangsa Mountain Range. It was built in 2009 and the location was about 3 km away from UPSI main campus named as Sultan Abdul Jalil Campus.

$PM_{2.5}$ Sampling Protocol

A total number of 15 $PM_{2.5}$ samples were collected using a low volume sampler (LVS) operated at a flow rate of 5 L min^{-1} on eight hour cycle (from 9.00 a.m. to 5.00 p.m.) for five consecutive weekdays at each sampling sites. The samplings were carried out between November to December 2018, according to Mohamad et.al (2016) with some modifications at three selected sampling sites; lecturer office, lecture hall, and laboratory. During the sampling period, the inlets of the indoor sampler are located approximately 1 m above the floor level, to stimulate the location of the people breathing zone who occupied the building. The sampler was positioned in the middle of the sampling area and at least 1-meter distance from the wall. The sampling sites chosen were in close proximity to the main

road, the highly occupied area and frequently used. $PM_{2.5}$ samples were collected on 47 mm (in diameter) pre-weighted micro fibre glass filter paper (0.2 µm pore size, Whatman). $PM_{2.5}$ mass concentrations were measured triplicate through the gravimetric method using 5-digit electronic microbalance with ± 0.001 mg uncertainty. The filters were equilibrated for 24 h inside a desicator to condition them. After sampling, the filter papers containing sample were then weighed and then stored in the refrigerator (4 ℃) until further analysis is carried out.

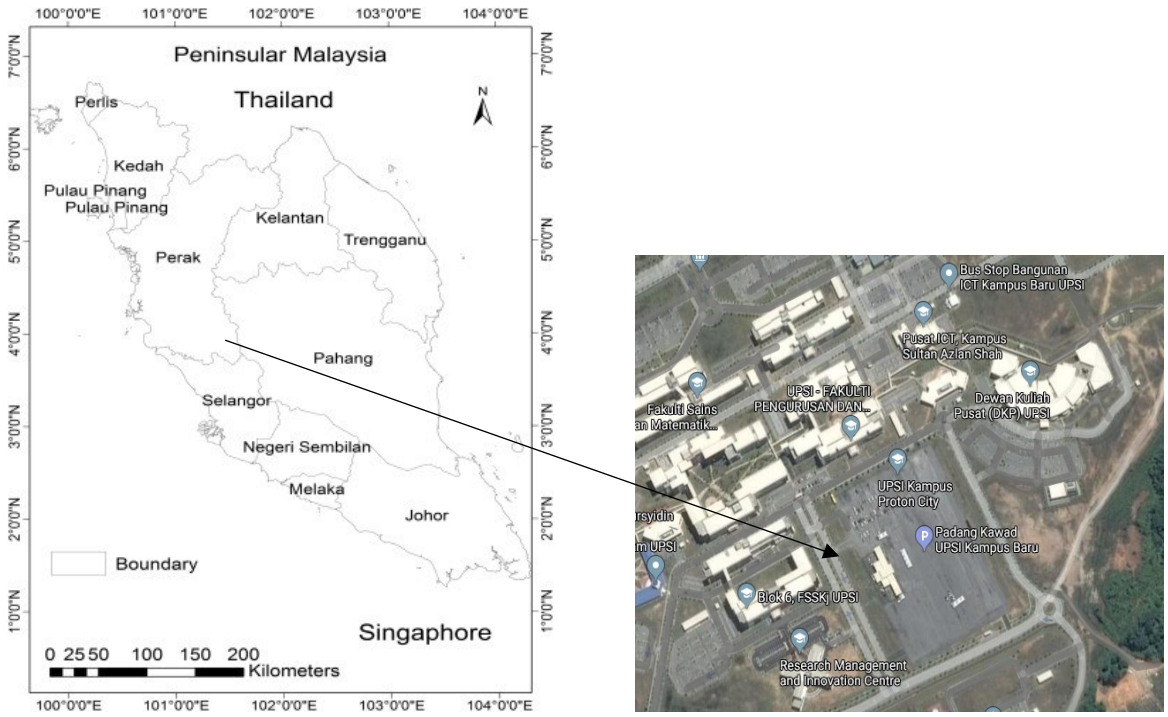

Figure 1. Locations of sampling stations in Sultan Azlan Shah Campus, Universiti Pendidikan Sultan Idris.

Airborne Microbial Sampling Protocols

The Model DUO SAS Super 360^{TM} IAQ (DUO Surface Air System Indoor Air Quality) was used to conduct the sampling of airborne microbiological contaminants with 350 L air sampled volume. The DUO SAS is an air sampler that suited for Indoor Air Quality assessment for microbial colonies in ambient air. The airflow was directed onto a petri dish containing Trypticase Soy Agar (TSA) treated with chloramphenicol antibiotic that was a medium for bacterial growth, and Malt Extract Agar (MEA) treated with cycloheximide antibiotic as a medium of growth of fungi. Two plates were placed in the air microbial sampler at both sides for each run and pointed near to the ventilation system and 3 m above from the floor level.

The airborne microbial contaminants were captured on the agar by impaction. After about 1 minute for each sampling session, the plates were taken out, sealed, labelled, and incubated. TSA plates were incubated for 24 – 48 h at 35 ℃ to enhance the bacterial growth while MEA plates were incubated at 25 ℃ for 5 d to enhance the growth of fungi before colony-forming unit was counted as suggested by NIOSH Manual of Analytical Method (NMAM) 0800. The results of the bacterial and fungal counts were expressed as the number of colony-forming units per cubic meter of air (CFU m^{-3}), calculated as an average from the readings. The data were recorded by using Equation 1.

$$CFU\ m^{-3} = (R/V) \times 1000 \qquad \text{(Eq. 1)}$$

where, R is Colony Forming Units counted on plate and V is Volume of sampled air (350 litres of air).

Statistical Analysis

In this study, the normality test was performed before running an appropriate analysis and Shapiro-Wilk was chosen due to its suitability with large sample size. The data were observed to be normally distributed after the normality test was conducted. Hence, the parametric test can be carried out to reach the objectives. The means of variables at different sampling sites (lecturer office, lecture hall and laboratory) were compared using one-way ANOVA test (XLSTAT 2017).

Quality Assurance/Quality Control (QA/QC)

In this study, quality assurance and quality control were implemented to avoid any error or interference during the sampling process, sample preservation, transport, and analysis. The blank samples were used in each analysis to ensure the reliability of the analysis. The field blank filter papers were handled in the same way as actual filter papers with great care by using gloves and plastic to avoid damage and contamination. All the glassware used in sample analysis were rinsed with distilled water, soaked into 20% nitric acid for at least 24 h and heated in the furnace at 300 ℃ for 5 h to volatilize and remove any impurities (Mohamad et al., 2016). Equipment including petri dishes and workstation were aseptically disinfected using 70% alcohol to prevent cross-contamination among samples. Besides, the process of going through the bottle mouth to Bunsen burner also being practised to ensure no contamination will occur during media pouring into petri dishes.

RESULTS AND DISCUSSION

$PM_{2.5}$ Concentrations

As a whole, $PM_{2.5}$ mass concentrations recorded for all sampling sites ranged between 25 ± 24.88 μg m^{-3} to 83.33 ± 19.06 μg m^{-3} (Figure 2). The average reading of $PM_{2.5}$ recorded at lecture hall was 88.54 ± 26.21 μg m^{-3}, lecturer office was 69.79 ± 19.06 μg m^{-3} and laboratory was 47.92 ± 24.88 μg m^{-3}. There was no significant difference ($p > 0.05$) was observed on $PM_{2.5}$ concentrations between these sampling sites. The average of $PM_{2.5}$ mass concentration measured in this study can be considered to be high because about 40% of the total samples that exceeded the 75 μg m^{-3} Malaysia Ambient Air Quality Standard 2015 (IT-1) (DOE 2015). A high $PM_{2.5}$ mass concentrations at lecture hall was believed due to the frequent student movements inside the lecture hall, in and out of lecture hall during the breaks in between lessons as well as cleaning activities that enhance deposited particle resuspension (Sulaiman et al., 2017). Raysoni et al. (2013) suggested that indoor air pollution was well-correlated with outdoor air pollution in terms of student activities, building envelope tightness, and air exchange rates. The average $PM_{2.5}$ mass concentrations in this study has quite similar patterns with a study carried out at Nankai University in Tianjin, China by Chen et al. (2015) which reported $PM_{2.5}$ concentration value was 97.5 μg m^{-3}.

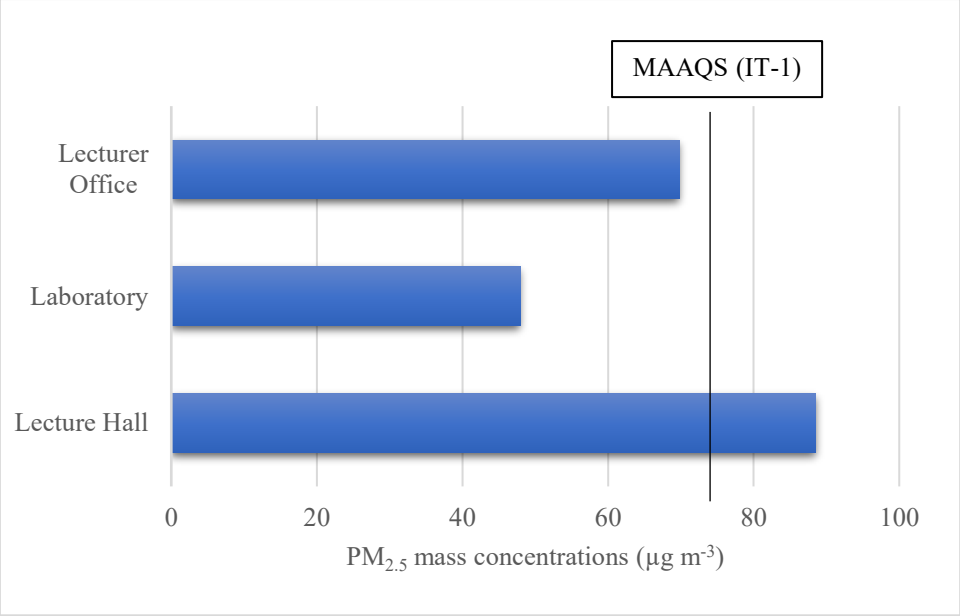

Figure 2. Descriptive statistics of 8 h $PM_{2.5}$ concentrations of sampling areas in Sultan Azlan Shah Campus.

Comfort Parameter

The temperature values ranged from 24 to 27 ℃, while for RH, the values ranged from 61 to 72%. The highest temperature reading was at the lecturer office with 25.95℃, while for relative humidity, the laboratory showed the highest reading, which was 68.5% (Table 1). The poor operating air conditioning system and lack of mechanical ventilation will also contribute to the increase in thermal discomfort levels among building occupants (Chen & Chang, 2012). A similar pattern also found in a study conducted in other university buildings (Nur Fadilah & Juliana, 2012). The lecturer office showed the highest reading for total bacterial counts (TBC) with a total of 112.10 cfu $m^{-3,}$ and the laboratory showed the smallest number of bacteria counts with only 32.71 cfu m^{-3}. This may be driven by the hygiene factor as well as operating air conditioning systems operates for a longer period compared with laboratory that is rarely used. According to Mazlan et al. (2015), the high reading relative humidity will enhance the proliferation of microbes. The one way ANOVA analysis (SPSS 25.0) shows that there were no significant differences ($p > 0.05$) between these parameters for all sampling sites. Overall, in this study, the mean of all comfort parameters was within the permissible limits for all sampling sites.

Table 1. Overall mean of temperature, relative humidity, total bacteria counts and total fungal counts for three sampling sites.

Parameter	DOSH ICOP-IAQ 2010	Mean		
		Lecture Hall	Laboratory	Lecturer Office
Temperature (°C)	23.0-26.0	24.65 ± 0.07	25.45 ± 1.34	25.95 ± 1.63
Relative Humidity (%)	40.0-70.0	65.00 ± 0.00	66.5 ± 7.78	68.5 ± 0.71
Total Bacterial Counts (cfu m^{-3})	500	121.74 ± 19.33	32.71 ± 5.91	112.10 ± 29.06
Total Fungal Counts (cfu m^{-3})	1000	115.33 ± 8.08	76.71 ± 21.50	124.67 ± 23.35

CONCLUSIONS

The present study revealed no significant different ($p > 0.05$) on $PM_{2.5}$ mass concentrations between these three sampling areas. The average 8-h of $PM_{2.5}$ concentration can be considered to be high as about 40% of the $PM_{2.5}$ samples exceeded the 75 µg m^{-3} of Malaysia Ambient Air Quality Standard 2015 (IT-1). The mean of relative humidity, temperature, total bacteria counts, and total fungal counts for all sampling areas were below the acceptable limit stipulated by Industrial Code of Practise on Indoor Air Quality 2010. It is crucial to control air quality effectively to minimize the potential health risks due to poor indoor air quality. Additionally, the air exchange rates, construction materials, and ventilation practices assessments are necessarily incorporated in the future study for better understanding of the indoor-outdoor air exchange as guidance to authorities to design effective control strategies to reduce pollutant emissions.

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