Frontiers in Environmental Microbiology
2018; 4(6): 124-132
http://www.sciencepublishinggroup.com/j/fem
doi: 10.11648/j.fem.20180406.11
ISSN: 2469-7869 (Print); ISSN: 2469-8067 (Online)

Research Article

Microbiological Quality of Indoor and Outdoor Air Within Biological Sciences Laboratories in Akwa Ibom State University, Nigeria

Senyene Umana[1, *], Nathan Edet[1], Mfoniso Uko[1], Bassey Agbo[2], Maria Bassey[1]

[1]Department of Biological Sciences, Akwa Ibom State University, Mkpat Enin, Nigeria

[2]Department of Microbiology, University of Calabar, Calabar, Nigeria

Email address:

senyeneumana@aksu.edu.ng (S. Umana)

[*]Corresponding author

To cite this article:

Senyene Umana, Nathan Edet, Mfoniso Uko, Bassey Agbo, Maria Bassey. Microbiological Quality of Indoor and Outdoor Air Within Biological Sciences Laboratories in Akwa Ibom State University, Nigeria. *Frontiers in Environmental Microbiology*. Vol. 4, No. 6, 2018, pp. 124-132. doi: 10.11648/j.fem.20180406.11

Received: November 26, 2018; **Accepted**: January 14, 2019; **Published**: February 18, 2019

Abstract: The microbiological quality of indoor air and outdoor air within Biological Sciences Laboratories (Microbiology and Biotechnology) was investigated. The settle plate technique using open Petri dishes containing different culture media was employed to collect sample twice daily for a period of 5 weeks at 7 days interval. Standard microbiological methods were employed for the identification of bacterial and fungal isolates. The results obtained revealed that the concentration of bacteria in the study area ranged from 2.05×10^2 to 1.53×10^3 CFU/m^3, while that of fungi was 2.05×10^2 to 1.79×10^3 CFU/m^3. A total of 8 bacterial and 10 fungal species were isolated and identified with varying frequencies of occurrence. This include *Bacillus* spp, *Staphylococcus aureus, Escherichia coli, Salmonella* spp, *Micrococcus* spp, *Citrobacter* spp, *Proteus* spp *and Corynebacterium* spp, while the fungal genera isolated include *Aspergillus niger, Aspergillus flavus, Rhodotorula harrison, Aspergillus terreus, Candida albicans, Mucor micheli, Cladosporium* spp, *Saccharomyces cerevisiae and Lecythophora hoffmannii.* The bacterial isolates *Bacillus* spp (27%) and *Micrococcus* spp (22.93%) were shown to be the most predominant airborne bacteria while *Aspergillus niger* (21.72%) and *Aspergillus flavus* (18.69%) were the most frequently isolated fungal species. The statistical analysis showed a significant difference between the microbial load of the indoor and outdoor air of Biological Sciences Laboratories at $P<0.05$. Data generated underline the usefulness of monitoring the air quality of the Laboratory environment.

Keywords: Bacteria, Fungi, Microbiological Quality, Air, Sedimentation Technique

1. Introduction

Microorganisms are found everyway in our environment and impact the whole ecosphere in one way or the other. They influence man in different ways. The diversity of microbial activities varies from causing diseases in human, other animals and plants. Microorganisms are sensitive indicators of environmental quality. Air serves as a very good dispersal medium for microbiota. The type of species and amount of organisms present in the air depends on physicochemical factors like the temperature, viscosity, lighting, suspension of organic and inorganic material and food availability. Human activities are also an important determining factor for the diversity of microbes in an area [1].

The air inhaled by people is abundantly loaded with microorganisms in form of bioaerosols [2]. Karwowska [3] defined bioaerosols as a colloidal suspension, formed by liquid droplets and particles of solid matter in the air, whose components contain or have attached to them viruses, fungal spores and conidia, bacterial endospores, plant pollen and fragments of plant tissues. Basically, bioaerosols are airborne particles that are living or originate from living organisms. Bioaerosols are ubiquitous, highly variable, complex, natural or man-made in origin. Aerosol particles of biological origin (cells, cell fractions or organic matter of animal, plant and

microbial origin) form a significant portion of atmospheric aerosols, sometimes reaching close to 50% numerically of all aerosol particles [4]. Pillai and Ricke [5] opines that composition and size of bioaerosol varies from 20 nm to >100 μm depending on the source, aerosolization mechanisms, and environmental conditions prevailing at the site. The inhalable fraction (PM 2.5) is of primary concern because it is the most susceptible portion of the bioaerosols to reach the deeper parts of the respiratory system.

Indoor air quality is one of the most important factors that influence our general life quality. An average human breathe 10 m^3air every day, and spend 80–95% of his or her live indoors [6]. Indoor air pollution can result in health problems and even an increase in human mortality [7]. Indoor environments contain a complex mixture of live and dead microorganisms, fragments, toxins, allergens, volatile microbial organic compounds and other chemicals.

Biologically derived materials are natural components of indoor and outdoor environments. But under certain circumstances, biological agents may be considered contaminants of outdoor environment. Among the various sources of outdoor air pollution, microorganisms are considered to be the most complex and the least investigated. A wide variety of microorganisms constitutes the air spora of any region and these are dispersed from the source by various agents. The transport and ultimate settling of bioaerosols are affected by its physical properties and the environmental parameters that it encounters while it is airborne. The size, density and shape of the droplets or particles comprise the most important physical characteristics, while the magnitude of air currents, relative humidity and temperature are the significant environmental parameters [8]. The incidence patterns of airborne particulate matters differ from place to place and season to season.

There is a growing evidence that exposure to biological agents in the indoor environment can have adverse health effects. A review made by World Health Organisation (WHO) on the number of epidemiological studies showed that, there is sufficient evidence for an association between indoor dampness-related factors and a wide range of effects on respiratory health, including asthma development, asthma exacerbation, current asthma, respiratory infections, upper respiratory tract symptoms, cough, sneeze and dyspnoea [9, 10].

Microbiological air quality is an important criterion that must be taken into account when laboratories are designed to provide a safe environment. The load of microorganisms in the air can be measured by using air sampler method or by using simple settle plate method and by calculating the colony forming units per cubic meter of air (CFU/m^3).

Recent studies have shown that there is an increase in a number of allergic reactions to microbial spores in which the young people do constitute a large number of allergy sufferers [9-11]. Therefore there is need to monitor air regularly in order to determine its quality as it affects the health of humans in the public as they go about their daily activities. In Nigeria, attention is yet to be given to the monitoring of airborne microorganism either indoor or outdoor. This study is focused on this problem at the Biological Science Laboratory of Akwa Ibom State University where students and laboratory scientists spend a great deal of their time inside these laboratories and their immediate surroundings with possible pollutants, which may lead to adverse health effect on them.

2. Materials and Method

2.1. Study Area

Akwa Ibom State University (AKSU) was conceived and funded by the Akwa Ibom State Government of Nigeria. It is a dual-campus institution. The Biological Science Laboratories (comprising Microbiology, Genetics and Biotechnology, Zoology, and Botany Laboratories), are at the main campus of the institution in Mkpat Enin local government area of Akwa Ibom State, Nigeria. With coordinates by time with latitude 4^0 37 ' 18 " N, and longitude 7^0 45 ' 50 " E.

The Laboratories serve dual purposes; carrying out experiments as lecture rooms due to unavailability of lecture halls in the institution. On the average, over 200 students and staff use these facilities daily, making it one of the busiest areas of the institution.

2.2. Sample Collection and Analysis

Air sample was collected for a period of 5 weeks at 7 days interval using the settle plate technique also known as sedimentation method [12]. Settle plate is a direct method of accessing the likely number of microorganisms depositing onto the surface in a given time. The sampling was carried out twice a day for five weeks; each day, before the students and staff come into the laboratory (8.00), and during the peak of the day when there is maximum activities in the laboratory (14: 00). The Petri dishes containing media were exposed at strategic locations in the laboratory at a height of 1 to 1.5 m above the ground to avoid contamination from floor microbes for both indoor and outdoor for the duration of 20 minutes after which the lids were replaced and incubated at 37°C for 24 hours for bacterial media and at room temperature for five days for the fungal medium.

2.3. Analytical Media

Nutrient Agar (NA) was used to determine total heterotrophic bacteria counts (THBC), MacConkey Agar (MCA) was used to determine coliform counts, Eosine Methylene Blue Agar (EMBA) was used to determine faecal coliform (*E. coli*) counts, Salmonella–Shigella agar (SSA) was used to determine Salmonella and Shigella species while Saboroud Dextrose Agar (SDA) was used to determine fungal counts.

The media were prepared according to the manufacturer's instructions and sterilized by autoclaving at 121°C for 15 minutes.

2.4. Enumeration of Microbial Growth and Identification of Microbial Communities

The growth on each culture plate was enumerated by counting the number of colonies on each group of plate and finding the mean of related media.

Once colony forming units (CFU) were enumerated, CFU/m^3 were determined, taking into account the following equation described by Omeliansky [13].

$N = 5a \times 10^4 (bt)^{-1}$

Where N = microbial CFU/m^3 of indoor or outdoor air,

a = number of colonies per Petri dish,

b = dish surface area (cm^2), and

t = exposure time (min).

The bacterial colonies obtained from the samples were characterized using standard procedure as described by Bergey's Manual of Determinative Bacteriology [14]. The colonies were subjected to Gram's stain and various biochemical tests such as motility test, catalase test, urease test, coagulase test, citrate test, hydrogen sulphide test, sugars utilization test and MR-VP test. Fungal isolates were identified according to the method of Barnett *et al*., [15].

2.5. Meteorological Data Acquisition

The meteorological parameters measured for this study included temperature, relative humidity, wind speed, pressure. The measurement of the meteorological parameters was carried out using portable pieces of equipment. The equipment used is as stated in Table 1.

Table 1. *Meteorological Equipment.*

Parameter	Equipment
Temperature, Relative humidity, atmospheric pressure	Multi-purpose Hygro, Baro and Thermometer. Model: Baro, Germany
Wind speed	Anemometer. Model: Deuta Anemo Windspeed indicator

2.6. Data Analysis

The data collected were subjected to correlation matrix analysis to establish relationships between the microbial groups. A two factor Anova test without replication was employed for the comparison of the bioaerosol data sets of the outdoor and indoor air. The mean and variance were used to characterize the normally distributed data. The criterion for significance in the procedure was $P<0.05$.

3. Results

3.1. Microbial Loads of the Indoor and Outdoor Air in Biological Science Laboratories

The microbial loads of Microbiology and Biotechnology Laboratories are presented in Tables 2 – 5. The results revealed that the total microbial load of the indoor air and outdoor air of the two Laboratories varied with time. Table 2 showed that the highest THBC was recorded on week 5 at noon in the indoor air of Microbiology Laboratory. The highest *Salmonella-Shigella* loads were recorded in the indoor environment particularly on week 3. The study also revealed that the highest fungal loads were recorded in the indoor environment (Table 2 and 4). Table 3 showed that at week 4, the total fungal counts of the outdoor air in Microbiology laboratory was higher than the total heterotrophic bacteria count at noon. Similar observations were also made in the indoor air of Biotechnology laboratory at the same week 4.

Table 2. *Microbiological Load of Indoor Air of Microbiology Laboratory.*

Sampling period		THBC	TCC	FCC	S-S	TFC
WK 1	Morning	24	19	0	2	17
	Noon	20	15	0	0	14
WK 2	Morning	30	8	1	1	25
	Noon	13	10	0	0	22
WK 3	Morning	17	11	0	5	15
	Noon	31	15	1	7	38
WK 4	Morning	28	14	1	0	25
	Noon	52	18	0	4	52
WK 5	Morning	41	9	0	3	24
	Noon	31	7	0	2	28

Key: WK = week, THBC = total heterotrophic bacteria count, TCC = total coliform count, FCE = faecal coliform count, S-S = Salmonella-Shigella count, TFC = total fungal count.

Table 3. *Microbiological Load of Outdoor Air of Microbiology Laboratory.*

Sampling period		THBC	TCC	FCC	S-S	TFC
WK 1	Morning	20	16	0	5	12
	Noon	17	10	0	2	10
WK 2	Morning	23	3	2	1	22
	Noon	9	2	0	0	24
WK 3	Morning	11	3	0	6	22
	Noon	12	9	1	5	17

Sampling period		THBC	TCC	FCC	S-S	TFC
WK 4	Morning	22	17	0	3	23
	Noon	21	10	0	2	42
WK 5	Morning	32	2	1	2	11
	Noon	34	10	0	3	7

Key: WK = week, THBC = total heterotrophic bacteria count, TCC = total coliform count, FCE = faecal coliform count, S-S = Salmonella-Shigella count, TFC = total fungal count.

Table 4. *Microbiological Load of Indoor Air of Biotechnology Laboratory.*

Sampling period		THBC	TCC	FCC	S-S	TFC
WK 1	Morning	28	16	0	3	14
	Noon	35	16	0	1	17
WK 2	Morning	28	14	1	0	19
	Noon	19	3	0	0	14
WK 3	Morning	17	9	0	6	17
	Noon	19	10	0	7	18
WK 4	Morning	33	11	0	0	21
	Noon	43	13	0	2	61
WK 5	Morning	45	2	0	2	25
	Noon	37	5	2	1	19

Key: WK = week, THBC = total heterotrophic bacteria count, TCC = total coliform count, FCE = faecal coliform count, S-S = Salmonella-Shigella count, TFC = total fungal count.

Table 5. *Microbiological Load of Outdoor Air of Biotechnology Laboratory.*

Sampling period		THBC	TCC	FCC	S-S	TFC
WK 1	Morning	20	10	0	4	9
	Noon	14	9	0	3	7
WK 2	Morning	24	4	1	2	14
	Noon	7	0	0	0	13
WK 3	Morning	9	5	0	2	12
	Noon	18	10	1	5	15
WK 4	Morning	28	12	1	3	14
	Noon	19	10	1	1	33
WK 5	Morning	26	1	0	4	20
	Noon	26	12	0	3	12

Key: WK = week, THBC = total heterotrophic bacteria count, TCC = total coliform count, FCE = faecal coliform count, S-S = Salmonella-Shigella count, TFC = total fungal count.

3.2. Microbial Diversity of Microbiology and Biotechnology Laboratory

Precisely 8, 6 and 4 bacteria mould and yeast isolates were respectively characterized and identified. The results have revealed a rich microbial diversity of 4 Gram negative and 4 Gram positive bacterial isolates. The identified bacterial isolates include *Bacillus spp, Micrococcus spp, Staphylococcus spp, E. coli, Corynebacterium spp, Citrobacter spp, Salmonella spp* and *Proteus spp.* The identified mould species include *Mucor micheli, Aspergillus niger, Aspergillus flavus, Lecythophora hoffmannii, Cladosporium spp,* and *Aspergillus terreus.* Yeast species identified include *Cryptococcus spp, Candida albicans, Rhodotorula harrison* and *Saccharomyces cerevisiae*.

3.3. Occurrence and Distribution of Microorganisms Isolated From Biotechnology and Microbiology Laboratories

The occurrence and distribution of microbial isolates in Biotechnology and Microbiology Laboratory are presented in Tables 6 – 7. The results have revealed that *Proteus spp* was not detected in air in the Biotechnology laboratory but was only detected in Microbiology Laboratory (Table 6). Table 7 shows a richer fungal diversity in Microbiology Laboratory than in Biotechnology laboratory.

The frequency of occurrence rate is illustrated accordingly in Figure 1and 2. The research findings have revealed that among the bacterial isolates, *Bacillus spp* was the most predominant in the study site with a frequency of 27% while the least predominant isolate was *E. coli* with a frequency of 0.95% (Figure 1).

Among the fungi isolated from the indoor and outdoor air of Biotechnology and Microbiology laboratory, *A. niger* (21.72%), *A. flavus* (18.69%) and *A. terreus* (17.96%) were the most predominant (Figure 2).

Table 6. *Occurrence of Bacterial Isolates from Biotechnology and Microbiology Laboratories.*

Isolate	Microbiology Laboratory	Biotechnology Laboratory	Frequency of Occurrence	Percentage frequency (%)
S. aureus	111	136	247	16.76
Micrococcus spp	171	167	338	22.93
Citrobacter spp	87	71	158	10.72
Bacillus spp	206	192	398	27
E. coli	7	7	14	0.95
Salmonella spp	53	49	102	6.92
Corynebacterium spp	98	91	189	12.82
Proteus spp	28	0	28	1.9

Table 7. *Occurrence of Fungal Isolates from Biotechnology and Microbiology Laboratories.*

Isolate	Microbiology Laboratory	Biotechnology Laboratory	Frequency of Occurrence	Percentage frequency (%)
A niger	92	87	197	21.72
A terreus	68	80	148	17.96
Mucor micheli	28	31	59	7.16
C albicans	47	44	91	11.04
A flavus	83	71	154	18.69
Cryptococcus spp	19	9	28	3.4
Rhodotorula harrison	51	41	92	11.17
S cerevisiae	9	0	9	1.08
Lecythophora hoffmannii	27	0	27	3.28
Cladosporium spp	27	11	38	4.61

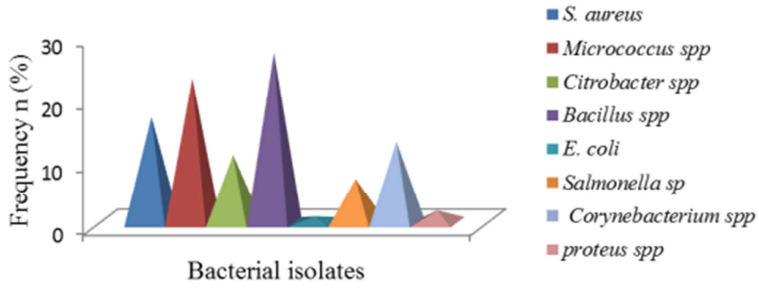

Figure 1. *Frequency of Occurrence of Bacteria Isolated from Microbiology and Biotechnology Laboratories.*

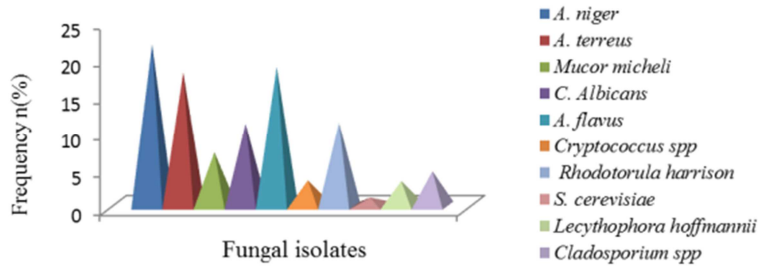

Figure 2. *Frequency of Occurrence of the Fungi Isolated from Microbiology and Biotechnology Laboratories.*

3.4. Meteorological Parameters of Indoor and Outdoor Air of Biological Science Laboratories (Microbiology and Biotechnology)

The results revealed variations in the different meteorological parameters of indoor and outdoor air of Biotechnology and Microbiology laboratories. The temperature around the Laboratories varied between 22 – 25°C in the morning and 24 – 27°C during the afternoon. There was a slight variation between the indoor and outdoor relative humidity of the Laboratories. The atmospheric pressure remained relatively constant while the wind speed fluctuated between 0 – 1.4 mph (Table 4.8 – 4.11)

Table 8. *Meteorological Parameters of Indoor Air of Microbiology Laboratory.*

Sampling period		Temp (°C)	RH (%)	Pres (atm)	WS (mph)
WK 1	Morning	22	95	0.995	0.1
	Noon	27	89	0.995	0.1
WK 2	Morning	25	94	0.996	0.9
	Noon	27	94	0.99	0.9

Sampling period		Temp (°C)	RH (%)	Pres (atm)	WS (mph)
WK 3	Morning	23	96	0.995	0.1
	Noon	26	87	0.9	1.4
WK 4	Morning	23	98	0.996	0
	Noon	25	98	0.995	0.9
WK 5	Morning	25	98	0.996	0.9
	Noon	27	96	0.99	0.9

Key: WK = week; Temp = temperature; Pres = pressure; RH = relative humidity; WS = wind speed.

Table 9. *Meteorological Parameters of Outdoor Air of Microbiology Laboratory.*

Sampling period		Temp (°C)	RH (%)	Pres (atm)	WS (mph)
WK 1	Morning	23	90	0.996	0.9
	Noon	27	87	0.995	0.1
WK 2	Morning	25	94	0.996	0.9
	Noon	27	94	0.99	0.9
WK 3	Morning	23	96	0.995	0
	Noon	24	95	0.995	0.9
WK 4	Morning	23	98	0.996	0
	Noon	25	98	0.995	0.9
WK 5	Morning	25	98	0.996	0.9
	Noon	27	96	0.99	0.9

Key: WK = week; Temp = temperature; Pres = pressure; RH = relative humidity; WS = wind speed.

Table 10. *Meteorological Parameters of Indoor Air of Biotechnology Laboratory.*

Sampling period		Temp (°C)	RH (%)	Pres (atm)	WS (mph)
WK 1	Morning	22	95	0.995	0.1
	Noon	27	89	0.995	0.1
WK 2	Morning	25	94	0.996	0.9
	Noon	27	94	0.99	0.9
WK 3	Morning	23	96	0.995	0.1
	Noon	26	87	0.9	1.4
WK 4	Morning	23	98	0.996	0
	Noon	25	98	0.995	0.9
WK 5	Morning	25	98	0.996	0.9
	Noon	27	96	0.99	0.9

Key: WK = week; Temp = temperature; Pres = pressure; RH = relative humidity; WS = wind speed.

Table 11. *Meteorological Parameters of Outdoor Air of Biotechnology Laboratory.*

Sampling period		Temp (°C)	RH (%)	Pres (atm)	WS (mph)
WK 1	Morning	23	90	0.996	0.9
	Noon	27	87	0.995	0.1
WK 2	Morning	25	94	0.996	0.9
	Noon	27	94	0.99	0.9
WK 3	Morning	23	96	0.995	0
	Noon	24	95	0.995	0.9
WK 4	Morning	23	98	0.996	0
	Noon	25	98	0.995	0.9
WK 5	Morning	25	98	0.996	0.9
	Noon	27	96	0.99	0.9

Key: WK = week; Temp = temperature; Pres = pressure; RH = relative humidity; WS = wind speed.

4. Discussion

The assessment of indoor and outdoor air quality is essential in determining microbial air pollution. Information on number and type of air borne microorganisms can be used to estimate the health hazard posed and create standards for air quality for both the indoor and outdoor environment [16, 17]. This study investigated the microbial qualities of both the indoor and outdoor air of Biological Science Laboratories (Microbiology and Biotechnology Laboratory) in Akwa Ibom State University using sedimentation method (settle plate technique).

Microorganisms are ubiquitous in the atmosphere with concentrations of bacteria cells typically exceeding 100 million m^3 of air over land. The results of this study have revealed fairly high microbial loads in the laboratory atmosphere. The research findings have shown that bacteria and fungi were detected in all the sites investigated. The total fungal concentration was higher in week 4 at noon than total bacteria concentrations. This observation is in contrast with

previous work carried out by Vijayalakshmi [17] who reported that the occurrence of individual bacterial species (5495 CFU/m^3), and their seasonal distributions were significantly higher than outdoor fungal concentrations (4344 CFU/m^3) from an outdoor environment in upper Silesia.

In this study, a high positive correlation was observed between indoor THBC and outdoor THBC (r = 0.988) for microbiology Laboratory in the morning and (r = 0.811) for Biotechnology laboratory in the morning at $P<0.05$. This is in contrast to the result obtained by Frankel *et al*., [18] who obtained a low positive correlation between indoor THBC, TFC and outdoor THBC, TFC respectively. However, the indoor FCC and S-S showed low to moderate positive correlation to the outdoor air concentration.

This study has also revealed the rich microbial loads with remarkable populations of heterotrophic bacteria but low densities of faecal coliforms, total coliforms and Salmonella-Shigella species. Air will often contain microorganisms such as viruses, bacteria and fungi. None of these actually live in the air; the atmosphere tends to kill off most of them. However, they are frequently transported attached to other particles such as flakes, soil, dust or dried residues from water droplets. Aggregation of cells into clumps can enhance their survival whilst airborne. Bacteria cells when they become airborne normally die within a few seconds due to evaporations of water associated with particles. Thus, with higher humidity higher bioaerosols can prevail.

Diverse species of bacteria and fungi were isolated from the indoor and outdoor air of the laboratories. A total of 18 microbial species were isolated in this study. These include 8 bacterial and 10 fungal species. The bacterial species include *Staphylococcus aureus, Bacillus spp, Micrococcus spp, Corynebacterium spp, Salmonella spp, Escherichia coli, Citrobacter spp,* and *Proteus spp.* Most of these bacteria encountered in this study have previously been reported by researchers [16, 19-21].

The fungal isolates include *Aspergillus spp, Rhodotorula Harrison, Saccharomyces cerevisiae, Mucor micheli, Lecythophora hoffmannii, Cladosporium spp, Candida albicans,* and *Candida albicans.* Ilundu and Nwoke [22] also reported the presence of these fungal species in the outdoor air environment of Delta State University Site III, Abraka, Nigeria.

The incidence of these microbial isolates however varied with the Laboratories. The research results have shown that among the bacterial isolates, *Bacillus spp*, *Micrococcus spp* and *Staphylococcus aureus* were the most predominant with 27%, 22.93% and 16.76% respectively. Among the fungi encountered in this study, *Aspergillus niger* (21.72%), *Aspergillus flavus* (18.69%) and *Aspergillus terreus* (17.96%) were the most predominant. This is similar to that obtained by Ekhaise and Ogboghodo [23] who isolated 10 bacteria species from indoor and outdoor of 2 hospitals in Benin City, Nigeria. Epidemiological studies have shown that high concentrations of microorganisms in the air can be allergenic; however, sometimes even very low concentrations of some particular microorganisms can cause serious diseases [24]. Among the microorganisms isolated from the indoor and outdoor air of Biological Sciences Laboratories, *Staphylococcus aureus*, *Bacillus spp* and *E. coli* are known to be pathogenic.

S. aureus is normally part of the skin flora. About 20% of the human populations are long term carriers of *S. aureus*. *S. aureus* are known to form aggregates in nature, so they tend to yield higher colony counts and also because of the possible breaking up of the clusters [25]. This bacterium is known to be carried in the nasopharynx, throat, skin, cuts, boils, nails and as such can easily contribute to the microflora of these laboratories which are always busy with academic activities.

Bacillus endospores have a usual resistance to chemical and physical agents, this explains their aerial distributions. This organism is a known primary agent of food poisoning [26].

E. coli is a Gram negative, facultatively anaerobic rod shaped bacterium that is an indicator of recent faecal contamination. Most *E.coli* strains are harmless but some serotypes can cause serious food poisoning in humans and are occasionally responsible for products due to food contamination [21, 26].

The relatively high concentrations of fungi in the air within Biological Sciences laboratories may pose only little health hazard to healthy individuals, but would pose serious danger and special risk to immunocompromised individuals [21, 27]. Frequent and high exposure to spores of *Aspergillus spp* can lead to pulmonary aspergillosis when inhaled. The majority of cases occur in people with underlying illnesses and low immunity [28, 29]. *A. niger* and other species of fungi have been implicated as pathogenic in causing mycotic infections [21]. Exposure to *C. albicans* can cause skin related infections. Most fungi are known to be associated with asthma both in babies [30] and adults [31].

Wind speed releases bacteria in air when it has to exceed a threshold speed to remove material from surface whereas at higher speeds bacterial concentrations may become diluted [32]. However, in this study, significant difference between temperature, wind speed and relative humidity was observed on microbial concentrations of the Microbiology and Biotechnology Laboratories. This is similar to the result obtained by Kumari *et al*., [1]. Therefore, the microbial concentrations of the indoor air and outdoor air for the two Laboratories could be attributed to correlation between total heterotrophic bacteria count and temperature, relative humidity and wind speed.

The statistical analysis revealed a significant difference between the outdoor and indoor microbial load of Biotechnology and Microbiology Laboratories except in the microbial load of Microbiology Laboratory for morning where there was no significant difference. The data was analyzed at a criterion for significance of $P<0.05$.

5. Conclusion

The study has shown the rich microbial loads of indoor and outdoor air of Biological Science Laboratories with remarkable populations of heterotrophic bacteria but low

densities of faecal coliforms and *Salmonella-Shigella* species. The most predominant bacterial and fungal isolates were Bacillus spp (27%) and *Aspergillus niger* (21.72%). The incidence of pathogenic organisms in this study clearly indicates the lower degree of cleanliness in Biological Science Laboratories and as such, poses a potential threat to the health and the wellbeing of the students and staff. Therefore regular inspection of the concentration of bioaerosols in the environment is recommended so as to improve the general wellbeing of the occupants, also there is need to construct lecture halls for students to reduce exposure to bioaerosols in the Laboratory.

References

[1] Kumari, S., Gond, D. K., Samuel, C. O. and Abbasi, P. (2011). A Comparative Study of Aeromycospora in Different Localities of Gorakhpur, U. P., India. *Journal of Scientific Research*, 2 (4):51-55.

[2] Wojtatowicz, M., Stempniewicz, R., Żarowska, B., Rymowicz, W. and Robak, M. (2008). Mikrobiologiaogolna. Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu, Wrocław.

[3] Karwowska, E. (2005). Microbiological Air Contamination in Farming Environment. *Polish Journal of Environmental Studies*, 14, 445 - 449.

[4] Jarnicke, R. (2005). Abundance of Cellular Material and Proteins in the Atmosphere. *Science*, 308, 73.

[5] Pillai, S. and Ricke, S. (2002). Bioaerosols from Municipal and Animal Wastes: Background and Contemporary issues. *Canadian Journal Microbiology*, 48, 681-96.

[6] Dacarro, C., Picco, A., Grisoli, R. and Redolfi, M. (2003). Determination of Aerial Contamination in Scholastic Sports Environment. *Journal of applied microbiology*, 95: 904-912.

[7] Cabral, C., Picco, A., Grisoli, R. and Redolfi, M. (2003). Determination of Aerial Contamination in Scholastic Sports Environment. *Journal of applied microbiology*, 95: 904-912.

[8] Lighthart, B. (2000). Mini-Review of the Concentration Variations Found in the Alfresco Atmospheric Bacterial Populations. *International Weekly Journal of Science*, 16 (1): 7–16.

[9] World Health Organization (WHO) (2009). WHO Guidelines for Indoor Air Quality: Dampness and Mould. Copenhagen, Denmark: World Health Organization. Available Online at http://www. euro.who.int/__data/assets/pdf_file/0017/43325/E92645.pdf. 25/03/2017.

[10] McMahon, S., Hope, J., Thrasher, J., Rea, W., Vinitsky, A. and Gray, M. (2012). Common Toxins in Our Homes, Schools and Workplaces. Global Indoor Health Network, Inc. Henderson, NV 89077-7308.

[11] Abed, E. (2014). Assessment of Indoor Microbial Quality of Science Laboratories at Three Universities in Gaza City. A Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Science in Environmental Sciences. The Islamic University, Gaza, Palestine.

[12] Ekhaise, F., Ighosewe, O. and Ajakpori, O. (2008). Hospital Indoor Airborne Microflora in Private and Government Owned Hospitals in Benin City, Nigeria. *World Journal of Medical Science,* 3 (1): 34-38.

[13] Gutarowska, B. (2010). Metabolic Activity of Moulds as a Factor of Building Materials Biodegradation. *Polish Journal of Microbiology*, 59, 119 - 124.

[14] Holt, J. G., Krieg, N. R., Sneath, P. H., Stanley, J. T. and William, S. T. (1994) Bergey's Manual of Determinative Bacteriology. Williams and Wilikins, Baltimore, 786 - 788.

[15] Barnett, J., Payne, R. and Yarrow, D. (2007). Yeasts: Characteristics and Identification, 3rd edition. Cambrige University Press. 1150p.

[16] Hayleeyesus, S. F. and Manaye, A. M. (2014). Microbiological Quality of Indoor Air in University Libraries. *Asian Pacific Journal of Tropical Biomedicine,* 4 (1): 312–317.

[17] Vijayalakshmi, S. (2010). Studies on the Atmospheric Microflora of and its Allergenicity in Chennei, Tamil Nadu, South India.

[18] Frankel, M., Beko, G., Timm, M., Gustavsen, S., Hansen, E. and Madsen, A. (2012). Seasonal Variations of Indoor Microbial Exposures and their Relation to Temperature, Relative Humidity and Air Exchange Rate. *Applied and Environmental Microbiology*, 78 (23): 8289–8297.

[19] Udosen, C. I., Essien, J. P., Umana, S. I., Ekong, U. E. and Nkanang, A. J. (2018). Microbiological Properties and Population Dynamics of Atmosphere in Mesotidal Estuarine of Iko River, Akwa Ibom State, Nigeria, Journal of Advances in Biology & Biotechnology, 17 (4): 1-19.

[20] Bomala, K., Saramanda, G., Reddy, B. and Kaparapu, J. (2016). Microbiological Indoor and Outdoor Air Quality Visakhapatnam City, India. *International Journal of Current Research*, 8 (4): 29059–29062.

[21] Makut, M., Nyam, M., Shehu, A. and Anzaku, S. (2014). A Survey of the Microflora in Outdoor Air Environment of Keffi Metropolis, Nasarawa state, Nigeria. *Academic Journal*, 8 (27): 2650–2655.

[22] Ilondu, E. M. and Nweke, O. C. (2016). Studies on the Mycoflora of the Outdoor Air Environment of Delta State University Site III, Abraka, Nigeria. *Journal of Chemistry and Biochemistry*, 4 (1), 47–61.

[23] Ekhaise, F. and Ogboghodo, B. (2011). Microbiological Indoor and Outdoor Air Quality of Two Major Hospitals in Benin City, Nigeria. *Sierra Leone Journal of Biomedical Research*, 3 (3): 169–174.

[24] Hannan Etzel, R., Balk, S., Bearer, C., Miller, M., Shannon, M. and Shea K. (1998). American Academy of Pediatrics: Toxic Effects of Indoor Moulds. *Pediatrics*, 101, 712 - 714.

[25] Lansing, A. E., Ivnik, R. J., Cullum, C. M. and Randolf, C. (1999). An Empirically Derived Short Form of the Boston Naming Test. *Archives of Clinical Neuropsychology*, 14, 481 -487.

[26] Kulkarni, D. S. (2017). Preliminary Study of Airborn Microbiota in Some Areas of Amaravati City. Research Journal of Life Sciences, Bioinformatics, Pharmaceutical and Chemical Sciences.

[27] Fracchia, L., Pietronave, S., Rinaldi, M. and Martinotti, M. (2006). The Assessment of Airborne Bacterial Contamination in three Composting Plants Revealed Site-related Biological Hazard and Seasonal Variations. *Journal of Applied Microbiology*, 100, 973-84.

[28] Shiaka, G. P. and Yakubu, S. E. (2013). Comparative Analysis of Airborne Microbial Concentrations in the Indoor Environment of Two Selected Clinical Laboratories. *Journal of Pharmacy and Biological Sciences,* 8 (4): 13–19.

[29] Bhatia, L. and Vishwakarma, R. (2010). Hospital Indoor Airborne Microflora in Private and Government Owned Hospitals in Sagar City, India. *World Journal of Medical Sciences,* 5 (3): 65-70.

[30] Jaakkola, J. J., Hwang, B. F. and Jaakkola, M. S. (2010). Home Dampnesss and Molds as Determinants of Allergic Rhinitis in Childhood: A 6 year population base-cohort studies. *American Journal of Epidemiology*, 172, 451–459.

[31] Karvala, K, Toskala, E., Laukkonen, R., Lappalainen, S. Utiti, and Nordman, H. (2010). New Onset Adult Asthma in Relation to Dump and Molidy Workplaces. *International Archives of Occupational and Environmental Health,* 83, 855-865.

[32] Jones, A. M. and Harrison, R. M. (2004). The Effects of Meteorological Parameters Factors on Atmospheric Bioaerosol Concentrations. *Science of the Total Environment*, 326, 151–180.