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INDOOR AIR QUALITY AND MICROBIAL ASSESSMENT OF A NIGERIAN UNIVERSITY CAMPUS IN LAGOS, NIGERIA

Good indoor air quality improves productivity at the workplace. On the other hand, poor indoor air quality could lead to losses in productivity as a result of comfort problems, ill health and sickness-absenteeism. The aim of the study was to assess indoor air quality in various rooms of university buildings covering the offices, lecture theatre, laboratory or workshops and public restroom across eight faculties in a conventional university. Investigations were conducted at twenty-nine indoor locations in the main campus of University of Lagos. Noise level, PM2.5, PM10, relative humidity and temperature, CO, SO_2, NOx, and the microbial quality (fungal and bacterial) were all determined. The microbial quality was determined using the sedimentation method (open petri dishes) containing different culture media for sample collection. Noise level ranged from 61.60 to 84.10 dBA. The noise level is quite high in almost all sampling points especially in the workshops, yet there was no significant difference (P>0.05) across all the indoor sampling points and the WHO limit.SO2 were mostly absence, however, the highest value of 0.4 ppm was recorded which was higher than recommended limit of 0.1 ppm.PM2.5 ranged between 4.0–25.0 µg/m^3 and PM10 were between 8.0–47.0 µg/m^3. Though, there was high variation in PM2.5 and PM10 across all the indoor sampling points, there were no significant difference (P>0.05). They were below the maximum limit of 150 µg/m^3.The total fungi load ranged from 10.4 to 963 CFU/m^3. There was generally higher number of fungi in the restroom than all the other indoor environments and they were significant in Faculty of social sciences. Fungi isolates include Aspergillus spp. (86.2%), unidentified mold (13.77%) and Sporothrix schenckii (0.03%). Total bacteria load ranged from 96.3 to 689 CFU/m^3. The lowest load of bacteria (9.63 x 101 CFU/m^3) was recorded in the dean's office at the faculty of environmental science. The rest rooms have higher bacterial load (6.89 x 102 CFU/m^3), which was higher than the recommended maximum limit of 500 CFU/m^3. Identification from the colonies showed that about 55% were gram negative and 45% were gram negative cells. Morphological studies showed that cocci were also more predominant over the bacillary shape bacteria (55% versus 45%).

Keywords: Indoor air quality, fungi, bacteria, noise, carbon monoxide, oxides of nitrogen

Introduction. Air pollution is the presence in the atmosphere of chemicals, particulate matter or biological materials in such quantity and for such duration that can cause harm and discomfort to humans and other living organisms (Njoku et al., 2016; Obanya et al., 2018). Common air pollutants in the environment include: sulphur dioxide (SO_2); oxides of nitrogen (NOx), carbon monoxide (CO); volatile organic compounds (VOCs); ozone (O_3); suspended particulate matter (SPM) also called particulates; and lead (Pb). Air pollutant can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made (USEPA, 2006). In recent times, indoor air quality has caught the attention of scientists and the general public because indoor levels of many pollutants are often higher than those typically encountered outside (Jurado et al., 2014). Indoor air pollution (IAP) would cause significant harmful health effects due to a long time period that people stay indoors (Klinmalee et al., 2008). Indoor air pollution concentrations depend on a large number of factors such as indoor sources and the emission rates, air exchange rate, the penetration of outdoor pollutants into the indoor environment, and the pollutant sink or removal rate on indoor surfaces (Beak et al. 1997; Klinmalee et al., 2008).

Air quality of indoor environments is one of the main factors affecting health, wellbeing and productivity of people (Hayleeyesus and Manaye, 2014). One of the problems of indoor air quality is affected by the presence of microorganisms which include bacteria, moulds and viruses (WHO, 2009a). People's exposure to indoor air pollution is determined by the concentrations of pollutants in the indoor environment and, most importantly, by the time individuals spend in polluted environments. Since, more than 90% of people spend majority of their times indoor by breathing on average 14 m³ of air per day (Brochu et al., 2006), therefore, good air quality is of utmost importance. Poor indoor air quality can pose problems that can be subtle and do not always produce easily recognizable impacts on the health and welfare of populations (USEPA, 2006). Several effects on the respiratory system have been associated with exposure to IAP including asthma development, asthma exacerbation, respiratory infections, upper

respiratory tract symptoms, cough, wheeze and dyspnoea (WHO, 2009a; Hayleeyesus and Manaye, 2014). Therefore, indoor air quality is of special concern for students and workers, particularly those sensitive to poor air quality as today's Universities can be regarded as ''mini cities" with large territorial coverage, diverse human activities, these having different degrees of effect on the environment (Alshuwaikhat and Abubakar, 2008).

Since air is an important vehicle for the dissemination of infectious agents and allergic components developing potential undesirable effects on human beings, the control of the microbial charge became an important key to define the environmental quality of ambient media surrounding wide human populations which are largely exposed to indoor air during their daily activities (Soto et al., 2009). The air quality inside buildings is affected by many factors. In an effort to conserve energy, modern building design has favoured tighter structures with lower rates of ventilation (Ezzati and Kammen, 2001). By contrast, in some areas of the world only natural ventilation is used; in other areas mechanical ventilation is common. Factors that can have a negative effect on health and comfort in buildings range from chemical and biological pollutants to occupant perceptions of specific stresses such as temperature, humidity, artificial light, noise and vibration. Air pollution is believed to kill more people worldwide than AIDS, malaria, breast cancer, or tuberculosis (WHO, 2009b).

Increase in commercial activities in our University environment as well as functioning of machinery in several business units, and an unquantifiable amount of emissions is now of concern especially from the burning of fossil fuels, poor building designs and poor ventilations. Also, recent developments in construction materials have resulted in the use of more synthetics and composites, which can affect air quality. Radical changes in technology have led to innovations such as air conditioners, computers and photocopiers that provide greater efficiencies and time savings, but they can also affect the quality of indoor air (Franklin, 2007). These potentially adverse effects are further complicated by the fact that people are spending more time than ever indoors. Thus indoor air quality (IAQ) is an important criterion that must be taken into account when indoor workplaces are designed to provide a safe environment. Good IAQ, it is an interaction of efficient ventilation and the lowest achievable amounts of chemical, inorganic or organic and microbial compounds which shouldn't evoke symptoms in the occupants. This study provides information on the current indoor air parameters and quality (relative humidity, temperature, VOCs, CO, SO_2, NO_x, H_2S), and also concentration of microorganisms, and also describes bacterial and fungal loads for different indoor environment of University of Lagos (offices, lecture theatres, laboratories and public rest rooms).

Materials and methods. *Study Area.* The study was conducted in various rooms of university buildings of the University of Lagos, Akoka, Lagos. University of Lagos is a comprehensive public institution established in 1962 located in the Western part of Lagos, Nigeria (Fig. 1). It is one of the major University campuses in Nigeria with an estimated 561 hectares of land area hosting 12 faculties, 330 staff housing units, 15 students' hostels and several administrative and academic buildings. It has 52,779 students' enrollment and 4688 members of staff (Adeniran et al., 2017). Only about 25% of the student population and 10% of staff are resident on campus. The University campus has an estimated 87,000 day population. Major activities on campus focused on teaching, research and community services. In carrying out these functions, academic, administrative, residential and commercial spaces are provided. Majority of the area have permanent structures which are often purposely built for specific activity. The twelve faculties are: Arts, Social Science, Business Administration, Law, Science, Environmental Science, Engineering, Clinical Science, Basic Medical Science, Dental Sciences, Pharmacy and Education. Eight faculties are however situated in the main campus, Akoka.

Sampling Designs and Data Collection. Twenty-nine points were sampled, and they included all faculties within the university's main campus. Within each faculty, the dean's office, one laboratory or workshop, one lecture theatre and one restroom were monitored. All equipment and meters were all properly pre-calibrated before each usage for quality assurance.

CW-HAT 200 meter was used for measuring particulate matter (PM2.5 and PM10), relative humidity and temperature level. Noise levels at each point were measured with a pre-calibrated digital readout noise meter (A CEM DT-805 noise level meter). The sensor of the noise meter was directed towards the source of noise and the average readings over a period of one hour were taken to be the noise-level at each point. CO measurement was obtained through the use of CO meter (CNY 670) at each of the selected sampling locations. NH_3, H_2S, SO2 and NOX were determined using multi-gas monitor (310 multi gas meter) for one hour exposure time. Environmental monitoring for each sample location was carried out between the hours of 8am-5pm. These air quality indicators were measured in confines indoor environments.

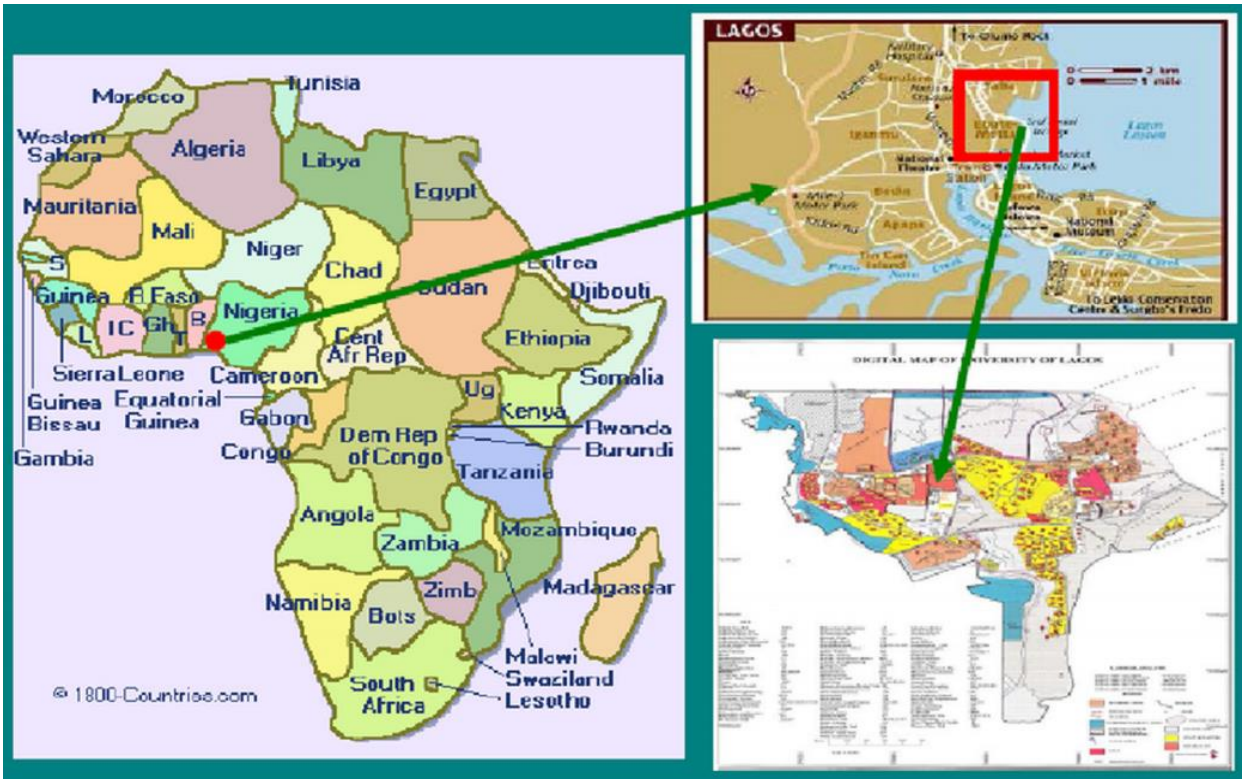

Fig. 1. Map of Africa showing Nigeria and the location of the University of Lagos (Adeniran et al., 2017)

Sedimentation technique using open Petri dishes containing different culture media was used (Augustowska and Dutkiewicz, 2006). Three plates of each medium were distributed at different parts of each room examined. The samplings were done during the hours of 8am and 5pm. The sampling height was approximated to human breathing zone (1 m above the floor) and at the centre of the room. The plates containing the culture media (blood agar and sabouraud dextrose agar) were exposed and allowed to stay for 15 minutes, after which the plates were covered and transferred to the microbiology laboratory for incubation. The blood agar plates were incubated at 37°C for 24 hours while the saboraud dextrose agar plates were incubated for 3 days at 28°C. The total numbers of colony forming units (cfu) were enumerated. The identification of the isolates was done according to standard procedures (Cheesebrough, 1991; Rajash and Rattan, 2008).

Statistical analysis. The data were subjected to analysis of variance (ANOVA) and mean separated using Duncan multiple range test using GraphPad with significant p value set at <0.05. Data were presented as tables and charts using Microsoft excel.

Results and discussion. The mean temperature and relative humidity across the various indoor environments in the university is shown in Figure 2. The dean's office in the faculty of social sciences had the lowest temperature of 20.00±0.00°C while the lecture theatre of faculty of Engineering had the highest temperature of 31.00±0.00°C. Out of all the four sampling points in each faculty, only the temperature of dean's office was below the WHO standard of 22.5–25.5°C while all others exceeded it. The lecture theater in faculty of sciences had the highest relative humidity value (96.00±0.01%) while the dean's office in faculty of Law had the lowest humidity value (49.00±0.01%). Most of the sampling points exceeded the WHO limit of <70% for indoor relative humidity. The very low temperature recorded in virtually all the offices (deans) can be attributed to the constant use of air-conditioning system in those rooms. The result is also similar to a study carried out by Jurado et al. (2014) in which air-conditioned rooms had lower temperature and relative humidity in comparison with naturally ventilated room. There was no significant difference at (P>0.05) in relative humidity from the different sampling points irrespective of the faculties.

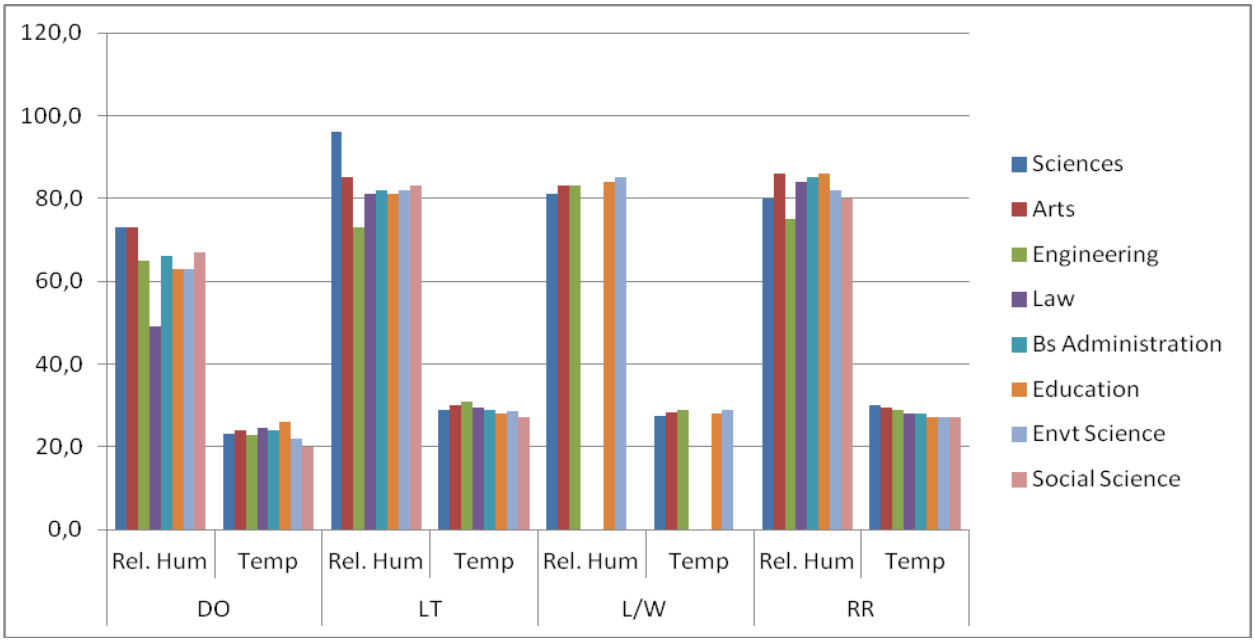

Fig. 2. Showing temperature (°C) and relative humidity (%) in the sampling locations (DO – Dean's office; LT – Lecture theatre; LB – Laboratory/Workshop; TT – Restroom)

The result of the noise level in the university rooms sampled is shown in figure 2. It ranged from 61.60±0.05 to 84.10±0.01 dBA. The noise level is quite high in almost all sampling points especially in the workshops, yet there was no significant difference (P>0.05) across all the indoor sampling points and WHO limit. The overall mean of the noise level showed that the lecture theatre had the highest noise level, and this can be attributed to the fact that the classes are quite large and used by a lot of students especially the first year students whose population is usually the largest in the school. Also, public address system is mostly being used to ensure the lecturer is being heard. The dean's office had the least over mean noise level of 70.64 dBA. The result is in line with a study carried out by Rasool et al., 2016 in which the indoor noise level in the institution ranged between 61.37 dBA and 75.37 dBA during the noon time.

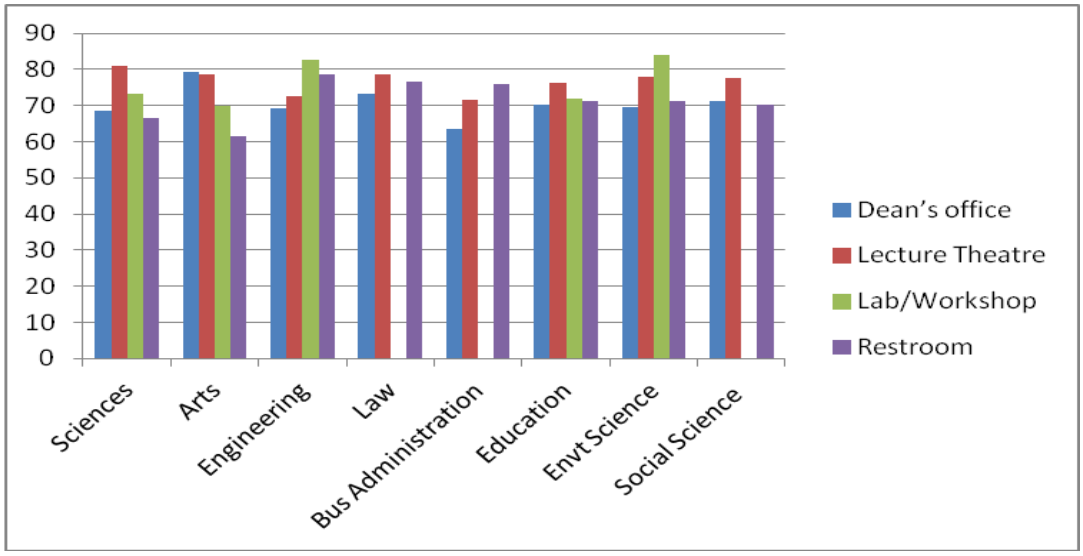

Fig. 3. Mean noise level (dBA) recorded in Indoor of University of Lagos

The laboratory in the faculty of Education had the highest level of PM2.5 (25.0±0.50 µg/m³), although the value ranged between 4.0±0.01–25.0±0.50 µg/m³ (Table 1). The faculty of education recorded the highest overall mean of 15.75 µg/m³. The highest value recorded for PM10 was 47±0.01 µg/m³ in the laboratory at the faculty of Education while the range was between 8.0±0.05–47.0±0.01 µg/m³. Despite the high variation in PM2.5 and PM10 across all the indoor sampling points, there were no significant difference (P>0.05). The highest overall mean PM10 level of 32.5 µg/m³ was recorded in the laboratory at the faculty of Education. All the values recorded were below the WHO limit of 150 µg/m³. Cao et al. (2005) and Klinmalee et al (2009) reported PM2.5 levels in rural homes and classrooms, averaged at 26 µg/m³,

respectively, which were also in the same range of our study. The levels recorded by Molnar et al. (2007) in high school classrooms in Stockholm, Sweden (8 μg/m³) is lower than the level found in our study. The result also do not corroborates that of the findings of Liu et al. (2004) which clearly showed wide variability within indoor PM10 and PM2.5 concentrations which are, resultantly, higher in restaurants, dormitories, and classrooms, rather than in supermarkets, computer rooms, offices, and libraries (PM10 and PM2.5 ranging, respectively, from 373.8 μg/m³ and 136.6 μg/m³ and 5.6 μg/m³ in libraries).

Table 1

Indoor particulate matter (PM 2.5 and PM 10) the various sampling points (μg/m³)

Faculties	DO		LT		L/W		RR	
	PM 2.5	PM 10	PM 2.5	PM 10	PM 2.5	PM 10	PM 2.5	PM 10
Sciences	5.0±0.01	11.0±0.01	8.0±0.01	16.0±0.15	10.0±0.01	18.0±0.01	8.0±0.01	16.0±0.01
Arts	6.0±0.01	11.0±0.01	4.0±0.01	8.0±0.02	7.0±0.01	19.0±0.05	6.0±0.01	11.0±0.01
Engineering	8.0±0.01	16.0±0.02	9.0±0.01	14.0±0.01	7.0±0.01	15.0±0.01	8.0±0.01	15.0±0.05
Law	7.0±0.01	14.0±0.01	6.0±0.01	11.0±0.01	-	-	5.0±0.01	10.0±0.05
Bus Administration	4.0±0.01	9.0±0.02	5.0±0.01	12.0±0.01	-	-	4.0±0.01	8.0±0.05
Education	16.0±0.01	36.0±0.01	12.0±0.50	26.0±0.01	25.0±0.50	47.0±0.01	10.0±0.01	21.0±0.01
Envt Science	6.0±0.01	13.0±0.01	7.0±0.01	13.0±0.02	8.0±0.01	15.0±0.05	6.0±0.01	14.0±0.01
Social Science	5.0±0.01	10.0±0.01	4.0±0.01	9.0±0.01	-	-	6.0±0.01	14.0±0.01

(DO- Dean's office, LT- Lecture Theatre, L/W- Laboratory/Workshop, RR- Restroom)

Most of the values recorded for sulphur dioxide (SO_2) were 0 ppm, however, the highest value of 0.4 ppm (Table 2) was recorded in the laboratory at the faculty of education which is above the recommended limit of 0.1 ppm (WHO, 2010). Common sources of Sulphur dioxide in offices or classrooms can include tobacco smoke or automobile exhaust from car parks close to the office building. Sulphur dioxide affects human health when it is breathed in. It irritates the nose, throat and airways causing coughing, wheezing, or a tight feeling around the chest. It is usually more severe in individuals suffering from asthma or similar conditions (Njoku et al., 2016). Long term exposure to even low levels of sulphur dioxide can cause lung function to deteriorate, aggravate existing heart disease and increase complications for people with asthma.

Table 2

Sulphur dioxide (SO_2) level recorded in University rooms (ppm)

Faculties	Dean's office	Lecture Theatre	Lab/Workshop	Restroom
Sciences	0.00	0.00	0.00	0.00
Arts	0.00	0.00	0.00	0.00
Engineering	0.00	0.00	0.00	0.00
Law	0.10	0.00	-	0.00
Bus Administration	0.00	0.00	-	0.00
Education	0.10	0.00	0.40	0.00
Envt Science	0.00	0.00	0.00	0.00
Social Science	0.00	0.00	-	0.00

Absence of carbon monoxide (CO), Hydrogen sulphide (H_2S) and Nitrogen oxide (NO_2) were recorded in all the sampling locations. The only way carbon monoxide can be introduced into indoor environment is through the infiltration of carbon monoxide from outdoor environment. This indicates that there was no infiltration of combustion gas from the car park into the office or classroom space. Similar results were observed by Ismail et al., (2010) and Tse and Oguoma, (2014). Presence of NO_x will form photochemical oxidants which may irritate the eyes and respiratory tracts and impair human health.

The average levels of fungal load air observed in the different indoor environments are shown in Table 3. The number of fungi in indoor air varied widely in the whole research period. The total number of fungi ranged from 10.4 to 963 CFU/m³. The lowest concentration (1.04×101 CFU/m³) was recorded in the lecture theatre in the faculty of Arts while the restroom in the faculty of social sciences had the highest concentration. There was generally higher number of fungi in the restroom than all the other indoor environments and they were significant in Faculty of social sciences. There is no uniform international standard available on levels and acceptable maximum bioaerosols loads (Jyotshna and Helmut, 2011). The work conducted by a WHO expert group on assessment of health risks of biological agents in indoor environments has set the guidelines of bioaerosols counts at 500 CFU/m³, if higher than this, the

environment is considered as contaminated. Aspergillus spp. was observed to be the highest identified fungi (86.2%) present in the indoor in the various sampling points (Figure 3). Mold (unidentified) was recorded in 13.77% of the total sampling points at the university while Sporothrix schenckii accounted for 0.03% of the total fungal load. This result may however be dependent on the time of exposure of the media plates to indoor air. Aspergillus sp. was also the most predominant fungi in a study carried out by Agbagwa and Onyemaechi (2014) in a general hospital and health centre in Rivers State. Fungal exposure can result in skin and breathing irritations and can even cause dangerous infection and toxicity (Fung and Hughson, 2003). Lou et al. (2012) also isolated Penicillium, Cladosporium, Alternaria, and Aspergillus in indoor air samples from university campuses, and concluded that airborne fungi may cause a number of allergic, inflammatory, and toxic reactions to students. Airborne microbiota may pose serious hazards to human health.

Table 3

The average fungal load across all the sampled indoor rooms (CFU/m³)

Faculties	Dean's office	Lecture Theatre	Laboratory/Workshop	Restroom
Sciences	2.22×10^{1}	1.41×10^{1}	2.96×10^{1}	2.00×10^{2}
Arts	1.48×10^{1}	1.04×10^{1}	7.40×10^{1}	3.70×10^{2}
Engineering	1.51×10^{1}	1.41×10^{2}	5.19×10^{1}	1.78×10^{2}
Law	1.33×10^{2}	2.73×10^{2}	NS	2.0×10^{2}
Bus Administration	8.80×10^{1}	2.00×10^{2}	NS	1.41×10^{2}
Education	1.33×10^{2}	8.89×10^{1}	1.41×10^{2}	2.00×10^{2}
Envt Science	8.80×10^{1}	3.00×10^{2}	1.40×10^{2}	1.63×10^{2}
Social Science	1.03×10^{2}	1.11×10^{2}	NS	9.63×10^{2}

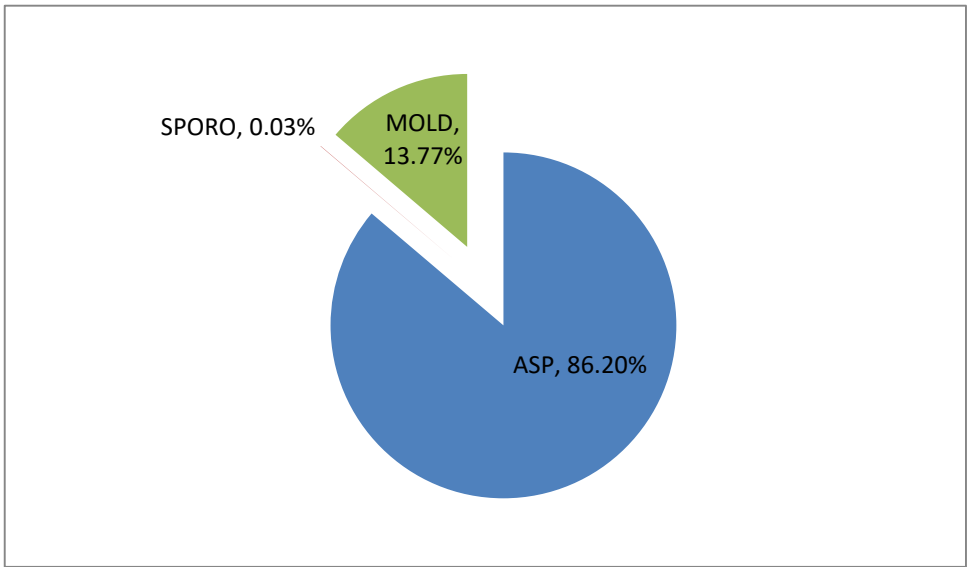

Fig. 3. Distribution of fungal species identified in various sampling points at the university (ASP = Aspergillus spp.; SPORO= Sporothrix schenckii; MOLD= Unspecified mould)

The average levels of indoor bacterial loads are shown in Table 4. The number of bacteria in indoor air varied widely in the whole research period. The total number of bacteria ranged from 96.3 to 689 CFU/m³. The lowest load of bacteria (9.63×10^{1} CFU/m³) was recorded in the dean's office at the faculty of environmental science. The rest room at the faculty of Law had the highest bacterial load (6.89×10^{2} CFU/m³), which was higher than the recommended maximum concentration of 500 CFU/m³ for total fungi count (WHO, 2010; OSHA, 2011). Identification of the bacteria from the colonies showed that about 55% of the isolates from the sampling points were gram negative and 45% stained as gram negative cells. On the other hand, morphological studies showed that cocci were also more predominant over the bacillary shape bacteria (55% versus 45%) (Figure 4). Bacilli can be found in almost every environment. They contain spores that enables them to survive for a long period of time in the environment. The bacterial species isolated in this study are similar to those isolated by Stryjakowska-Sekulsa et al. (2007) and Vlad et al. (2013). Microorganisms are well adapted to aerial transmission through nasopharyngeal secretions and saliva drops, and can easily survive dehydration; therefore, they can be easily transmitted from one host to another (Brooks et al., 1998). Although bacteria are part of normal skin and nasal passages flora,

some species can cause a large range of illnesses from minor skin infections (furuncles, pimples, impedigo, abscesses) to life-threatening diseases (pneumonia, meningitis, sepsis) (Kluytmans et al., 1997). Airborne microorganisms affect human health, especially generating respiratory allergies, and infectious lung diseases (Fracchia et al., 2006).

Table 4

Average Bacterial load across all the sampled indoor rooms (CFU/m³)

Faculties	Dean's office	Lecture Theatre	Lab/Workshop	Restroom
Sciences	3.11×10^2	4.44×10^2	1.26×10^2	3.7×10^2
Arts	1.41×10^2	4.88×10^2	5.33×10^2	4.44×10^2
Engineering	1.04×10^2	3.04×10^2	4.44×10^2	6.51×10^2
Law	2.07×10^2	2.22×10^2	-	6.89×10^2
Bus Administration	1.85×10^2	2.80×10^2	-	4.60×10^2
Education	4.07×10^2	4.18×10^2	1.93×10^2	4.96×10^2
Envt Science	9.63×10^1	4.67×10^2	2.96×10^2	4.89×10^2
Social Science	1.48×10^2	4.10×10^2	-	1.04×10^2

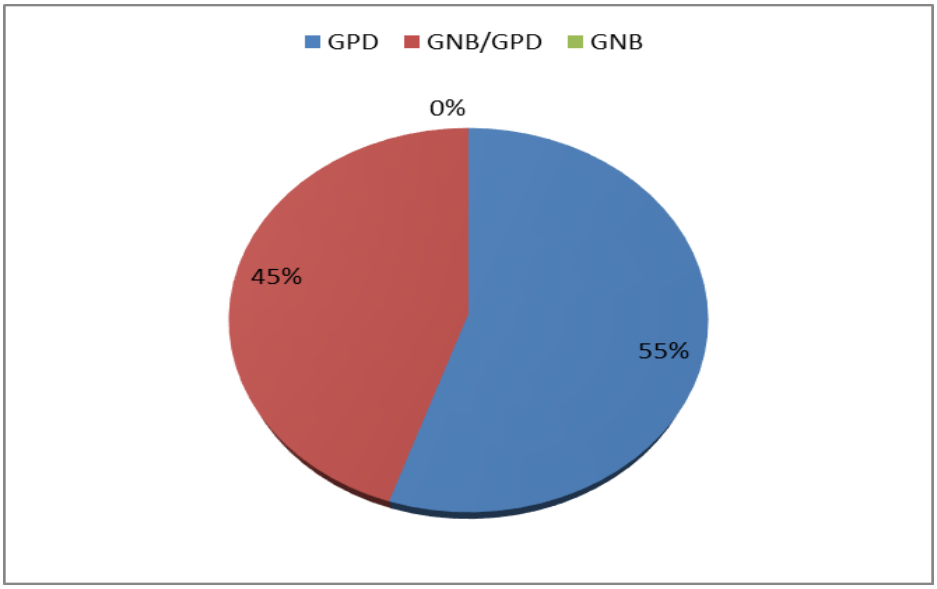

Fig. 4. Distribution of bacteria species identified in various university rooms (GNB= Gram Negative Bacilli; GPD= Gram Positive Diplococii)

Conclusion. Indoor air pollution assessment is very important as it has been linked to public health problems. The levels of Carbon monoxide, Nitrogen dioxide, Hydrogen sulphide, Volatile organic compounds and Particulate matter (PM2.5 and PM10) were all below the standard limits. Sulphur dioxide was also exceeded in some sampling points and this was attributed to the possible infiltration of mobile vehicle exhaust to the indoor environment. The temperature and relative humidity recorded in the various sampling points at the university was above the WHO limit of 24°C and 60% respectively. The high relative humidity may be responsible for the presence of mould especially Aspergillus spp. which was found in the all sampling points. Studies have shown that Aspergillus spp. are indicators of moisture in buildings which can also pose a health threat to the occupant. It is recommended that more intense environmental monitoring of indoor air in the university should be carried to provide comprehensive information on IAQ. And also to outline ways to improve the indoor air quality and ensuring safe work environment (Indoor Air Quality Plan and Procedures).

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