Archives of Pharmaceutical Sciences and Biotechnology Journal

Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X

Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

ARCHIVES OF PHARMACEUTICAL SCIENCES AND BIOTECHNOLOGY JOURNAL

VOLUME 3 ISSUE 2, December 2023

ISSN 2971 – 611X

©ALL RIGHTS RESERVED

Published by the Faculty of Pharmaceutical Sciences, Kaduna State University, Kaduna

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

MULTIDRUG RESISTANCE IN BACTERIA ISOLATED FROM INDOOR AIR OF OFFICES IN A TERTIARY INSTITUTION IN NORTH-WESTERN NIGERIA

***Obajuluwa A.F., Igwe J.C, Parom S.K. and Bege K.B**

Department of Pharmaceutical Microbiology and Biotechnology, Faculty of Pharmaceutical Sciences, Kaduna State University, Kaduna, Nigeria.

*Corresponding author email and phone number: afobajuluwa@gmail.com +234 8036207703

ABSTRACT

Background: The quality of air breathed in can affect man's quality of health. Persistent presence of multi-drug resistant (MDR) bacteria strains in indoor air can be a potential source health risk.
Aim: The aim of this study was to assess multi-drug resistant airborne bacteria in Kaduna State University, Nigeria.
Methods: A total of 46 samples were collected from the indoor air of selected offices, toilets, lecture rooms and laboratories using settled plate technique. Total bacterial load was determined, the bacteria were identified and isolated using conventional biochemical methods and Gram staining. Antibiotic susceptibility testing of the isolates was also carried out using disc agar diffusion method. All the isolates which showed resistance to one or more antibiotics from 3 or more antimicrobial classes were classified as multidrug resistant.
Results: The total mean bacteria count from the various sampling site ranged from 0.9 x 10^3 to 6.5 x 10^3 CFU/m^3. A total of 50 bacteria were isolated with *Staphylococcus aureus* 15 (30%) having the highest occurrence followed by *Bacillus subtilis* 11 (22%), *Micrococcus* spp 11 (22%), *Streptococcus* spp 7 (14%), *Clostridium* spp 5 (10%), and *Ps. aeruginosa* 1 (2%). All the isolates were resistant to ceftriazone, 85.1% to cefoxitin, and 80.9% resistance to amoxicillin/clavulanic acid and chloramphenicol. All the bacteria isolates showed 100% multidrug resistance except *Streptococcus* spp (85.7%). However, vancomycin was the most active antibiotic (68.1%).
Conclusion: The indoor air sampled had high and very high bacteria load. High percentage of multidrug resistance was also observed in the study.
Keywords: multidrug resistance, indoor air, antibiotics, bacteria, microbial load.

INTRODUCTION

There is an increasing rate of studies about indoor air quality, because the quality of air people breathe in determine to a large extent their quality of health, which can also affect their wellness and productivity [1]. Both outdoor and indoor air have pollutants but sometimes indoor air can be more harmful. The reason being that indoor environment may have limited ventilation compared with outdoor where winds are stronger, drops of rain can also reduce level of pollutants outside [2]. Environmental Protection Agency reported that the level of indoor air pollutants are often 2 to 5 times higher than outdoor levels, and that in some cases these levels can exceed 100 times that of outdoor levels of the same pollutants [3]. Reports have shown that most people (about 90%) spend 22 hours indoor daily either in offices, lecture rooms, worship houses, business centers and others [4]. It is believed that on the average, humans breathe 11,000 litres of air daily, and depending on the environment,

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

for example in the tropics the air breathed in could contain 50000 organism cells during daytime, and 30 to 100 times that amount at night [4,5].

Bioaerosols are airborne suspended particles, larger molecules or volatile compounds that are living or released from living organisms [6]. The smaller sized bioaerosols can remain in the air for a longer time while the larger ones are deposited on surfaces. In indoor airborne bacteria are major issues. The types of microorganisms in the air are responsible for mortality and morbidity among susceptible hosts [7, 8]. The potential health risks resulting from exposure to airborne bacteria can occur at workplaces and offices, lecture rooms, laboratories and residential locations [9]. Representatives of the following genera are among the bacteria strains found in indoor air: *Bacillus, Micrococcus, Kocuria and Staphylococcus, Streptomyces albus, Pantoea agglomerans, Pseudomonas chlororaphis, Arthrobacter globiformis, Thermoactinomyces vulgaris and Corynebacterium* spp. [10].

Airborne biological particulate matter can be concentrated in the indoor environment through activities such as talking, sneezing, coughing, etc. The problem of poor indoor air quality in developing countries can be made worse by design flaws and insufficient ventilation [11, 12]. Many of the facilities in the government–owned institutions are old and lack adequate maintenance [13]. Some of the lecture theatres are overcrowded and lacking proper ventilation. Therefore the presence of pathogenic bacteria in the indoor air of such places over a long period of time can put the health of the occupants at risk. Likewise offices, lack of adequate office accommodation has led to having more than required number of staff in offices. The following health effects have been associated with indoor air microorganisms: respiratory irritation and nonspecific symptoms, respiratory infections, asthma and allergy, alveolitis, chronic bronchitis and organic dust toxic syndrome [14].

According to European Center for Disease Control (ECDC) and Centre for Disease Control and Prevention (CDC), Atlanta, Multidrug resistance (MDR) was defined as acquired non-susceptibility to at least one agent in three or more antimicrobial categories [15]. At present antimicrobial resistance poses a great threat to global health and has led increased mortality and morbidity, increased length of hospital stay and economic loss [16, 17]. This study is aimed at detecting incidence of MDR bacterial isolates from indoor air of some offices, lecture rooms and laboratories in Kaduna State University, Nigeria.

MATERIALS AND METHODS

Study area and sample collection

The study was carried out in specific indoor locations in Kaduna State University. Samples were collected from the following places: Faculties of Pharmaceutical Sciences, Arts, Science, and Social Management Sciences. In each Faculty of the University samples were collected from Offices of the all the deans, two (2) toilets, and three (3) lecture rooms. Samples were collected from the offices of the Heads of Departments and laboratories in Faculty of Sciences and Pharmaceutical sciences. A total of 46 samples were collected. Each sample was collected in duplicate.

Air sampling technique and determination of total bacterial count

Air sample was collected using the settle plate technique also known as the

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

sedimentation method [18]. The Petri dishes containing nutrient agar were exposed at strategic locations for 10 minutes at a height of 1 meter above the ground to avoid contamination from floor microbes. The lids were thereafter replaced and incubated at 37°C for 24 hours. The number of microorganisms expressed as CFU/m^3 was estimated using the following equation described by Omeliansky [19, 20].

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

Where N = microbial cfu/m^3 of indoor air
a = number of colonies per petri dish
p = the surface measurement of the petri dish used in cm^2
t = the time of exposure of the petri dish (min)

Identification and Isolation of Bacteria

Gram staining was carried out according to Cheesbrough [21] to classify the organism to either positive or negative Gram stain. The organisms were also cultured onto selective media such as cetrimide agar, mannitol salt agar, macConkay agar for further identification. The following biochemical tests were carried out to further identify the organisms into specific bacterial isolates: coagulase test, methyl red, Voges Proknauer test, citrate, oxidase, indole, catalase and urease tests.

Antibiotics Susceptibility Test

Agar disc diffusion method according to Clinical Laboratory Standard Institute (CLSI) recommendations [22] was used to carry out the antibiotics susceptibility test. A standard inoculum (approx. 10^8 CFU/ml) was prepared by making a turbid suspension of the isolates in sterile normal saline and compared with 0.5 McFarland Standard. A sterile swab was dipped into the bacteria suspension, pressed on the side of the bottles to allow excess drip-off, and then used to evenly streak the entire surface of the Mueller-Hinton agar plates. Sterile forceps were then used to place the antibiotic discs in a circular pattern on the media. The process was carried out for all the identified isolates, the plates were kept on the bench for about 30 minutes to allow the antibiotics to diffuse into the agar, the plates were thereafter incubated at 37°C for 24 hours. After incubation, the zone of inhibition in diameter for each antibiotic was measured and interpreted as either sensitive, intermediate or resistant according to CLSI guidelines.

The following antibiotic discs were tested: Erythromycin (15µg), Gentamicin (10µg), Chloramphenicol (30µg), Vancomycin (30µg), Ceftriaxone (30µg), Cefoxitin (30µg), Amoxicillin/Clavulanic acid (30µg), Ciprofloxacin (5µg), Trimethoprim/Sulphamethoxazole (25µg) and Tetracycline (30µg).

Determination of Multidrug Resistance

All the bacterial isolates that were resistant to one or more antibiotics from three or more antibiotic class were classified as multidrug resistant.

RESULTS

Comparing the indoor air quality of lecture rooms in the faculties sampled, the mean bacteria count ranged from 0.9×10^3 to 6.3×10^3 CFU/m^3, and that of toilets was 1.5×10^3 – 6.5×10^3 CFU/m^3 (Table 1).

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

Table 1: Mean total bacterial count of in-door air in some Faculties of Kaduna State University

S/N	Sampling Site/mean bacteria colony count (CFU/m^3)				
		Faculty of Pharmaceutical Sciences	Faculty of Arts	Faculty of Sciences	Faculty of Social and Management Sciences
1.	Dean's Office	2.9×10^3	2.7×10^3	3.7×10^3	2.1×10^3
2.	Toilets 1.	5.1×10^3	1.5×10^3	2.8×10^3	4.5×10^3
3.	Toilet 2.	2.6×10^3	3.6×10^3	6.5×10^3	4.6×10^3
4.	Lecture room 1.	1.6×10^3	2.4×10^3	1.0×10^3	1.6×10^3
5.	Lecture room 2.	1.4×10^3	0.9×10^3	1.6×10^3	1.5×10^3
6.	Lecture room 3.	1.1×10^3	6.3×10^3	2.5×10^3	2.2×10^3

The indoor air of staff offices and the Dean's office in the Faculty of Pharmaceutical Sciences had total bacteria count that ranged from 1.3×10^3 to 2.9×10^3 CFU/m^3. The laboratories in Faculty of Pharmaceutical Sciences had mean bacteria count of 1.2×10^3 to 3.9×10^3 CFU/m^3 (Table 2).

Table 2: Mean Total Bacteria Count of in-door air of the Departments in Pharmaceutical Sciences

S/N	Sample site/mean bacteria colony count (CFU/m^3)		
	Department	**HOD's office**	**Laboratory**
1.	Pharmaceutical microbiology and Biotechnology	2.3×10^3	3.9×10^3
2.	Pharmaceutics and Industrial Pharmacy	1.8×10^3	2.9×10^3
3.	Pharmaceutical and Medicinal Chemistry	2.6×10^3	1.2×10^3
4.	Pharmacology and Toxicology	1.3×10^3	1.7×10^3
5.	Pharmacognosy and Drug Development	1.5×10^3	1.6×10^3
6.	Clinical Pharmacy and Pharmacy Management	1.5×10^3	-

The bacteria count in the indoor air of the Heads of the Departments' offices in the Faculty of Sciences ranged from 0.7×10^3 to 5.4×10^3 CFU/m^3 while that of laboratories in the Faculty was $0.9 \times 10^3 - 2.8 \times 10^3$ CFU/m^3 (Table 3).

Table 3: Mean total bacteria count of in-door air of some Departments in Faculty of Science

S/N	Sample Site/Mean Bacteria Colony Count (CFU/m^3)		
	Department	**HOD's office**	**Laboratory**
1.	Chemistry	2.4×10^3	2.3×10^3
2.	Biology	1.4×10^3	2.7×10^3
3.	Physics	0.7×10^3	0.9×10^3
4.	Biochemistry	5.5×10^3	2.8×10^3
5.	Microbiology	5.4×10^3	2.2×10^3
6.	Geography	0.8×10^3	-

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

A total of 50 bacteria was isolated with *S. aureus* having the highest occurrence in all the faculty indoor air except in Faculty of Art where *Bacillus subtilis* had the highest occurrence of 40%. *Ps aeruginosa* was detected only in the Faculty of Sciences while *Clostridium* spp. was absent in Faculty of Arts (Table 4). Most of the bacteria isolates were Gram positive (98%), and only 2% were Gram positive.

Table 4: Occurrence of Bacterial Isolates in Indoor Air of Faculties in Kaduna State University

Bacteria	Pharmaceutical Sciences (n = 15)	Sciences (n = 15)	Social Management (n = 10)	Art (n = 10)	Total
S. aureus	5 (33.3%)	5 (33.3%)	4 (40.0%)	1 (10.0%)	15 (30.0%)
B. subtilis	3 (20.0%)	4 (26.7%)	0	4 (40.0%)	11 (22.0%)
Micrococcus spp	2 (13.3%)	3 (20.0%)	3 (30.0%)	3 (30.0%)	11 (22.0%)
Streptococcus spp	4 (26.7%)	0	1 (10.0%)	2 (20.0%)	7 (14.0%)
Clostridium spp	1 (6.7%)	2 (13.3%)	2 (20.0%)	0	5 (10.0%)
Ps. aeruginosa	0	1 (6.7%)	0	0	1 (2.0%)
Total	**15**	**15**	**10**	**10**	**50**

The result of the antibiotic susceptibility testing of all the isolates showed vancomycin (68.1%) to be the most active antibiotic, followed by tetracycline (51.1%), and gentamicin (42.6%). All the isolates were resistant to ceftriaxone (100%), cefoxitin (85.1%), amoxicillin-clavulanic acid (80.9%), chloramphenicol (80.9%), trimethoprim-sulphamethoxazole (68.8%), and ciprofloxacin (66%) (Table 5).

Table 5: Antibiotic Susceptibility Profile of Indoor Air Isolates from Offices in Kaduna State University

	No of Isolates (n) = 47		
Antibiotics	**Percentage sensitive (%)**	**Percentage intermediate (%)**	**Percentage resistant (%)**
Erythromycin	11 (23.4)	6 (12.8)	30 (63.8)
Gentamicin	20 (42.6)	0	27 (57.4)
Chloramphenicol	9 (19.1)	0	38 (80.9)
Vancomycin	32 (68.1)	0	15 (31.9)
Ceftriaxone	0	0	47 (100)
Cefoxitin	7 (14.9)	0	40 (85.1)
Amoxicillin clavulanic acid	8 (17.0)	1 (2.1)	38 (80.9)
Ciprofloxacin	12 (25.5)	4 (8.5)	31 (66.0)
Trimethoprim/ Sulphamethoxazole	17 (36.2)	0	30 (68.8)
Tetracycline	24 (51.1)	5 (10.6)	18 (38.3)

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

Comparing the antibiotic susceptibility of *Micrococcus* spp with that of *Streptococcus* spp, it was observed that vancomycin (63.6%) was the most active against the *Micrococcus* spp while erythromycin (57.1%), vancomycin (57.1%), and tetracycline (57.1%) were the most active against the *Streptococcus* spp (Table 6).

Table 6: Antibiotic Susceptibility Profile of *Micrococcus* and *Streptococcus* spp

Antibiotics	*Micrococcus spp* (n=11)			*Streptococcus spp* (n=7)		
	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)
Erythromycin	0	3 (27.2)	8 (72.7)	4 (57.1)	1 (14.3)	2 (28.6)
Gentamicin	3 (27.2)	0	8 (72.7)	3 (42.9)	0	4 (57.1)
Chloramphenicol	2 (18.2)	0	9 (81.8)	1 (14.3)	0	6 (85.7)
Vancomycin	7 (63.6)	0	4 (36.4)	4 (57.1)	0	3 (42.9)
Ceftriaxone	0	0	11 (100)	0	0	7 (100)
Cefoxitin	2 (18.2)	0	9 (81.8)	2 (28.6)	0	5 (71.4)
Amoxicillin clavulanic acid	3 (27.3)	0	8 (72.7)	0	0	7 (100)
Ciprofloxacin	4 (36.4)	0	7 (63.6)	3 (42.9)	1 (14.3)	3 (42.9)
Trimethoprim/ sulphamethoxazole	2 (18.2)	0	9 (81.8)	2 (28.6)	0	5 (71.4)
Tetracycline	5 (45.5)	0	6 (54.5)	4 (57.1)	1 (14.3)	2 (28.6)

Keys: S = Sensitive, I = Intermediate, R = Resistant

Vancomycin and gentamicin were the most active against *S. aureus* and *Bacillus subtilis* while the two organisms were highly resistant to ceftriaxone, cefoxitin and chloramphenicol (Table 7). In all, the isolates demonstrated a high percentage multidrug resistance (Figure 1).

Table 7: Antibiotic Susceptibility Profile of *S. aureus* and *Bacillus subtilis*

Antibiotics	*S. aureus* (n = 14)			*Bacillus subtilis* (n = 10)		
	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)
Erythromycin	4 (28.6)	1 (7.1)	9 (64.3)	2 (20)	0	8 (80)
Gentamicin	8 (57.1)	0	6 (42.8)	4 (40)	0	6 (60)
Chloramphenicol	2 (14.3)	0	12 (85.7)	2 (20)	0	8 (80)
Vancomycin	10 (71.4)	0	4 (28.6)	7 (70)	0	3 (30)
Ceftriaxone	0	0	14 (100)	0	0	10 (100)
Cefoxitin	2 (14.3)	0	12 (85.7)	0	0	10 (100)
Amoxicillin clavulanic acid	2 (14.3)	0	12 (85.7)	2 (20)	1 (10)	7 (70)
Ciprofloxacin	1 (7.1)	2 (14.3)	11 (78.6)	3 (30)	0	7 (70)
Trimethoprim/ Sulphamethoxazole	4 (28.6)	0	10 (71.4)	4 (40)	0	6 (60)
Tetracycline	7 (50.0)	2 (14.3)	5 (35.7)	5 (50)	2 (20)	3 (30)

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

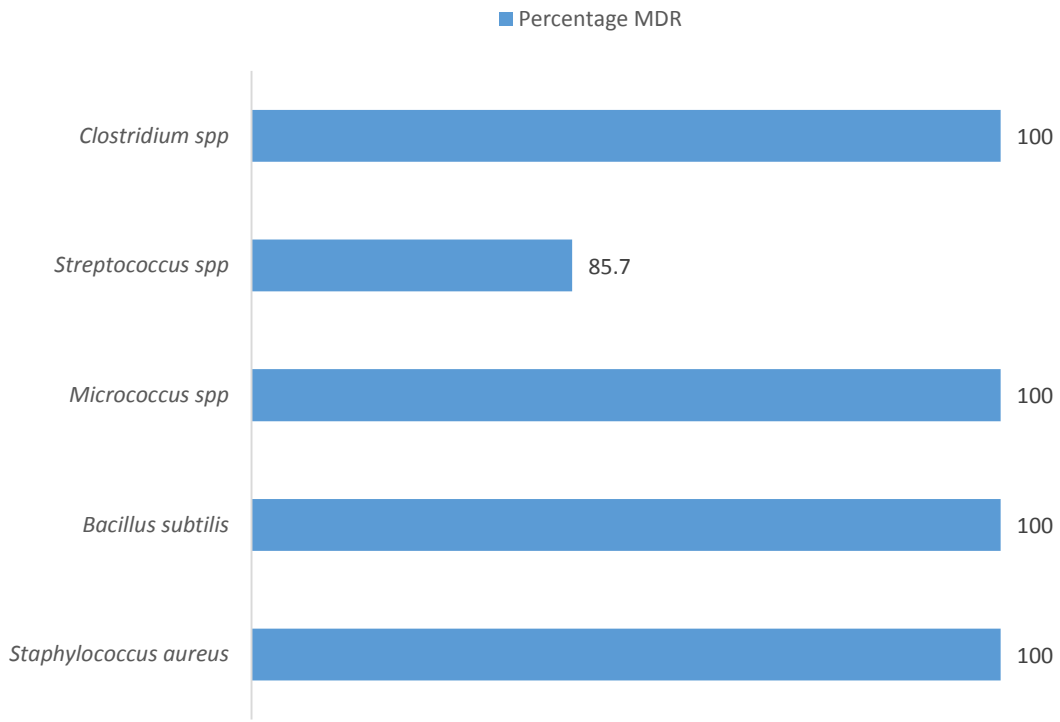

Figure 1: Percentage Multidrug Resistance (MDR) in the Isolates

DISCUSSION

The microbial quality of indoor air can affect the quality of health of the occupants [1]. In the lecture rooms sampled in this study from the four faculties, the highest bacteria count was observed at Faculty of Arts. From the toilets, Faculty of Art had the least bacteria count (1.5 x 10^3 CFU/m^3) while Faculty of Sciences toilets had the highest bacteria count (6.5 x 10^3). Faculty of Sciences and Faculty of Arts usually accommodate the highest number of students in the university especially first year students who must pass through either of the Faculties to take the preliminary courses before proceeding to their main course of study beginning from the second year in the University. The Dean's office in the Faculty of Pharmaceutical Sciences had the highest bacteria count among all the offices sampled. Among the laboratory indoor air sampled, Pharmaceutical microbiology laboratory had the highest bacteria load (3.9 x 10^3). The bacteria load observed from the various sampling sites in this study was higher than some previous studies. For example, Shittu [23] reported 96.3 – 689 CFU/m^3 bacteria load from indoor of a Nigerian University Campus in Lagos, Nigeria. Also a study described a lower range of bacteria load from lecture theatres in University of Benin [24]. However, a higher bacteria load was reported from the indoor air of offices in Veritas University, Abuja, Nigeria [25], but a similar bacteria load as that obtained in this study was reported from indoor air of classrooms of University of Science Vietnam National University, Ho Chi Minh City [26].

According to the European Commission, <50 CFU/m^3 indoor air bacteria load is

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

considered as 'very low', 50-100 CFU/m^3 as 'low', 100-500 CFU/m^3 as 'intermediate', 500-2,000 CFU/m^3 as 'high'and above 2,000 CFU/m^3 as 'very high' bacterial load [27]. The bacteria load in the air sampled in this study can be categorized to be high and very high.

Most of the bacteria isolates in this study were Gram positive, this was in accordance with previous studies [28-30]. *S. aureus* had the highest occurrence in this study, this maybe because *S. aureus* is a normal human body flora and most of these offices, toilets and laboratories sampled are occupied by both students and lecturers for about 8 – 12 hours daily. Other organisms isolated were *B. subtilis, Micrococcus spp, Clostridium spp* and *Ps. aeruginosa.* These are pathogenic bacteria, their long persistence in the air, and inhalation, touching of the surfaces having these bioaerosols and using such hands to touch mouth, nose or eyes can be a source transmission of these pathogenic organisms among the occupants of these offices. This can be very dangerous to health and well-being of the occupants. Some authors had reported isolation of similar bacteria from indoor air of some university campuses [25, 31-34].

The isolates were highly resistant to ceftriaxone and other beta lactam antibiotics used in this study. The high level of multidrug resistance observed in this study is of great concern, this may be an indication that many of the occupants of those offices and lecture rooms sampled had been exposed to the antibiotics tested. Antibiotic resistance is a global problem especially in developing countries where antibiotics can easily be obtained over the counter instead of being a prescription-only drug. However, vancomycin is active against most of the bacteria isolates (68.1%), even though it is not a commonly prescribed drug in Nigeria due to its unavailability. Tetracycline and gentamicin (these can be obtained in Nigeria) also demonstrated moderate activity against the isolates.

CONCLUSION AND RECOMMENDATION

The indoor air of the offices, toilets and laboratories sampled from Kaduna State University had high and very high bacterial load according to European Commission standard. The following bacteria were isolated: *S. aureus, Micrococcus spp, B. subtilis, Clostridium spp* and *Ps. aeruginosa.* High percentage of multidrug resistance bacteria was observed in this study. This implies that the use and misuse of antibiotics among the University community should be checked. It is recommended that advocacy against abuse of antibiotics should be flagged in the University.

Conflict of Interest

The authors have no conflict of interest to declare.

Authors' Contributions

Obajuluwa A.F. designed the study, wrote the protocol, Igwe JC and Parom S.K. managed the literature searches; Bege K.B. carried out the data analysis and interpretation. All the authors read and approved the final manuscript.

REFERENCES

1. https://www.epa.gov/indoor-air-quality-iaq/inside-story-guide-indoor-air-quality
2. Sasan Sadrizadeh, Runming Yao, Feng Yuan, Hazim Awbi, William Bahnfleth, Yang Bi, Guangyu Cao, Cristiana Croitoru, Richard de Dear, Fariborz Haghighat, Prashant Kumar,

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

Mojtaba Malayeri, Fuzhan Nasiri, Mathilde Ruud, Parastoo Sadeghian,
3. Pawel Wargocki, Jing Xiong, Wei Yu, Baizhan Li, Indoor air quality and health in schools: A critical review for developing the roadmap for the future school environment,Journal of Building Engineering,Volume 57, 2022, 104908, ISSN 2352-7102, https://doi.org/10.1016/j.jobe.2022.104908.
4. https://www.epa.gov/indoor-air-quality-iaq/inside-story-guide-indoor-air-quality
5. Sasan Sadrizadeh, Runming Yao, Feng Yuan, Hazim Awbi, William Bahnfleth, Yang Bi, Guangyu Cao, Cristiana Croitoru, Richard de Dear, Fariborz Haghighat, Prashant Kumar, Mojtaba Malayeri, Fuzhan Nasiri, Mathilde Ruud, Parastoo Sadeghian, Pawel Wargocki, Jing Xiong, Wei Yu, Baizhan Li, Indoor air quality and health in schools: A critical review for developing the roadmap for the future school environment,Journal of Building Engineering,Volume 57, 2022, 104908, ISSN 2352-7102, https://doi.org/10.1016/j.jobe.2022.104908.
6. https://mana.md/indoor-air-vs-outdoor-air/#:~:text=According%20to%20the%20EPA%2C%20however,harmful%20than%20the%20air%20outside.
7. U.S. Environmental Protection Agency. Report to Congress on indoor air quality: 1989; Volume 2. EPA/400/1-89/001C. Washington, DC.
8. U.S. Environmental Protection Agency. The total exposure assessment methodology (TEAM) study: Summary and analysis.1987. EPA/600/6-87/002a. Washington, DC.
9. Seltzer JM. Biological contaminants. J Allergy Clinical Immunology. 1994. 94 (2 Pt 2):318–26.
10. Sharma R., Gaur S.N., Singh V.P., Singh A.B. Association between Indoor fungi in Delhi Homes and Sensitization in Children of Respiratory Allergy. *Med Mycol*. 2011a. 50 (3):281–290. doi:10.3109/13693786.2011.606850
11. Sharma R., Deval R., Priyadarshia V., Gaur S.N., Singh V.P, Singh A.B.Indoor fungal concentration in the homes of allergic/asthmatic children in Delhi India. Allergy Rhinol. 2011b.;2:21–32.
12. Halide, A., Ahmet, A., Muserref, T.O. Indoor and outdoor airborne bacteria in child day-care centers in Edirne City (Turkey), seasonal distribution and influence of meteorological factors", Environmental Monitoring and Assessment. 2009; 164: 53-66.
13. Dutkiewicz, J., Krysinska-Traczyk, E., Skorska, C. et al. Exposure to airborne microorganisms and endotoxin in a potato processing plant. Ann Agric Environ Med. 2002; 9: 225-235.
14. Srikanth P, Sudharsanam S, Steinberg R. Bio-aerosols in indoor environment: composition, health effects and analysis. *Indian J Med Microbiol*. 2008; 26:302-312.
15. Onmek N, Kongcharoen J, Singtong A, Penjumrus A, Junnoo S. Environmental factors and ventilation affect concentrations of microorganisms in hospital wards of

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

Southern Thailand. *J Environ Public Health*. 2020; 2020:7292198.
16. Ayotunde Babalola. (2023). Facility Management Challenges of Public Educational Facilities in Nigeria. Qeios. doi:10.32388/XI78WQ.
17. Husman, T. Health effects of indoor-air microorganisms. Scandinavian Journal of Work, Environment & Health. 1996; 22(1), 5–13. http://www.jstor.org/stable/40966495
18. Magiorakos A.-P., Srinivasan A., Carey R. B., et al. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. Clinical Microbiology and Infection. 2012; 18(3):268–281. doi: 10.1111/j.1469-0691.2011.03570.x.
19. Rosenberger L. H., Hranjec T., Politano A. D., et al. Effective cohorting and 'superisolation' in a single intensive care unit in response to an outbreak of diverse multi-drug-resistant organisms. Surgical Infections. 2011; 12(5):345–350.
20. Morales E., Cots F., Sala M., et al. Hospital costs of nosocomial multi-drug resistant *Pseudomonas aeruginosa* acquisition. BMC Health Services Research. 2012; 12(1, article 122) doi: 10.1186/1472-6963-12-122.
21. Usmana S, Edet N, Uko M, Agbo B, Bassey M. Microbiological Quality of Indoor and Outdoor Air within Biological Sciences Laboratories in Akwa Ibom State University, Nigeria. Frontiers in Environmental Microbiology. 2018; 4(6), 124-132.
22. Borrego S., Guiamet P., de Saravia S.G., Batistini P., Garcia M and Lavin P. The quality of air at Archives and the Biodeterioration of Photographs. *Int. Biodetetrior. Biodegradation.* 2010*;* 64: 134-145
23. Gutarowska B. Metabolic activity of moulds as a factor of building materials Biodegradation. *Pol J. Microbiol*. 2010; 59: 119-124.
24. Cheesbrough, M. District Laboratory Practice in Tropical Countries. Part. The Anglo-Egyptian Bookshop. Cambridge University Press. 2000; 70-234.
25. Clinical and Laboratory Standards Institute. Performance standards for antimicrobial susceptibility testing approved standard M100, M02, M07, and M11. 2018; 28th Edition. Clinical and Laboratory Standards Institute, Wayne, PA.
26. Shittu A.I., Njoku K.L., Adesuyi A.A. Indoor air quality and microbial assessment of the Nigerian University Campus in Lagos, Nigeria. Ecological Safety and Balanced Use of Resources. 2019; 1(19): 94-103.
27. Idemudia , I.B., Momoh, A.M. and Michael , E.I. Indoor Air Quality of Selected Lecture Theatres in Faculty of Life Sciences, University of Benin Nig. J. Pure & Appl. Sci. 2022; 35 (1): 4250-4255.
28. Ozoude TO, Francis EE, Amachree EU, Anyanwu JC. Microbiological assessment of air quality of selected locations within Veritas University, Abuja, Nigeria; Journal of Biodiversity and Environmental Sciences (JBES), 2023; 22 (3): 22-27
29. Diep Yen Nga Dang, Hong Nhung Vuong, Thi Tam Nguyen, Thi Thanh

Archives of Pharmaceutical Sciences and Biotechnology Journal
Volume 3 Issue 2 December 2023, Page 72 -83 ISSN: 2971_611X
Submitted 18/2/2024 Accepted 13/3/2024 APSBJournal

Thao Phan. Microbiological contamination of indoor air in university classrooms (Case study: University of Science - Vietnam National University, Ho Chi Minh city). Vietnam Journal of Science, Technology and Engineering; 2020; DOI: 10.31276/VJSTE.62(4).30-35.

30. Wanner H.U., Gravesen S. (1993). Biological Particles in idoor environments: European Collaborative Action. Indoor air quality and its impact on man Report No 12. Luxembourg: Office for Official Publications of the European Commiunities.
31. Atalay Y.A., Embialle M., Alemu T., Belete B., Getachew A., Gebeyehu N.A., and Gelaw K.A. Indoor air bacterial load and antibiotic susceptibility pattern of isolates at Adare General Hospital in Hawassa, Ethiopia, Frontiers in Public Health. 2023; 11:1194850. doi: 10.3389/fpubh.2023.1194850
32. Stefanovic O.D., Radosavljevic J.D., Kosanic M.M. Microbiological indoor air quality in faculty's rooms: Risks on students' health. *Kragujevac J. Sci.* 2021; 43: 63-72.
33. Akindele O. O., Ana G.R., Uchendu O.C., Fakunle A.G., Bello T.B. Indoor Airborne Microbial Load of Selected Offices in a Tertiary Institution in South-Western Nigeria. Journal of Health and Environmental Research, 2018; 4,(3):113-118. DOI: 10.11648/j.jher.20180403.15
34. Lambu, Z.N., Ado, A.S., Shehu, A.A., Aminu, M.S., Karfi, I. A. and Mahmud, T. Microbiological Assesment of Indoor Air in Kano University of Science and Technology, Wudil, Kano State. Bayero Journal of Pure and Applied Sciences, 2022; 13(1): 211 – 215, ISSN 2006 – 6996, Special Conference Edition.
35. Osuolale O, Ekpemiata E, Odiwe A. Air microflora study of selected offices In Elizade University, Ilara-Mokin, Environmental Epidemiology, 2019; 3: 297 DOI:10.1097/01.EE9.0000609220.37904.0f
36. Aniebo CM, Stanley HO, Onwukwe CD. Assessment of the Indoor Air Quality of Majors' Biological Laboratories in Ofrima Complex, University of Port-Harcourt, Nigeria. J Pet Environ Biotechnol, 2016; 7: 285. doi: 10.4172/2157-7463.1000285
37. Ezemba,A.S., Nwabisi, C.M., Udemezue, I.O., Osuala, O..J., Ezeokoli, E.M., Ezemba, C. C. Microbial assessment of indoor air quality of the microbiology laboratory Nnamdi Azikiwe University Awka Nigeria. Asian journal of biochemistry genetics and molecular biology, 2022; 11(3): 16-24