$PM_{2.5}$ AND COMPOSITION OF MICROBIAL AEROSOL FROM SELECTED BIOLOGY LABORATORIES IN A UNIVERSITY BUILDING

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Abstract. Laboratories' air quality has an impact on employees' and students' comfort and health. Particulate matter can be regarded as one of the most important and frequently encountered indoor air pollutants. This study aims to measure the concentrations of $PM_{2.5}$, total bacterial counts (TBC) and total fungal counts (TFC), as well as the morphological structure of $PM_{2.5}$ in selected laboratories at Level 2 and 3, Block 2, Faculty of Science and Mathematics, Sultan Azlan Shah Campus, UPSI. The data collection took place in three different laboratories. During the 8-hour sampling session, samples of $PM_{2.5}$ were collected using a low-volume air sampler (LVS). In addition, airborne microorganisms were collected using a microbial sampler. The morphological structure of $PM_{2.5}$ was also observed using the Field-Emission Scanning Electron Microscope (FESEM). Results revealed the average concentration of $PM_{2.5}$ of 0.56 ± 0.24 μgm^{-3}, with Lab A (biochemistry laboratory) exhibited the highest concentration (0.83 ± 0.04 μgm^{-3}), followed by Lab B and C (microbiology laboratory). The mean values of the TBC for these three laboratories was 88.25 ± 7.81 cfu m^{-3} with the highest TBC recorded from Lab B (125.71 ± 13.86 cfu m^{-3}). However, Lab C showed the highest value of TFC with 42.86 ± 4.58 cfu m^{-3}. FESEM image revealed that the $PM_{2.5}$ were of different shapes, and forms with morphologies ranging from rounded to prismatic with distinct geometric faces. As a result, the results obtained are in good values and still in the acceptance level. These amenities guarantee that all individuals inside the premises can work in a conducive environment for productivity, benefiting both present and future generations.

Keywords: $PM_{2.5}$, microbial aerosol, total bacteria count, total fungal count, biology laboratory

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1. INTRODUCTION

Air pollution is a huge environmental crisis for most of the emerging nations [1]. The world health organisation (WHO) estimates that around 3.8 million people die each year because of indoor air pollution (IAP) [2]. Indoor air pollution (IAP) can be produced by occupant activities or releases from building materials inside homes or structures. Carbon monoxide (CO), volatile organic compounds (VOCs), particulate matter (PM), aerosols, biological contaminants, and others are harmful pollutants that can be found inside buildings [3]. Exposure to organic solvents or carcinogenic substances has been linked to a higher risk of developing some types of cancer while working [4].

Particulate matter that is the size of 2.5 μm or less ($PM_{2.5}$) has a significant impact on human health and air quality and has the characteristics of a lengthy residence time and long transmission distance [5]. The exposure to $PM_{2.5}$ is known to contribute significantly to health problems, surpassing the impact of other air pollutants [6]. According to epidemiological research, $PM_{2.5}$ can impair the immunological system, the neurological system, the cardiovascular system, and the respiratory system [7], microbial aerosols are airborne microbiological particles, that are typically present in the environment daily and they are also particulate matter that are suspended in a gas to the environment [8] which can be found anywhere, both indoor and outdoor air. Microbial aerosols are harmful to humans because they can enter the body through skin injury, mucosa, the respiratory tract, and the digestive tract, and they might harm different bodily systems permanently [9].

Managing air quality is a crucial responsibility as its elevated concentration can have adverse effects on human health [10]. Many researchers focused on the atmospheric ambient $PM_{2.5}$ and did not focus on microbial aerosol of the indoor air. By taking this issue into account, this study focuses on $PM_{2.5}$ concentration and microbial aerosol composition, which takes place at selected biology laboratories in a university building as laboratories' air quality has an impact on employees' and students' comfort and health. Biology laboratories have been selected as there are biochemistry and microbiology labs to look into the air quality between these labs as different experiments will be carried out inside the labs. In addition, a morphological study of $PM_{2.5}$ is also conducted in this study.

2. MATERIALS AND METHODS

2.1 Sampling sites

The samples were obtained from three biology laboratories of Universiti Pendidikan Sultan Idris (UPSI) located at Sultan Azlan Shah Campus, Faculty of Science and Mathematics (3.7211 ^{o}N, 101.5263 ^{o}E). In this study, three biology laboratories were chosen for the sampling and each lab's sampling will be carried out for five working days for nine hours of sampling starting at 8 a.m. until 5 p.m. Figure 1 shows the laboratory floor plan for all laboratories: Lab A, Lab B and Lab C.

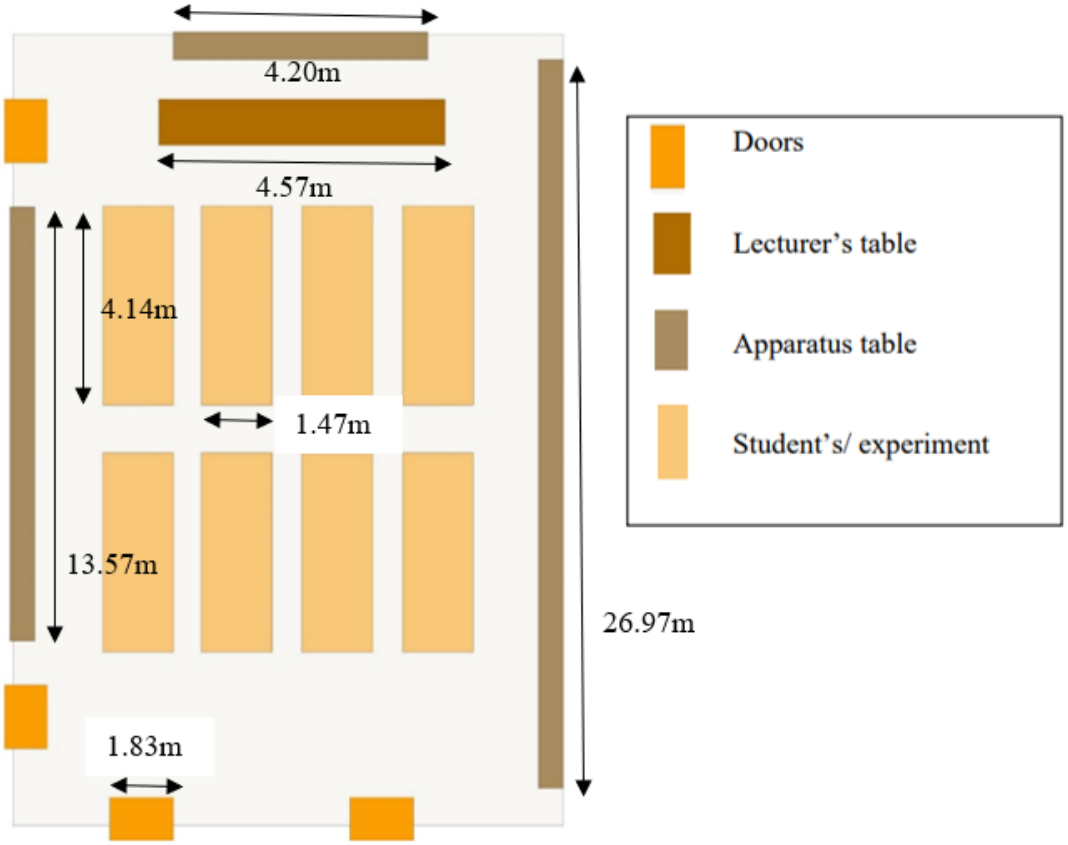

Figure 1: Floor plan of laboratory for Lab A, B and C, all labs have the same floor plan as they are arranged identically to each other

2.2 $PM_{2.5}$ Sampling Protocol

In this study, five samples were collected on five consecutive business days using a low-volume air sampler (LVS) operated at a flow rate of 5 L min^{-1} for an eight-hour cycle (9 a.m. to 5 p.m.). The samplings were conducted between August and September 2023 at three chosen biology laboratories: Lab A (biochemistry laboratory), Lab B and Lab C (microbiology laboratory). Laboratory B is regularly used for microbiology lectures and practical training, and laboratory C is used by microbiology research students. The inlet of the indoor sampler is positioned approximately one meter above the ground during the sampling period to stimulate the location of the breathing zone of the building occupants. The sampler had to be placed at least one meter away from the wall and in the center of the sampling area.

$PM_{2.5}$ samples were collected using pre-weighed microfiber glass filter paper with a pore size of 0.2 µm (manufactured by Whatman) and a diameter of 47 mm. $PM_{2.5}$ mass concentrations were determined using a 5-digit electronic microbalance and a triple gravimetric method, with an uncertainty of 0.001 mg The filters were equilibrated and dried in a drying chamber for 24 hours. After sampling, the filter papers containing the samples were weighed and stored in a refrigerator at 4 °C for further analysis.

2.3 Microbial Aerosol Sampling Protocols

The Model DUO SAS Super 360TM IAQ (DUO Surface Air System Indoor Air Quality) microbial air sampler was utilized to capture airborne microbial pollutants with a 350 L sample volume. Specifically designed to assess indoor air quality, the DUO SAS focuses the airflow onto a petri plate containing trypticase soy agar (TSA) treated with an antibiotic of cycloheximide to stop bacterial growth, as well as, chloramphenicol for malt extract agar (MEA) to stop bacterial growth. During each run, two plates were positioned in the sampler, one on each side, with one meter above the floor and facing the ventilation system.

The impaction process is a process where an air sampler will be used to collect or impact air-borne particles into the agar inside the device. Through the impaction process, the agar medium successfully captured the airborne microbiological contaminants. After every sampling session, the plates were taken out of the instrument; they were then sealed, labelled, and put back in the incubator after about a minute. To promote bacterial growth, the TSA plates were placed in an incubator at 35 °C for 24 to 48 hours. Likewise, the MEA plates were incubated at 25 °C for five days to encourage fungal growth. The average observed data was used to calculate the number of colony-forming units per cubic meter of air (CFU m^{-3}) for both bacteria and fungi using Equation 1.

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

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

To support the data, an environmental meter (EXTECH Instruments EN510), was used to capture the comfort parameters data from these three laboratories. Relative humidity and temperature were recorded to investigate the influence of the comfort parameters to the TBC and TFC values as conducted by Wahid et al. [11].

2.4 Field Emission Scanning Electron Microscope (FESEM) Analysis

The surface characteristics and elemental composition of $PM_{2.5}$ collected from filter paper were analyzed using a field-emission scanning electron microscope (FESEM, Hitachi, SU 8020) equipped with an energy dispersion system (EDS, Horiba Xmax Model) for microanalysis. A cut of filter paper of about 0.5 cm was attached directly to the aluminium SEM stub with a double-sided adhesive film and then the sample was placed in a sputter coater, and the sample was coated with platinum (Pt). With an accelerating voltage of 5 kV, the imaging setup of the microscope was modified to ensure high contrast and brightness of the particle visualization [11].

2.5 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 the statistical package for the social sciences (SPSS version 18).

3. RESULTS AND DISCUSSION

3.1 $PM_{2.5}$ Concentrations

The results showed that there were 0.56 ± 0.24 μgm^{-3} of $PM_{2.5}$ in the air on average, with Lab A (biochemistry laboratory) having the greatest concentration of $PM_{2.5}$ (0.83 ± 0.04 μgm^{-3}) followed by microbiology laboratory: Lab B (0.42 ± 0.03 μgm^{-3}) and Lab C (0.42 ± 0.03 μgm^{-3}). According to environmental protection authority Victoria's report on $PM_{2.5}$ particles in the air for 2023 [12], values of $PM_{2.5}$ may also be impacted by where the lab's monitoring equipment is located and the value for $PM_{2.5}$ acceptance rate is lower than 50µgm-3. Higher readings may result from being close to possible sources of pollution, such as dust, smoke from fires, automobile exhaust, and industrial emissions [6]. In addition, Lab A is situated closer to the parking lot and the construction site.

3.2 Microbial in the Aerosol

3.2.1 Bacteria

The total CFU for microbial growth at Lab A was 34.67 CFU/ml. For Lab B the reading was 44 CFU/ml followed by Lab C with a reading of 14 CFU/ml. The highest TBC was observed from Lab B (125 ± 13.86 μgm^{-3}), significantly different compared to Lab A and Lab C ($p < 0.05$). The mean values of the TBC for all three laboratories were 88.25 ± 7.81 μgm^{-3}.

3.2.2 *Fungi*

The total CFU for fungal growth at Lab A was 15 CFU/ml followed by Lab B and A with readings of 14.33 CFU/ml and 13 CFU/ml respectively. With a reading of 42.86 ± 4.58 μgm^{-3}, Lab A had the highest value of TFC followed by Lab B at 40.95 ± 3.51 μgm^{-3} and Lab C at 37.14 ± 1.00 μgm^{-3} with no significant difference ($p > 0.05$). The mean values for all three labs are 40.31 ± 1.00 μgm^{-3}. A greater total fungal count in a laboratory setting might be caused by several variables. These elements could be the presence of organic contaminants, high humidity, poor air filtering, insufficient ventilation, and a lack of routine upkeep and cleaning. According to the past study, these circumstances foster the growth and multiplication of fungi, increasing the overall number of fungi in the lab [13]. Table 1 shows the humidity and temperature data that were taken three times for each lab.

Table 1: Humidity and temperature for Lab A, B and C

	Humidity (%RH)			**Temperature (ºC)**		
	Lab A	**Lab B**	**Lab C**	**Lab A**	**Lab B**	**Lab C**
Average	52.5	50.1	51.5	27.4	26.7	28.5

Based on the environmental protection agency (EPA), the normal and suitable indoor humidity must be between 30 % to 50 % and it should not exceed 60 % [14]. Nevertheless, the humidity level must not exceed 60 %. The normal room temperature for Malaysia according to the thermal comfort of residential buildings in Malaysia (CORE), the recommended indoor temperature for the climate in Malaysia is between 23 ºC to 26 ºC, according to a standard indoor environment design [15].

An acceptable humidity level was observed in lab A, with an average humidity of 52.5 %. In contrast, lab A's average temperature was 27.4 ºC, which is regarded as a little higher than the recommended temperature. An acceptable humidity reading for lab B is 50.1 % on average. An appropriate temperature is 26.7 ºC, which is the average temperature for Lab B. The average humidity for lab C was 51.5 %, indicating a satisfactory humidity result. In Lab C, the average temperature was 28.5 ºC, which is hot according to the recommended temperature. According to Romero et al. [16], the prediction of global outbreaks of fungal diseases depends on the elevation of temperature and the percentage of humidity, 36.4 % of all the postings detailing fungal outbreaks from 2014 to 2019 suggested that the outbreak might have been sparked or made easier by a rise in relative humidity. It was discovered that, despite the $PM_{2.5}$ mass concentration being two to three times higher during high-temperature weather in summer compared to low-temperature periods, the high-temperature weather facilitated the dispersion of pollutants [17].

3.3 Field Emission Scanning Electron Microscopy (FESEM) Analysis

The surface morphological characteristics of airborne particles collected from indoor $PM_{2.5}$ by FESEM analysis are presented in Figures 2, 3 and 4. As shown by FESEM images, the unique morphology of particles is identified.

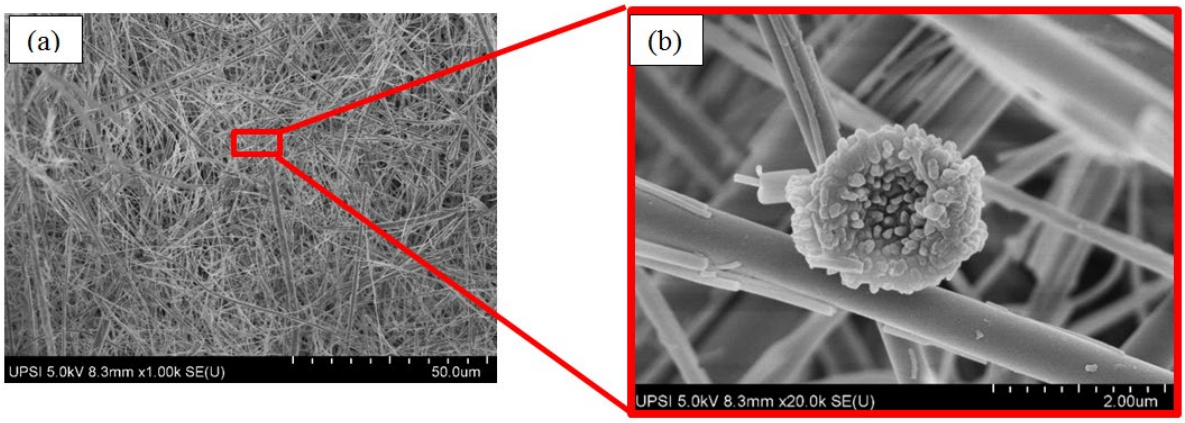

Figure 2: Particles and fungal spores found at Laboratory A: (a) low and (b) high magnifications

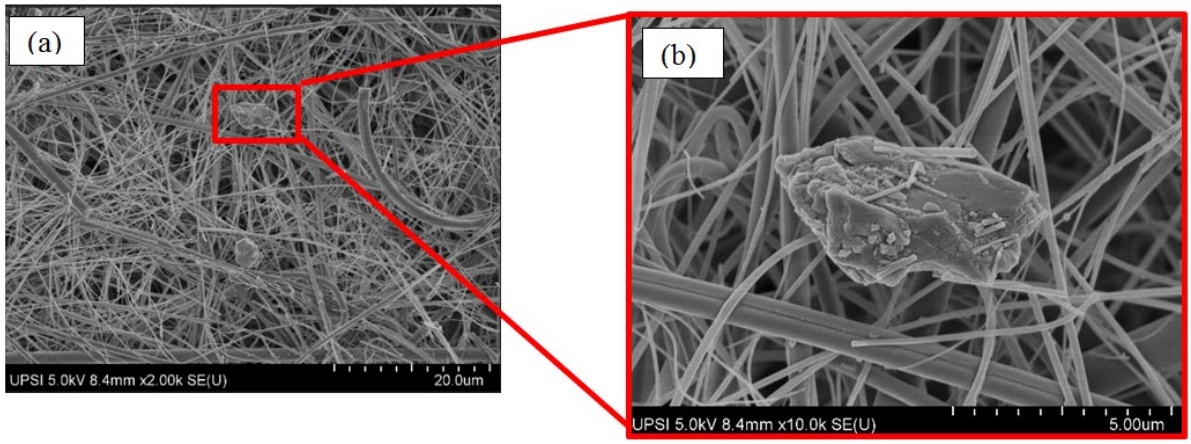

Figure 3: Particles found at Laboratory B; (a) low and (b) high magnification

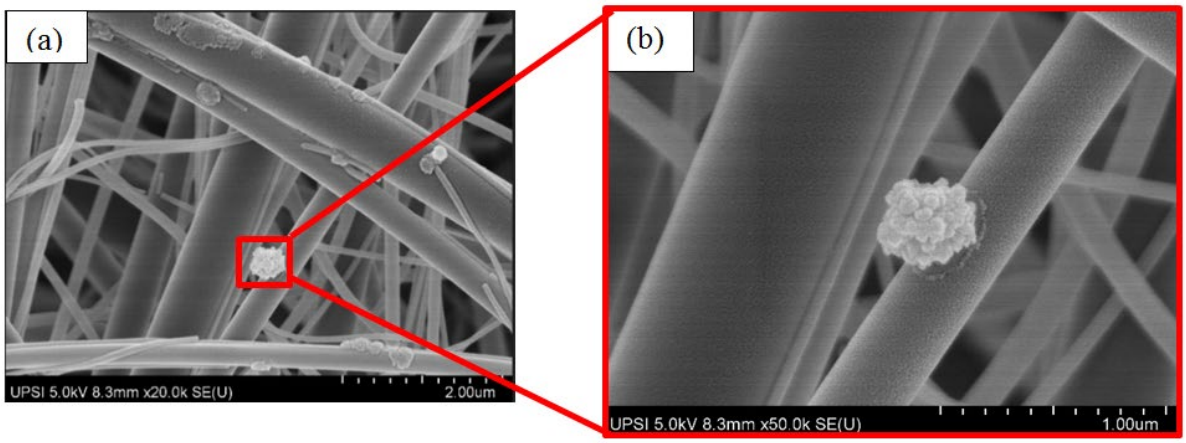

Figure 4: Particles found at Laboratory C (a) low and (b) high magnifications

The surface properties of samples A, B and C undergo a quantitative analysis of the fine dust particles. From the micrographs of the FESEM, using 2.00 k magnification, without being zoomed by using higher magnification, particles are visible for laboratory B meanwhile for laboratories A and C, higher magnification of 20.0 k magnification had to be used to see particles. Laboratory A is a biochemistry lab whereas Laboratories B and C are microbiology labs. For laboratory A and B they are frequently used by students as classes and lab experiments will be held there. For laboratory C, post-graduate students will use it not as frequently as labs A and B. There will be more movement of students going in and out of Lab A and B. The movement of students going in and out of the lab causes street dust, especially in a metropolitan setting, and plays a substantial role in augmenting the pollution levels within the urban atmosphere [11].

The FESEM image of sample A has a spore-type particle that indicates the presence of fungi. For image (a) from Figure 2, at 20.0k magnification, a particle of spore was found at 2.00 µm still to be reliably identified as a fungi. It is estimated archaea and fungi are a few orders of magnitude less abundant than bacteria in the air and that fungi have a spore as shown in image (a) (Figure 2) with the predominant size range of more or less than 4.00 µm. Therefore, the total bacterial count and total fungal count along with the low-volume sampling for $PM_{2.5}$ were used to estimate the cellular density within particles in the air that are sorted by size [18].

4. CONCLUSIONS

The data indicates varying levels of microbial growth and TBC across the three laboratories. Lab B exhibited the highest total CFU for microbial growth at 44 CFU/ml, Additionally, the highest TBC was observed in Lab B, with a reading of 125 ± 13.86 μgm^{-3}. Notably, Lab A had the highest value of TFC at 42.86 ± 4.58 μgm^{-3}. The results indicate notable variations in microbial growth and total bacterial count across the labs, with Lab B consistently showing higher levels. Further study of bacteria and fungi in each lab could offer valuable insights into these findings.

To conclude the findings, the average value of each comfort parameter followed the industry code of practice on indoor air quality 2010. Humidity levels should not exceed 60 % and all of them were below 60 %. Meanwhile, for temperature, it should be between 23 ºC to 26 ºC but there were values exceeding 26 ºC. The goals of the national policy on the environment (DASN), which aims to create an environment that is clean, safe, healthy, and

conducive to productivity for both the present and future generations, are in line with the objectives of the current study. The results highlight how crucial it is to keep an eye on and reduce $PM_{2.5}$ levels to protect lab workers' health and well-being. To reduce the risk of airborne pathogen transmission, strict cleaning procedures and ventilation systems are required, as shown by the presence of microbial aerosols. This study adds to our knowledge of indoor air quality in lab environments and highlights how important it is to put policies in place that guarantee a secure and healthy working environment for everyone engaged in biological research.

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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

No ethical standards were related for the study.

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