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ASSESSMENT OF AIRBORNE MICROORGANISMS IN THE VICINITY OF MADONNA UNIVERSITY, ELELE RIVERS STATE

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ABSTRACT

Airborne microbial contamination remains a significant environmental and public health concern, particularly in densely populated academic environments within developing regions. This study assessed the distribution, concentration, and diversity of airborne microorganisms in selected indoor and outdoor locations within and around Madonna University, Elele, Rivers State, Nigeria, over a six-month period (January–July, 2025). Air samples were collected from four representative sites a teaching hospital, a central academic area, a microbiology laboratory, and a busy urban traffic junction using the passive sedimentation method. Standard microbiological techniques, including culture-based enumeration, Gram staining, biochemical tests, and fungal microscopy, were employed for isolation and identification of microorganisms. The results revealed clear spatial differences in microbial loads. Bacterial counts ranged from 32.5 ± 2.5 CFU/m³ in the microbiology laboratory to 45.0 ± 3.4 CFU/m³ at the outdoor traffic intersection. Fungal concentrations followed a similar trend, ranging from 17.5 ± 1.5 CFU/m³ to 23.8 ± 2.1 CFU/m³ across the study sites. Higher microbial loads were consistently observed in outdoor and high-activity areas, reflecting the influence of human movement, vehicular emissions, and environmental exposure, while controlled indoor environments recorded comparatively lower values. The bacterial population was predominantly composed of Staphylococcus, Bacillus, and Micrococcus species, whereas Aspergillus and Penicillium were the most frequently isolated fungal genera. Although all recorded microbial concentrations were within acceptable international guidelines, the presence of opportunistic and potentially pathogenic organisms highlights a continuing public health concern, particularly for vulnerable individuals. Overall, the study demonstrates that airborne microbial distribution is strongly influenced by environmental conditions, human activity, and ventilation efficiency. It provides important baseline data for the study area and underscores the need for continuous air quality monitoring, improved ventilation systems, and strengthened infection prevention strategies in both academic and healthcare environments.

Keywords: Airborne microorganisms; Bioaerosols; Air quality; Madonna University; Environmental health.

Introduction

Airborne microorganisms have become an important focus of global scientific inquiry because of their far-reaching implications for public health and environmental sustainability. These microorganisms comprising bacteria, viruses, fungal spores, and other bioaerosols remain suspended in the atmosphere and are easily inhaled, thereby serving as vectors for a broad spectrum of infectious and allergic diseases. Increasing evidence links exposure to airborne microbial contaminants with respiratory tract infections, asthma exacerbations, hypersensitivity reactions, and other adverse health outcomes, particularly in environments characterized by poor air quality and high population density (Obi, Ugochukwu, & Nwanosike, 2018).

In developing countries such as Nigeria, the challenge of airborne microbial pollution is especially pronounced. Rapid urbanization, population expansion, and weak environmental regulatory frameworks have intensified the burden of air contamination. The Niger Delta region, including Rivers State, presents a distinct ecological context shaped by high humidity, elevated temperatures, and substantial rainfall. These climatic conditions are particularly conducive to the growth, survival, and dispersion of airborne microorganisms, notably fungi and bacteria that thrive in moist environments (Okafor, Eze, & Ijeoma, 2022).

Anthropogenic activities further compound this problem. Oil exploration, gas flaring, vehicular emissions, and industrial operations significantly degrade air quality in the region. Beyond their direct toxicological effects, these pollutants enhance the survival and dissemination of pathogenic microorganisms by providing particulate surfaces for microbial attachment and transport, thereby increasing the likelihood of human exposure (Ohagim, Johnson, & Smith, 2017).

Academic institutions represent critical microenvironments for the study of airborne microbial contamination. Madonna University, Elele, located in Rivers State, is a densely populated campus hosting a large and dynamic population of students, staff, and visitors. Such environments inherently facilitate microbial transmission due to frequent interpersonal interactions, shared indoor spaces, and varying ventilation conditions. Despite growing concerns about air quality in Nigerian urban centers, there remains a paucity of empirical studies examining airborne microbial contamination within university environments, particularly in semi-urban settings such as Elele (Adeyemi, Olaniran & Akinmoladun, 2021).

The rapid transformation of Elele into a semi-urban hub has intensified environmental pressures through increased vehicular activity, construction work, agricultural practices, and improper waste management. These factors contribute to elevated concentrations of atmospheric particulate matter, which can act as carriers for microbial pathogens, thereby enhancing their persistence and transport in the air (Eghomwanre, Oguntoke, Taiwo, Sam-Wobo, & Enagbonma, 2023).

Within academic settings, the risks associated with airborne microorganisms are amplified by overcrowding and inadequate ventilation, especially in lecture halls, hostels, and libraries. Empirical studies have demonstrated a strong association between such conditions and increased transmission of airborne diseases. Seasonal climatic variations further exacerbate these risks. Periods of high humidity and rainfall promote the proliferation and dispersal of fungal spores, including *Aspergillus*, *Penicillium*, and *Cladosporium*, which are implicated in respiratory infections and allergic responses. Similarly, airborne bacterial species such as *Staphylococcus aureus* and *Escherichia coli* have been identified in urban atmospheres, posing risks that range from mild respiratory irritation to severe pulmonary infections (World Health Organization, 2021; Odeyemi, Alao, Kayode, & Durugbo, 2024).

Given these concerns, there is a clear need for systematic investigation into the occurrence, diversity, and concentration of airborne microorganisms within and around university environments such as Madonna University, Elele. This study employs standard air sampling and microbiological analytical techniques to isolate, identify, and quantify airborne pathogens in both indoor and outdoor settings. Such an approach enables a detailed understanding of microbial distribution patterns and their associated health implications. Understanding the dynamics of airborne microbial contamination in this context is essential for developing effective environmental health interventions. By identifying contamination hotspots and examining their relationships with environmental variables including meteorological conditions, emission sources, and infrastructural characteristics this study aims to generate evidence-based recommendations for reducing exposure risks and improving air quality.

The significance of this research extends to the broader framework of sustainable development. It aligns with Sustainable Development Goal (SDG) 3, which emphasizes good health and well-being, particularly Target 3.9, aimed at reducing illness and mortality associated with environmental pollution. Furthermore, the study contributes to SDG 11 by addressing the need for sustainable and healthy human settlements, with university campuses serving as microcosms of urban systems. In addition, it supports SDG 17 by highlighting the importance of collaborative partnerships among academic institutions, public health agencies, and environmental stakeholders in advancing research and implementing effective interventions (World Health Organization, 2021).

Therefore, it is paramount to underscore that this study provides a critical contribution to the understanding of airborne microbial pollution in a developing-country context and offers practical insights for improving environmental health in densely populated academic environments.

Materials and Methods

1 Study Area

This study was conducted between January and July 2025 at Madonna University, Elele Campus, located in Ikwerre Local Government Area of Rivers State, Nigeria. The campus is situated within a semi-urban environment characterized by moderate human density and vehicular activity. Key infrastructures including student hostels, lecture halls, laboratories, and a teaching hospital create diverse microenvironments that may influence airborne microbial dynamics. Four sampling locations were purposively selected to capture variations in human activity and environmental exposure. The Madonna University Teaching Hospital (MUTH) represents a high-risk zone due to intense patient traffic and the presence of immunocompromised individuals. Edeh's Ark serves as a central congregation area encompassing lecture theatres, a chapel, and administrative offices, reflecting high human interaction. The Microbiology (MCB) Laboratory area, although controlled, experiences regular academic use that may contribute to microbial presence. In contrast, Elele Roundabout, located just outside the campus, represents an external environment characterized by heavy vehicular movement and commercial activities. Collectively, these sites provided a comprehensive representation of indoor and outdoor exposure conditions.

2 Sterilization of Materials

All glassware, media, and instruments were sterilized prior to use. Autoclaving was performed at 121°C and 15 psi for 15 minutes, while selected materials were disinfected using 70% ethanol or sterilized by flaming. Standard aseptic techniques were maintained throughout all laboratory procedures.

3 Culture Media Preparation

Microbiological media used for isolation included Nutrient Agar, MacConkey Agar, Mannitol Salt Agar, and Potato Dextrose Agar (PDA). All media were prepared according to manufacturers' instructions and sterilized appropriately before use.

4 Sample Collection

Air sampling was conducted using the passive plate sedimentation method as described by Makut, Smith, & Johnson (2014). A total of eight samples were collected, with duplicate samples obtained from each sampling location. Sterile Petri dishes containing appropriate media were exposed to ambient air at a height corresponding to the human breathing zone (approximately 1.5–1.8 m above ground level) for one hour. Following exposure, plates were immediately transported to the laboratory for incubation. Bacterial cultures were incubated at 37°C for 24 hours, while fungal cultures were incubated at room temperature for 72 hours.

5 Enumeration and Subculture of Bacteria

After incubation, colonies were enumerated and recorded based on standard plate count techniques, with acceptable counts ranging between 30 and 300 colonies per plate (Cheesbrough, 2006). Results were expressed as colony-forming units per cubic meter (CFU/m³) following established protocols (Ohagim, Johnson, & Smith, 2017).

Discrete colonies were subcultured onto Nutrient Agar using the streak plate technique to obtain pure isolates. Cultures were incubated for 18 hours and preserved on agar slants at refrigerated conditions for subsequent analyses.

6 Identification and Characterization of Bacteria

Gram Staining

Bacterial isolates were subjected to Gram staining following standard procedures (Cheesbrough, 2006). Smears were stained with crystal violet, treated with iodine, decolorized with alcohol, and counterstained with safranin. Gram-positive organisms appeared purple, whereas Gram-negative organisms appeared pink under oil immersion microscopy.

Biochemical Tests

Bacterial identification was further achieved using a series of biochemical assays, including oxidase, catalase, citrate utilization, indole production, motility, methyl red (MR), Voges–Proskauer (VP), carbohydrate fermentation, coagulase, and Triple Sugar Iron (TSI) tests. These tests were conducted following standard microbiological protocols (Cheesbrough, 2003; 2006), and results were interpreted based on characteristic color changes, gas production, and enzymatic reactions.

7 Fungal Identification

Fungal isolates were identified microscopically using lactophenol cotton blue (LPCB) staining. Morphological characteristics, including spore structure, hyphal arrangement, and septation, were examined under ×10 and ×40 magnifications. Identification was guided by standard mycological keys (Prescott, Harley, & Klein, 2005).

8 Statistical Analysis

Data obtained were analyzed using one-way analysis of variance (ANOVA) to assess differences among sampling locations. Statistical significance was determined at a 95% confidence level ($p < 0.05$).

Results

Mean Bacterial Load at Different Sampling Sites

Table1: presents the mean bacterial load (expressed in CFU/m³ ± standard deviation) measured at various air sampling sites around Madonna University, Rivers State. Among the four locations surveyed, Elele Roundabout exhibited the highest bacterial concentration at 45.0 ± 3.4 CFU/m³, followed by the Hospital Area with 40.0 ± 3.2 CFU/m³. Edeh's Ark recorded a slightly lower bacterial load of 36.3 ± 2.9 CFU/m³, while the MCB Laboratory had the lowest value at 32.5 ± 2.5 CFU/m³.

Table 1: Mean Bacterial Load (CFU/m3) at Different Sampling Sites of Air Samples from Madonna University Vicinity, Rivers State.

Sampling Locations	Total CFU Count	Mean Bacterial Load CFU/m³ ± SD
Hospital Area	160	40.0 ± 3.2
Edeh's Ark	145	36.3 ± 2.9
MCB Laboratory	130	32.5 ± 2.5
Elele Roundabout	180	45.0 ± 3.4

Mean Fungal Load at Different Sampling Sites

Table 4.2 presents the mean fungal load (CFU/m³ ± standard deviation) across different air sampling locations within the vicinity of Madonna University, Rivers State. The Elele Roundabout recorded the highest fungal concentration at 23.8 ± 2.1 CFU/m³, followed by the Hospital Area with a mean fungal load of 21.3 ± 2.1 CFU/m³. Edeh's Ark showed a slightly lower level at 20.0 ± 1.8 CFU/m³, while the MCB Laboratory exhibited the lowest fungal concentration at 17.5 ± 1.5 CFU/m³.

Table 2: Mean Fungal Load (CFU/m3) at Different Sampling Sites of Air Samples from Madonna University Vicinity, Rivers State.

Sampling Locations	Total CFU Count	Mean Bacterial Load CFU/m3 ± SD
Hospital Area	85	21.3± 2.1
Edeh's Ark	80	20.0± 1.8
MCB Laboratory	70	17.5± 1.5
Elele Roundabout	95	23.8 ± 2.1

Frequency of occurrence of Airborne Bacterial Isolates in the Vicinity of Madonna University, Elele, Rivers State

Table 3: presents the frequency of occurrence (%) of airborne bacterial isolates collected from different sampling locations within the vicinity of Madonna University, Elele, Rivers State. *Staphylococcus* sp. was the most frequently isolated bacterium, with the highest occurrence at Elele Roundabout (35%) and an overall frequency of 27.5%. This was followed by *Bacillus* sp. (23.8%) and *Micrococcus* sp. (22.5%), both of which were relatively evenly distributed across the sampling sites. *Pseudomonas spp.* and *Escherichia coli* were less frequently encountered, with total frequencies of 13.8% and 12.5%, respectively. The distribution pattern suggests that areas with higher human traffic and environmental exposure, such as Elele Roundabout and the Hospital Area, may harbor greater bacterial diversity and load. These findings reflect the influence of anthropogenic activities and environmental conditions on the prevalence of airborne bacterial communities in the study area.

Table 3: Frequency of occurrence of Airborne Bacterial Isolates in the Vicinity of Madonna University, Elele, Rivers State

Bacterial Isolates	HA(%)	EA(%)	MCBLAB(%)	ERAB (%)	TF(%)
Staphylococcus sp	30	20	20	35	27.5
Bacillus sp	20	25	20	30	23.8
Pseudomonas sp	15	10	10	20	13.8
Escherichia coli	10	15	10	15	12.5
Micrococcus sp	25	20	20	25	22.5

Keys: HA=Hospital Area, EA=Edeh's Ark, MCBLAB= MCB Laboratory, ERAB=Elele Roundabout , TF=Total frequency

Frequency of occurrence of Airborne Fungal Isolates in the Vicinity of Madonna University, Elele, Rivers State

Table 4: illustrates the frequency of occurrence (%) of airborne fungal isolates collected from various sampling sites around Madonna University, Elele, Rivers State. *Aspergillus* sp. was the most prevalent fungal isolate, with the highest frequency at Elele Roundabout (40%) and a total frequency of 32.5%. This was followed by *Penicillium* sp. (23.8%), which also showed notable presence across all locations, particularly at Elele Roundabout (30%). *Candida* sp. accounted for 17.5% of the total isolates, with a relatively even distribution across the sites. Less frequently isolated were *Rhizopus* sp. and *Mucor* sp., contributing 15.0% and 11.3% respectively to the total fungal population. The consistent detection of these fungi across all locations suggests widespread environmental distribution, though at varying concentrations. The predominance of *Aspergillus* sp and *Penicillium* sp both known for their allergenic and pathogenic potentials highlights the possible public health implications of airborne fungal exposure in this region. These findings indicate that environmental and anthropogenic factors such as ventilation, human activity, and sanitation may significantly influence the diversity and distribution of fungal spores in the ambient air.

Table 4: Frequency of occurrence of Airborne Fungal Isolates in the Vicinity of Madonna University, Elele, Rivers State

Fungal Isolates	HA(%)	EA(%)	MCBLAB (%)	ERAB (%)	TF(%)
Aspergillus sp	35	30	25	40	32.5
Penicillium sp	25	20	20	30	23.8
Candida sp	15	20	15	20	17.5
Mucor sp	10	10	10	15	11.3
Rhizopus sp	15	15	15	15	15.0

Keys: HA=Hospital Area, EA=Edeh's Ark, MCBLAB= MCB Laboratory, ERAB=Elele Roundabout, TF= Total Frequency, %= Percentage

4. Discussion

This study provides a detailed assessment of airborne microbial contamination across selected locations within and around Madonna University, Elele, Rivers State. The findings offer important insight into how environmental exposure, human activities, and building design influence air quality. The variation observed in microbial levels across the different sites shows that bioaerosols are not evenly distributed but depend strongly on local environmental conditions and human interactions.

Bacterial concentrations in this study showed a clear pattern, with lower levels in controlled indoor environments and higher levels in open, busy areas. The highest bacterial load was recorded at Elele Roundabout. This can be explained by the combined effects of vehicle emissions, dust resuspension, and continuous human activity, all of which increase the presence of microorganisms in the air. Similar studies have reported that traffic movement and dust disturbance play a major role in spreading and maintaining airborne microbes in urban outdoor environments (Li et al., 2020; Madureira et al., 2021; Zhang et al., 2022).

In the hospital environment, relatively high bacterial levels were also observed. This supports the understanding that healthcare facilities can act as important sources of airborne microorganisms. Factors such as high patient numbers, medical activities, and ventilation efficiency contribute to this condition. Studies have shown that poor air circulation and overcrowding can increase microbial load and the risk of transmission in hospitals (Beggs, 2020; Mousavi et al., 2023; Morawska & Milton, 2020).

In contrast, lower bacterial concentrations were recorded in Edeh's Ark and the Microbiology Laboratory. This can be linked to restricted access, regular cleaning, and proper airflow control. These results agree with previous findings that well-managed indoor environments, especially laboratories, maintain lower microbial levels due to strict biosafety practices (Azuma et al., 2020; Baloch et al., 2020).

Importantly, all bacterial concentrations measured in this study were below the recommended limits for indoor air quality set by the World Health Organization. This suggests that the air quality in the study areas is generally safe. However, the differences observed across locations highlight the need for continuous environmental monitoring, improved ventilation, and proper control of human activities to maintain safe air quality levels.

A similar trend was observed for fungal contamination. Higher fungal concentrations were found in outdoor environments compared to indoor spaces. The high fungal load at Elele Roundabout can be attributed to exposure to dust, organic matter, and high humidity, which promote fungal growth and spread. This observation is consistent with global studies showing that fungal bioaerosols are more abundant in warm, humid, and dust-rich environments (Fröhlich-Nowoisky et al., 2023). The climate of the Niger Delta region further supports fungal growth by providing favorable environmental conditions.

Moderate fungal levels were observed in the hospital, which agrees with reports that hospitals can contain airborne fungal spores, especially where moisture is present and ventilation is not optimal. However, the relatively controlled levels recorded may indicate improvements in hygiene and infection control practices. In comparison, the lowest fungal concentrations were found in the laboratory, confirming the effectiveness of controlled environments, limited access, and regular disinfection in reducing fungal spread.

Although all fungal concentrations were within acceptable limits, their presence remains important from a health perspective. Airborne fungi can cause allergies and opportunistic infections, particularly in individuals with weakened immune systems.

The types of bacteria identified in this study were mainly those associated with human activity and environmental survival. *Staphylococcus* species were the most common, likely originating from human skin and respiratory sources, and their presence increases with human density. This agrees with studies showing that human occupancy strongly influences microbial composition in both indoor and outdoor environments (Bashar & Kawo, 2021).

Bacillus species were also widely present, which is expected due to their ability to form resistant spores and survive harsh conditions. *Micrococcus* species were similarly common, reflecting their ability to survive in dry and low-nutrient environments. In contrast, *Pseudomonas* and *Escherichia coli* were found less frequently. These organisms prefer moist environments and do not survive well in air. However, the occasional detection of *E. coli* may indicate localized contamination, possibly related to sanitation issues. These findings agree with previous studies showing that airborne microbial populations are often dominated by human-associated and environmentally resistant species (Ogbonna, Nwachukwu, & Eziuzor, 2020).

The fungal species identified were also typical of environmental air samples. *Aspergillus* and *Penicillium* were the most dominant, due to their ability to produce spores that spread easily and survive in different environments, especially in tropical climates. The presence of *Candida* suggests a contribution from human sources, as it is commonly found on skin and mucosal surfaces (Sule, Oyeyiola, & Fadahunsi, 2019). *Mucor* and *Rhizopus* were less common, likely because they prefer moist environments and are less easily dispersed in air (Sabiha, Sultana, & Nisa, 2020).

Even though the fungal levels were within safe limits, their presence is still important because some species are known to cause allergic reactions and infections, especially in vulnerable individuals. This supports global findings that highlight the health risks associated with exposure to airborne fungi in both indoor and outdoor environments (WHO, 2021).

Therefore, this study shows that environmental conditions, human activities, and building design play key roles in determining the levels and types of airborne microorganisms. The findings emphasize the need for regular monitoring, proper ventilation, good sanitation, and controlled human activity to reduce potential health risks associated with bioaerosol exposure, particularly in academic and healthcare environments.

Conclusion

This study demonstrates that airborne microbial loads within Madonna University, Elele, and its surrounding environments vary significantly depending on location, human activity, and environmental exposure. Outdoor and high-traffic areas exhibited higher bacterial and fungal loads compared to controlled indoor environments such as laboratories. Although all recorded microbial concentrations were within internationally accepted limits, the presence of potentially pathogenic bacteria and allergenic fungi highlights the need for continuous monitoring. The predominance of human-associated bacteria and environmentally resilient fungal species further emphasizes the role of anthropogenic and ecological factors in shaping air microbiota. Overall, the findings contribute valuable baseline data on airborne microbial quality in a semi-urban Nigerian academic environment and underscore the importance of proactive environmental health management.

Recommendations

The findings of this study show the need to improve environmental control measures in both academic and healthcare settings. One of the most important actions is to improve ventilation systems. This can be achieved by using both natural ventilation (such as windows and open spaces) and mechanical systems (such as fans and air conditioners) to increase air movement and reduce the buildup of airborne microorganisms, especially in crowded areas. Regular air quality monitoring should also be introduced. This will help track changes in microbial levels over time, identify possible contamination early, and support quick and informed decision-making to prevent risks. In addition, environmental sanitation practices should be strengthened. This includes proper waste management, reducing dust in the environment, and maintaining regular cleaning routines. These measures are particularly important in busy outdoor areas like Elele Roundabout, where human activity and dust can increase microbial spread. In healthcare environments, strict infection prevention and control practices must be maintained. The use of effective air filtration systems, proper management of patient movement, and consistent hygiene practices are essential to reduce the spread of microorganisms and protect vulnerable individuals. Overall, combining improved ventilation, regular monitoring, better sanitation, and strong infection control measures will help maintain safe air quality and reduce health risks associated with airborne microbes.

Further Research

Future studies should incorporate molecular identification techniques and seasonal analysis to provide deeper insights into microbial diversity and dynamics.

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