*Salud, Ciencia y Tecnología*. 2025; 5:1152
doi: 10.56294/saludcyt20251152

**ORIGINAL**

# Appraisal of Microbial Indoor Air Quality in Applied Medical Sciences College

## Evaluación de la calidad microbiana del aire interior en la Facultad de Ciencias Médicas Aplicadas

Mohamed Abdel-Monem El-Sakhawy[1]

[1]Department of Medical Laboratory, College of Applied Medical Sciences, Prince Sattam bin Abdulaziz University, Al-Kharj 11942, Saudi Arabia.
[2]Department of Medicinal and Aromatic Plants, Desert Research Center, Cairo, Egypt.

**Cite as:** El-Sakhawy MA. Appraisal of Microbial Indoor Air Quality in Applied Medical Sciences Collage. Salud, Ciencia y Tecnología. 2025; 5:1152. https://doi.org/10.56294/saludcyt20251152

**Submitted:** 10-08-2024 **Revised:** 15-12-2024 **Accepted:** 23-02-2025 **Published:** 24-02-2025

**Editor:** Prof. Dr. William Castillo-González

**Corresponding author:** Mohamed A. El-Sakhawy

## ABSTRACT

**Introduction:** human activities like talking, sneezing, coughing, walking, washing, and toilet use contribute to an increased airborne microbiological load. The air is full of various microorganisms, which act as a medium for their transmission or dissemination. This study aimed to determine the types and concentrations of bacterial and fungal aerosols, evaluate the indoor air quality, and determine the factors responsible for their presence in the College of Applied Medical Sciences building, PSAU, KSA.
**Method:** indoor microbial loads were evaluated by collecting 84 samples from different localities using the settle plate method.
**Results:** the average indoor microbiological air ranges from 0 to 150,7 and 13,1 to 242,5 CFU per $m^3$ for fungi and bacteria, respectively. In the indoor-to-outdoor ratio, the results recorded 0,033 to 0,067 and 0,022 to 0,049 for fungi and bacteria, respectively. A total of 282 bacteria were identified, 2 isolates belonging to Gram-positive cocci (*Kocuria rhizophila* 3,3 %, and *Staphylococcus epidermidis* 15 %), Gram-positive cocci (14 %), and Gram-positive rod belonging to *Bacillus* spp. (39 %). One isolate was identified as *Sphingomonas paucimobilis* (0,7 %). Fungal indoor isolates (n=48) were isolated; 46 isolates were filamentous fungi identified as 9(18,8 %) *Aspergillus* spp. (*A. niger, A. terreus, A. ochraceus*, and other *Aspergillus* spp.), 9(18,8 %) *Alternaria* spp., 8(16,7 %) *Penicillium* spp., 3(6,3 %) *Fusarium* spp., 2(4,2 %) *Rhizopus* spp., 2(4,2 %) *Cladosporium* spp., 1(2,1 %) *Drechslera* sp., and 12(25 %) different unknown species, in addition to two yeast isolates.
**Conclusions:** the building is safe and suitable for the current number of students, and the building's design is in the same condition.

**Keywords:** Indoor; Air Quality; Bacteria; Fungi; Indoor-to-Outdoor Ratio; Identification; Microscopic; Macroscopic.

## RESUMEN

**Introducción:** las actividades actividades humanas como hablar, estornudar, toser, caminar, lavarse y usar el inodoro contribuyen a aumentar la carga microbiológica del aire. El aire está lleno de diversos microorganismos, que actúan como medio para su transmisión o diseminación. Este estudio estudio pretendía determinar los tipos y concentraciones de aerosoles bacterianos y fúngicos hongos, evaluar la calidad del aire interior y determinar los factores responsables en el edificio de la Facultad de Ciencias Médicas Aplicadas, PSAU, KSA. En el edificio de la Facultad de Ciencias Médicas Aplicadas, PSAU, KSA.
**Método:** se evaluaron las cargas microbianas interiores recogiendo 84 muestras de diferentes localidades mediante el método de la placa de sedimentación. de diferentes lugares mediante el método de la placa de sedimentación.

**Resultados:** la media microbiológica del aire interior oscila entre 0 y 150,7 y entre 13,1 y 242,5 UFC por m3 para hongos y bacterias, respectivamente. En cuanto a la relación interior-exterior, los resultados registraron de 0,033 a 0,067 y de 0,022 a 0,049 para hongos y bacterias, respectivamente. Se identificó un total de 282 bacterias, 2 aisladas pertenecientes a cocos grampositivos (*Kocuria rhizophila* 3,3 %, y *Staphylococcus epidermidis* 15 %), cocos grampositivos (14 %), y bastoncillos grampositivos pertenecientes a *Bacillus spp.* (39 %). Un aislado se identificó como *Sphingomonas paucimobilis* (0,7 %). Se aislaron hongos de interior (n=48); 46 aislados eran hongos filamentosos identificados como 9(18,8 %) *Aspergillus spp. (A. niger, A. terreus, A. ochraceus* y otros *Aspergillus spp.),* 9(18,8 %) *Alternaria spp*, 8(16,7 %) *Penicillium spp.,* 3(6,3 %) *Fusarium spp.,* 2(4,2 %) *Rhizopus spp.*, 2(4,2 %) *Cladosporium spp.,* 1(2,1 %) *Drechslera sp.,* y 12(25 %) diferentes especies desconocidas, además de dos levaduras aisladas.
**Conclusiones:** el edificio es seguro y adecuado para el número actual de estudiantes, y el diseño del edificio está en las mismas condiciones.

**Palabras clave:** Interior; Calidad del Aire; Bacterias; Hongos; Relación Interior-Exterior; Identificación; Microscópico; Macroscópico.

## INTRODUCTION

Generally, an infectious disease starts as a pathogen-induced illness or a hazardous substance that spreads to a susceptible host from an infected person, animal, or contaminated inanimate object.[1] Pathogenic microbes can spread through the air or by direct or indirect physical contact.[2] Excreta from animals, human bodies, wallpaper, carpets, suspended particles, air conditioners, non-bioaerosol particles (such as smoke, cooking residue, dust, and gases), and outdoor air are among the sources of contaminants found in indoor air.[3,4]

From a health perspective, indoor air pollutants due to microbes might potentially cause infections, so pollutants of biological origin are known as biological contaminants or bio-contaminants. Bioaerosols are aerosols that contain microorganisms (viruses, bacteria, protozoa, fungi, algae, and mites), insect detritus, and animal epithelia or organic compounds generated from microbes (endotoxins, metabolites, toxins), and other microbial pieces are major elements in the air.[5,6]

The size and composition of bioaerosols range from 20 nm to less than 100 µm, contingent upon the source, the processes involved in aerosolization, and the local ecosystem.[7] The study of live microorganisms suspended in the air is known as aeromicrobiology. The aeromicrobiological pathway explains the following processes: the release of bioaerosols into the atmosphere, the movement of these particles through diffusion and dispersion, and the eventual deposition of these particles.[8]

Because the inhaled proportion of the bioaerosols is most likely to enter the deeper regions of the respiratory system, it is the portion that should be of greatest concern.[9]

Recent years have seen an increase in interest in the sampling and analysis of airborne microorganisms because of worries about bacterial and mold contamination of indoor environments, the possibility of bioterrorism, and the occurrence of related health effects such as infectious diseases, acute toxic effects, allergies, and cancer.[10,11,12,13]

Human diseases can be caused by bioaerosols in a variety of ways. Just two instances of these illnesses are pulmonary infections and allergic disorders. Human health may be affected by bioaerosol-caused diseases either immediately or gradually.[14,15] A more comprehensive comprehension of the populations of airborne microorganisms would facilitate a more accurate assessment of the bioaerosol exposure observed in an occupational setting. Numerous microorganisms can be found in the air, bacteria and fungi are among the most common bioaerosols, indicators of microbial load contamination, and easy to evaluate.[16]

The bioaerosols have been shown to contain bacteria, for instance, *Staphylococcus aureus*, *Stenotrophomonas maltophilia, E. coli, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, Stenotrophomonas maltophilia, Haemophilus influenzae, Legionella pneumophila, Streptococcus pneumonia, Chlamydia pneumonia, Mycoplasma pneumonia,* and *Mycobacterium tuberculosis*, depending on the infectious status of the individual.[17,18,19]

Both inhalation and skin contact are routes by which harmful germs spread as aerosols. The virulence of the bacteria, the environment, the exposure route, and the host's immunological response all impact the possible effects they may have. Infectious infections, allergy disorders, acute toxic effects, respiratory disorders, neurological impacts, and perhaps cancer can all result from bioaerosol exposure and the spreading of resistant bacteria among bacterial aerosols.[20,21]

The following airborne fungi can cause allergic reactions and respiratory infections: *Mucor*, *Aspergillus*, *Cladosporium*, *Penicillium*, *Paecilomyces*, and *Acremonium*, but *Aspergillosis* is the most frequent illness, which can occur in immunocompromised hosts after inhaling fungal spores or their toxins.[22]

Asthma patients with a chronic condition may eventually develop colonization of *Aspergillus fumigatus*,

*Wangiella dermatitidis*, or *Bipolaris hawaiiensis* in their bronchial tubes. Aeroallergens include *Fusarium*, *Aspergillus*, and *Stachybotrys*.[23] In addition, other fungi, including *Coccidioides*, *Blastomyces*, and *Histoplasma*, have been connected to exposure to animal- or wind-borne contaminants. [24] Also, other products of microorganisms transmitted by air can cause infection, including mycotoxins and other secondary metabolites in addition to Glucan. ß-(1-3)-glucans, considered glucose polymers found in fungi and certain bacteria, have been linked to heightened respiratory symptoms in several occupational contexts.[25,26,27]

The concentration amounts of airborne fungi and bacteria (indoor and outdoor) are $10^2$–$10^3$ spores per $m^3$ and $10^2$–$10^6$ CFU per $m^3$, respectively.[28]

On the other hand, temperature, humidity, air exchange rate, building location, and other environmental conditions all contribute to the formation and proliferation of bioaerosols in the indoor atmosphere due to inefficient design, ventilation, airflow, and internal area.[4,29]

Therefore, research on indoor aeromicrobiology has highlighted the need for improved ventilation systems and hygiene practices to reduce microbial contamination indoors. Monitoring environmental variables can be a helpful technique for illuminating potential sources of bioaerosol[12,30] and updating safety guidelines for those working in laboratories.[31]

The types and amounts of airborne microorganisms indoors can be influenced by various factors, including building materials, ventilation systems, occupancy levels, air conditioners, fans, humidifiers, and cleaning techniques. People breathe in ten cubic meters of air each day on average. Furthermore, because adolescents spend the majority of their time indoors (≥90%), they are continuously exposed to airborne microorganisms.[4]

Research has been done to examine indoor air quality, as it is becoming a more significant concern for public and occupational health.[32,33] It is important to evaluate indoor air in hospitals, public buildings, student and staff staying places, inside laboratories, inadequate ventilation, the outside environment, and changes in building practices.[34,35,36]

In contrast to many other buildings, schools and universities place greater emphasis on appropriate indoor air quality. Students' productivity, focus, and learning processes are all impacted by the indoor air quality of universities.[37] Moreover, several studies conducted in educational settings have shown that the air quality in classrooms is frequently insufficient, increasing the risk of respiratory ailments and other health-related symptoms.[36]

Indoor air quality in all workplaces and public places needs to be assessed and evaluated in schools and universities.[38]

The main objective of this work is to determine the types and concentrations of bacterial and fungal aerosols and the indoor air quality of different places in one of the health college buildings, PSAU, KSA. In addition, assess the effects of occupancy, activities, and the environment within the buildings on the levels and types of airborne microorganisms. The present study will compare the findings to available standards and guidelines for bioaerosols and indoor air quality.

## METHOD

Prince Sattam bin Abdulaziz University (PSAU) is a public higher educational institution that was established in August 2009 (9/1430 H.) under Royal Decree No. M/7305. The university includes colleges in five governorates of Riyadh Region—Saudi Arabia, which are Al Kharj, Al Aflaj, Al Slayel, Hotat Bani Tamim, and Wadi Addawasir. PSAU holds about 28 000 students, and it includes 20 faculties. The College of Applied Medical Sciences building is one of the university buildings on the main campus located in Al Kharj. The College of Applied Medical Sciences includes five departments.

### Air conditioning system

The air conditioner system of the CAMS building is operated by a chilled water fan coil unit and an air handling unit, Zamil Air Conditioners in offices and labs, respectively. The current of air in these systems has been transported through filters (aluminum and bag) to purify it.

### Sampling

*Sampling area*

Bacterial and fungal numbers and types of microorganisms present in indoor air were inspected in the Applied Medical Sciences building collage (CAMS) for males at Al-Kharj, KSA, in selected labs, clinics, and rooms. The study was conducted in April and May 2023. Samples were duplicated and gathered from various locations of the college, including labs (general microbiology, mycology, bacteriology, hematology, histology, immunology, and clinical biochemistry), classrooms, halls, library, and office rooms.

Indoor microbial loads were evaluated by collecting 84 samples in duplicate from 42 places, including different localities (labs, classrooms, halls, libraries, staff office rooms, administrative offices, and physical therapy clinics) in CAMS building No. 5 in Al-Kharj, PSAU, KSA, in addition to outdoor sample.

*Sampling collection and procedures*

The settle plate, known as the passive air sampling technique, was used for microbial (bacteria and fungi) measurements. The Petri dishes used in this technique, which were 90 mm in diameter, were put 100–150 cm above the floor in the middle of the room, which was the sampling height that roughly corresponded to the human breathing zone. Also, the conditions during the sampling and other things that may affect the microbial load during sampling were recorded, including place temperature according to the working of the air conditioner, the opening of windows, and the presence of persons (students, workers, or staff) in the places.

Bacterial air samples were collected using Nutrient Agar (NA) and Tryptic Soy Agar (TSA), while fungi were collected using Sabouraud Dextrose Agar (SDA) and Malt Extract Agar (MEA), plates, respectively. The sampling durations of 30 to 60 minutes were chosen in order to have the right surface density for counting and to calculate the load concerning exposure time. Moreover, samples were collected during the active daytime from 9:00 a.m. to 1:00 p.m. After exposure, the Petri dishes containing samples were taken to the microbiology lab and incubated aerobically at 37 °C for 24-48 h for bacteria and at 27 °C for 2–7 days for fungi. The number of bacterial colonies present was determined after the incubation period, while the number of fungal colonies present was assessed every day within the incubation period. The total number of colony-forming units (CFU per $m^3$) was calculated using the standard equation given below.[39,40,41,42]

Number of microbes (N) expressed by CFU/$m^3$ = $5a\times10^4$ $(bt)^{-1}$,a; no. of colonies/Petri dish, b; dish surface (square centimeters), t; exposure time (minutes).

**Identification of microbial isolates**

The solid powder materials for each bacterial and fungal medium preparation were dissolved in one liter of distilled water, and the mixture was then heated to 60–70 °C while being stirred until completely homogenized. The media were sterilized by autoclaving for 20 minutes at 121°C, and then they were cooled and poured onto nine-centimeter Petri dishes in diameter.

*Bacteria*

Nutrient Agar (NA), MacConkey Agar (MA), Mannitol Salt Agar (MSA), and Tryptic Soy Agar (TSA) media produced by Scharlau, Barcelona, Spain, 5 % sheep blood plates were used for the isolation, maintenance, and identification of bacteria.

The morphologically distinct bacterial colonies were compared with each other, and every morphological group discovered was represented by a single isolated strain, which was chosen and isolated in separate Petri dishes. Then the isolates were stained by the Gram stain and examined by light microscopy to determine the morphological characteristics of the bacterial isolates and Gram reactions.

Bacterial isolates were inoculated into the appropriate VITEK identification using VITEK 2 Compact Systems (BioM_erieux, France). In addition, it is confirmed by several biochemical tests (for instance, catalase, coagulase, etc.) and different media. the confirmation of bacterial isolate identification according to standard methods.[43,44,45]

*Fungi*

Malt Extract (MEA), Potato Dextrose (PDA), and Sabouraud Dextrose (SDA) Agar Media (Scharlau, Barcelona, Spain) were used for the isolation, maintenance, and identification of fungi, according to Smith and Onions [46]; and Dewitte-Orr *et al*, [47] Yang and Heinsohn [48].

For purification and identification, colonies deemed morphologically unique and distinct were separated and subsequently compared with other colonies. This allowed for the selection of a single distinct isolated strain that was typical of each morphological group discovered sub-cultured in the same medium. Or suspended in sterilized saline (NaCl 0,9 %) tubes as serial dilations, then cultured in a fungal culture medium.

In addition to measuring the diagnostic structures that defined the species, measurements were made of gross morphology, which includes the rate of growth, colony diameter, texture, color, and reverse pigmentation. Certain fungus strains were subjected to varying culture conditions, including temperature (20–28 ºC) and duration of incubation (5–12 days), as well as other culture media. To identify fungi taxonomically, the vegetative mycelium and the reproductive structures' physical features were taken into consideration.[49,50,51,52,53,54,55,56] The micromorphological features of filamentous fungi were examined and photographed using a Nikon (Eclipse LV100 POL Polarizing) microscope.

**Statistical analysis**

The collected data were organized, tabulated, and statistically analyzed using SPSS software (Statistical Package for the Social Sciences, version 23, SPSS Inc., Chicago, IL, USA). Descriptive analysis used the mean to describe bacterial and fungal loads. To assess the difference between bacterial and fungal loads in different places (labs, classrooms, halls, libraries, staff office rooms, administrative offices, and physical therapy clinics), an ANOVA test was used to describe this difference. Significance was adopted at $p<0,05$ for results interpretation

according to the significance test.

## RESULTS

Estimating the health risks and developing guidelines for indoor air quality control require knowledge of the indoor microbial concentrations of airborne bacteria and fungi, which may affect students, workers, and staff members in one of the most common university buildings in Saudi Arabia. After the collection of microbial indoor air samples, bacterial and fungal colonies were counted and identified, and the air microbiological load was assessed and evaluated according to the following:

Microbial loads were increasingly affected during sampling by many conditions, including the opening of windows (especially with the increasing current of air), the increasing number of people (students, workers, or staff), and the increase in room temperature (not working conditioner). On the other hand, the microbial loads were not affected meaningfully by the kind of study inside all microbiology laboratories; in other words, the air in all microbiology laboratories was not contaminated or was not affected (non-statistically significant) by the microbiological studies inside the microbiology laboratories. In the same context, the microbial loads were decreasing greatly indoors compared to outdoors. The microbial load was not affected (non-statistically significant, $p$=0,748) by the two air conditioner systems of the CAMS building (a chilled water fan coil unit and an air handling unit) achieved in offices and laboratories. Moreover, microbial air load is not affected (non-statistically significant) in the different indoor places studied. Figure 1 shows the colonial morphology and morphological characteristics of the most common mold isolated from indoor air.

The results of this study, interested in the concentration and average concentration range of bacterial and fungal aerosols appraised with the settle plate method found at the different CAMS places under investigation, are displayed in tables 1–3. The average microbiological air quality in CAMS indoors ranges from 0 to 150,7 and 13,1 to 242,5 CFU per $m^3$ for fungi and bacteria, respectively, while the outdoor average recorded 629,1 and 1932,2 CFU per $m^3$ for fungi and bacteria, respectively. For understanding the indoor/outdoor relationship by calculating the I/O ratio, the results recorded 0,033 to 0,067 and 0,022 to 0,049 for fungi and bacteria, respectively. The average of aeromicrobiology ranged from 0 to 242,5 CFU per m3. The indoor-to-outdoor ratio (I/O) was calculated as a mean and ranged from 0,022 to 0,067. In addition, microbial identification was listed in tables 4 -6 and figure 1. The microbial concentration of indoor air differs from the sampling area to other areas, as shown in tables 1–3 and figures 1.

**Table 1.** The average indoor air microbial count (CFU per $m^3$) of different medical laboratory department (MLAB) labs

| | Bacteriology lab | Biochemistry lab | Clinical chemistry lab | General microbiology lab | Hematology lab | Mycology lab | I/O | ANOVA test | *P* value |
|---|---|---|---|---|---|---|---|---|---|
| Bacteria | 144,2 | 13,1 | 13,1 | 13,1 | 26,2 | 52,4 | 0,022 | 5,167 | 0,166 |
| Fungi | 13,1 | 8,7 | 13,1 | 13,1 | 39,3 | 39,3 | 0,033 | 3,581 | 0,160 |

**Note:** I; Indoor (mean), O; Outdoor (mean), $p$<0.05; statistically significant

Bacterial and fungal indoor microbial aerosol loads in different laboratories of the medical laboratory sciences department were evaluated (table 1). The highest bacterial aerosol noted in the bacteriology lab was 144,2, and the highest fungal aerosol noted in the mycology lab was 39,3 CFU per $m^3$, while the lowest bacterial and fungal aerosols were calculated 13,1 and 8,7 CFU per $m^3$ in indoor air, respectively.

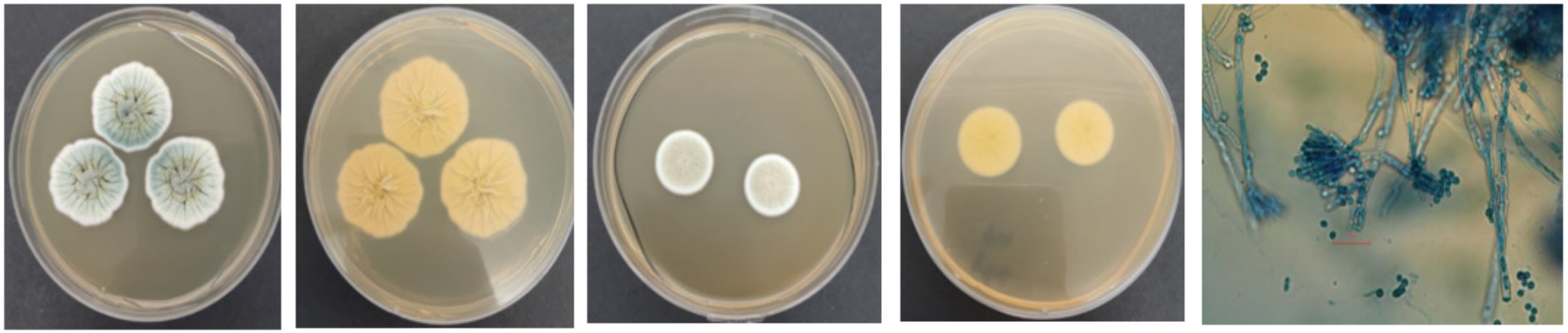
Bacterial and fungal indoor microbial aerosol loads in different CAMS departments' laboratories were evaluated in table 2. The highest bacterial and fungal aerosols were evaluated as 144,8 and 65,5 CFU per $m^3$, respectively. The highest fungal load in the air was recorded in the Biomedical Technology (BT) Department labs.

In the same context, bacterial and fungal indoor microbial aerosol loads in different CAMS departments' staff offices were evaluated in table 2. The highest bacterial and fungal aerosols were calculated (242,5 and 150,7 CFU per $m^3$, respectively) in the Physical Therapy and Health Rehabilitation (PTHR) Department.

In addition to bacterial and aerosol fungal concentrations in CAMS, different places were recorded as 94,78 and 42,36 CFU/$m^3$ in Physical Therapy and Health Rehabilitation Department offices (table 3).

A total of 282 bacterial colonies were separately purified from samples. Three bacterial isolates percentages were identified in this study, as shown in tables 4 and 5, and the rest were not identified. Among them, 2 isolates belong to Gram-positive cocci (*Kocuria rhizophila* 3,3 %, and *Staphylococcus epidermidis*15 %), Gram-positive Cocci (14 %), Gram-positive rods belonging to *Bacillus* spp. (39 %). One isolate of gram-negative bacteria was identified as *Sphingomonas paucimobilis* (0,7 %), and the rest were not identified (29 %).

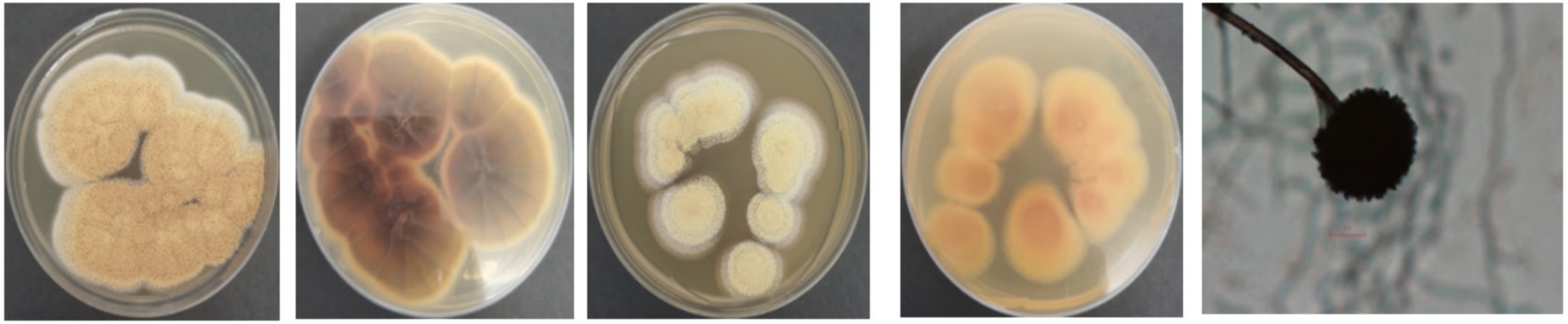
https://doi.org/10.56294/saludcyt20251152



a b c d e

*Penicillium* sp. growth on SDA (a & b) and MEA (c & d) at 27°C for 7 days culture surface and reverse

*Penicillium* sp. under a × 20-lens microscope.

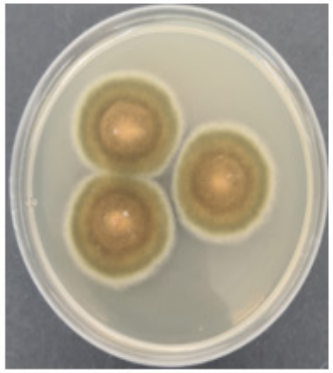


a b c d e

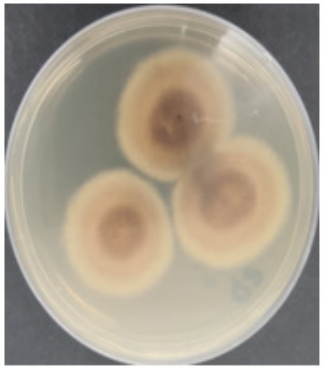
*Aspergillus ochraceus* growth on SDA (a & b) and MEA (c & d) at 27°C for 6 days culture surface and reverse

*Aspergillus ochraceus*, under a × 20-lens microscope.

https://doi.org/10.56294/saludcyt20251152

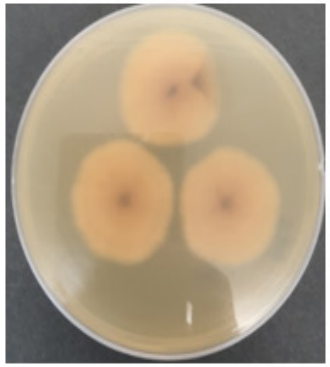


a

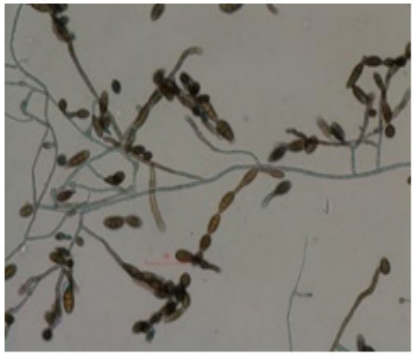


b

c



d

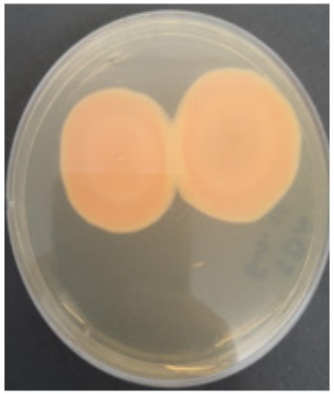


E

*Alternaria* sp. growth on SDA (a & b) and MEA (c & d) at 27°C for 4 days culture surface and reverse

*Alternaria* sp. under a × 20-lens microscope.

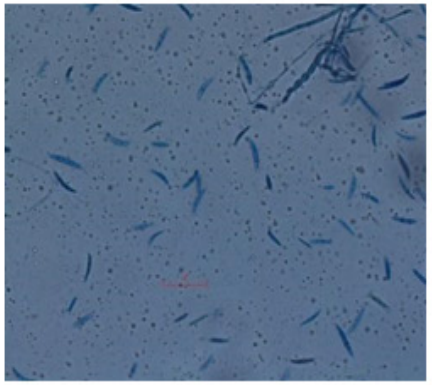
a



b

c

d



E

*Fusarium* sp. growth on SDA (a & b) and MEA (c & d) at 27°C for 6 days culture surface and reverse

*Fusarium* sp. under a × 20-lens microscope.

https://doi.org/10.56294/saludcyt20251152

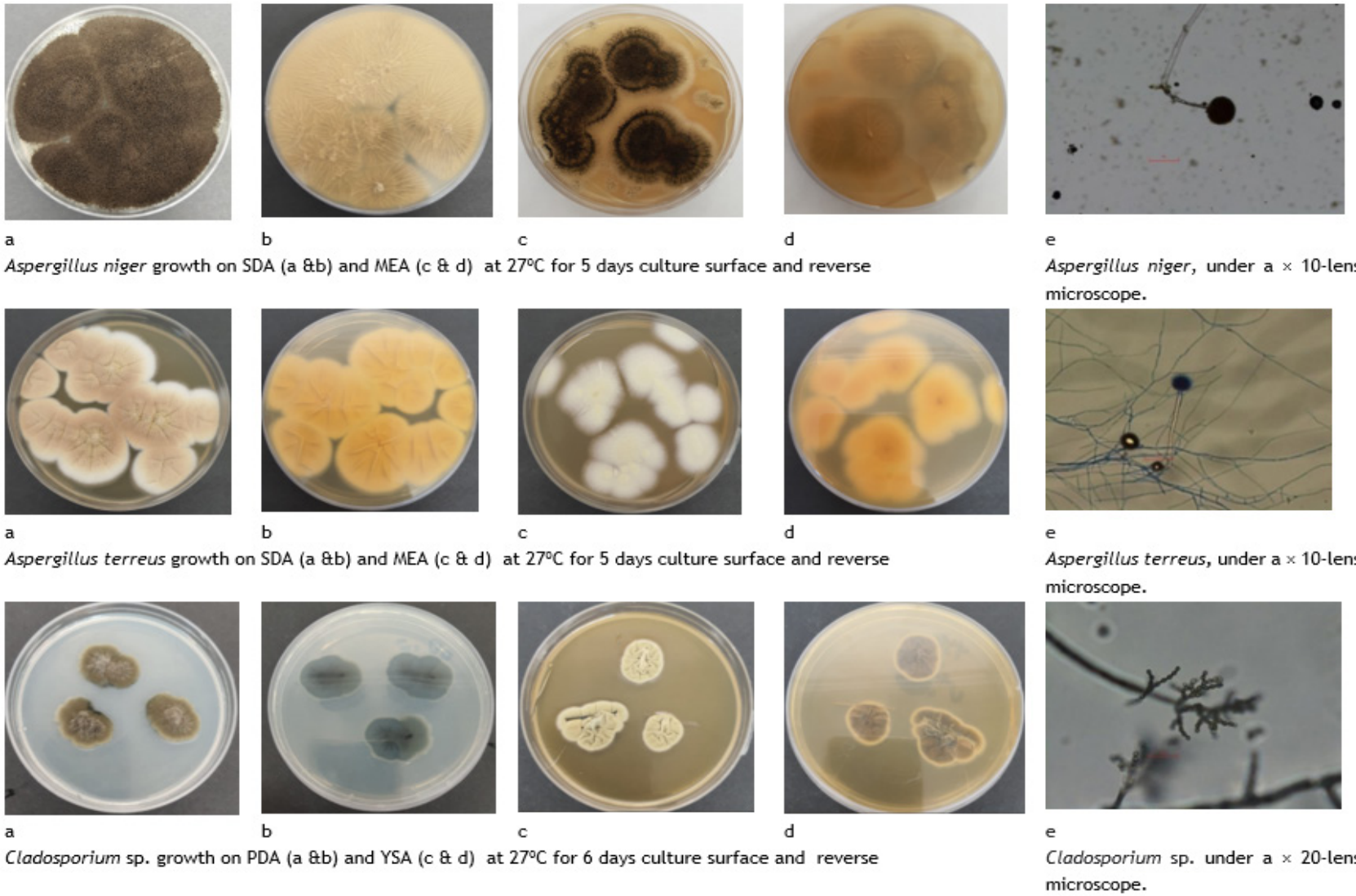



**Figure 1.** Macroscopic examination (culture morphology) explained the culture surface (a & c) and reverse (b & d), of the most common isolated fungi. Microscopic morphology examination (e), using the inclined cover slip technique stained with lactophenol cotton blue (LPCB), Bar = 100 µm using, and images taken by a Nikon Eclipse LV100 POL Polarizing Microscope, Japan.

https://doi.org/10.56294/saludcyt20251152

**Table 2.** The average indoor air microbial count (CFU per $m^3$) of labs and staff offices of Applied Medical Sciences College (CAMS) departments

| | Biomedical Technology (BT) dep. | Medical laboratory dep. | Nursing dep. | Physical therapy and health rehabilitation dep. | Radiology and medical imaging dep. | I/O | ANOVA test | *P* value |
|---|---|---|---|---|---|---|---|---|
| | | | | Labs | | | | |
| Bacteria | 104,8 | 43,7 | 104,8 | 104,8 | 32,8 | 0,040 | 1,143 | 0,467 |
| Fungi | 65,5 | 21,1 | 52,4 | 13,1 | 0 | 0,048 | 1,634 | 0,357 |
| | | | | Staff offices | | | | |
| Bacteria | 150,8 | 26.2 | 26,2 | 242,5 | 28,2 | 0,049 | 6,333 | 0,282 |
| Fungi | 13,1 | 8,7 | 13,1 | 150,7 | 26,2 | 0,067 | 1,333 | 0,550 |

**Note:** I; Indoor (mean), O; Outdoor (mean), $p<0,05$; statistically significant

**Table 3.** The average air microbial count (CFU per $m^3$) of Applied Medical Sciences College (CAMS) in different places

| | Administrative Offices | Collage labs | Classrooms | Library | Staff offices | Physiotherapy Clinic | Outdoor | I/O |
|---|---|---|---|---|---|---|---|---|
| Bacteria | 13,1 | 78,2 | 52,4 | 39,3 | 94,78 | 39,3 | 1932,2 | 0,027 |
| Fungi | 13,1 | 30,4 | 13,1 | 0 | 42,36 | 13,1 | 629,1 | 0,029 |

**Note:** I; Indoor (mean), O; Outdoor (mean), $p<0,05$; statistically significant

**Table 4. Distribution (%) of bacterial forms isolated from different places of Applied Medical Sciences College**different places

| | Gram +ve | | | Gram -ve | |
|---|---|---|---|---|---|
| | Bacilli | Cocci | | Bacilli | Cocci |
| Percentage (%) | 39 % | Catalase +ve 18,3 % | Catalase -ve 14 % | 29,7 % | 0 % |
| | | 32,3 % | | | |

**Table 5. Frequency distribution of bacterial isolates from different places of Applied Medical Sciences College**

| | *Kocuria rhizophila* | *Staphylococcus epidermidis* | Gram +ve Cocci(Catalase -ve) | Gram +ve Bacilli | *Sphingomonas paucimobilis* |
|---|---|---|---|---|---|
| No. of isolated colonies (%) | 11(3,3) | 43(15) | 41(14) | 109 (39) | 2 (0,7) |

**Table 6. Frequency distribution of fungal isolates from different places of Applied Medical Sciences College**

| Fungal species | *Aspergillus* spp. | *Alternaria* spp. | *Penicillium* spp. | *Fusarium* spp. | *Rhizopus spp.* | *Drechslera spp.* | *Cladosporium spp.* | *Different unknown spp.* | *Yeast* |
|---|---|---|---|---|---|---|---|---|---|
| No. of isolated colonies (%) | 9(18,8) | 9(18,8) | 8(16,7) | 3(6,3) | 2(4,2) | 1(2,1) | 2(4,2) | 12(25) | 2(4,2) |

A total of 48 fungal indoor isolates were isolated and purified belonging to 4 divisions. Among them, 46 isolates were filamentous fungi identified as 9 (18,8 %) *Aspergillus spp.* (including *Aspergillus niger, Aspergillus terreus, Aspergillus ochraceus* and other *Aspergillus* species), 9(18,8 %) *Alternaria* sp. 8(16,7 %) *Penicillium* spp., 3(6,3 %) *Fusarium* spp., 2(4,2 %) *Rhizopus* spp., 2(4,2 %) *Cladosporium* spp., 1(2.1%) *Drechslera* spp., and 12(25 %) different unknown species, in addition to two yeast isolates (table 6).

## DISCUSSION

Pollution has hazardous effects on the human body. People are subjected to several hazards in the air, including microaerosols. It has been determined that outdoor air pollution is a carcinogen or substance that causes cancer.[57,58] Bioaerosols have been linked to several detrimental health impacts; they are a matter of concern. Human diseases can be caused by bioaerosols in a variety of ways. The two most common instances of these illnesses are pulmonary infections and allergic disorders. Human health may be affected by bioaerosol-caused diseases either immediately or gradually.[14] People breathe in ten cubic meters of air each day on average. In the new lifestyle, people spend most of their time (≥ 80 % or more) indoors and are continuously exposed to airborne microorganisms.[4,59] Therefore, residents of public buildings that typically have higher concentrations of bioaerosols may be at higher risk for health issues.[60, 61] Workers and students in public

buildings are more vulnerable to infectious diseases such as tuberculosis, SARS, and influenza, which can spread through bioaerosols.[62, 63] Assessing the quality of indoor air through aeromicrobiology is a crucial examination to identify indoor air pollution caused by microbes. It can also be used as an aeromicrobiological indicator to measure the building's suitability for use and its effects on those working in it and those who frequent it. It is still difficult to understand the advancements and constraints of indoor air quality research globally without a thorough assessment of peer-reviewed indoor air quality studies that particularly address the relationship between the interior features of various building environments and indoor air quality.[64,65]

In the current study, air microbial loads were increasingly affected during sampling by many conditions, including windows opening, especially with the increasing current of air, the student activities or student number, workers or staff, and the increase in room temperature. These results agreed with several previous studies, which found that personnel activities, presence, movement, and talking activities, including heavy inhalation and exhalation, increased the microbioaerosols suspended in the air. The outdoor microbial load increases upon indoor air, so the air current from outdoors increases the air microbial load when it enters, and it is loaded with microbes suspended from the external environment. The increases in temperature and humidity induce the microbes to multiply or create favorable conditions for them to survive.[66,67,68,69,70]

In the same context, the microbial loads were decreasing greatly indoors compared to outdoors. WHO (World Health Organization) recommends limiting bacterial loads to $10^3$ CFU per $m^3$ indoors and 300 CFU per $m^3$ in work environments.[71,72] Other studies recorded that the concentration amounts of airborne fungi and bacteria (indoor and outdoor) are $10^2$–$10^3$ spores per m3 and $10^2$–$10^6$ CFU per $m^3$, respectively.[28] Also, this agrees with the I/O ratio; the I/O ratio of all places was recorded as less than one in the previous study. According to Alonso-Blanco et al.[73], I/O ratios < 1,0 suggest that indoor sources contribute less than outdoor ones.[73] So in the current study, the indoor air in all CAMS places was within the normal range; furthermore, the low microbial load means the indoors are safe for students, workers, and staff, and the air conditioning and filtration are good according to the desert weather of the building location.

In the current study, two isolates belong to Gram-positive cocci, including *Kocuria rhizophila* (3,3 %) and *Staphylococcus epidermidis* (15 %). In the Madsen et al.[74] study, Gram-positive bacteria *Kocuria rhizophila* was detected in high concentrations (>50 %) in many samples. *Kocuria rhizophila* had a positive correlation with relative humidity and a negative correlation with temperature and air change rate.[74] *Kocuria rhizophila* and *Staphylococcus* spp. are prevalent in indoor air in Greater Copenhagen residences.[75] The current results remained steady and unaffected by the sampling strategy. People are regularly exposed to these microorganisms through breathing. Several studies have reported that *Kocuria* spp. can be found in both the environment and human skin. *Kocuria* spp. have become human pathogens, primarily in compromised hosts with significant underlying illnesses. A rising number of *Kocuria* infections have been observed, with stomach pain being the most prevalent symptom, followed by a murky effluent and fever.[76,77] *Staphylococcus epidermidis*, in particular, is the most common species isolated from human epithelia. *Staphylococcus epidermidis*, which typically colonizes the axillae, head, and nares, is the leading cause of infections on medical devices. The prevalence of *Staphylococcus* epidermidis on human skin increases the risk of device contamination after insertion. *Staphylococcus epidermidis* infections are rarely life-threatening.[78]

In the current study, Gram-positive rods Bacillus spp. was found in considerable amounts. Other investigations have revealed a diverse range of Bacillus species in air samples from various occupational situations [79,74] and interior surfaces.[80] *Kocuria*, *Bacillus*, and Micrococcus species were the most prevalent bacterial taxa in Hong Kong and China's indoor air.[81]

In the previous study, the most prevalent fungal isolates identified were *Aspergillus* spp., *Alternaria* spp., *Penicillium* spp., *Fusarium* spp., and other different species with low load fungal concentrations. This agrees with the previous studies that confirmed that *Aspergillus* spp., *Alternaria* spp., *Fusarium* spp., and *Penicillium* spp. were also reported in other research articles.[82,83,84] These fungi prevail, including *Aspergillus* spp., *Alternaria* spp., and *Penicillium* spp., which may be attributed to the nature, size, weight, and structure of fungal spores or mycelium adaptation, or may be caused by other environmental factors like the spreading of the plant around the building. Previous studies on indoor air microbiomes in damp buildings show similarities in microbial ecology, including fungal ecology and the prevalence of indoor molds from the genera *Aspergillus* and *Penicillium*.[85,86,87,88] Asthma patients with a chronic condition may eventually develop colonization of *Aspergillus fumigatus*, *Wangiella dermatitidis*, or *Bipolaris hawaiiensis* in their bronchial tubes. Aeroallergens include *Fusarium*, *Aspergillus*, and *Stachybotrys*.[23] Also, other products of microorganisms transmitted by air can cause infection, including mycotoxins, other secondary metabolites, and Glucan. ß-(1-3)-glucans, the last compound is glucose polymers found in fungi and certain bacteria, have been linked to heightened respiratory symptoms in several occupational contexts. [26]

Indoor exposure to *Aspergillus* and *Penicillium* can pose health risks for millions of individuals in flood-prone areas in the US.[89] *Aspergillus, Penicillium*, and some mold proliferation may increase the risk of secondary fungal infections in communities affected by COVID-19. Other negative health effects include a worsening of existing upper respiratory symptoms such as coughing, wheezing, and asthma, as well as the onset of new

asthma cases in children. Additionally, the transmission of these fungi to the mouth or other different parts of the body may lead to various infections in individuals.[88,90]

## CONCLUSIONS

Air microbiological load monitoring can be used to detect the source of bacterial and fungal infections and determine the source and spread of airborne microorganisms to control related infections in public buildings, universities with high student populations, and inside medical labs. This will also function as a biosafety measurement tool while working with biohazardous products. The study of bioaerosols and their effects on human health, indoor air quality, and the environment are subjects of increased public awareness. Indoor bacterial and fungal loads are lower than outdoor loads in the same locality if the ventilation and filtration of the air conditioning system work efficiently, but this process needs to be evaluated periodically. Many things or conditions affect the indoor fungal and bacterial loads, including human activities or several people in the indoor place, the elevation of indoor temperature, air conditioning, ventilation, and opened windows and doors to the entrance of outdoor air, which may be a source of nosocomial infection. Assessing the quality of indoor air through aeromicrobiology is a crucial examination to identify indoor air pollution caused by microbes. It can also be used as an aeromicrobiological indicator to measure the building's suitability for use and its effects on those working in it and those who frequent it. The aeromicrobiology range in the building under the current study is less than 103 CFU per m3 for fungi and bacteria, and it is in the normal range. This means the building is safe and suitable for the current number of students, and the building's design is in the same condition.

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## ACKNOWLEDGMENT

This study is supported via funding from Prince Sattam bin Abdulaziz University project number (PSAU/2025/R/1446).

## FINANCING

No financing.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## AUTHORSHIP CONTRIBUTION

*Conceptualization:* Mohamed A. El-Sakhawy.
*Data curation:* Mohamed A. El-Sakhawy.
*Formal analysis:* Mohamed A. El-Sakhawy.
*Research:* Mohamed A. El-Sakhawy.
*Methodology:* Mohamed A. El-Sakhawy.
*Project management*: Mohamed A. El-Sakhawy.
*Resources:* Mohamed A. El-Sakhawy.
*Supervision:* Mohamed A. El-Sakhawy.
*Validation:* Mohamed A. El-Sakhawy.
*Display:* Mohamed A. El-Sakhawy.
*Drafting - original draft:* Mohamed A. El-Sakhawy.