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Research Article
Evaluation of Indoor Microbial Air Quality of Government Primary Schools

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Abstract

Background and Objective: Reduced indoor air quality is a burden in schools because of the large number of pupils per classroom, especially in government-owned schools. This work investigated microbial indoor air quality in 25 randomly selected classrooms of five public primary schools and their general toilets. **Materials and Methods:** Institutional based cross-sectional study was conducted between April and June, 2021 to evaluate the bacterial and fungal load of these rooms using the settle plate method. An Independent sample Mann-Whitney U test was implemented on the data. **Results:** In the morning, school 1 primary 2 and primary 1 had the lowest and highest hemolytic bacterial count of 1.3×10^4 and 3.1×10^4 CFU m^{-3}, respectively. School 1primary 4 and toilet had the lowest and highest staphylococcal count of 8.1×10^3 and 8.0×10^4 CFU m^{-3}. School 1 primary 4 and toilet had the highest fungal count of 1.3×10^3 and 1.8×10^4 SFU m^{-3}. Bacteria presumptively identified were *Streptococcus pneumoniae*, *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Streptococcus pyogenes*, *Staphylococcus epidermidis* and *Enterococcus faecalis*. Fungi presumptively identified were *Aspergillus fumigatus*, *Aspergillus niger*, *Cladosporium sphaerospermum* and *Aspergillus flavus*. Mann-Whitney U test revealed that the distribution of bacteria count using blood agar is significantly different from mannitol salt agar. **Conclusion:** High microbial load was found in government public primary schools in the Akure City of Nigeria in comparison to indoor air biological standards of WHO. This indicates a high risk of air-borne infections to government school pupils and a call for attention by stakeholders in authority.

Key words: Bacterial counts, fungal counts, haemolytic, indoor air, settle plate method, staphylococcal, frequency of occurrence

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Indoor air quality is the air quality within and around buildings and structures. Indoor air quality is known to affect the health, comfort and well-being of building occupants. Indoor air quality is part of indoor environmental quality, which includes indoor air quality as well as other physical and psychological aspects of life indoors (e.g., lighting, visual quality, acoustics and thermal comfort)[1]. Poor indoor air quality has been linked to sick building syndrome, reduced productivity and impaired learning in schools. Indoor air quality can be affected by gases (including carbon monoxide, radon, volatile organic compounds), particulates, microbial contaminants (mould, bacteria) or any mass or energy stressor that can induce adverse health conditions[2]. Source control, filtration and the use of ventilation to dilute contaminants are the primary methods for improving indoor air quality in most buildings[3]. Residential units can further improve indoor air quality by routine cleaning of carpets and area rugs. Determination of indoor air quality involves the collection of air samples, monitoring human exposure to pollutants, collection of samples on building surfaces and computer modelling of airflow inside buildings[4]. Indoor air quality has been the object of several studies due to an increasing concern within the scientific community on the effects of indoor air quality upon health, especially when people tend to spend more time indoors than outdoors[5].

Frequently, pollutants from indoor sources may build up to appreciable levels due to the slowness of air exchange. It is estimated that a quarter of the world population is exposed to unhealthy concentrations of air pollutants and children are the ones most at risk of these indoor air pollutants due to their respiratory organ systems immaturity[6]. Moreover, children are susceptible to air pollutants because they breathe in relatively greater air volume than adults. The indoor air quality of schools is gaining much attention in recent years. Children spend almost 25-30% of their time, inside classrooms and worldwide, the length of the education expectancy of children over the age of five increased from 10.1 years in 1999-11.0 years in 2007[7]. School environments differ from adult work environments because children have special habits such as unprotected coughs and sneezes, less likely to wash their hands and more likely to share the "tools of the trade" such as pencils, that encourage the spread of infectious disease. Moreover, children are more sensitive to air pollutants, since their organs are in the developing stage they breathe more air relative to their body size than adults[8]. Poor indoor air quality can increase the chance of long-term and short-term health problems for students and staff, reduce the productivity of teachers and degrade the student learning environment and comfort levels[9].

This study is therefore, designed to isolate and enumerate bacterial and fungal isolates from indoor air samples of selected government primary schools, presumptively identify bacteria and fungi enumerated from government primary schools as well as determine the frequency of occurrence of bacterial and fungal isolates from indoor air in government primary school.

MATERIALS AND METHODS

Study design and study area: An Institutional based cross-sectional study was carried out to investigate indoor bacterial and fungal loads of government public primary schools in Akure city, Nigeria. Akure is the capital of Ondo State in Southwestern Nigeria. It is located between latitude 7°12'N-7°58'N and between longitude 5°15'E-5°17'E. The climate of Akure is subtropical with two main distinct seasons: Rainy and dry seasons. The humidity of the air masses over the city varies from 60% in January, to 80% in July (NIMET, 2016). This study was carried out at the Microbiology Department, Federal University of Technology Akure, Nigeria from June-August, 2021.

Experimentation: The exposed air culture technique was adopted for estimating the air microflora of the sampling areas. Blood agar and mannitol salt agar plates, were rendered in the air at 1.5 m above the ground for 10-15 min. Exposed plates were incubated at 37°C for 18-24 hrs as described by Udochukwu *et al.*[10]:

$$\text{Colony-forming unit per cubic metre (CFU m}^{-3}) = \frac{a \times 10000}{p \times t \times 0.2}$$

Where:

a = Number of colonies on the petri dishes
p = Surface of the petri dishes
t = Time of petri dish exposure

After which the frequency of occurrence of this bacteria and fungi count was placed on a frequency table and interpreted. Individual bacterial isolates were identified using standard methods (including colonial morphology, microscopy and biochemical tests).

Statistical analysis: Analysis was performed using a Statistical Package for Social Sciences (SPSS) version 20.0. Data obtained were subjected to analysis of variance and expressed as

Mean±Standard error. Statistical significance was determined at values ($p \leq 0.05$) and the means were separated using Duncan's Multiple Range Test. An Independent sample Mann-Whitney U test was implemented on the data.

RESULTS

Table 1 shows the bacterial and fungal counts of indoor air samples from government primary school 1 in the morning, it revealed a total haemolytic, staphylococcal and fungal counts of 1.1×10^5, 6.4×10^4 CFU m^{-3} and 5.3×10^4 SFU m^{-3}, respectively. The bacterial and fungal counts of indoor air samples from government primary school 2 in the morning were represented in Table 2 and revealed a total haemolytic, staphylococcal and fungal counts of 6.8×10^4 CFU m^{-3}, 5.9×10^4 CFU m^{-3} and 1.9×10^4 SFU m^{-3}, respectively. The result of Table 3, 4 and 5 equally showed the bacterial and fungal counts of indoor air samples from government primary schools 3, 4 and 5 in the morning while Table 6-10 revealed the bacterial and fungal counts of indoor air samples from government primary schools 1 to 5 observed in the afternoon.

Generally, school 1 primary 1 had the highest haemolytic bacteria count of 3.1×10^4 CFU m^{-3} while primary 2 and primary 4 had the least haemolytic bacterial count of 1.3×10^4 CFU m^{-3} blood agar. School 1 toilet had the highest count of 8.0×10^4 CFU m^{-3} while primary 4 has the least lactose fermenter count of 8.1×10^3 CFU m^{-3} on mannitol salt agar.

School 1, primary 5 had the highest haemolytic bacteria count of 2.7×10^4 CFU m^{-3} while primary 2 had the least haemolytic bacterial count of 7.5×10^3 CFU m^{-3} on blood Agar in the afternoon exposure. School 1 the toilet had the highest lactose fermenter count of 2.7×10^4 CFU m^{-3} while primary 5 had the least lactose fermenter count of 5.6×10^3 CFU m^{-3} on mannitol salt agar. School 1 primary 2 had the highest fungal count of 1.2×10^4 SFU m^{-3} while primary 1 and primary 2 had the least with 3.8×10^3 SFU m^{-3} each on potato dextrose agar.

Figure 1 illustrated the occurrence of *Staphylococcus aureus* in each school for morning and afternoon exposure, so also, Fig. 2-11 revealed the occurrence of *S. epidermis*, *Klebsiella pneumonia*, *Streptococcus pyogenes*, *Escherichia coli*, *Streptococcus pneumonia*, *Enterococcus faecalis*, *Aspergillus flavus*, *A. fumigatus*, *A. niger* and *Cladosporium sphaerospermum* in each school for morning and afternoon exposure, respectively.

In general, *Staphylococcus aureus* had the highest occurrence of 2.0×10^1 CFU in school 1 primary 5 and the least of 0 CFU in school 3 toilets. While it had the highest occurrence of 2.3×10^1 CFU in school 1 primary 1 in the morning. *Staphylococcus aureus* had the highest occurrence of 2.3×10^1 CFU in school 1 primary 1 and the least of 1 CFU in school 3 primary 5 in the afternoon. *Staphylococcus epidermis* had the highest occurrence of 33 CFU school 2 primary 5 in the morning. *Aspergillus flavus* had the highest occurrence of 9 CFU in school 4 primary 2 and the last occurrence of 1 CFU in school 3 primary 5 while *Aspergillus flavus* had the highest occurrence of 15 CFU in school 3 primaries 4 and the last occurrence of 1 CFU in the afternoon.

Table 11 presents descriptive statistics of bacteria count using blood agar and Mannitol salt agar. It is found that there is a small difference in the mean bacteria count for the two agar types. Figure 12a-b presents a boxplot of bacteria count using blood agar and mannitol salt agar. The range of bacteria count using blood agar is higher than when mannitol salt agar is used, except for a few outlying counts. Also, high variability of bacteria count using Mannitol salt agar was observed compared with blood agar. A test of the hypothesis was conducted to test if the distribution of bacteria count is the same for different agar types (blood agar and mannitol salt agar). An Independent sample Mann-Whitney U test was performed. The test rejects the null hypothesis that the distribution of bacteria count is the same using blood agar and mannitol salt agar ($p = 0.001$) at a 5% level of significance and concludes that the distribution of bacteria count using blood agar is significantly different from mannitol salt agar. This difference is shown in Fig. 12.

Table 1: Bacterial and fungal counts of indoor air samples from government primary school 1 in the morning

Classes	Haemolytic (CFU m^{-3})	Staphylococcal (CFU m^{-3})	Fungal (SFU m^{-3})
Primary 1	3.1×10^4	8.1×10^3	3.1×10^3
Primary 2	1.3×10^4	8.0×10^4	1.3×10^3
Primary 3	1.8×10^4	1.3×10^4	1.1×10^4
Primary 4	1.3×10^4	1.0×10^4	1.1×10^4
Primary 5	1.8×10^4	1.9×10^4	1.8×10^4
Toilet	1.9×10^4	9.4×10^3	7.5×10^3
Total	1.1×10^5	6.4×10^4	5.3×10^4

CFU m^{-3}: Colony-forming unit per cubic meter and SFU m^{-3}: Spore-forming unit per cubic meter

Table 2: Bacterial and fungal counts of indoor air samples from government primary school 2 in the morning

Classes	Haemolytic (CFU m^{-3})	Staphylococcal (CFU m^{-3})	Fungal (SFU m^{-3})
Primary 1	8.8×10^{3}	3.1×10^{3}	6.3×10^{4}
Primary 2	1.0×10^{4}	8.8×10^{3}	3.1×10^{3}
Primary 3	1.1×10^{4}	6.3×10^{4}	NG
Primary 4	1.3×10^{4}	8.1×10^{3}	3.1×10^{3}
Primary 5	1.3×10^{4}	2.1×10^{4}	8.0×10^{4}
Toilet	1.3×10^{4}	1.3×10^{4}	1.3×10^{3}
Total	6.8×10^{4}	5.9×10^{4}	1.9×10^{4}

CFU m^{-3}: Colony-forming unit per cubic meter and SFU m^{-3}: Spore-forming unit per cubic meter

Table 3: Bacterial and fungal counts of indoor air samples from government primary school 3 in the morning

Classes	Haemolytic (CFU m^{-3})	Staphylococcal (CFU m^{-3})	Fungal (SFU m^{-3})
Primary 1	8.1×10^{3}	8.8×10^{3}	3.1×10^{3}
Primary 2	6.9×10^{3}	6.9×10^{3}	3.8×10^{3}
Primary 3	9.4×10^{3}	7.5×10^{3}	8.0×10^{4}
Primary 4	2.0×10^{4}	6.9×10^{3}	1.0×10^{4}
Primary 5	6.3×10^{3}	8.1×10^{3}	3.1×10^{3}
Toilet	1.0×10^{4}	1.3×10^{3}	6.3×10^{2}
Total	6.1×10^{4}	3.9×10^{4}	2.6×10^{4}

CFU m^{-3}: Colony-forming unit per cubic meter and SFU m^{-3}: Spore-forming unit per cubic meter

Table 4: Bacterial and fungal counts of indoor air samples from government primary school 4 in the morning

Classes	Haemolytic (CFU m^{-3})	Staphylococcal (CFU m^{-3})	Fungal (SFU m^{-3})
Primary 1	2.8×10^{4}	7.5×10^{3}	6.9×10^{3}
Primary 2	2.1×10^{4}	2.5×10^{3}	1.1×10^{4}
Primary 3	7.5×10^{3}	4.4×10^{3}	5.6×10^{3}
Primary 4	1.4×10^{4}	8.0×10^{4}	8.1×10^{3}
Primary 5	1.0×10^{4}	4.4×10^{3}	8.1×10^{3}
Toilet	8.1×10^{3}	1.1×10^{4}	2.3×10^{4}
Total	7.9×10^{4}	3.6×10^{4}	6.3×10^{4}

CFU m^{-3}: Colony-forming unit per cubic meter and SFU m^{-3}: Spore-forming unit per cubic meter

Table 5: Bacterial and fungal counts of indoor air samples from government primary school 5 in the morning

Classes	Haemolytic (CFU m^{-3})	Staphylococcal (CFU m^{-3})	Fungal (SFU m^{-3})
Primary 1	7.5×10^{3}	5.6×10^{3}	1.9×10^{3}
Primary 2	9.4×10^{3}	1.9×10^{3}	1.9×10^{3}
Primary 3	8.8×10^{3}	0	2.5×10^{3}
Primary 4	7.5×10^{3}	3.1×10^{3}	3.8×10^{3}
Primary 5	7.5×10^{3}	1.3×10^{3}	9.4×10^{3}
Toilet	5.3×10^{4}	2.3×10^{4}	2.5×10^{3}

CFU m^{-3}: Colony-forming unit per cubic meter and SFU m^{-3}: Spore-forming unit per cubic meter

Table 6: Bacterial and fungal counts of indoor air samples from government primary school 1 in the afternoon

Classes	Haemolytic (CFU m^{-3})	Staphylococcal (CFU m^{-3})	Fungal (SFU m^{-3})
Primary 1	9.4×10^{3}	2.4×10^{4}	1.0×10^{4}
Primary 2	7.5×10^{3}	1.0×10^{4}	1.2×10^{4}
Primary 3	2.0×10^{4}	7.5×10^{3}	9.4×10^{3}
Primary 4	1.4×10^{4}	1.1×10^{4}	7.5×10^{3}
Primary 5	2.7×10^{4}	5.6×10^{3}	3.8×10^{3}
Toilet	1.0×10^{4}	2.7×10^{4}	4.4×10^{3}
Total	8.8×10^{4}	8.5×10^{4}	4.7×10^{4}

CFU m^{-3}: Colony-forming unit per cubic meter and SFU m^{-3}: Spore-forming unit per cubic meter

Table 7: Bacterial and fungal counts of indoor air samples from government primary school 2 in the afternoon

Classes	Haemolytic (CFU m^{-3})	Staphylococcal (CFU m^{-3})	Fungal (SFU m^{-3})
Primary 1	1.1×10^{4}	1.2×10^{3}	5.6×10^{3}
Primary 2	1.4×10^{4}	9.4×10^{3}	1.1×10^{4}
Primary 3	1.9×10^{4}	6.3×10^{4}	8.8×10^{3}
Primary 4	1.8×10^{4}	1.1×10^{4}	6.3×10^{4}
Primary 5	1.3×10^{4}	1.0×10^{4}	7.5×10^{3}
Toilet	1.3×10^{4}	1.2×10^{4}	1.9×10^{3}
Total	8.8×10^{4}	6.7×10^{4}	4.1×10^{4}

CFU m^{-3}: Colony-forming unit per cubic meter and SFU m^{-3}: Spore-forming unit per cubic meter

Table 8: Bacterial and fungal counts of indoor air samples from government primary school 3 in the afternoon

Classes	Haemolytic (CFU m^{-3})	Staphylococcal (CFU m^{-3})	Fungal (SFU m^{-3})
Primary 1	8.8×10^{3}	2.6×10^{4}	3.8×10^{3}
Primary 2	1.2×10^{4}	1.3×10^{4}	3.8×10^{3}
Primary 3	1.1×10^{4}	8.8×10^{3}	4.4×10^{4}
Primary 4	2.5×10^{4}	8.1×10^{3}	9.4×10^{3}
Primary 5	1.4×10^{4}	6.3×10^{4}	6.3×10^{4}
Toilet	8.8×10^{3}	6.3×10^{2}	0
Total	7.1×10^{4}	5.3×10^{4}	2.9×10^{4}

CFU m^{-3}: Colony-forming unit per cubic meter and SFU m^{-3}: Spore-forming unit per cubic meter

Table 9: Bacterial and fungal counts of indoor air samples from government primary school 4 in the afternoon

Classes	Haemolytic (CFU m^{-3})	Staphylococcal (CFU m^{-3})	Fungal (SFU m^{-3})
Primary 1	2.8×10^{3}	8.1×10^{3}	8.8×10^{3}
Primary 2	2.1×10^{4}	6.3×10^{3}	1.1×10^{4}
Primary 3	8.8×10^{3}	8.1×10^{3}	1.2×10^{4}
Primary 4	2.4×10^{4}	6.3×10^{3}	1.0×10^{4}
Primary 5	1.3×10^{4}	7.5×10^{3}	1.0×10^{4}
Toilet	1.4×10^{4}	1.3×10^{4}	3.1×10^{3}
Total	1.1×10^{5}	4.9×10^{4}	5.4×10^{4}

CFU m^{-3}: Colony-forming unit per cubic meter and SFU m^{-3}: Spore-forming unit per cubic meter

Table 10: Bacterial and fungal counts of indoor air samples from government primary school 5 in the afternoon

Classes	Haemolytic (CFU m^{-3})	Staphylococcal (CFU m^{-3})	Fungal (SFU m^{-3})
Primary 1	1.0×10^{4}	8.1×10^{3}	4.4×10^{3}
Primary 2	1.3×10^{4}	2.1×10^{4}	6.3×10^{2}
Primary 3	1.4×10^{4}	1.9×10^{3}	9.0×10^{3}
Primary 4	9.4×10^{3}	8.1×10^{3}	6.3×10^{2}
Primary 5	9.4×10^{3}	9.4×10^{3}	3.8×10^{3}
Toilet	1.0×10^{4}	1.8×10^{4}	4.4×10^{3}
Total	6.6×10^{4}	6.6×10^{4}	1.9×10^{4}

CFU m^{-3}: Colony-forming unit per cubic meter and SFU m^{-3}: Spore-forming unit per cubic meter

Table 11: Descriptive statistics of bacteria count using blood agar and mannitol salt agar

Agar types	Minimum	Maximum	Mean	Std. deviation
Blood agar	2800	53000	13811.67	7762.231
Mannitol salt agar	0	80000	13611.67	16885.24

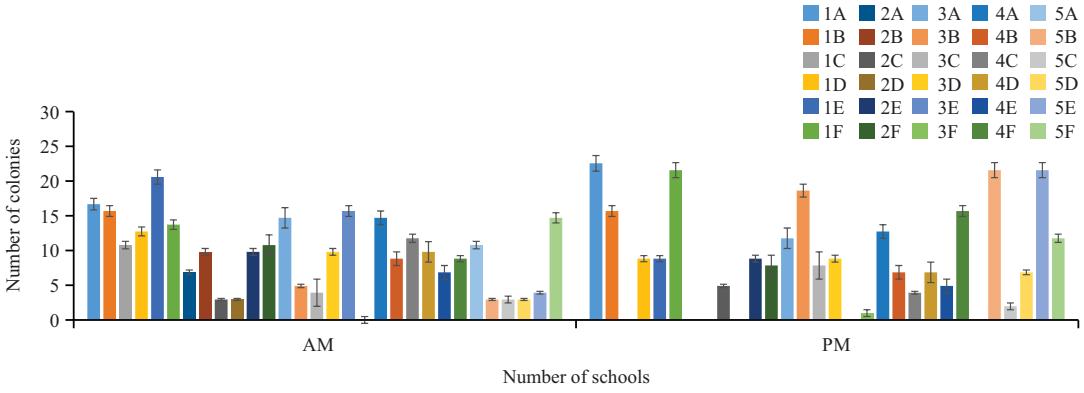

Fig. 1: Occurrence of *Staphylococcus aureus* in each school for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

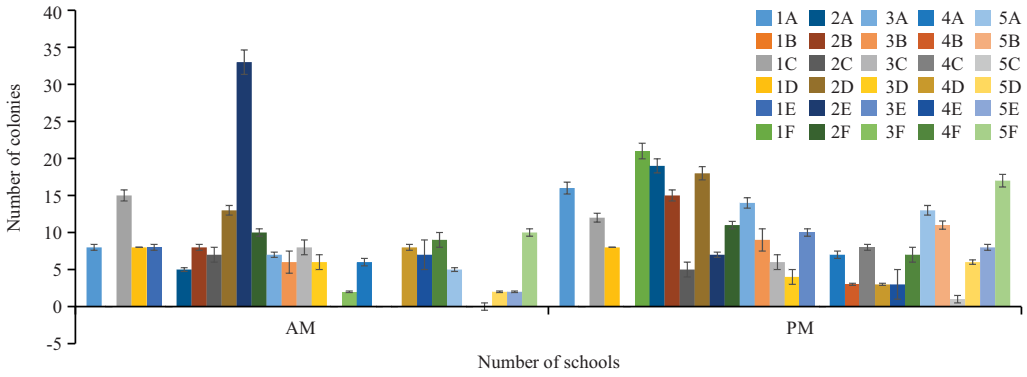

Fig. 2: Occurrence of *Staphylococcus epidermis* in each school for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

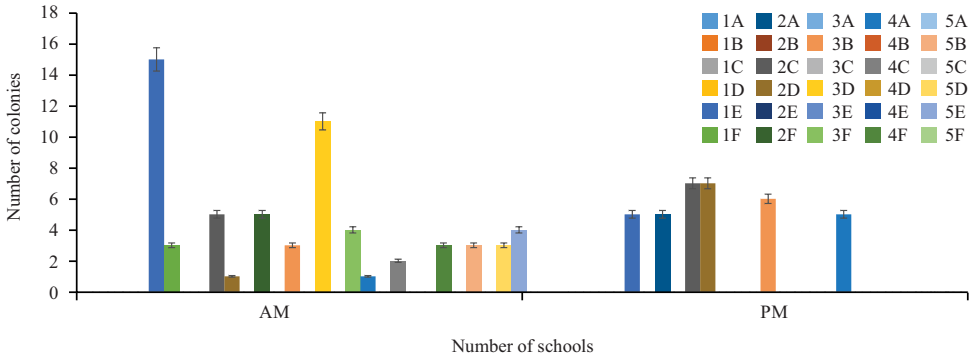

Fig. 3: Occurrence of *Klebsiella pneumoniae* in each school for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

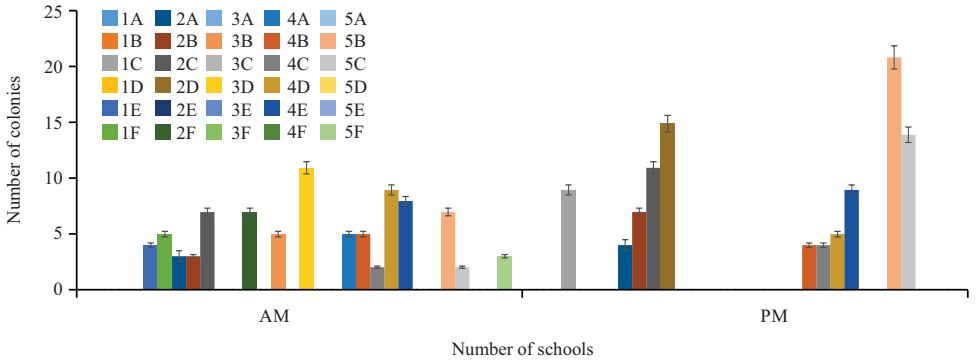

Fig. 4: Occurrence of *Streptococcus pyogenes* in each school for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

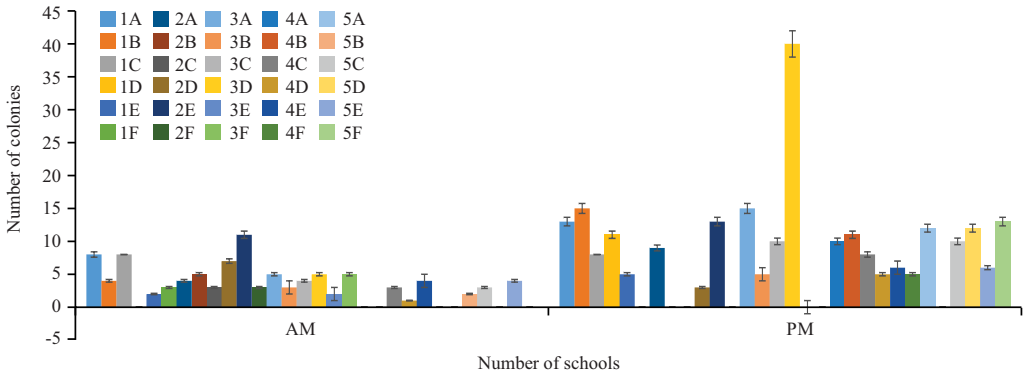

Fig. 5: Occurrence of *Escherichia coli* in each school for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

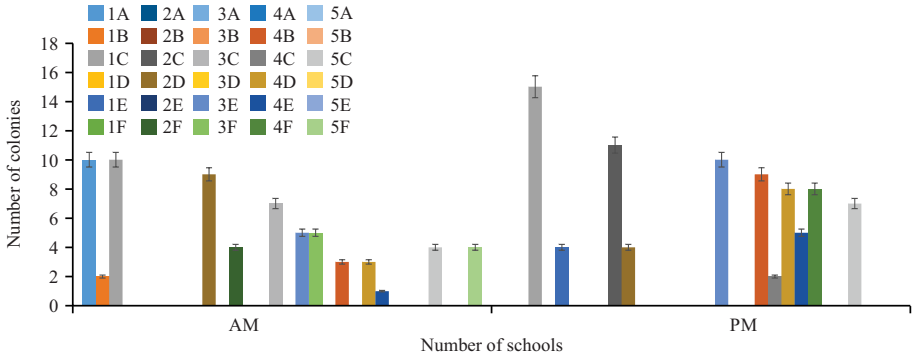

Fig. 6: Occurrence of *Streptococcus pneumoniae* in each school for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

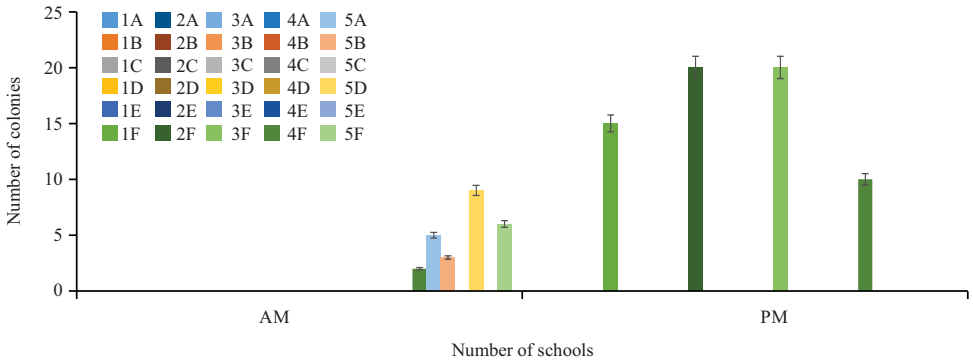

Fig. 7: Occurrence of *Enterococcus faecalis* in each school for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

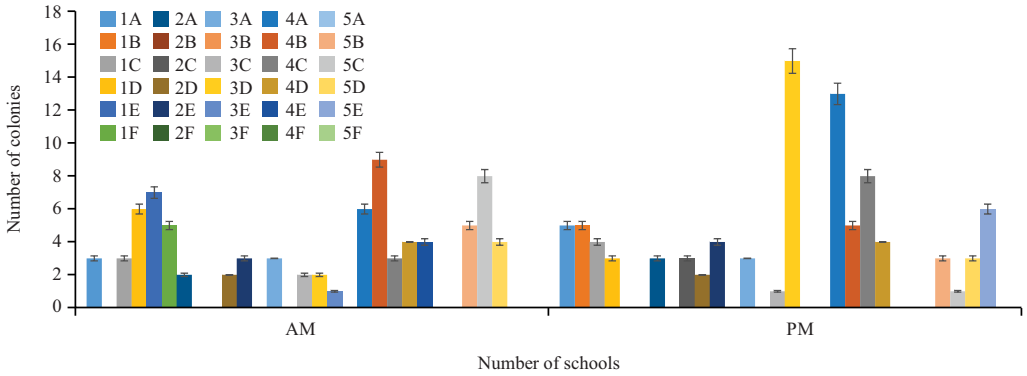

Fig. 8: Occurrence of *Aspergillus flavus* in each school for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

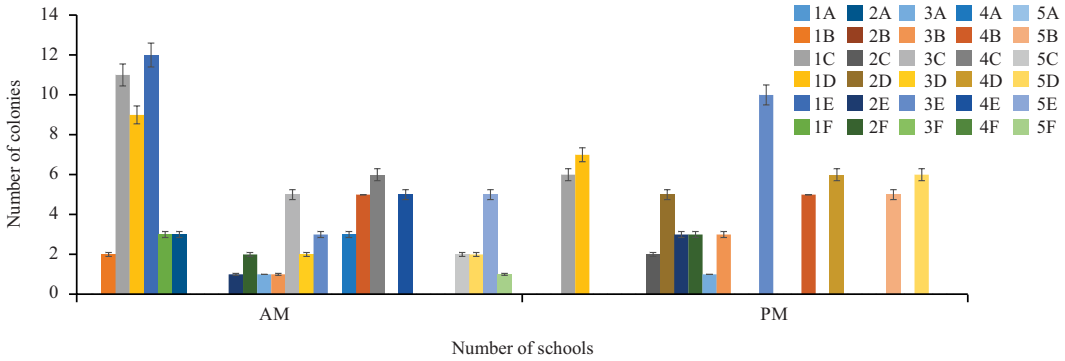

Fig. 9: Occurrence of *Aspergillus fumigatus* in all schools for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

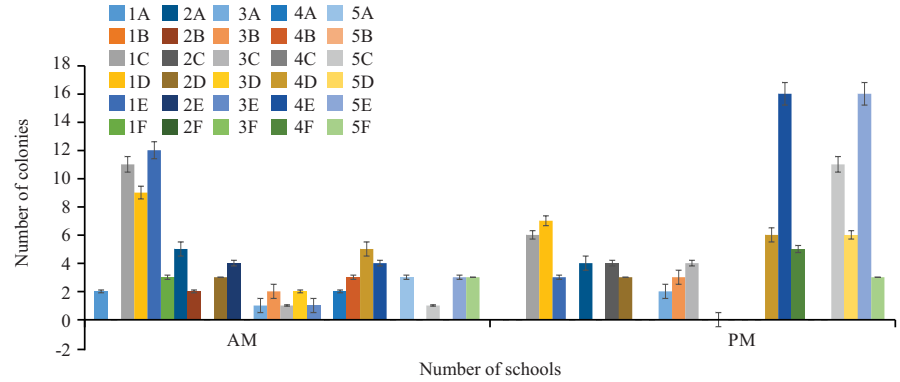

Fig. 10: Occurrence of *Aspergillus niger* in each school for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

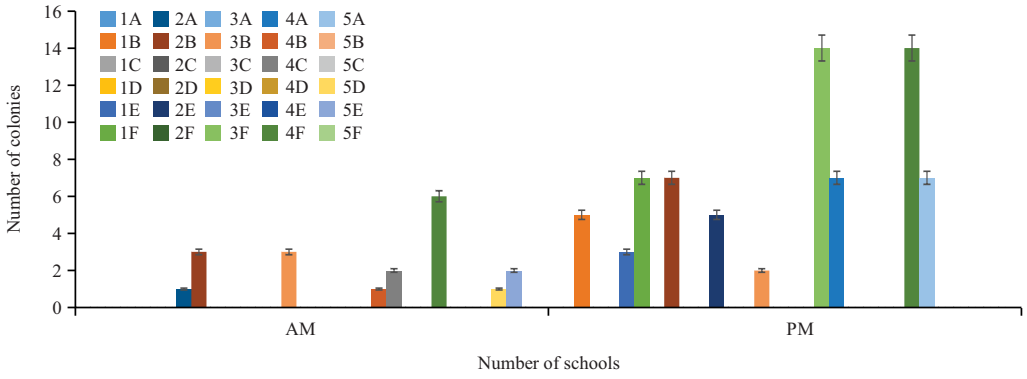

Fig. 11: Occurrence of *Cladosporium sphaerospermum* in each school for morning and afternoon exposure

1A: School 1 primary 1, 1B: School 1 primary 2, 1C: School 1 primary 3, 1D: School 1 primary 4, 1E: School 1 primary 5, 1F: School 1 toilet, 2A: School 2 primary 1, 2B: School 2 primary 2, 2C: School 2 primary 3, 2D: School 2 primary 4, 2E: School 2 primary 5, 2F: School 2 toilet, 3A: School 3 primary 1, 3B: School 3 primary 2, 3C: School 3 primary 3, 3D: School 3 primary 4, 3E: School 3 primary 5, 3F: School 3 toilet, 4A: School 4 primary 1, 4B: School 4 primary 2, 4C: School 4 primary 3, 4D: School 4 primary 4, 4E: School 4 primary 5, 4F: School 4 toilet, 5A: School 5 primary 1, 5B: School 5 primary 2, 5C: School 5 primary 3, 5D: School 5 primary 4, 5E: School 5 primary 5, 5F: School 5 toilet, AM: Morning and PM: Afternoon

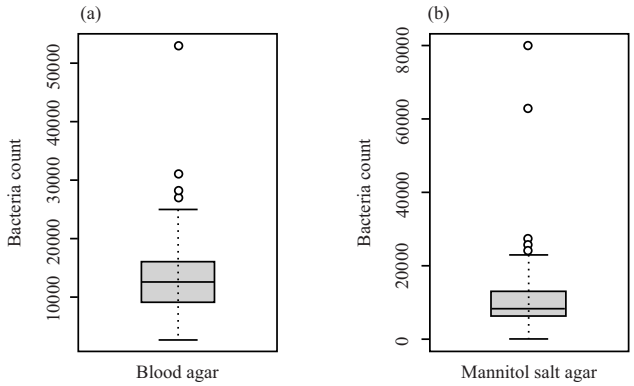

Fig. 12(a-b): Boxplot of bacteria count using (a) Blood agar and (b) Mannitol salt agar

DISCUSSION

A study on the indoor microbial air quality in government primary schools in Akure Metropolis, Nigeria was evaluated in this study. The concentrations of bacteria and fungi aerosols in the indoor air environment as sampled in this research work estimated with the use of the plate method is in parallel with the observation of Amengialue *et al.*[5]. There was variation in concentration of bacteria and fungi across the various sample sites as primary 5 and toilet generally recorded the highest count while primary 1 recorded the least count. This could be attributed to the variation in density of human population activities taking place before and during sampling time as well as the variation of ventilation conditions. These findings do agree with earlier reports by Graudenz *et al.*[6] and Wemedo *et al.*[7]. However, there was a slightly significant difference between the morning and the evening counts, with an observable increase in the afternoon counts over the morning counts. This difference could be attributed to the fact that there were many activities in the afternoon due to the human activities of the day. This finding is in agreement with the work done by Hayleeyesus and Manaye[8], where the microbial load was more in the afternoon compared to the morning. Another determinant factor in the characteristics of microbial load in the air that was taken into consideration in this study is atmospheric conditions. This played an important role in the determination of internal air quality. The variation of bacterial load in indoor environments might be due to environmental factors such as the ventilation system of the classroom, temperature, humidity and particulate matter concentration. In addition, the activities of students such as playing and running could also have contributed to bacterial counts. Traced the sources of classroom airborne contamination to several factors such as students' own normal floral, uniforms, bags, foot-wears as well as activities such as sneezing, coughing, talking and talking and yawning.

Faustman *et al*.[3] also reveal that materials in the classrooms and offices such as cupboards, books and files have been implicated as viable sources and these were present in the school understudy. The students and staff undertake a lot of housekeeping activities such as sweeping or applying dry mops can also create aerosols carrying particles that may contain microorganisms.

The bacteria associated with indoor air in this study compared with the identified bacterial general are *Staphylococcus aureus*, *Staphylococcus epidermis*, *Klebsiella pneumoniae*, *Streptococcus pyogenes*, *Escherichia coli*, *Streptococcus pneumoniae* and *Enterococcus faecalis*. The identified isolates are in partial agreement with Mohan *et al*.[9], who reported also *Bacillus* sp., *Enterococcus* sp., *Micrococcus* sp. and *Staphylococcus* sp. Similarly, it agrees with the report of Udochukwu *et al*.[10] on *Escherichia coli*, *Pseudomonas* and *Staphylococcus* species. The fungal organism associated with indoor air in this study compared with the identified bacterial general is *Aspergillus fumigatus*, *Aspergillus niger*, *Cladosporium sphaerospermum* and *Aspergillus flavus*. These outcomes are in full agreement with Kumari *et al*.[11]. Also, it agrees with the reports of Enitan *et al*.[12] on *Alternaria* sp., *Aspergillus niger*, *Penicillium* sp. and *Rhizopus* sp. The study, therefore, opines that the occupants within the sampled enclosures are frequently exposed to health hazards associated with this bioaerosol.

CONCLUSION

The findings of this study have described the overview of the air microflora of selected densely populated government primary schools in the Akure Metropolis. This study shows the diversity of different bacterial and fungi associated with indoor air in this study. Based on the result of this study, it is recommended that the possible health consequences of air microflora causing harmful respiratory diseases thereby affecting human health necessitates proper sanitary practices across different government primary schools adopted for this study to reduce the potential incidence of bacterial and mycotic infections.

SIGNIFICANCE STATEMENT

This study discovered that the indoor air of selected government primary schools in Akure harboured bacteria and fungi including haemolytic bacteria. The unacceptable microbial air quality of the air samples will help researchers to uncover the dangers the pupils and school workers are exposed to and design studies related to respiratory infectious diseases.

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