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Research Article
Microbiological Assessment of Indoor and Outdoor Air Quality in a General Hospital in North-East Nigeria

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Abstract

Background and Objective: Air harbours large quantity of bacteria and fungi and the knowledge of their number is very important as an index of hygiene for any particular environment. It becomes imperative to carry out microbiological analysis of the indoor and outdoor air in General Hospital Wukari. **Materials and Methods:** Seven points, male ward, female ward, paediatrics, antenatal unit, outpatient department (OPD), walk way and outside the hospital gate were sampled and assessed daily for 3 days, in the morning (8.00-10.00 am) and evening (4.00-6.00 pm) using the settled plate methods. **Results:** The result revealed the isolation of 6 fungal and 6 bacteria isolates. These include *Aspergillus niger* (67%), *Aspergillus flavus* (67%), *Trycophyton* spp. (33%) *Ulacladium* spp. (33%), *Aspergillus fumigatus* (33%), *Aspergillus verssicolor* (33%), *Staphylococcus aureus* (100%), *Staphylococcus epidermidis* (33%), *Bacillus* spp. (67%), *Staphylococcus* spp. (33%), *Escherichia coli* (33%) and *Micrococcus* spp. (33%). The highest bacterial and fungal counts were 1.52×10^5 CFU m^{-3} and 1.5×10^4 SFU m^{-3} (indoor) and 5.2×10^4 CFU m^{-3} and 1.2×10^4 SFU m^{-3} (outdoor), respectively. *Aspergillus niger* and *Aspergillus flavus* were shown to be the most frequently isolated airborne fungal organisms while *Staphylococcus aureus* and *Staphylococcus epidermidis* were the most frequently isolated bacteria. **Conclusion:** The factors which encourage the growth and multiplication of airborne microbes need to be controlled in the Hospital environment to reduce the rate of nosocomial infections.

Key words: Air quality, hospital environment, microbial load, indoor air, cleanliness

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

INTRODUCTION

The quality of air inhaled by an individual within his environment determines to a greater degree of the well-being of that individual. Some infectious agents are suspended in the air, therefore, the hospital environment could be a potential route for the transmission of hospital acquired infections[1,2]. 10-20% of reported endemic nosocomial infections are caused by airborne microbial pathogens[3]. Insufficient ventilation, high association of personnel and improper management of hospital monitoring are the main sources of indoor air contamination in the hospital[4].

The transmission of pathogens by air can be direct or indirect. In indirect transmission, droplets containing microbes from infected persons are propelled through the air and deposited on the host's body. Droplets are generated from the source mainly when the person coughs, sneezes and during the performance of certain procedures such as bronchoscopy. Dissemination can be by air-borne droplets containing microorganisms that remain suspended in the air for a long period of time or dust particles containing the infectious agents[1,5]. Microorganisms carried in this manner can be dispersed widely through the air by air current and may be inhaled by a susceptible individual. An air-borne bacterium in the hospital environment has been a major source of post-operative infection and a serious problem in the intensive care unit[2,6]. Hospital indoor air may contain a wide range of pathogenic and non-pathogenic microorganisms which could originate from patients, the staff, visitors, ventilation and air conditioning systems and outdoors[2,5].

Bacteria and fungi that are often associated with hospital acquired infections are *Staphylococcus aureus*, *Micrcoccus* species, *Pseudomonas* species, *Proteus* species, *Escherichia coli*, *Enterobacter* species, *Bacillus cereus*, *Clasdoporium* species and *Aspergillus* species[6,7]. However, it is not only patients and visitors in the hospital that are at risk of infection, health care workers are also at risk of being infected. Moreover, some microorganisms can impact negatively on the health of most hospitalized patients and immune compromised individuals may be at an increased risk[8].

The microbial contamination of indoor air of an area at a given period is determined by the quality of air, the number of individuals in the area, the type of activities and degree of ventilation. Human activities such as sweeping, walking, waving of clothes etc., can raise dust which is a good vehicle of airborne contamination. Droplets containing airborne microorganisms can be generated through sneezing[9,10].

Fungi are commonly associated with indoor as well as outdoor environments, causing allergy in nearly 10% of people worldwide[11]. People exposed to aerosol with airborne microorganisms and their by-products can develop respiratory disorders, hypersensitivity pneumonitis and toxic syndromes[12,13]. Fungi and bacteria that cause damage in indoor and outdoor environments may play important role in the biogeochemical transformation of the area. However, the relative humidity of an environment determines to what extent different types of microorganisms are able to grow and multiply on indoor or outdoor materials or environment[14,15].

Efforts to prevent hospital acquired infections are geared towards effective use of antiseptics, disinfectants, adequate cleaning, sterilization and quarantine[16] with less attention to indoor and outdoor air as a factor to nosocomial infections[10]. However, monitoring indoor and outdoor air-borne microorganisms in hospital environment could be used as nosocomial infection control measure and quality control measures. Therefore, this study evaluates the microbiological quality of indoor and outdoor air of a general hospital in North-East, Nigeria.

MATERIALS AND METHOD

Study area and sampling site: The study was carried out in a General Hospital Wukari, Taraba State, Nigeria between June and September, 2018. Wukari is located at southern guinea savanna with coordinate's latitude 7°, 51′N-7.850°N and longitude 9°, 47′E-9.783°E, annual precipitation of 1205 mm and it has an average temperature of 26.8°. The general Hospital Wukari is located off Kente road in Wukari local Government Area. The samples were collected from various wards and the outdoor environment in General Hospital Wukari: male ward, female ward, pediatrics, antenatal unit, outpatient department, major walkway and the main gate. An informed consent was sort and granted by the Hospital management before sampling was done.

Sample collection: A total of 126 samples were collected using settle plate methods described by Pasquerella *et al.*[17]. The prepared media were placed in sterile petri plate's holder and taken to the collection site. The media were placed open 1 m above the ground for 15 min at each sample site, after which they were covered and placed back into sterile plate holder and were taken to the laboratory for incubation. The samples were collected two times, morning h (8.00-10.00 am WAT) and evening h (4.00-6.00 pm WAT) at intervals of 5 h for 3 consecutive days.

Determination of bacteria load: The Petri plates exposed at the various sampling points were incubated at 37 and 28°C

for bacteria and fungi plates, respectively for 24 h and afterward examined for discrete colonies and then counted. The counts were expressed as colony forming units per meter cube (CFU m^{-3}) for bacteria and spore forming unit per metre cube (SFU m^{-3}) for fungi.

Identification of the isolates: Distinct colonies were sub-cultured on freshly prepared nutrient medium and successively streaked to obtain pure cultures while pure fungi cultures were obtained using spot inoculation. Pure cultures of bacteria were characterized and identified using, colonial characteristics, microscopy, biochemical tests and sugar fermentation tests as described by Okereke and Kanu[18] and with reference to manual for the identification of medical bacteria[19]. The fungi were identified based on their cultural characteristics and with reference to Larone[20].

RESULTS

The female ward has the highest bacterial count with 5.2×10^4 CFU m^{-3} followed by the male ward (3.6×10^4 CFU m^{-3}) in the morning and the highest in the evening with 1.5×10^5 CFU m^{-3}. The fungal load was highest in pediatrics ward with 1.4×10^4 SFU m^{-3} followed by the male ward with 1.2×10^4 and 1.5×10^4 SFU m^{-3} for both in the morning and evening as shown in Table 1.

Table 2 presented the bacteria and fungi load of the outdoor air of the hospital environment. The result showed that the highest bacterial and fungal load of the main gate was 5.2×10^4 CFU m^{-3} and 4.7×10^4 SFU m^{-3}, 1.0×10^4 CFU m^{-3} and 1.2×10^4 SFU m^{-3} for both morning and evening, respectively.

The bacteria isolated from the indoor samples and their distributions were presented in Fig. 1a. This shows that *Staphylococcus aureus* was highest in the male ward (100%), followed by antenatal (67%) and the outpatient department (67%) in the morning. *Bacillus* species recorded the highest in the female ward (67%) and Pediatrics (67%) in the morning and the Outpatient department (67%) in the evening. *Micrococcus* species recorded 33% in the morning of female ward and evening of antenatal and outpatient wards, respectively while *Escherichia coli* only recorded 33% in the morning of both female and antenatal ward.

Figure 1b presents the fungi isolated from the indoor air samples of the hospital and their distribution. The result showed that *Aspergillus niger* recorded highest in the female ward (67%)in the morning and Pediatrics (67%) both in the morning and evening, Antenatal (67%) in the evening and Outpatient department (67%) in the evening, followed by *Aspergillus flavus* which was highest in the female ward (67%) in the evening. *Aspergillus fumigates* was observed 33% in the morning h from male, pediatrics and antenatal

Table 1: Enumeration of bacteria and fungi of the indoor hospital environment

	Male ward		Female ward		Pediatrics		Antenatal		Outpatient department	
Sampling time	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening
Bacterial viable count (CFU m^{-3})										
Day 1	2.9×10^4	3.1×10^4	1.5×10^4	1.7×10^4	1.6×10^4	1.8×10^4	1.4×10^4	8.0×0^3	8.0×10^3	4.5×10^4
Day 2	1.6×10^4	6.4×10^4	5.2×10^4	9.2×10^4	1.0×10^4	2.5×10^4	1.8×10^4	3.1×10^4	1.3×10^4	1.7×10^4
Day3	3.6×10^4	1.5×10^5	2.4×10^4	5.6×10^4	1.6×10^4	9.5×10^4	3.2×10^4	8.3×10^4	1.2×10^4	4.8×10^4
Fungal viable count (SFU m^{-3})										
Day 1	1.2×10^4	1.5×10^4	9.0×10^3	1.1×10^4	6.0×10^3	5.0×10^3	8.0×10^3	1.0×10^4	4.0×10^3	9.0×10^3
Day 2	6.0×10^3	3.0×10^3	8.0×10^3	5.0×10^3	4.0×10^3	5.0×10^3	3.0×10^3	2.0×10^3	7.0×10^3	3.0×10^3
Day 3	1.0×10^4	9.0×10^3	1.2×10^4	6.0×10^3	1.4×10^4	1.0×10^4	6.0×10^3	3.0×10^3	1.2×10^4	1.0×10^4

Table 2: Enumeration of bacteria and fungi of the outdoor hospital environment

	Main gate		Walk way	
Sampling time	Morning	Evening	Morning	Evening
Bacterial viable count (CFU m^{-3})				
Day 1	2.4×10^4	2.3×10^4	1.0×10^4	1.4×10^4
Day 2	1.2×10^4	4.7×10^4	5.2×10^4	2.8×10^4
Day3	5.2×10^4	2.0×10^4	2.8×10^4	3.2×10^4
Fungal viable count (SFU m^{-3})				
Day 1	5.0×10^3	8.0×10^3	4.0×10^3	5.0×10^3
Day 2	6.0×10^3	4.0×10^3	2.0×10^3	3.0×10^3
Day 3	1.0×10^4	1.2×10^4	9.0×10^3	7.0×10^3

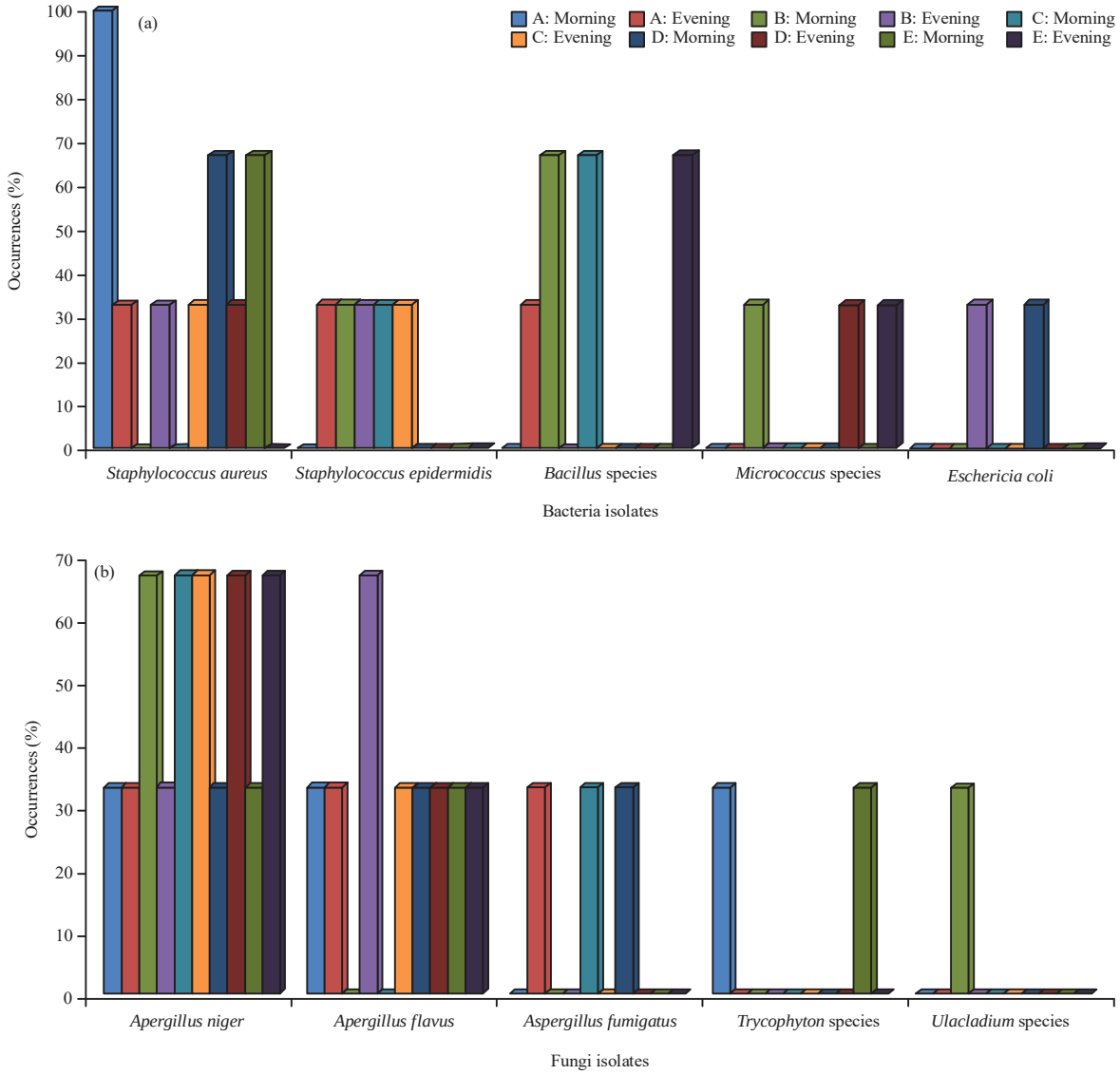

Fig. 1(a-b): Indoor hospital (a) Air bacteria and (b) Air fungi isolates and their percentage distribution
A: Male ward, B: Female ward, C: Pediatrics, D: Antenatal, E: Outpatient department

wards, respectively. *Trycophyton* species was observed 33% in the morning h from male and outpatient wards, respectively while *Ulacladium* species was only observed 33% in the morning h from female ward.

In the outdoor environment (Main gate and Walk way), *Staphylococcus aureus* and *Bacillus* species were having the highest percentage (66.7%) at the main gate and the walk way in the evening while *Aspergillus niger* and *Aspergillus flavus* were found to be the highest (66.7%) at the main gate and the walk way in the morning and in the evening while *Aspergillus versicolor* was observed only on the walkway of the hospital (Table 3).

DISCUSSION

This study evaluated the indoor and outdoor microbial air quality of a hospital environment in Wukari, Nigeria. The range of bacteria and fungi loads (2.0×10^3 to 9.5×10^4 CFU m^{-3}) were relatively low. However, it gives information about the sanitary conditions of the wards and the environment. The environment where patients are treated (hospital) influences their rate of recovering or acquiring more infections that may lead to complications[9]. Moreover, Ekhaise and Ogboghodo[21] noted that the number and type of airborne microorganisms can be used to determine the degree of cleanliness of an area

Table 3: Distribution of bacteria and fungi isolated from outdoor environment the hospital

	Main gate		Walk way	
Isolates	Morning (%)	Evening (%)	Morning (%)	Evening (%)
Staphylococcus aureus	0.00	66.67	0.00	0.00
Staphylococcus epidermidis	33.33	0.00	0.00	0.00
Bacillus species	33.33	33.33	33.33	66.67
Micrococcus species	33.33	0.00	33.33	33.33
Escherichia coli	0.00	0.00	0.00	0.00
Aspergillus niger	66.67	33.33	33.33	66.67
Aspergillus flavus	0.00	66.67	33.33	33.33
Aspergillus fumigatus	33.33	0.00	0.00	0.00
Aspergillus versicolor	0.00	0.00	33.33	33.33

or environment. Hence, the need for interventions to control factors that favours the growth and multiplication of airborne microorganisms in the study area.

In this study, the bacteria isolated include *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Escherichia coli*, *Bacillus* spp. and *Micrococcus* spp. Similar observation and isolates have been reported by Ekhaise and Ogboghodo[21], who isolated *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Escherichia coli*, *Bacillus cereus*, *Serratia marcescens* and *Micrococcus* species, in their study on airborne microflora in the atmosphere of an hospital environment of university of Benin Teaching Hospital (UBTH), Benin City, Nigeria. Moreover, previous report indicated the presence of *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Escherichia coli*, *Proteus mirabilis* and *Streptococcus* species in microbiological indoor and outdoor air quality of 2 major hospitals in Benin City, Nigeria[9]. These microorganisms are known to be associated with nosocomial infections[6,7]. *Staphylococcus aureus* is known to cause infections of the skin, deeper tissue and organs as well as pneumonia[22]. This microorganism is known to be primary agent of nosocomial infections. These bacteria in the wards could originate from the staff, visitors, ventilation and air conditioning systems or patients[2].

The species of fungi isolated from this study include, *Aspergillus niger*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus verssicolor*, *Trycophyton* spp. and *Ulacladium* spp. *Aspergillus niger* (100%) and *Aspergillus flavus* (80%) were the most frequently isolated fungi. Similar observations have been reported by other researchers in indoor and outdoor environment of houses in the United Arab Emirates, University of Benin Teaching Hospital and two major hospitals in Benin City, Nigeria[9,21,23]. Similarly, a survey of filamentous fungi in three hospitals in Greece indicated that *Aspergillus flavus* and *Aspergillus fumigatus* were the most common[24]. Spores of *Aspergillus* species may lead to aspergillosis in immunocompromised hosts[21].

The present study shows that similar bacteria and fungi isolates in both the indoor and outdoor environment of the general hospital Wukari. However, there was high frequency of airborne bacteria isolates in the evening than in the morning as compared to the frequency of airborne fungal isolates, which was predominant in the morning. It is an established fact that temperature and relative humidity are 2 important factors for fungal spore generation, release and dispersal, particularly in indoor environments[7]. The dry atmosphere and hot temperature in the morning influence the movement of airborne microbial particles and thus support evidences for the concentration of fungal species within the period. Also, visitors and vehicular movement can contribute to the suspension of these organisms in air.

SIGNIFICANCE STATEMENT

This study discovers that potential pathogenic bacteria and fungi which could contribute to hospital acquired infections are present in the indoor and outdoor air of the studied hospital environment. This study will help the researcher to explore the possible environmental factors that favours the growth and multiplication of airborne microbes in hospital environment. Thus ways of mitigating these factors and reduce nosocomial infections could be achieved.

CONCLUSION

The present study has shown that potential pathogenic microorganisms were present in both the indoor and outdoor environment of General Hospital Wukari and there was correlation of the organisms in terms of number and species. The bacteria and fungi concentrations of air obtained in this study might be of potential risk factors for spread of nosocomial infection in the hospital wards. Thus, there is need for regular air quality monitoring to identify and control those environmental factors which favours the growth and multiplication of microbes.

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