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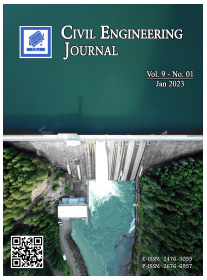

# Airborne Microbial Quality Assessment in the Educational Buildings during the COVID-19 Pandemic

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**Abstract**

Rooms with pollutants have a poor impact of 2-5 times greater than outdoors. The lecture hall had the potential to experience a decrease in air quality. This study was conducted to assess microbiological air quality in the general lecture building I Institut Teknologi Sumatra, Lampung, Indonesia, during the COVID-19 pandemic and its relationship with environmental conditions. This study was conducted using a settling sampling technique to count the number of bacteria and fungi in the air. Samples were collected twice daily for five working days. The results showed that the highest concentrations of bacteria and fungi were found at the wifi corner location, at 36.7–1237.2 CFU/m$^3$ and 225.4–1431.2 CFU/m$^3$, respectively. The highest average concentrations of bacteria and fungi at the wifi corner location were found in the afternoon at 479.1 ± 438.1 CFU/m$^3$ and 800 ± 548.4 CFU/m$^3$, respectively. The three locations did not meet the standards of room suitability for humans with immunodeficiencies based on the ACGIH. The location of the wifi corner did not meet the standards of the Minister of Manpower of the Republic of Indonesia No. 5 of 2018 and the WHO regarding microbial standards in the room. The highest value of the Global Microbial Contamination Index (GIMC/m$^3$) was found in the wifi corner (G4: ≥2000 – ≤4000), which is closely related to population density and ventilation. Environmental factors influence the density of bacteria and fungi at the sampling sites. The relative humidity strongly influenced the concentration of fungi. In addition to relative humidity, bacterial density is also affected by light intensity and the number of people. This indicates that despite restrictions on activities during the COVID-19 pandemic, the room at GKU 1 did not meet the eligibility requirements for students with immune disorders.

*Keywords:* Indoor Air; Airborne Microorganism; Education Buildings; Microbiological Index; Environmental Factors.

## 1. Introduction

Indoor air quality is complex and dynamic because it contains biological (bacteria, fungi, and viruses) and non-biological contaminants [1]. According to the National Health and Medical Research Council (NHMRC), indoor air is the air within a building occupied for at least one hour by people with various health conditions. During the COVID-19 pandemic, most people are indoors approximately 90% of the time [2]. This causes the exposure to indoor air pollutants to be 2-5 times or even 100 times greater than that of outdoor air. In addition, indoor air pollutants are consistently ranked fourth as an environmental factor that poses a risk to public health [3]. Biological particles and products affect human health and productivity [4]. Microorganisms in the air contribute 5-34% of indoor contaminants [5].

Bacterial and fungal bioaerosols are ubiquitous microorganisms in indoor environments, and some may act as airborne pathogens [6, 7]. Normal flora rarely causes human diseases, although some are agents of hypersensitivity,

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infectious, or inflammatory diseases. Endotoxins from bacteria can inflame the airways, cause asthma attacks, and cause bronchial hyperreactivity [8]. *Cladosporium*, *Alternaria*, *Aspergillus*, and *Fusarium* are the most common fungal genera associated with respiratory allergies [9]. The growth of indoor bacteria and fungi is influenced by environmental factors, including temperature, humidity, light intensity, the number of occupants in the room, types of human activities, types of ventilation, and building maintenance [10–13]. The intensity of people, occupant activity, and dust agitation significantly increased microbial concentrations [14].

The quality of indoor microbes has recently become a public concern, especially during the COVID-19 pandemic, particularly those related to public facilities, such as educational institutions, including schools and universities [15–17]. The higher education sector represents a unique work environment for faculty members, a learning environment for students, and a home environment for students [18]. Therefore, office buildings have a high population density of more than eight hours per day, five days a week [18–20]. Because many epidemic diseases are correlated with microorganisms in the air, microbiology-based studies, especially in universities, should be conducted regularly [21]. The assessments of microbiological contamination in universities have been carried out in several facilities, such as classrooms, sports halls, laboratories, rooms, entrances, libraries, cafeterias, and restaurants [19, 20, 22–29]. However, the previous studies were not carried out during the COVID-19 pandemic. A study has shown that the microbial community in the air varies according to the type of indoor environment [30]. The condition of the classroom environment plays a vital role in students' health, achievement, and behavior. Problems become more complicated and severe when dealing with students with special needs, those diagnosed with a health disorder that requires special attention and treatment [31]. The outbreak of the SARS-CoV-2 virus infection in 2019 reminds us of the importance of monitoring and controlling airborne microorganisms (bioaerosols) in public facilities, especially educational facilities. Routine cleaning and disinfection procedures due to the COVID-19 pandemic effectively eliminated SARS-CoV-2. However, the surface environment is often contaminated with other microorganisms, such as bacteria and fungi. This could be a finding of increased resistance to biocides and various environmental factors that can contribute to the spread of microbial contamination in indoor air (bioaerosols) [32].

Biological factors should be measured to determine the suitability of the number of microorganisms (bacteria and fungi) to meet quality standards [33]. Various adverse health effects may be felt if bacteria and fungi in the indoor air grow beyond the maximum index limit set by quality standards. According to the quality standards set by the Regulation of the Minister of Manpower of the Republic of Indonesia No. 5 of 2018 concerning Occupational Safety and Environmental Health, the maximum permissible index limits are 700 CFU/$m^3$ (bacteria) and 1000 CFU/$m^3$ (fungi). Until now, no specific regulations have discussed quality standards for educational institutions. However, the use of quality standards can refer to the PERMENAKER RI No. 5 of 2018 because activities within the scope of lectures are not much different from the scope of offices. In addition to PERMENAKER RI No. 5 of 2018, the Standards of the American Conference of Governmental Industrial Hygienists (ACGIH) [34] and the World Health Organization (WHO) Standard [35], can also be used as comparisons for information on the number of microorganisms in the air and analysis of conformity with the level of quality standards. Estimating health hazards and establishing control standards for air quality are indispensable.

General Lecture Building I (GKU 1) is one of the lecture buildings of the Institut Teknologi Sumatera. GKU 1 is intended to be a place for learning and teaching activities. There are library facilities, a wifi corner, and a hall that can be accessed by anyone interested. However, during the COVID-19 pandemic, learning and teaching activities cannot be carried out face-to-face at GKU 1, thus learning and teaching are online. Although face-to-face learning and teaching activities are not carried out, activities in GKU 1 during the COVID-19 pandemic are still ongoing. The office space and administrative services of the Department of Regional Infrastructure Technology (JTIK) are the places most frequently visited by the academic community under the auspices of the Department of Regional Infrastructure Technology of the Institut Teknologi Sumatera, and all those. They are interested in the Department of Regional Infrastructure Technology during the COVID-19 pandemic. In addition, services and activities are still carried out even in a pandemic situation. In this COVID-19 pandemic situation, the public wifi corner space can still be accessed by anyone, and the library remains open to the public with a limited number of visitors daily. Meanwhile, the GKU 1 hall can only be accessed on a limited basis based on permission from the campus. Therefore, this study aims to assess the microbiological quality of the air in actively visited places of GKU 1 during the COVID-19 pandemic.

## 2. Material and Methods

### 2.1. Research Site, Tools, and Material

The location of this study was carried out in one of the lecture buildings of the Institut Teknologi Sumatera, namely the General Lecture Building 1 (GKU 1), Lampung, Indonesia (Figure 1). Air samples were analyzed at the Microbiology Laboratory of the Institut Teknologi Sumatera from April to June 2021. The tools used were an autoclave, incubator, hygrometer, lux meter, petri dish, tally counter, and glassware. The materials used were Nutrient Agar (NA) medium, Potato Dextrose Agar (PDA) medium, chloramphenicol, and ketoconazole.

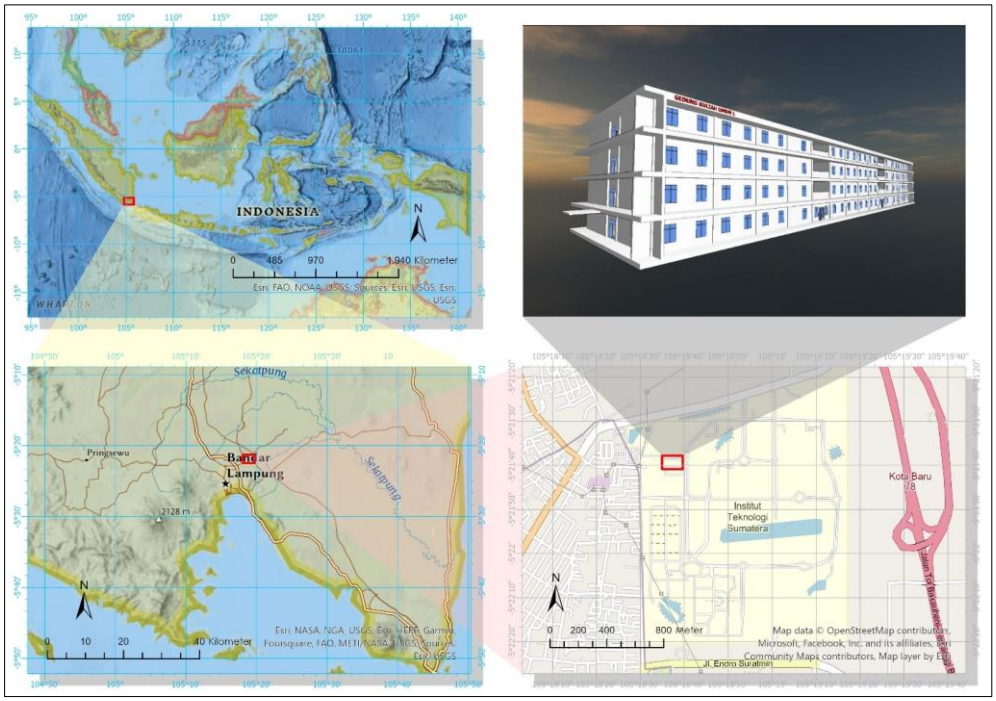



**Figure 1. Map location of sampling site**

## 2.2. Population and Sample

The population in this study was one of the Institut Teknologi Sumatera lecture buildings, namely the General Lecture Building 1 (GKU 1) (Figure 2). The sample selection technique was a purposive sampling technique, which determines samples with various considerations considering the current situation facing the COVID-19 pandemic. The sample locations were actively used and accessible to many people, even in pandemic conditions. The sampling locations must be effective and efficient with limited time and availability of equipment in the laboratory. Based on these considerations, the most suitable locations for sampling were the wifi corner on the 1st floor, the JTIK administration room, and the library. The wifi corner is a public space that does not have limited access, and the wifi corner is still crowded even in a pandemic situation. Of the four wifi corners in GKU 1, wifi corner on the first floor was selected because the wifi corner is more crowded than the other floors. The JTIK administration room was chosen because during the COVID-19 pandemic, the JTIK administration room continued to open services for everything related to the Infrastructure Technology Department, whether it was educators, study program administration services, students, and anyone who has interests and territories in the GKU 1. Furthermore, the library was chosen because the general public can still visit the library despite the COVID-19 pandemic.


**Figure 2. Sampling location plan, (a) main building sampling location, (b) location plan layout, (c) library, (d) JTIK administration room, (e) wifi corner**

## 2.3. Research Method

### *Air Sampling Data Collection:*

Bacterial and fungal samples were collected using the settling plate method, namely the placement of agar plates (NA medium was used to obtain the number of bacteria and PDA to obtain the number of fungi). The sampling procedure was carried out according to the applicable air sampling method regarding AFL Texas and Pasquarella (2000) with the following procedure [36, 37]. Sampling data were collected by placing a petri dish containing media at a distance of 80-100 cm from the floor openly at five sampling points at each sampling location (wifi corner 1st floor, JTIK administration room, and the library) for 30 minutes. Sampling was carried out at two different times to compare the beginning and end of working hours, so the sampling was carried out in the morning at 08.00 - 10.00 WIB and in the afternoon at 15.00-17.00 WIB. To obtain data variation, sampling was repeated five times on working days from Monday to Friday (Figure 3).

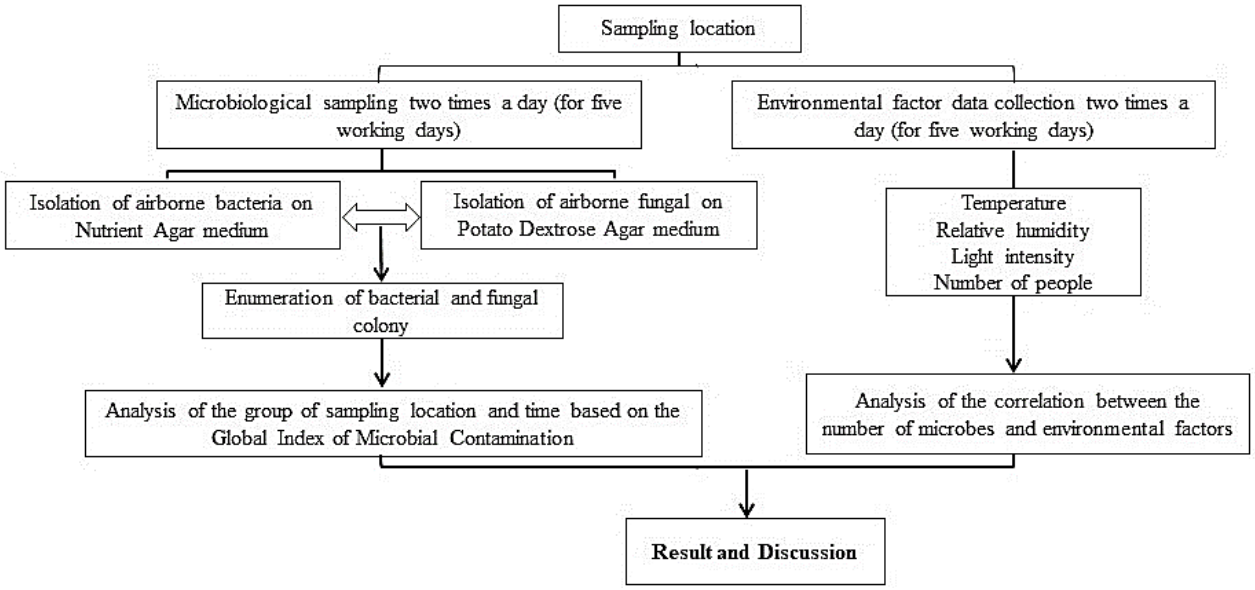



**Figure 3. Flow chart of the research methodology**

Therefore, the number of sample data obtained was 300 sample data. Petri dishes that were left to open for 30 minutes were closed again and wrapped in plastic wrap. The samples were then brought to the laboratory using a cooler bag and ice gel for the incubation process. The incubation process on bacterial samples was carried out for 24 hours at a temperature of 32 ºC. The incubation process in fungal samples was carried out for 48 hours at a temperature of 28 ˚C. Samples that had been incubated were then analyzed by calculating the number of colonies grew on media in Petri dishes using the plate count method or Total Plate Count (TPC). The colony calculation was carried out with the requirements that referred to the provisions of the Food and Drug Administration (FDA) [38]. The calculated number of colonies was then converted into CFU/$m^3$ units using the Omeliansky equation [27, 39–41]. The Omeliansky equation is shown in Equation 1.

$$\frac{\text{CFU}}{m^3} = \frac{N \times 10.000}{A \times t \times 1/5} \quad (1)$$

where N is the number of colonies on media in the Petri dishes, A is the surface area of the media in the petri dish ($cm^2$), and t is the time for the media exposure to the air (minutes). The conversion results CFU/$m^3$ were described using descriptive statistics to see the size of the diversity or variation in the statistical data and a description of the data was performed. Descriptive statistics were used to analyze and describe the data obtained as they are without drawing general conclusions [42]. The results were then adjusted to the analysis of the conformity of quality standards with the Regulation of the Minister of Manpower of the Republic of Indonesia Number 5 of 2018. In addition to analyzing descriptive statistics, various tests using inferential statistics had also been carried out to test various hypotheses. Inferential statistics analyze sample data whose results are applied to a clear population.

### *Environmental Factors Data Collection:*

Environmental factor data taken include temperature, humidity, light intensity, and the number of people in the sample location. During the bacterial and fungal sample data collection process, environmental factor data collection was carried out. Data on temperature and humidity were obtained at each sampling location using a hygrometer. Light intensity data collection used a lux meter. Measurement of light intensity was carried out at the point where the horizontal line intersects the length and width at any given distance. The distance was distinguished based on the area of the room with the provision that if the area of the room is <10 $m^2$, the point of intersection of the length and width of the room is

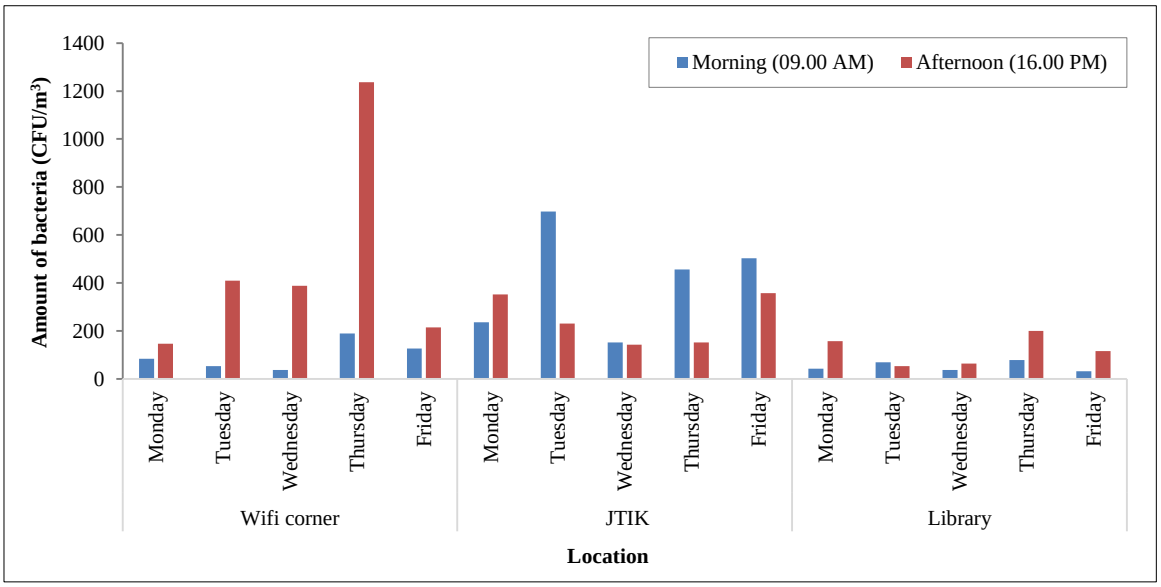
at a distance of every 1 meter. If the room area is 10 $m^2$ to 100 $m^2$, the point where the horizontal line intersects the length and width of the room is every 3 meters. If the room area is >10 $m^2$, the horizontal cut-off point for the length and width of the room is every 6 meters [43]. The area of the JTIK room and the wifi corner is 80 $m^2$, thus the point of intersection of the horizontal line length and width of the room is at a distance of every 3 meters with a measurement layout. The area of the library room is 576 $m^2$ so the horizontal intersection of the length and width of the room is at a distance of 6 meters with a measurement layout. For data collection, the number of people was done by manual calculation process using a tool in the form of a tally counter.

## 3. Results and Discussion

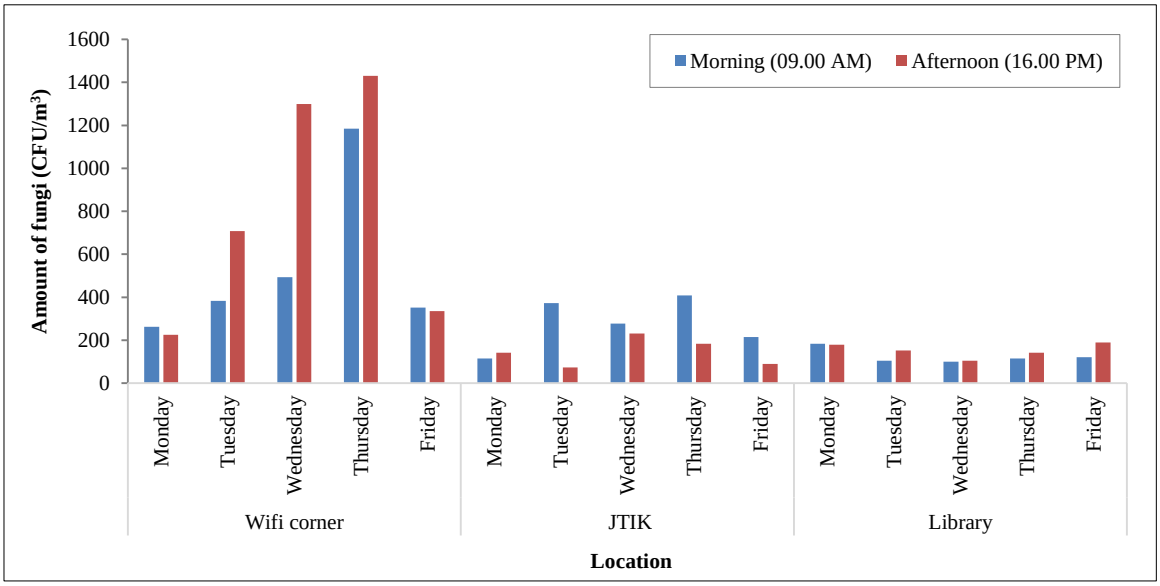
### 3.1. Variation of Microorganism Concentration in the Air of General Lecture Building I

The number of bacteria and fungi in the Public Lecture Building (GKU) 1 ITERA had differences based on the location and sampling time. Of the three sampling locations, the wifi corner was the location with the highest number of bacteria compared to other locations, which is 36.7 CFU/$m^3$-1237.2 CFU/$m^3$. The JTIK administration room was in second place, with a bacterial count range of 141.5 CFU/$m^3$-697.2 CFU/$m^3$. The library was the location with the lowest number of bacteria at 31.5 CFU/$m^3$-199.2 CFU/$m^3$ (Figure 3a). The main reason for the high number of microbes found in these locations was the students' high number and activity [39]. These results are in line with those reported in previous studies, that the highest concentrations of bacteria are found in school corridors [44] and dormitories [39]. The wifi corner was also the location with the highest number of fungi at 225.4 CFU/$m^3$-1431.2 CFU/$m^3$. The JTIK administration room was in second place at 73.4 CFU/$m^3$-408.9 CFU/$m^3$. The lowest fungi count was found in the library at 99.6 CFU/$m^3$–188.7 CFU/$m^3$ (Figure 3b). The concentration of fungi in the GKU 1 building was lower than the number of fungi in the teaching area of 1,151 CFU/$m^3$ and the office area of 791 CFU/$m^3$ in the Hangzhou University Building, Southeast China [21].

Based on the sampling time, Thursday afternoon was when the highest bacteria were found in the wifi corner location, and the lowest was on Wednesday morning. Tuesday morning was the time with the highest number of bacteria in the JTIK administration room while the lowest number of bacteria was on Wednesday afternoon. Libraries had the highest bacterial counts on Thursday afternoons and the lowest on Friday mornings (Figure 4-a). The highest number of fungi in the wifi corner was found on Thursday afternoons and the lowest was on Monday afternoons. The highest number of fungi in the JTIK administration room was found on Thursday morning, and the lowest was on Tuesday afternoon. Friday afternoon was the time with the highest concentration of fungi found in the library while the lowest number was on Wednesday morning (Figure 4-b). If the number of bacteria and fungi on each day of sampling is averaged, then the highest number of bacteria in the wifi corner compared to other locations is 479.1 ± 438.1 CFU/$m^3$ in the afternoon. The highest presence of fungi was also found in the wifi corner at 800 ± 548.4 CFU/$m^3$ in the afternoon (Table 1**).** In polish university buildings, higher indoor bacterial and fungal concentrations in the afternoon than in the morning are also reported [23]. The same conditions are also reported in the library at Torun University, Poland. Fungal concentration in the morning is 893 CFU/$m^3$ and fluctuated in the afternoon to 1,373 CFU/$m^3$ [45]. This may be because some students have not carried out activities at the sampling location at the time of sampling in the morning (09.00). This is because there are activity restrictions due to the COVID-19 pandemic. Currently, especially during the COVID-19 pandemic, students spend around 90% of their daily time in closed places, especially at home [2]. So, there is not much outdoor air exchange in the room, as reported at the Muhammadiyah University of East Kalimantan, Indonesia [46] and the student dormitory of Jimma University [47].




(a)




(b)

**Figure 4. The concentration of total airborne environmental (a) bacteria and (b) fungal at different locations and time**

**Table 1. Descriptive statistics of bacteria and fungus at different times**

| Locations | | Bacteria (CFU/m³) | | Fungi (CFU/m³) | |
|---|---|---|---|---|---|
| | | Morning | Afternoon | Morning | Afternoon |
| Wifi Corner | mean | 97.5 | 479.1 | 534.7 | 800 |
| | range | 36.7-188.7 | 146.8-1237.2 | 262.1-1184.8 | 225.4-1431.2 |
| JTIK | mean | 408.9 | 246.4 | 277.8 | 143.6 |
| | range | 152.0-697.2 | 141.5-356.5 | 115.3-408.9 | 73.4-230.7 |
| Library | mean | 51.4 | 117.4 | 124.8 | 153 |
| | range | 31.5-78.6 | 52.4-356.5 | 99.6-183.5 | 104.8-188.7 |

The two-way ANOVA analysis showed the location variable's significance value of 0.000 ($p<0.05$) on the fungal bacteria parameter. The value of sig.<0.05 means a significant difference in the number of bacteria and fungi based on each sampling location. This proved that the selection of sample locations influences the number of bacteria and fungi in the air of the Public Lecture Building I. Based on the post hoc test, it was known that there were significantly different numbers of bacteria between the wifi corner and the library, and between JTIK and the library. However, there was no significant difference in the number of bacteria between the wifi corner and the library. In addition, there was a significantly different number of fungi between the wifi corner and JTIK, and between the wifi corner and the library. However, there was no significant difference between the library and the JTIK administration room.

Indonesia has a national standard for microbial concentration in the form of PERMENAKER RI No. 5 of 2018. The recommended limit for bacteria in the room is 700 CFU/m$^3$, and fungi are 1000 CFU/m$^3$ [33]. Another standard of comparison is based on the American Conference of Governmental Industrial Hygienists (ACGIH) for people with immunodeficiency, the value of the bacterial concentration is limited to 100 CFU/m3 [34]. However, another standard for fungal use is the World Health Organization (WHO) Standard, which is 500 CFU/m$^3$ [35]. Based on Permenaker RI No. 5 of 2018, the location of the wifi corner on Thursday afternoon showed 76.7% of the number of bacteria that exceeded the standard limit. The exceeded number was also found in the fungi at the exact location and day. The fungal concentration in the wifi corner exceeded the 18.5% limit in the morning and 43.1% in the afternoon. In addition to Thursday, the wifi corner also exceeded the mushroom standard limit on Wednesday afternoon, with the percentage exceeding the standard limit of 30%. If it refers to the ACGIH standard, then all observation locations do not meet the appropriateness of air quality in the room, especially in the afternoon. All sampling locations dominated the percentage of exceeding the standard limit in the afternoon.

In this study, the location in the morning did not exceed the limit values standardized by ACGIH. This ACGIH value is related to the limit value for residents/visitors with immunity deficiency, so it is necessary to be careful if they are in the room for a long time. The size of the particles plays a vital role in the transmission and deposition of microbes in the atmosphere and respiratory tract [48]. A bacterial size of 7 µm is likely to stick to other particles as aggregates [49], so

they stick and are deposited in the room for a long time. Poor air quality due to the high number of microbes in the air allows it to penetrate the respiratory system [50]. Likewise, the size of fungal spores of <2.5 µm, straightforward to find in the environment, and very aerodynamic [51] causes the room to have poor air quality because it is filled with fungi. The same pattern is shown in fungal concentrations using WHO standards. The wifi corner locations had a percentage that crossed the line in the afternoon, especially on Tuesdays, Wednesdays, and Thursdays, which are 41.5%, 160%, and 186.2%, respectively. Only one time exceeded the WHO standard on Thursday morning by 137% (Table 2). The study of microorganisms in the room is an essential issue from ecological and health aspects. Indoor mesophyll bacteria are commonly found in *Bacillus*, an aerobic saprophyte that forms endospores, and are widely distributed in the atmosphere [15]. Although this species is very abundant in the environment and less harmful, this bacterium has the potential to become an opportunistic pathogen [52], if left in uncontrolled conditions. The composition of the fungus in the air is related to the release of fungal spores in public buildings to environmental factors and geographic location. The types of fungi in indoor air are dominated by *Alternaria*, *Cladosporium*, *Aspergillus*, and *Penicillium*. This type of fungal flora is dominant throughout the world; because they can grow in various habitats in various ways [53], there is a need to control over room conditions.

**Table 2. Frequency (%) of exceedance to standards of microbial levels for monitored sites during the sampling time**

| Location | Time | Bacterial Standards | | | | Fungal Standards | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ACGIH (100 CFU/m$^3$) | | PERMENAKER RI No.5 (2018) (700 CFU/m$^3$) | | WHO (500 CFU/m$^3$) | | PERMENAKER RI No.5 (2018) (1000 CFU/m$^3$) | |
| | | 09.00 AM | 16.00 PM | 09.00 AM | 16.00 PM | 09.00 AM | 16.00 PM | 09.00 AM | 16.00 PM |
| Wifi corner | Monday | 0 | 46.8 | 0 | 0 | 0 | 0.0 | 0 | 0 |
| | Tuesday | 0 | 308.9 | 0 | 0 | 0 | 41.5 | 0 | 0 |
| | Wednesday | 0 | 287.9 | 0 | 0 | 0 | 160.0 | 0 | 30.0 |
| | Thursday | 88.7 | 1137.2 | 0 | 76.7 | 137.0 | 186.2 | 18.5 | 43.1 |
| | Friday | 25.8 | 114.9 | 0 | 0 | 0 | 0 | 0 | 0 |
| JTIK | Monday | 135.9 | 251.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Tuesday | 597.2 | 130.7 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Wednesday | 52.0 | 41.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Thursday | 356.1 | 52.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Friday | 403.3 | 256.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| Library | Monday | 0 | 57.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Tuesday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Wednesday | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Thursday | 0 | 99.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Friday | 0 | 15.3 | 0 | 0 | 0 | 0 | 0 | 0 |

## 3.2. Microbiological Contamination Index

Indoor microbial air quality was evaluated using the microbiological contamination index: Global Index of microbial contamination per cubic meter of air (GIMC/m$^3$). Sampling locations were grouped (G) according to the distribution of GIMC/m$^3$ into (G1) ≥100 – ≤500 GIMC/m$^3$; (G2) ≥500 – ≤1000 GIMC/m$^3$; (G3) ≥1000 – ≤2000 GIMC/m$^3$; (G4) ≥2000 – ≤4000 GIMC/m$^3$ and (G5) ≥4000 GIMC/m$^3$ (Table 3). The GIMC/m$^3$ value for each location was the most categorized in the G1 group. Groups G2 and G3 were only found at the wifi corner and JTIK locations. Croup G4 was only found at the wifi corner on Thursday afternoon and was the time with the highest number of bacteria and fungi observed from all locations and times. The GIMC/m$^3$ value includes the contribution of different microbial counts (bacteria in the environment, including mesophilic bacteria and fungi). This value is related to the density and inadequate ventilation (air exchange) [54, 55]. Indoor air quality is influenced by outdoor air quality, building materials, ventilation systems, and the density of occupants [46]. The type, efficiency, and regular air conditioners are essential for maintaining better hygiene and creating healthy indoor air quality [56]. Healthy indoor air quality can be improved by avoiding overcrowding, good system design [47, 57], and suitable construction materials [29]. Density in the room causes poor indoor air quality, especially for increased temperature, humidity, and carbon dioxide [58]. Monitoring indoor air quality is needed to reduce symptoms of sick buildings, especially for parameters: temperature, humidity, carbon monoxide, carbon dioxide, and luminosity [59]. High concentrations of indoor aerosols require careful attention to avoid risks to children's health [60].

**Table 3. The group (G) of sampling locations and times related to the Global Index of Microbial Contamination**

| Group | GIMC/m³ | Building and time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Monday | | Tuesday | | Wednesday | | Thursday | | Friday | |
| | | 09.00 AM | 16.00 PM | 09.00 AM | 16.00 PM | 09.00 AM | 16.00 PM | 09.00 AM | 16.00 PM | 09.00 AM | 16.00 PM |
| G1 | ≥100 – ≤500 | WC; JTIK; LI | WC; JTIK; LI | WC; LI | JTIK; LI | JTIK; LI | JTIK; LI | LI | JTIK; LI | WC; LI | JTIK; LI |
| G2 | ≥500 – ≤1000 | - | - | - | - | WC | - | JTIK | - | JTIK | WC |
| G3 | ≥1000 – ≤2000 | - | - | JTIK | WC | - | WC | WC | - | - | - |
| G4 | ≥2000 – ≤4000 | - | - | - | - | - | - | - | WC | - | - |
| G5 | ≥4000 | - | - | - | - | - | - | - | - | - | - |

Description: WC: Wifi Corner, JTIK: JTIK Administration Office, LI: Library

### 3.3. Microenvironmental Factors

The temperature conditions during sampling were in the temperature range of 24 -29 ºC. The results of the Spearman rank correlation test stated that temperature had no significant relationship to the number of bacteria in the air (sig. 0.688 (p>0.05)). This result did not show a significant relationship between environmental factors, temperature, and the number of bacteria in the air. However, the temperature still has an effect of 0.6% on the growth of bacteria in the air with a very weak relationship level and a positive value with a correlation coefficient of (r = 0.076). A positive value means that the higher the temperature rise, the more bacterial growth will increase. The temperature also did not have a significant relationship with the presence of fungi in the air (sig. 0.108 (p>0.05)). However, the temperature still affects 9% of the growth of fungi in the air with a weak correlation level and a positive value with a correlation coefficient of (r = 0.300). The higher the temperature rises; the more fungus growth will increase (Table 4).

**Table 4. Measurements of environmental factors and the number of people during the sampling time**

| Location | Time | Temperature (°C) | | Relative Humidity (%) | | Light Intensity (Lux/m²) | | Number of people | |
|---|---|---|---|---|---|---|---|---|---|
| | | 09.00 AM | 16.00 | 09.00 | 16.00 | 09.00 | 16.00 | 09.00 | 16.00 |
| *Wifi Corner* | Monday | 27.5 | 28.9 | 79.3 | 70.0 | 486.3 | 657.7 | 6.0 | 15.0 |
| | Tuesday | 26.0 | 28.7 | 90.0 | 76.3 | 483.8 | 371.8 | 5.0 | 29.0 |
| | Wednesday | 26.8 | 26.6 | 82.0 | 92.7 | 489.2 | 99.5 | 1.0 | 16.0 |
| | Thursday | 27.0 | 25.3 | 92.0 | 93.0 | 498.0 | 55.7 | 9.0 | 29.0 |
| | Friday | 26.3 | 26.6 | 93.0 | 85.7 | 469.2 | 637.0 | 4.0 | 10.0 |
| JTIK | Monday | 26.0 | 27.3 | 71.0 | 60.3 | 248.3 | 251.7 | 16.0 | 12.0 |
| | Tuesday | 25.0 | 26.2 | 77.7 | 56.7 | 235.7 | 240.5 | 12.0 | 10.0 |
| | Wednesday | 26.0 | 26.1 | 73.3 | 72.3 | 231.3 | 205.0 | 9.0 | 9.0 |
| | Thursday | 25.7 | 26.0 | 81.0 | 78.0 | 247.2 | 210.0 | 11.0 | 9.0 |
| | Friday | 25.0 | 26.9 | 78.0 | 66.0 | 222.5 | 226.3 | 13.0 | 21.0 |
| Library | Senin | 25.8 | 25.8 | 55.0 | 63.7 | 365.4 | 342.4 | 13.0 | 23.0 |
| | Monday | 24.9 | 26.5 | 56.0 | 59.3 | 362.8 | 315.9 | 19.0 | 9.0 |
| | Tuesday | 25.4 | 25.6 | 54.0 | 57.0 | 361.9 | 368.8 | 9.0 | 11.0 |
| | Wednesday | 25.0 | 24.0 | 58.0 | 56.7 | 380.3 | 313.1 | 12.0 | 18.0 |
| | Thursday | 25.0 | 26.3 | 68.0 | 67.3 | 364.1 | 513.3 | 6.0 | 15.0 |

The relative humidity value in the GKU 1 ranged from 54% to 93%. Relative humidity has a significant relationship with the concentration of bacteria (sig. 0.047 (p<0.05)) and fungi (sig. 0.000 (p<0.05)) in the air. Relative humidity affects 13.3% of the growth of bacteria in the air with a weak relationship. Relative humidity has a very strong influence of 72.6% on fungal growth in the air. The higher the relative humidity value, the growth of bacteria and fungi will increase in the GKU 1 air. The light intensity during sampling in the GKU 1 ranged from 55.7 to 657.7 Lux. The results of the Spearman rank correlation test stated that the light intensity factor had a significant relationship with the number of bacteria in the air (sig. 0.003 (p<0.05)). The intensity affects 27.4% of the growth of bacteria in the air with a moderate level of relationship and a negative value with a correlation coefficient of (r = -0.523). A negative value means that the lower the light intensity, the growth of bacteria will grow. On the other hand, the light intensity did not have a significant relationship with the presence of fungi in the air in GKU 1 (sig. 0.709 (p>0.05)). However, the light intensity had an effect of 0.5% with a very weak level of interaction on fungal growth in the air of GKU 1 (Table 5).

**Table 5. The spearman rank correlation value between environmental factors and the number of people to the presence of microorganisms**

| Environmental Factors | Microorganisms | Sig | r | $r^2$ | $r^2$ (%) | Interaction level |
|---|---|---|---|---|---|---|
| Temperature | bacteria | 0.688 | 0.076 | 0.006 | 0.6 | Very weak |
| | fungi | 0.108 | 0.300 | 0.090 | 9 | Weak |
| Relative Humidity | bacteria | 0.047 | 0.365 | 0.133 | 13.3 | Weak |
| | fungi | 0.000 | 0.852 | 0.726 | 72.6 | Very strong |
| Light Intensity | bacteria | 0.003 | -0.523 | 0.274 | 27.4 | Moderate |
| | fungi | 0.709 | 0.071 | 0.005 | 0.5 | Very weak |
| Number of People | bacteria | 0.001 | 0.558 | 0.311 | 31.1 | Moderate |
| | fungi | 0.540 | -0.116 | 0.013 | 1.3 | Very weak |

Description: Sig.= Significance level, r= Correlation coefficient, $r^2$ = Value determination

Temperature and relative humidity have a complex relationship with air microorganisms, building conditions, and microbial types. This is associated with microbial aerosols' nature, so it is very influential with temperature and humidity conditions [54]. However, this study showed that indoor temperature did not affect the presence of bacteria and fungi. The same result was also reported in Malaysian school buildings, that indoor temperature did not affect the generative pattern of bacteria and fungi in the air, but the room's relative humidity affected the concentration of bacteria in the air [15, 61, 62]. Temperature and relative humidity are associated with the drying and rehydration of water, thus affecting the survival of bacteria, fungi, and viruses in the air [63]. Low relative humidity (<65%) harms bacterial growth and significantly affects fungal concentrations [39, 64]. The concentration of fungi will increase along with the suitability of temperature and relative humidity, causing optimal microbiological activity [54]. Another factor in the form of light intensity, light intensity usually affects photosynthetic bacteria. Light is the main energy source for autotrophic and photosynthetic organisms related to biomass growth and nutrient absorption [65]. The intensity of light that influences the presence of bacteria is in the range of 18-270 Lux/$m^2$, as reported on the border market in Thailand [62].

During sampling, the number of people in GKU 1 was 1–29. It was detected that the highest number of bacteria and fungi were found when the room was at the highest number of people, namely 29 people. The lowest number of bacteria was found when the number of people in the room was low (only 1). However, the fungi concentration remained at a reasonably high concentration. The results of the Spearman rank correlation test stated that the number of people had a significant relationship (sig. 0.001 ($p<0.05$)) to the number of bacteria in the air. The number of people who suggested an effect of 31.1% on the growth of bacteria in the air with a moderate level of relationship ($r=0.558$). However, the number of people did not have a significant relationship (sig. 0.540 ($p>0.05$) to the number of fungi in GKU 1. The number of people only had an effect of 1.3% on fungal growth in the air, with a very weak relationship level and a negative value ($r = -0.116$). The fewer people, the growth of fungi in the air of GKU 1 will increase.

The concentration of bacteria in a room is correlated with human/occupant activity and the intensity of people [66], while fungi are influenced by biotic environmental sources [67]. A room occupied by 4-26 people has a higher bacterial count than a room occupied by 1-5 people [47]. The presence of humans is a source of bioaerosols in the room [15]. Activities such as talking, sneezing, and coughing can generate and increase the transmission of indoor bioaerosols [6, 9]. Discussing and talking to each other was detected as having a significant role in increasing the number of microbes at the sampling location, especially at the wifi corner location (Table 6). It should be mentioned that the main limitations in this study are the microbial flora analyzed using culture-based techniques, which can only grow 1% of the total microbes in the room [44]. The microbial concentration varies significantly in space and in time, as well as in the relative number of samples used. Low and short sampling times may not accurately reflect these results.

**Table 6. Types of people's activity detected during the sampling time**

| Activity | Location | | |
|---|---|---|---|
| | Wifi Corner | JTIK | Library |
| Discuss | yes | no | no |
| Interact | yes | yes | yes |
| Talk to each other | yes | yes | no |
| Using laptop | yes | yes | yes |
| Using Smartphone | yes | yes | yes |
| Passing by | yes | yes | no |
| Play with cat | yes | no | no |
| Busy and unfavorable activity | yes | no | no |
| Busy and conducive activity | no | yes | no |
| Calm and conducive activity | no | no | yes |

## 4. Conclusion

This study has provided important information on the status of microorganisms in the air and an initial evaluation of the microbial quality of the air in lecture halls during the COVID-19 pandemic. This evaluation was carried out with the condition that face-to-face activities were abolished, but activities inside the building were still running well. The concentration of bacteria and fungi in the air of the lecture hall is influenced by environmental factors such as relative humidity, light intensity, the number of people, and types of human activities. The concentration of fungi depends on the relative humidity of the room. Building areas with busy human activities have a strong impact on the presence of bacteria in the air so that their density becomes high. Additionally, bacterial density is also affected by relative humidity and light intensity. Air quality that does not meet the requirements between each area of the building is strongly influenced by human activities. This can be seen from the Global Index Value of Microbial Contamination (GIMC/$m^3$) that both rooms (JTIK room and Wifi corner) were in Group G3 with a bacterial range (≥1000 – ≤2000). Both areas have the highest human activity. The highest GIMC/$m^3$ value was found in the wifi corner (G4: ≥2000 – ≤4000) which has a close relationship with population density and ventilation. The GIMC/$m^3$ value was also directly proportional to the air quality status of the wifi corner area according to Indonesian Minister of Manpower Regulation No. 5 of 2018 and WHO, which is classified as not meeting the standards. In addition, the entire sampling area also did not meet the room eligibility standards for students with immunodeficiency. This showed that under the conditions of the COVID-19 pandemic, with some restrictions on face-to-face lectures, the microbiological air quality in the GKU-1 building is still not feasible. This will be even more worrying if face-to-face learning is carried out again. In order to improve air quality, it is necessary to arrange the appropriate number of students for each class, design adequate ventilation, and regularly clean the classrooms.

## 5. Declarations

### 5.1. Author Contributions

Conceptualization, M.A. and S.S.; methodology, M.A; validation, M.A, and A.Z.; formal analysis, M.A. and S.S; investigation, M.A. and S.S; resources, M.A. and S.S; data curation, M.A. and A.Z.; writing—original draft preparation, S.S; writing—review and editing, M.A.; visualization, M.A.; supervision, M.A. and A.Z. All authors have read and agreed to the published version of the manuscript.

### 5.2. Data Availability Statement

The data presented in this study are available in the article.

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### 5.5. Conflicts of Interest

The authors declare no conflict of interest.

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