MICROBIAL AEROSOL AND PARTICULATE MATTER ($PM_{2.5}$) IN SELECTED UNIVERSITY ROOMS

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Abstract. The quality of indoors in university buildings is vital to ensure a conducive learning environment and health and well-being. The objectives of this study are to investigate microbial aerosols and the concentration of particulate matter ($PM_{2.5}$) in a university building. The data was collected from three lecturers' rooms (Room A, B and C). The microbial aerosol was collected using a microbial air sampler, while Total Bacterial Count (TBC) and Total Fungi Count (TFC) were counted to analyze the colony-forming unit. In addition, $PM_{2.5}$ was obtained using a low-volume air sampler (LVS), for five hours. The Field-Emission Scanning Electron Microscope (FESEM) was used to analyze the morphological composition of indoor $PM_{2.5}$. The findings indicated that Room A shows the highest concentration of TBC (251.43 ± 32.74 cfu m^{-3}) and TFC (28.57 ± 2.65 cfu m^{-3}) compared to the two other rooms. In addition, the TBC showed a significantly higher amount (p<0.05) compared to TFC, for all rooms studied. The average $PM_{2.5}$ was 0.33 ± 0.15 μgm^{-3}, and the highest level of $PM_{2.5}$ was found in Room A (0.50 ± 0.01 μgm^{-3}). Based on the FESEM image, it can be observed that the $PM_{2.5}$ exhibits distinct variations in terms of their sizes and characteristics with morphologies ranging from rounded to polygonal with distinct geometric. Exposure to indoor air pollution in university buildings, as investigated in this study, revealed varying levels of microbial aerosols and particulate matter ($PM_{2.5}$), emphasizing the importance of monitoring indoor air quality for potential health implications.

Keywords: $PM_{2.5}$, microbial, aerosol, TBC, TFC

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1. INTRODUCTION

The influence of indoor air quality (IAQ) goes beyond just providing comfort, since it directly affects the health and efficiency of the academic community. The existence of bacterial contamination in academic buildings, particularly teachers' or lecturers' rooms, indicates an urgent issue. The presence of microorganisms is affected by various factors, including human activity, the effectiveness of cleaning methods, and the quality of ventilation systems [1-2]. Strict procedures are essential to reduce the risks of bacterial contamination, considering the potential consequences for the health and well-being of the room occupants [2-3]. The study conducted by [4] highlights the vulnerability of lecturers' rooms to fungal infection, underlining the importance of implementing effective moisture control methods and regular maintenance operations. In addition to the visual presence of mould, the possible release of allergenic spores and mycotoxins highlights the importance of taking proactive actions to guarantee a safe and conducive learning environment [4].

$PM_{2.5}$, which denotes particulate matter with a diameter of 2.5 micrometers or smaller, poses a significant concern regarding the quality of indoor air (IAQ) [5-7]. The introduction of $PM_{2.5}$ from external sources, such as automotive emissions and industrial operations, presents a multifaceted challenge [8-9]. The presence of this particulate matter can enter indoor areas, leading to health problems and discomfort for those inside the building [10-12]. The presence of academic buildings in Perak, Malaysia, is affected by urbanization and industrial operations, which increase the levels of indoor $PM_{2.5}$. This requires careful and deliberate measures to effectively reduce these levels [13]. Indoor $PM_{2.5}$ is particularly relevant based on the research conducted by Farhadi et al. [14], which shows initiatives like the implementation of improved ventilation and air filtration systems are becoming essential elements of a comprehensive plan.

The combination of $PM_{2.5}$, bacterial pollutants, and fungal components in lecture rooms poses significant health risks for both lecturers and students. The health effects linked to increased exposure to $PM_{2.5}$, such as respiratory and cardiovascular problems, have been extensively demonstrated in research [15]. To ensure the overall health and well-being of the academic community, it is crucial to prioritize the reduction of $PM_{2.5}$ exposure and implement thorough IAQ management. By taking this issue into account, this study aims to investigate microbial aerosols and the concentration of particulate matter ($PM_{2.5}$) in a university building, located in Perak, Malaysia. In addition, micrograph images of these particulate were also identified.

2. MATERIALS AND METHODS

2.1 Sampling Locations

The $PM_{2.5}$ samples and comfort parameters were collected from the Faculty of Science and Mathematics, Sultan Azlan Shah Campus, Universiti Pendidikan Sultan Idris (UPSI), situated at Tanjung Malim, Perak (3.7211 ^{o}N, 101.5263 ^{o}E). UPSI was located in a suburban section of Perak, approximately 80 km away from the capital city of Kuala Lumpur. The selection of rooms for sampling is that the rooms are air-conditioned, have carpets and have wooden furniture.

2.2 Comfort Parameters Sampling

To collect data on comfort parameters (relative humidity and temperature) in the three lecturers' rooms (Room A, Room B, and Room C), an environmental meter was used to take three repetition readings for each room. The environmental meter was placed in each room, ensuring that it was not directly affected by any external factors such as windows or air conditioning vents. The readings were taken at the same time each day, maintaining consistency in the data collection process. This data collection method allowed for a thorough assessment of the relative humidity and temperature levels in the lecturers' rooms, providing valuable insights into the indoor environmental conditions.

2.3 Microbial Aerosol Sampling Protocol

Figure 1 shows the floor plan of the sampling site. The monitoring of airborne microbiological pollutants was conducted using the DUO SAS Super 360TM IAQ (DUO Surface Air System Indoor Air Quality), with a sampled volume of 350 L. The DUO SAS is a specialized air sampling device designed specifically for evaluating indoor air quality (IAQ) by quantifying the presence of colonies of microbes. The airflow headed towards a petri dish that contained Trypticase Soy Agar (TSA) supplemented with chloramphenicol antibiotic, which served as a growth medium for bacteria. Additionally, Malt Extract Agar (MEA) supplemented with cycloheximide antibiotic was utilized as a medium for the growth of fungi. In each trial, a pair of plates were positioned within the air microbiological sampler facing towards the ventilation system, and placed at a height of one meter above the ground level.

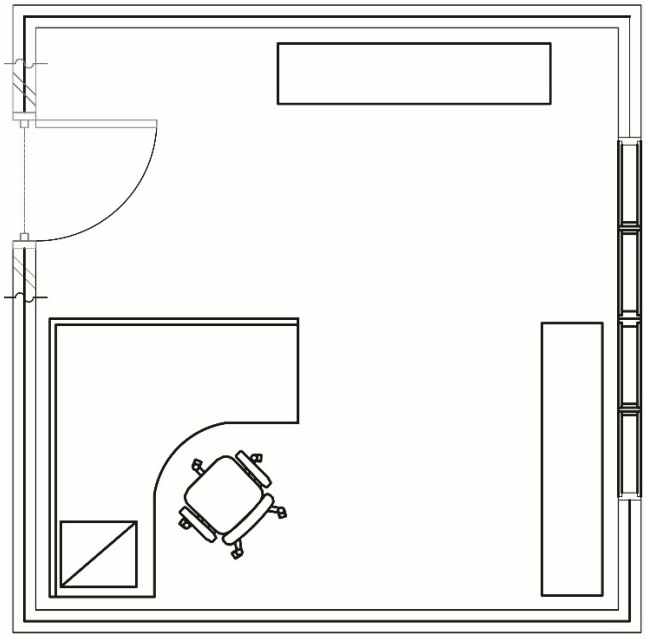

Figure 1: Lecturer's room floor plan

2.4 Sampling Protocol for $PM_{2.5}$

Three sets of $PM_{2.5}$ samples were obtained by employing a low volume sampler (LVS) operating at 5 L min^{-1} flow rate for five hours (from 9.00 a.m. to 2.00 p.m.) on three consecutive weekdays at each designated sampling location. The data collection occurred from August to September 2023. The sampling sites were situated in the lecturer's office. During the duration of the sampling period, the indoor sampler's inlets were situated at an approximate height of one meter above the ground level. This placement was intended to simulate the position of the breathing zone of individuals present within the building.

The sampler was centrally positioned within the sampling area, maintaining a minimum distance of 1 meter from the wall. $PM_{2.5}$ samples were obtained using pre-weighed microfiber glass filter paper, which had a diameter of 47 mm and a pore size of 0.2 μm. The filter paper was manufactured by Whatman. The $PM_{2.5}$ level was measured in triplicate using the gravimetric technique, utilizing a 5-digit electronic microbalance with an uncertainty of ± 0.001 mg. The filters were conditioned for 24 hours within a desiccator to achieve equilibrium. After the sampling procedure, the filter papers were weighed and then placed in a refrigerated setting at a temperature of 4 ºC for storage until further analysis was performed.

2.5 Airborne Microbial Analysis

The agar medium effectively captured the airborne microbial pollutants through the process of impaction. Following each sampling session, the plates were removed from the incubator after approximately one minute, sealed, labeled, and subsequently incubated. The TSA plates were subjected to incubation at a temperature of 35 ºC for a period of 24 to 48 hours to promote bacterial development. Similarly, the MEA plates were incubated at a temperature of 25 ºC for 5 days to facilitate the growth of fungi. Following the incubation period, the colony-forming units were enumerated following the guidelines outlined in the NIOSH Manual of Analytical Method (NMAM) 0800. The bacterial and fungal counts were calculated by the utilization of Equation 1.

$$CFU\ m^{-3} = (R/V) \times 1000 \quad (1)$$

where:

R : Colony Forming Units counted on plate
V : Volume of sampled air (350 liters of air).

2.6 Morphological Structures Analysis

The field-emission scanning electron microscopy (FESEM, Hitachi SU 8020) coupled with Energy Dispersion System (EDS, Horiba Xmax Model) was used to examine the surface morphology of $PM_{2.5}$. The sample was first affixed directly to the stubs using a double-sided adhesive film to adhere the sample. Then, the sputter coater was used to coat the sample with platinum (Pt) coating. This sputter coater used an electric field and argon gas. To complete the analysis, a 5 kV accelerating voltage was used on the FESEM. The images were then modified with a specific contrast-to-brightness ratio to provide the best image, as done by Nor et al. [9].

2.7 Statistical Analysis

To determine the results of this study, several statistical analyses were used such as descriptive statistics, paired t-test and ANOVA after all the data found in normal distribution. The data collected was analyzed using Microsoft Excel.

2.8 Quality Control

To ensure the analysis was reliable, blank samples were collected. The field blank filter papers were handled with utmost caution, employing the use of gloves and plastic materials to prevent any potential harm or contamination. The glassware utilized in the analysis of samples underwent rinsing with distilled water, while equipment such as Petri dishes and workstations were subjected to aseptic disinfection using 70% alcohol. This precautionary measure was implemented to mitigate the risk of cross-contamination between samples.

3. RESULTS AND DISCUSSION

3.1 TBC, TFC and Comfort Parameter

Table 1 indicates the Total Bacterial Counts (TBC), Total Fungal Counts (TFC) and comfort parameters (temperature and relative humidity) for all sampling locations. The blank samples for both TBC and TFC are in the range of 0.00 to 0.89 cfu m^{-3}. The average TBC concentration was 136.19 ± 21.08 cfu m^{-3} while for average TFC concentration was 19.37 ± 2.28 cfu m^{-3} The findings indicated that Room A shows the highest concentration of TBC (251.43 ± 32.74 cfu m^{-3}) and TFC (28.57 ± 2.65 cfu m^{-3}) compared to two other rooms. The lowest concentration of TBC (59.05 ± 11.93 cfu m^{-3}) and TFC (9.52 ± 0.58 cfu m^{-3}) is in Room C. This could be attributed to the hygiene element (such as cleanliness, air quality, and the control of microbial contaminants like bacteria and fungi). For these rooms, the air conditioning operates from 7 am to 7 pm every day, except Sunday. The value for temperature varied between 26 ºC and 28 ºC , while the relative humidity (RH) was in the range between 54% and 57%. Room B recorded the highest temperature reading at 27.47 ºC. Regarding relative humidity, Room A and Room C recorded the greatest measurement, reaching 56.63%.

Table 1: TBC, TFC and comfort parameters of the sampling locations

Parameter	DOSH ICOP-IAQ 2010	Mean		
		Room A	Room B	Room C
Total Bacterial Counts (cfu m^{-3})	500	251.43 ± 32.74	98.10 ± 18.58	59.05 ± 11.93
Total Fungal Counts (cfu m^{-3})	1000	28.57 ± 2.65	20.00 ± 3.60	9.52 ± 0.58
Temperature (°C)	23.0-26.0	27.07 ± 0.15	27.47 ± 0.6	26.83 ± 0.15
Relative Humidity (%)	40.0-70.0	56.63 ± 0.67	54.33 ± 0.68	56.63 0.32

The inadequate functioning of the air conditioning system and absence of mechanical ventilation would only worsen the rise in thermal discomfort experienced by individuals occupying the building [16]. Based on the research conducted by past researchers [17], an

elevated level of relative humidity is likely to promote the growth and spread of microorganisms. Overall, the average value of all parameters measured was within the DOSH acceptable range (temperature: 23.0 ºC - 26.0 ºC , relative humidity: 40.0% - 70.0%) for all locations where samples were taken.

3.2 $PM_{2.5}$ Concentrations

Table 2 shows the concentration of $PM_{2.5}$ from the sampling locations. The blank samples of $PM_{2.5}$ are in the range of 0.000 to 0.002 μgm^{-3}. The average $PM_{2.5}$ concentration was 0.33 ± 0.15 μgm^{-3}, and the highest concentration of $PM_{2.5}$ was recorded from Room A (0.50 ± 0.01 μgm^{-3}). According to the study findings, the average $PM_{2.5}$ mass concentration can be categorized as low since all the samples were below the threshold of 35 μgm^{-3} set by the Malaysia Ambient Air Quality Standard 2020 [18-19].

Table 2: $PM_{2.5}$ concentration for Lecturer Room A, B and C

Room	$PM_{2.5}$ mass concentrations (μgm^{-3})
A	0.50 ± 0.01
B	0.29 ± 0.01
C	0.21 ± 0.01

3.3 Morphological Structures of $PM_{2.5}$

Figures 2 to 4 show the micrographs of particles found at lecturer's rooms; A, B and C respectively. Analyzed using FESEM, suspended dust particles in indoor areas for Room A, B, and C exhibited aggregation of small and big particles. From the micrographs, it could be observed that Room B micrograph can be seen with a lot of particles with 5.00 k magnification compared to micrograph for Room A and C where it has to be zoomed into 50.0 and 10.0 k magnification, respectively to get a closer look into the particles.

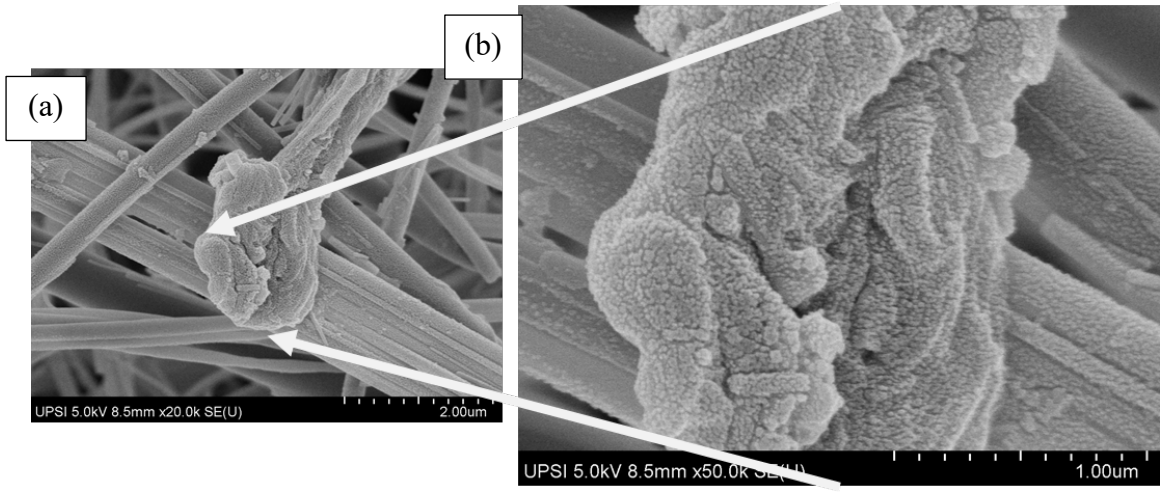

Figure 2: SEM images of $PM_{2.5}$ from Room A at different magnifications, (a) 20.0 k magnification and (b) 50.0 k magnification

Additionally, certain particles were observed to possess FESEM images of the indoor samples obtained from site A, B, and C exhibited the presence of micro-aggregates, well-

defined edges, crystalline structures, fibrous materials, and spherical forms. These particles may consist of minerals, fly ash, and soot particles. This phenomenon can be related to the dispersal of dust particles caused by outside construction operations and the movement of vehicles can infiltrate into the building through open windows, doors, and the ventilation system, leading to increased indoor $PM_{2.5}$ levels. Plus, vehicle emissions from nearby roads or parking lots are another major source of air pollutants that can degrade indoor air quality in lecturer rooms. Emissions from vehicle exhaust can enter the building and accumulate, especially if the ventilation system is not properly designed or maintained. The particles produced from burning coal, known as fly ash, typically exhibit a spherical morphology and mostly consist of silicon (Si) and aluminium (Al). The occurrence of silica and mineral particles in indoor environments may be attributed to construction operations. Soot particles are derived by the combustion of coal and emissions from vehicles [20]. They possess sharp edges and exhibit microstructure variability. Unfortunately, in this study, the image of spore cannot be found and identified. This might be due to a low number of fungal counts.

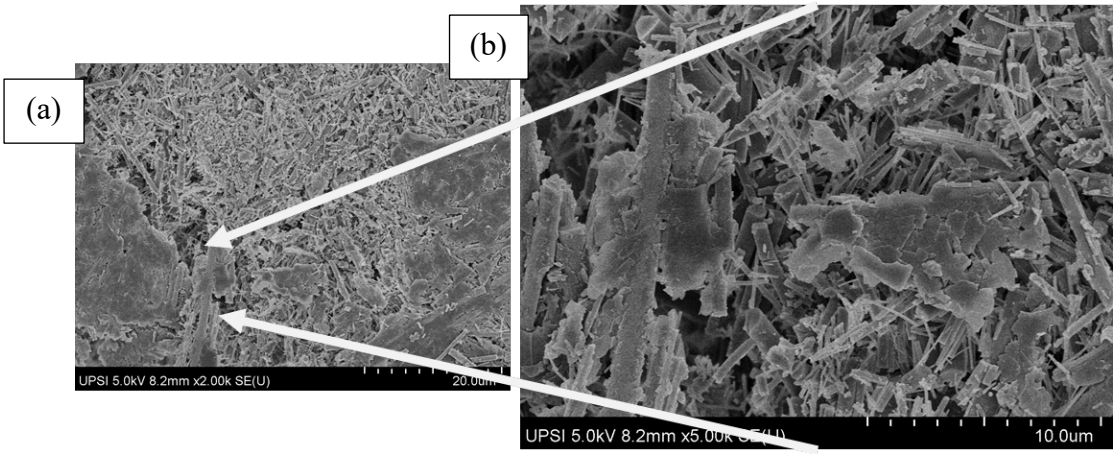

Figure 3: SEM images of $PM_{2.5}$ from Room B at different magnifications, (a) 2.00 k magnification and (b) 5.00 k magnification

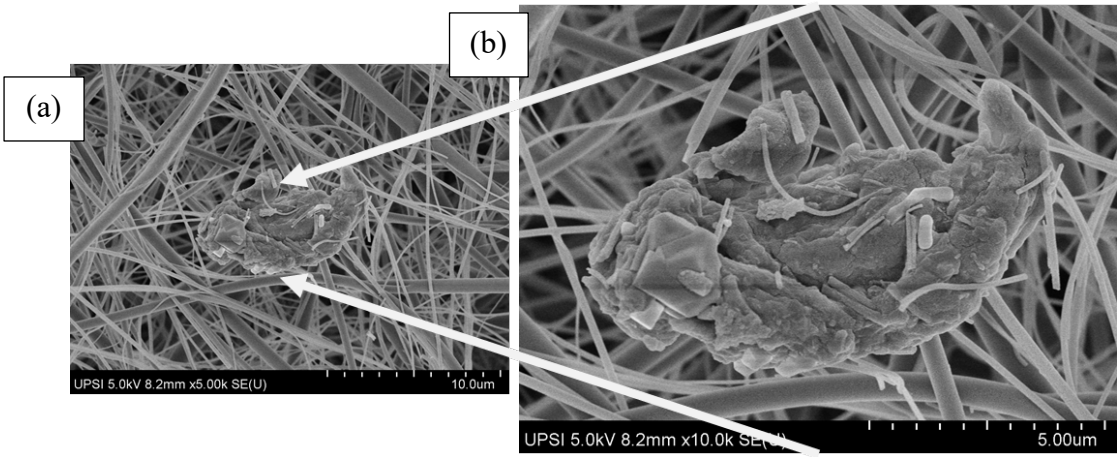

Figure 4: SEM images of $PM_{2.5}$ from Room C at different magnifications, (a) 5.00 k magnification and (b) 10.0 k magnification

4. CONCLUSIONS

The results of this research which are 136.19 ± 21.08 cfu m^{-3} for average TBC concentration, 19.37 ± 2.28 cfu m^{-3} for average TFC concentration and 0.33 ± 0.15 μgm^{-3} for $PM_{2.5}$ concentration indicate that the average values of each parameter align with the guidelines outlined in the Industry Code of Practice on Indoor Air Quality 2010. The results of this study align with the purpose of the National Policy on the Environment (DASN), which aims to create an environment that is clean, safe, and conducive to promoting productivity for present and future generations.

The investigation conducted in lecturer rooms has provided significant knowledge of the microbial aerosols and $PM_{2.5}$ concentration in the atmosphere within these rooms. The findings highlight the importance of monitoring and mitigating $PM_{2.5}$ levels to safeguard the health and well-being of lecturers. To mitigate the potential spread of airborne pathogens, it is imperative to implement strict cleaning protocols and employ effective ventilation systems, as evidenced by the existence of microbial aerosols. This study contributes to our understanding of indoor air quality and highlights the significance of implementing regulations that ensure a safe and healthy working environment.

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Author Contributions

All authors contributed toward data analysis, drafting and critically revising the paper and agree to be accountable for all aspects of the work.

Disclosure of Conflict of Interest

The authors have no disclosures to declare.

Compliance with Ethical Standards

The work is compliant with ethical standards.

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