Original Article

Microbiological assessment of indoor air quality at different sites of a tertiary hospital in South-South Nigeria

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Abstract

Background: The risk of nosocomial infection is increasing due to the increasing number of patients with immune depression. Good ventilation is one of the methods used to reduce the ambient air levels of the causative agents, but this is rarely observed in Nigeria as hospital designs used to shut out the inclement weather in temperate countries are copied without many modifications, and without adequate provisions to constantly power the mechanical ventilation mechanisms. This study tested the microbiological air quality at different areas of the University of Port Harcourt Teaching Hospital to ascertain the levels of airborne bacteria and fungi in the ambient air.

Methods: The study was carried out in July 2015 in randomly selected inpatient wards, outpatient clinics, and clinical laboratories of the hospital. The assessment was carried out by exposing Petri dishes containing the appropriate culture media for about 30 min at a convenient place in each of the nine study sites. Thereafter, the plates were covered and immediately transferred to the laboratory for incubation at 37°C, for 24–48 h, for bacteria; and at room temperature, for 5–7 days, for fungi. The number and types of bacteria and fungi in the cultures were determined at the end of the incubation period.

Results: There were detectable bacteria and fungi in the ambient air of all the study sites. The mean bacterial count ranged from 9.5 colony forming unit per cubic meter (CFU/m^3) in the urology ward to 199.33 in the HIV clinic, with a mean of 80.0 CFU/m^3, while the mean fungal count ranged from 10.5 CFU/m^3 in the surgery outpatient clinic (SOC) to 23.5 in the Anatomical Pathology Laboratory (APL), with a mean of 16.9 CFU/m^3. *Staphylococcus and Streptococcus* were the most common bacteria in the SOC; *Klebsiella* was predominant in the immunization clinic; *Escherichia coli* were the most common in the APL, while bacillus was most frequently isolated in the gynecology ward. The fungi cultured from the study sites include *Aspergillus*, *Penicillium*, *Fusarium*, *Trichophyton*, *Candida*, and *Rhizopus*. Unlike the bacteria count, the fungal count increased in all the study sites at the end of the working day.

Conclusion: The number and types of bacteria and fungi cultured from the study sites have the potential to cause ill health. Corrective actions are therefore needed.

Keywords: Airborne bacteria, airborne fungi, indoor air quality, Nigeria, Port Harcourt

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Introduction

Although the prevalence of noncommunicable diseases has been on the increase in Nigeria in recent years, communicable diseases are still the most prevalent diseases in Nigeria.[1] Nigerian patients with communicable diseases prefer Western medicine for the treatment of their conditions because of the high cure rate achieved with the diseases,[2] but while in the hospital, the patients aggregate the various causative agents of their diseases in one place, placing other patients, visitors to the hospital, and health-care workers at risk. The risk of infection in a hospital is further increased by the increasing number of patients with immune depression as a result of HIV/AIDS and other immune-suppressing diseases such as cancer and diabetes.[3]

Hospitals are increasingly becoming epicenters of outbreaks of certain communicable diseases, including tuberculosis,[4] diarrheal diseases,[5] and viral hemorrhagic diseases.[6] It is estimated that 5–30% of patients a year develop one or more infections during a stay in hospital, costing as much as one billion Pounds a year to treat in England alone.[7] This public health problem is further exacerbated by the growing incidence of diseases such as AIDS that result in greater hospitalization and susceptibility, and the increasing resistance of the hospital-acquired infections to common antibiotics.[8]

Several of the hospitals acquired infections are airborne, and good ventilation is recognized as one of the most effective ways of reducing the risk of transmission of airborne infections in hospitals.[9] Ventilation rates lower than 2 air changes per hour (ACH) have been associated with higher tuberculin skin test conversion rates among health workers;[10] hence, the WHOs recommendation of a minimum of 80 L/s/patient (hourly average ventilation rate) for airborne precaution rooms such as theatres, and a minimum of 60 L/s/patient for general wards and outpatient departments to reduce the risk of airborne infections in the hospital.[11]

The required ventilation is not often achieved in Nigerian hospitals because of the growing practice of adopting hospital designs used to shut out the inclement weather in temperate countries without many modifications, and without adequate provisions to constantly power the mechanical ventilation mechanisms required to achieve the required number of ACH.[12] We therefore suspect that the wards, clinics, and laboratories of these hospitals are poorly ventilated and are therefore putting the health of patients, hospital visitors, and health-care workers at risk. To test this hypothesis, we assessed the microbiological air quality of the laboratories, wards, and clinics of a tertiary hospital in Port Harcourt, before and after the peak working period. We hope that the results of the study would draw attention to the hazards posed by poor ventilation, enough to elicit corrective actions. This is especially as previous Nigerian studies had failed to make this vital connection.[13,14]

Materials and Methods

The study was carried out at the University of Port Harcourt Teaching Hospital, one of the two multispecialty tertiary health-care institutions in Port Harcourt, the capital of Rivers State, South-South Nigeria. Although located in Port Harcourt, the catchment area of the hospital extends beyond Rivers State to include much of the Niger delta region; a catchment population that can be conservatively put at 10 million people. The hospital is an 800-bed multispecialist teaching hospital located in a large expanse of land, but housed in interconnected multistorey buildings that occupy a small percentage of the total land space and ventilated by both natural and mechanical ventilation. The hospital offers not only tertiary health care services but also secondary and primary health care, encouraged by the near collapse of the other facilities in the state and region. It is heavily patronized with average bed occupancy of more than 78%, and a daily average outpatient attendance of 624. It carries out an average of 8.42 surgical operations every day and handles an average of 9.24 deliveries each day.

A descriptive, cross-sectional study design was used. The microbiological air quality of randomly selected inpatient wards, outpatient clinics, and clinical laboratories of the hospital was assessed using the appropriate measuring equipment. The hospital has 23 inpatient wards, 17 outpatient clinics, and 4 clinical laboratories; out of these, only those that attend to a minimum of thirty patients in each service day were considered for the study. Subsequently, four outpatient clinics (immunization clinic, HIV clinic, surgery outpatient clinic, and antenatal clinic), three inpatient wards (gynecological ward, male surgical ward, and urology ward), and two laboratories (medical microbiology and anatomical pathology) were randomly selected for the study.

The study was carried out in July 2015 the peak of the rainy season in the study area. The assessment was carried out by exposing Petri dishes containing the appropriate culture media at a convenient place in each of the nine study sites, and at approximately one meter above the floor to simulate the breathing zone. Nutrient agar plates were used for the bacteria, while Sabouraud dextrose agar plates were used for the fungi. The Petri dishes were exposed for about 30 min to allow time for the microorganisms in the ambient air to settle into the plates. Thereafter, the plates were covered and immediately transferred to the laboratory of the department of microbiology of the University of Port Harcourt for incubation. The plates for the assessment of bacteria were incubated at 37°C for 24–48 h,

while the plates for the assessment of fungi were incubated at room temperature for 5–7 days.

The microbiological assessments were carried out twice a day, between 9 and 11 am, at the peak of clinical activities, and later in the day, between 4 and 6 pm, at the end of the peak working period, in each of the study sites.

At the end of the incubation period, the number and types of bacteria and fungi in the cultures were determined as carried out in similar other studies.[13-15] The bacteria were identified based on their morphology, Gram-staining, endospore formation, and catalyze activity; and counted based on the colony forming units (CFUs) per cubic meter (CFU/m^3). The number of fungi were similarly counted, while the morphology and characteristics of each of the colonies were as described by Barnet and Hunter[16] and used in other studies.[13,14]

The data collected during the study were put in a database, and then analyzed using IBM's SPSS statistical package, Version 20 and Microsoft's Excel 2016 after checking for consistency and completeness. Summary measures were calculated for each outcome of interest, while the test of significance was conducted using the relevant statistical test at 95% confidence interval, with $P \leq 0.05$ considered statistically significant.

Ethical consideration

The approval to undertake the study was sought and obtained from the Ethics Review Committee of the University of Port Harcourt, Port Harcourt, while informed consent was sought and obtained from the management of the University of Port Harcourt Teaching Hospital and the heads of all the study sites.

Results

A total of 36 air quality measurements were carried out in nine study sites in the hospital. The wind speed in the study sites ranged from 0.07 m/s in the Anatomical Pathology Laboratory (APL) and the antenatal clinic to 0.27 m/s in the urology clinic, with a mean of 0.13 m/s. There were detectable bacteria and fungi in the ambient air of all the study sites. The mean bacteria count of the ambient air of the study sites are presented in Table 1. The mean bacterial count ranged from 9.5 CFU/m^3 in the urology ward to 199.33 in the HIV clinic, with a mean of 80.0 CFU/m^3 for the nine study sites.

The bacteria cultured from the study sites include *Staphylococcus* (25.10%), *Streptococcus* (20.28%), *Bacillus cereus* (21.73%), *Klebsiella* (8.98%), and *Escherichia coli* (18.36%). *Staphylococcus* (36.36%) and *Streptococcus* (27.27%) were the most frequent bacteria isolated in the surgery outpatient clinic (SOC); *Klebsiella* (15.79%) was the most predominant in the immunization clinic; *E. coli* (28.57%) were the most common in the APL, while *B. cereus* (36.36%) was most frequently isolated in the gynecology ward.

The bacteria count during and after the peak working hours are presented in Table 2. The bacterial count increased at the end of the working day in all the wards and clinics, except at the antenatal clinic where the count decreased from 227.33 CFU/m^3 when the clinic was in session to 49.00 CFU/m^3, an hour after the last patient was seen. On the other hand, the bacterial counts were highest in the laboratories during the peak working hour, with a mean count of 105.67 CFU/m^3 recorded at the microbiology laboratory during the peak working hours compared to 62.33 CFU/m^3 at the close of work.

The mean fungi count of the ambient air of the study sites is presented in Table 1. The mean fungi count ranged from 10.5 CFU/m^3 in the SOC to 23.5 in the APL, with a mean of 16.9 CFU/m^3 for all the study sites. The fungi cultured from the study sites include *Aspergillus* species (20.30%), *Penicillium* species (23.54%), *Fusarium* (2.50%), *Trichophyton* (5.21%), *Candida* species (25.37%), and *Rhizopus* (23.04%). *Aspergillus* species (37.48%) had the highest count in the HIV clinic, *Penicillium* species (38.46%) were the highest in the SOC, *Fusarium* (8.11%) was highest in the HIV clinic,

Table 1: The mean bacteria count of the ambient air of the study sites

Study site	Mean bacterial count (CFU/m^3)	Mean fungal count (CFU/m^3)
HIV clinic	199.33	22.67
Immunization clinic	65.33	17.67
Anatomical pathology laboratory	151.83	23.5
Surgery outpatient clinic	41.5	10.5
Microbiology laboratory	84	16.33
Antenatal clinic	138.17	12.33
Gynecology ward	13.17	12.17
Male surgical ward	17	20.5
Urology ward	9.5	16.17

CFU/m^3: Colony forming unit per cubic meter

Table 2: The bacteria count of the study sites during and after the peak working hours

Study site	During peak working period (CFU/m^3)	After peak period (CFU/m^3)
HIV clinic	139.67	259.00
Immunization clinic	31.00	99.67
Anatomical pathology laboratory	228.00	75.67
Surgery outpatient clinic	14.67	68.33
Microbiology laboratory	105.67	62.33
Antenatal clinic	227.33	49.00
Gynecology ward	10.00	16.33
Male surgical ward	10.33	23.67
Urology ward	5.33	13.67

CFU/m^3: Colony forming unit per cubic meter

Trichophyton (13.85%) was highest in the immunization clinic, *Candida* (43.75%) was highest in the antenatal clinic, while *Rhizopus* (34.78%) was predominant in the gynecology ward. The fungal count during and after the peak working hours are presented in Table 3. The fungal count increased in all the study sites at the end of the working day.

Discussion

The study showed the presence of different species of bacteria and fungi in the ambient air of all the study sites. This is consistent with the findings of the other studies carried out in Nigeria[13,14] and the developed countries.[15] The types and number of airborne bacteria and fungi in the study sites seem to be influenced by the type of activities carried out in the study site; the type and number of patients at the site, the level of ventilation, and the level of hygiene of the study site.

The type of activities carried out is likely to be responsible for the high levels of airborne bacteria recorded in the laboratories during the peak working time. This is because laboratory services, especially those carried out in the microbiology and the anatomical pathology laboratories, in countries where communicable diseases are still very prevalent often results in the generation of airborne microorganisms.[17]

The type and number of patients at the study sites possibly explain the high bacteria and fungi counts recorded at the HIV clinic and the antenatal clinic. HIV patients are known to also suffer from several other communicable diseases;[18] they also have an overgrowth of the normal body flora, both of which can be discharged into the air, especially with the level of immune-depression suffered by many of the HIV patients. The high prevalence of candidiasis among pregnant women[19] is also likely to be responsible for the very high level of *Candida* species recorded in the ambient air of the antenatal clinic.

There is a direct relationship between ventilation and indoor levels of bacteria and fungi, with high ventilation associated with lower levels.[11] The wind speed in the APL and the antenatal clinic was just 0.07 m/s, which is obviously not enough to achieve the recommended minimum of 60 L/s/patient for general wards and outpatient departments, needed to reduce the levels of airborne microorganisms in the ambient air.[11] The poor ventilation at the laboratory and clinic is therefore an important explanation for the high level of bacteria and fungi in these study sites.

Table 3: The fungi count of the study sites during and after the peak working hours

Study site	During peak working period (CFU/m^3)	After peak period (CFU/m^3)
HIV clinic	17.00	28.33
Immunization clinic	12.00	23.33
Anatomical pathology laboratory	21.67	25.33
Surgery outpatient clinic	8.33	12.67
Microbiology laboratory	13.00	19.67
Antenatal clinic	7.00	17.67
Gynecology ward	6.67	17.67
Male surgical ward	12.00	29.00
Urology ward	11.67	20.67

CFU/m^3: Colony forming unit per cubic meter

The hygiene practices at the study sites can be the explanation for the decrease in the bacteria count recorded in the laboratories at the end of the working day, and for the increase in the fungi count recorded in all the study sites, after the peak working period. Most of the specimens handled in the laboratories of the study hospital contained microorganisms that could have been sent airborne in the course of working on the specimens, especially with the little containment measures used in the laboratories.[17] The airborne microorganisms accumulate in the laboratory in the course of the working day but decreases, especially with the thorough cleaning that takes place at the end of the working day. The fungi count in all the study sites however remained high after the working day, possibly because some of the cleaning agents used in the hospital are not effective against fungi,[20] which therefore continue to build up until they are slowly dispersed by air flow. The fact that fungi commonly grow in various areas of the hospital environment and can be dispersed in the course of work[17,21] is also a possible explanation for the build-up of fungi at the end of the working day in all the study sites.

The bacteria and fungi cultured from the study sites are the same as the ones cultured in the other Nigerian studies.[13,14] The cultured bacteria are mostly pathogenic and have been implicated in many nosocomial infections. *Staphylococcus* species and *Streptococcus* species formed 25.1% and 21.27% of all the bacteria cultured from the study sites but are also associated with a large proportion of surgical site infections.[22] *Klebsiella* species are the most common bacteria cultured from the immunization clinic, but the bacteria is also able to cause urinary tract infection and bacteremia in the under-five children that receive the childhood immunization at the clinic.[23] *B. cereus* was found in all the study sites, especially in the gynecology ward where it is able to exacerbate nausea and vomiting that are common in pregnant women, apart from other gastrointestinal symptoms.[24]

Mycobacteria tuberculosis was not cultured from the study sites, especially in the HIV clinic. This is not likely to be due to the absence of the bacteria in the study sites, considering the prevalence of active tuberculosis among HIV-positive patients. It is however more likely to be due to the fact that the *M. tuberculosis* is very difficult to culture, and almost impossible to culture with the sedimentation method we used

for the study.[25] Airborne *M. tuberculosis* in hospitals have been shown to be very infectious, such that health workers in endemic countries ultimately become infected in course of their working life.[10]

Fungi were detected in the ambient air of all the study sites; their medical importance is not only in their roles in nosocomial infections[26] but also in their actions as allergens and toxins.[27] Fungi such as the *Penicillium* species, *Rhizopus*, and *Aspergillus* species cultured from all the study sites are prolific sources of allergens that can trigger off the asthmatic attack and other allergic reactions.[27]

The health hazards posed by the type and count of the bacteria and fungi in the ambient air of the study sites call for corrective actions. Whereas little ethical actions can be taken to reduce the source of the microorganisms in patients, there are however many corrective actions that can be applied to reduce the ambient levels of the bacteria and fungi. These actions include increasing the ventilation in the study sites to a minimum of 60 L/s/patient and improving the hygiene levels in the study sites, especially in sites such as the HIV clinic with high counts of bacteria and fungi in their ambient air, with vulnerable patients that can be infected. These corrective actions are not one-off but require sustained and coordinated efforts that are better delivered by a deliberate Indoor Air Quality Management Programme. This program should be headed by an engineer in the works department of the hospital, but with useful inputs from the environmental health department.[28]

A major limitation of our study is the inability of the culture media used for the study to effectively culture some microorganisms such as *M. tuberculosis* that are of great clinical significance.

Conclusion

The number and types of bacteria and fungi cultured from all the study sites have the potential to cause ill health. Corrective actions are therefore needed to keep the microorganisms within regulatory levels by improving ventilation and hygiene, especially in at-risk sites.

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Conflicts of interest

There are no conflicts of interest.

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