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Research Article

BACTERIOLOGICAL ASSESSMENT OF INDOOR AND OUTDOOR AIR IN FEDERAL UNIVERSITY GUSAU CLINIC, ZAMFARA STATE, NIGERIA

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Abstract

Air quality in clinical environments plays a crucial role in ensuring the health and safety of patients, staff, and visitors. The study aimed to conduct a comparative bacteriological assessment of indoor and outdoor air in Federal University Gusau (FUG) Clinic environment. A total of 30 air samples were collected from FUG Clinic at different locations (Waiting Room, Treatment Room, Corridor, Window Area, and Entrance) and analyzed using standard microbiological methods. Bacterial isolation was performed on Blood agar, Tryptic Soy agar, and Mannitol Salt agar and isolates were identified through Gram staining and biochemical tests. Antibiotic susceptibility testing was conducted using the Kirby-Bauer disk diffusion method against a panel of antibiotics, including Gentamycin, Streptomycin, Pefloxacin, Cotrimoxazole, Amoxicillin, Ofloxacin, Ciprofloxacin, Chloramphenicol, Sparfloxacin, Augmentin, Erythromycin, Ceftriaxone, Cefuroxime, and Ampiclox. The prevalence rate of bacterial isolates was highest in the Waiting Room (32.1%), and the least prevalence was observed in the Window Area (14.3%). The distribution of isolates across the five sampled locations showed that the waiting room had the highest number of *Staphylococcus* spp. (18 isolates), while *Pseudomonas* spp. was more prevalent near outdoor areas such as the window and entrance, likely due to its environmental ubiquity. The most frequently isolated bacteria were *Staphylococcus* spp. (42.85%), followed by *Escherichia coli* (26.79%), *Klebsiella* spp. (17.86%), and *Pseudomonas* spp. (12.5%). Gentamicin, Sparfloxacin, and Ciprofloxacin showed highest efficacy against the isolates, while common antibiotics like Augmentin, Amoxicillin, and Erythromycin exhibit reduced effectiveness. The study highlights the predominance of *Staphylococcus* spp. in FUG Clinic and emphasizes the importance of indoor air quality monitoring and proper ventilation, especially in waiting areas and treatment zones where human waiting traffic is highest.

Keywords: Bacteriological Assessment, Indoor Air, Outdoor Air, Federal University, Gusau Clinic, Antibiotic Resistance.

INTRODUCTION

Air quality in clinical environments plays a crucial role in ensuring the health and safety of patients, staff, and visitors (Argyropoulos *et al.,* 2023). Poor air quality, especially in terms of microbiological contamination, poses risks of airborne infections, including hospital acquired infections (HAIs), which have significant morbidity and mortality implications (Bonadonna *et al.,* 2021). In these settings, monitoring the bacterial composition of both indoor and outdoor air is essential to prevent the spread of pathogens and to manage air contamination sources effectively (Elsaid and Ahmed, 2021). Insufficient ventilation, high association of personnel and improper management of hospital monitoring are main sources of indoor air contamination in the hospital (Ibrahim *et al.,* 2022). Microorganisms carried in this manner can be dispersed widely through the air by air current and may be inhaled by a susceptible individual (Argyropoulos *et al.,* 2023). Indoor air in clinical settings is subject to contamination from numerous sources (Rosário Filho *et al.,* 2021). The quality of indoor air in terms of microbial contamination in a given time period is said to be determined by the quality of air entering the space, the number of occupants, their physical activities and resultant aerosol generation, human traffic and the degree of ventilation. In healthcare facilities, bacteria can be introduced and dispersed through human activity, healthcare procedures, cleaning practices, and equipment use (WHO, 2023). High-traffic areas such as emergency rooms, operating theaters, and intensive care units are particularly vulnerable to contamination. Studies highlight those airborne bacterial concentrations in hospitals are strongly influenced by human activity, ventilation systems, and environmental controls (Jalali *et al.,* 2024). The presence of airborne bacteria such as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii* in clinical environments is of particular concern, as these species are often associated with HAIs (Sebola *et al.,* 2023). The use of mechanical ventilation systems and High-Efficiency Particulate Air (HEPA) filters is critical in controlling indoor air quality. However, factors such as filter maintenance, air circulation efficiency, and of biofilms on HVAC systems can impact the effectiveness of air purification. Studies have shown that poorly maintained systems can harbor and disseminate bacteria, exacerbating contamination rather than reducing it (Endale *et al.,* 2023). Indoor air in clinics, heavily influenced by patient movement, healthcare personnel, and equipment, often shows a high bacterial load (Bonadonna *et al.,* 2021). This bacterial presence is compounded by poor ventilation and the recirculation of air, factors known to foster pathogen accumulation (Elsaid and Ahmed, 2021). Studies reveal that airborne bacteria include both transient microorganisms from the environment and resident bacteria, which can become persistent if conditions are favorable (Sessitsch *et al.,* 2023). While outdoor air often contains a natural, diluted bacterial population, pollutants and particulates from the external environment may also introduce pathogenic bacteria indoors (Kumar *et al.,* 2023). In recent years, research for outdoor air quality has increased because of increasing awareness of the variety of health problems potentially caused by airborne microorganisms. Thus, understanding both indoor and outdoor bacterial profiles is essential to manage and reduce bacterial transmission risks within clinics. However, it is not only patients and visitors in the hospital that are at risk of infection, healthcare workers are also at risk of being infected (Du *et al.,* 2021). An aerosol is a suspension of microscopic solid and/or liquid particle in air or gas (Hinds and Zhu, 2022). Biological aerosols are single

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microorganisms or clumps of microorganisms attached to solid or liquid particles suspended in the air (Ogah, 2022). The composition of bio aerosol includes: bacteria, yeast, molds, spores of bacteria and molds, microbial fragments, toxins, metabolites, viruses, parasites and pollen (Atta, 2023). Microorganisms in bio aerosols may attach to dust particles or may survive as free-floating particles surrounded by a coating of dried organic or inorganic material. Location and environmental conditions such as humidity, density and temperature have a great effect on the type of population and rate of microorganisms in enclosed air. Whilst all types of microorganisms can cause problems indoors. Bacteria and fungi are commonly associated with outdoor air quality complaints (Kumar *et al.,* 2022). Exposure to bio-aerosols, containing airborne microorganisms and their by-products, can result in respiratory disorders and other adverse health effects such as infections. Hypersensitivity, pneumonitis and toxic reactions (Goswami *et al.,* 2024). Microbial damage in indoor/outdoor areas, is caused most frequently by molds and bacteria (Du *et al.,* 2021). These microorganisms have a very important role in the biogeochemical cycle, as their task consists of disintegrating organic mass to reusable metabolites. In the environment spores of molds and bacteria may become airborne and are therefore ubiquitous (Ogah, 2022). They can enter indoor areas either by means of passive ventilation or by means of ventilation systems. Many genera are also emitted by indoor sources like animals, flowerpots and wastebaskets (Durugbo *et al.,* 2023). In most cases, normal flora is not harmful. However, growth conditions like excessive humidity and/or a high-water content of building materials are encountered on a more frequent basis, which in most cases can be described as the limiting factor for microbial growth. This is caused by shortcomings of the buildings due to the lack of thermal insulation, as well as the incorrect behavior of users of wards. The relative humidity and/or the moisture content of the materials determines the extent at which different micro-organisms grow in indoor or outdoor materials (Sousa, 2022). Air-borne bacteria in the hospital environment has been a major source of post-operative infection and a serious problem in the intensive care unit (Durugbo *et al.,* 2023). Airborne pathogens, such *as Micrococcus sp., Proteus sp., Escherichia coli, Enterobacter, Bacillus cereus, Cladosporium sp., Staphylococcus aureus* and *Pseudomonas aeruginosa*, are well-documented contributors to healthcare-associated infections (HAIs) (Luzala *et al.,* 2022). Studies on *S. aureus and P. aeruginosa* highlight their high prevalence in hospital air and their association with respiratory infections and wound contamination (Viksne *et al.,* 2023). Additionally, antibiotic-resistant strains of bacteria, notably Methicillin-resistant Staphylococcus aureus (MRSA), are increasingly isolated in clinic air samples, underscoring the threat of airborne resistance transmission (Tsai *et al.,* 2024).

MATERIALS AND METHODS

Study area

The study was carried out within Gusau metropolis in Zamfara State. Zamfara State is located in the North Western Nigeria, with coordinate latitude 12.09-12.5°N and longitude 6.67°E, covering a total of 3364 KM square. According to the National Population Commission of Nigeria (NPCN, 2022), the estimated Population of Gusau Local Government Area as of March 21, 2022, was approximately 682,000.

Media for bacterial cultivation

The media used for this research work include: Tryptic Soy Agar (TSA) for general bacterial growth, Blood Agar for detecting hemolytic bacteria, Mannitol Salt Agar for *Staphylococcus spp.* or *Pseudomonas spp.* and Mueller-Hinton agar for antibiotic susceptibility testing.

Collection of sample

For indoor sampling, the samples were collected from specific areas within the clinic, including the waiting rooms, treatment areas, and corridors. The outdoor sampling was conducted near entrances, windows, or ventilation outlets. A total of 30 samples were collected using settle plate method (Andriana *et al.,* 2023). The prepared media (Tryptic Soy Agar (TSA), Blood Agar and Mannitol Salt Agar) were placed in holder and taken to the collection site. The media were placed open on wooden stand 1m above the ground for 1 hour at each sample site, after the exposure period, they were covered with their lids to prevent contamination, labeled with relevant information, including the date, time, location, and exposure duration and placed back into container. The plates were taken to the laboratory within 30 minutes and were incubated at 37°C for 24hours. The samples were collected morning and evening respectively.

Isolation of bacteria

Distinct colonies from the cultures were sub cultured on freshly prepared Nutrient agar plate using the quadrant method of streak plate technique as stated by Ogodo *et al.,* (2022). Inoculated plates were then incubated aerobically at 37°C for 24hours.

Gram staining

A drop of normal saline was placed on a clean grease free glass slide and a portion of the growth was picked and smeared on the slide using a sterilized wire loop. The preparation was allowed to air dry, heat fixed using a burning flame then placed on staining rack. The slides were stained using crystal violet for 1 minute then rinsed with water. The slides were flooded with iodine for another 1 minute, after which the slides were rinsed with water. Acetone was used to flood the slides for 10 seconds then rinsed again with water. Then slides were flooded again with safranin for 1 minute then rinsed again with water. The slides were allowed to air dry in a dust free environment then observed under x100 oil immersion lens of a compound microscope. Gram negative cells appeared pink or red while gram positive organisms appeared purple (Paray *et al.,* 2023).

Biochemical identification and characterization of the isolates

Biochemical identification and characterization of pure isolates was carried out. Pure isolates from each sample were subjected to various biochemical tests in order to identify them. The different conventional biochemical tests carried out include catalase test, coagulase test, methyl red, indole, oxidase test, and Voges Proskauer.

Catalase test: A drop of hydrogen peroxide was placed on a clean grease free slide using Pasteur pipette. A small portion of the growth was picked using a sterile wire loop and placed in

the hydrogen peroxide on the slide. The preparation was examined for the presence or absence of bubbles. Presence of bubbles indicated a positive reaction and absence of bubbles indicated a negative reaction (Cheesbrough, 2020).

Coagulase test: A drop of plasma was placed on a grease free slide. A portion of the growth was picked using a sterile wire loop and was placed in the plasma on the slide. The preparation was examined for the presence or absence of agglutination. Presence of agglutination indicates a positive reaction and absence of agglutination indicates a negative reaction (Koneman *et al.,* 2022).

Oxidase test: A portion of the growth was picked using applicator stick. A drop of oxidase reagent was placed on a clean filter paper using a Pasteur pipette. The portion of the growth was emulsified on the clean filter paper damped with the oxidase reagent. The preparation was observed for color change deep purple coloration indicates positive reaction and no coloration indicates negative reaction (Cheesbrough, 2020).

Indole test: The media was prepared base on the manufacturer's instruction and the isolated colony was inoculated at 37°C for 24/28 hours then Kovac reagent was added to the broth culture. Formation of pink to red color at the top surface of the medium within seconds of adding the reagents indicate positive and no color change indicated negative (Cheesbrough, 2020).

Methyl red test: The broth was prepared according to the manufacturer's instructions and the organism was inoculated and incubated for 18/24 hours then methyl red reagent color changed to red indicating positive and no color change indicating negative (Princewill *et al.,* 2025).

Voges-proskauer test: The broth was prepared according to the manufacturer's instruction and the organism was inoculated then incubated for 18/24 hours then add VPI and VPII reagents, color changed and ring formation indicate positive and no color change indicate negative.

Triple Sugar Iron test: The aim of the test is to identify the ability of organism to utilize citrate as a carbon source and energy. About 2.4g of citrate agar was dissolved in 100ml of distilled water. About 10ml of citrate medium was dispensed into each tube an was covered, then sterilized and allowed to cool in a slanted position. The tubes were inoculated by streaking the organism once across the surface. A change from green to blue indicate utilization of the citrate (Cheesbrough, 2020).

The medium was carefully prepared according to the manufacturer's instruction, dispensed into tubes in slant form and the test organisms inoculated by streaking the slant surface and stabbing the butt of the tube with a sterile wire loop. After 24hours of incubation, color change to bright pink or bright red indicated a positive result, meaning the bacteria produce urease (Koneman *et al.,* 2022).

Antibiotic Susceptibility Testing

Antibiotic susceptibility of isolates was tested by the Kirby Bauer disk diffusion method, using commercially available disc; Gentamicin, Amikacin, Erythromycin, Ciprofloxacin, Oxacillin, Clindamycin, and Ceftriaxone. With the use of a sterile wire loop, colonies of the test organism were emulsified in 2 ml of sterile physiological saline.

The turbidity of the suspension was matched with the turbidity standard (0.5 McFarland Solution); this was viewed against a sheet of paper for easier comparison. Using a sterile syringe, 2 drops of the suspension was placed on the surface of a Mueller Hinton plate, with the use of a sterile glass rod; the suspension was evenly spread on the surface of the medium, rotating the plate approximately 60° to ensure even distribution. With the Petri dish lid in place, it was allowed to stand for about 5 min for the surface of the agar to dry. Using sterile forceps, the antibiotic disc was placed on the surface of the plate. Within 30 min of applying the disc, the plate was inverted and incubated aerobically at 35°C for 18 h. After overnight incubation, a ruler was used to measure the zone of inhibition in mm underside of the plate (CLSI, 2023)

RESULTS

The findings of the study present the comparative bacteriological assessment of indoor and outdoor air in Federal University Gusau Clinic environment. A total of 30 samples were collected using the settle plate method, comprising 18 indoor and 12 outdoor samples. Following incubation and sub-culturing, a total of 56 distinct bacterial isolates was recovered: 39(69.6%) from indoor air and 17(30.3%) from outdoor air. The highest number of isolates (18, representing 32.1%) was obtained from the waiting room, suggesting it is the most contaminated area, likely due to human waiting traffic and prolonged occupancy. This was followed by the treatment room (19.6%), and the corridor (17.9%). The lowest number of isolates was recorded at the window area (14.3%), which may be attributed to better ventilation and reduced crowding. The results are detailed in table 1 below.

Table 1. Distribution of Bacterial Isolates by Sampling Location

Sample Location	No. of Samples	No. of Positive Samples	No. of Isolates	Prevalence (%)
Waiting Room (Indoor)	6	6	18	32.1
Treatment Room	6	6	11	19.6
Corridor	6	6	10	17.9
Entrance (Outdoor)	6	6	9	16.1
Window Area	6	6	8	14.3
Total	30	30	56	100

Key: No= Number

Urease Test

Table 2. Presents the Morphology, Gram Reaction, and Biochemical Identification of the Isolates

Isolate	Morphology	Gram	Catalase	Coagulase	Indole	Oxidase	Urease	MR	VP	TSI					Probable organism
										Glu.	Lac.	Suc.	H2S	Gas	
WR1	Cocci	+	+	+	+	-	N/A	-	+	+	+	+	-	+	*Staphylococcus specie*
WR2	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	+	-	*Escherichia coli*
WR3	Rod	-	+	N/A	-	+	-	+	+	+	+	+	-	+	*Klebsiella specie*
WR4	Cocci	+	+	+	-	+	N/A	+	-	+	-	-	-	-	*Staphylococcus specie*
WR5	Cocci	+	+	+	-	+	N/A	+	+	+	+	+	-	-	*Staphylococcus specie*
WR6	Cocci	+	+	+	-	+	N/A	+	-	+	+	+	-	-	*Staphylococcus specie*
WR7	Cocci	+	+	+	-	+	N/A	+	-	+	+	+	-	+	*Staphylococcus specie*
WR8	Rod	-	+	N/A	+	-	N/A	-	+	+	-	-	-	-	*Escherichia coli*
WR9	Rod	-	+	N/A	-	+	-	+	-	+	-	-	+	-	*Pseudomonas specie*
WR10	Cocci	+	+	+	+	-	N/A	-	+	+	+	+	-	+	*Staphylococcus specie*
WR11	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Klebsiella specie*
WR12	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
WR13	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
WR14	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
WR15	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
WR16	Rod	-	+	N/A	-	+	+	+	-	+	-	-	-	-	*Pseudomonas specie*
WR17	Cocci	+	+	+	-	+	N/A	+	+	+	+	+	-	-	*Staphylococcus specie*
WR18	Cocci	+	+	+	-	+	N/A	+	-	+	+	+	-	-	*Staphylococcus specie*
TR1	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
TR2	Rod	-	+	N/A	-	+	-	+	+	+	+	+	-	+	*Klebsiella specie*
TR3	Rod	-	+	N/A	-	+	+	+	-	+	-	-	-	-	*Pseudomonas specie*
TR4	Cocci	+	+	+	-	+	N/A	+	+	+	+	+	-	-	*Staphylococcus specie*
TR5	Cocci	+	+	+	-	+	N/A	+	-	+	+	+	-	-	*Staphylococcus specie*
TR6	Cocci	+	+	+	-	+	N/A	+	-	+	+	+	-	+	*Staphylococcus specie*
TR7	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
TR8	Rod	-	+	N/A	-	+	-	+	-	+	-	-	+	-	*Pseudomonas specie*
TR9	Cocci	+	+	+	+	-	N/A	-	+	+	+	+	-	+	*Staphylococcus specie*
TR10	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Pseudomonas specie*
TR11	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Klebsiella specie*
CR1	Cocci	+	+	+	-	+	N/A	+	-	+	+	+	-	+	*Staphylococcus specie*
CR2	Cocci	+	+	+	-	-	N/A	+	-	+	+	+	-	+	*Staphylococcus specie*
CR3	Rod	-	+	N/A	-	+	-	+	-	-	+	-	-	+	*Klebsiella specie*
CR4	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
CR5	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Klebsiella specie*
CR6	Cocci	+	+	+	+	-	N/A	-	+	+	+	+	-	+	*Staphylococcus specie*
CR7	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
CR8	Rod	-	+	N/A	-	+	-	+	+	+	+	+	-	+	*Klebsiella specie*
CR9	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
CR10	Cocci	+	+	+	-	+	N/A	+	+	+	+	+	-	-	*Staphylococcus specie*
ET1	Cocci	+	+	+	-	+	N/A	+	-	+	+	+	-	-	*Staphylococcus specie*
ET2	Cocci	+	+	+	-	+	N/A	+	-	+	+	+	-	+	*Staphylococcus specie*
ET3	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
ET4	Rod	-	+	N/A	-	+	-	+	-	+	-	-	+	-	*Pseudomonas specie*
ET5	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Klebsiella specie*
ET6	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
ET7	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Klebsiella specie*
ET8	Cocci	+	+	+	-	+	N/A	+	-	+	+	+	-	+	*Staphylococcus specie*
ET9	Cocci	+	+	+	-	-	N/A	+	-	+	+	+	-	+	*Staphylococcus specie*
WA1	Cocci	+	+	+	+	-	N/A	+	-	-	+	-	-	+	*Staphylococcus specie*
WA2	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*
WA3	Cocci	+	+	+	-	+	N/A	+	-	+	+	+	-	+	*Staphylococcus specie*
WA4	Rod	-	+	N/A	-	+	-	+	-	+	-	-	+	-	*Pseudomonas specie*
WA5	Cocci	+	+	+	+	-	N/A	+	-	-	+	-	-	+	*Staphylococcus specie*
WA6	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Klebsiella specie*
WA7	Cocci	+	+	+	+	-	N/A	+	-	-	+	-	-	+	*Staphylococcus specie*
WA8	Rod	-	+	N/A	+	-	N/A	-	+	+	+	+	-	+	*Escherichia coli*

MR = Methyl red, VP =Voages pro, TSI = Triple sugar iron.

Table 3: Frequency of Occurrence of Bacterial Isolates

Bacterial Species	Indoor (n 39)	Outdoor (n = 17)	Total (n = 56)
Staphylococcus spp.	16	8	24
Escherichia coli	11	4	15
Pseudomonas spp.	5	2	7
Klebsiella spp.	7	3	10
Total	39	17	56

Table 4 Antibiotic Susceptibility Profiles of the Gram-Negative Bacterial Isolates

Antibiotics	Disk Content	*E. coli* (n=15)			*Klebsiella* spp. (n=10)			*Pseudomonas* spp. (n=7)		
		S	I	R	S	I	R	S	I	R
PEF	30µg	10(67%)	3(20%)	2(13%)	7(70%)	2(20%)	1(10%)	3(43%)	2(28.5%)	2(28.5%)
OFX	10µg	12(80%)	2(13%)	1(7%)	8(80%)	1(10%)	1(10%)	5(72%)	1(14%)	1(14%)
STR	30µg	9(60%)	3(20%)	3(20%)	6(60%)	2(20%)	2(20%)	3(43%)	2(28.5%)	2(28.5%)
SXT	30µg	8(53%)	4(27%)	3(20%)	5(50%)	3(30%)	2(20%)	2(28.5%)	2(28.5%)	3(43%)
CHL	30µg	7(47%)	5(33%)	3(20%)	6(60%)	2(20%)	2(20%)	3(43%)	2(28.5%)	2(28.5%)
SPF	10µg	13(86%)	1(7%)	1(7%)	9(90%)	1(10%)	0(0%)	4(57%)	1(14%)	2(29%)
CPX	30µg	12(80%)	2(13%)	1(7%)	8(80%)	1(10%)	1(10%)	5(72%)	1(14%)	1(14%)
AMX	30µg	5(33%)	4(27%)	6(40%)	3(30%)	2(20%)	5(50%)	2(28.5%)	2(28.5%)	3(43%)
AUG	10µg	4(40%)	5(33%)	6(27%)	3(30%)	3(30%)	4(40%)	2(28.5%)	2(28.5%)	3(43%)
GEN	30µg	11(73.3%)	2(13.3%)	2(13.3%)	8(80%)	1(10%)	1(10%)	4(57%)	2(29%)	1(14%)

Table 5. Antibiotic Susceptibility Profiles of Gram-Positive Bacterial Isolates

Antibiotics	Disk Content	*Staphylococcus* spp. (n = 22)		
		S	I	R
PEF	30µg	20(83.3%)	2(8.3%)	2(8.3%)
STR	30µg	18(75%)	3(12.5%)	3(12.5%)
SXT	30µg	14(58%)	5(21%)	5(21%)
CPX	30µg	19(79%)	2(8%)	3(13%)
AMX	30µg	6(25%)	5(21%)	13(54%)
GEN	30µg	17(71%)	4(17%)	3(12%)
CRO	30µg	8(33%)	6(25%)	10(42%)
ERY	15µg	7(29%)	5(21%)	12(50%)
CXM	30µg	13(54%)	5(21%)	6(25%)
AMP	15µg	10(42%)	6(25%)	8(33%)

KEY:

Abbreviation	Full meaning	Class
S	Susceptible	-
R	Resistant	-
I	Intermediate	-
PEF	Pefloxacin	Fluoroquinolone
OFX	Ofloxacin	Fluoroquinolone
STR	Streptomycin	Aminoglycoside
SXT	Cotrimoxazole	Sulfonamide
CHL	Chloramphenicol	Broad-spectrum Antibiotic
SPF	Sparfloxacin	Fluoroquinolone
CPX	Ciprofloxacin	Fluoroquinolone
AMX	Amoxicillin	β –lactam (Penicillin group)
AUG	Augmentin	β-lactam/ β-lactamase inhibitor
GEN	Gentamicin	Aminoglycoside
CRO	Ceftriaxone	Cephalosporin
ERY	Erythromycin	Macrolide
CXM	Cefuroxime	Cephalosporin
AMP	Ampiclox	Penicillin combination

Identification and Biochemical Characterization of Bacterial Isolates

Table 2: Summarizes the morphology, Gram reaction, and biochemical characteristics of each isolate.The biochemical tests carried out include; catalase, coagulase, indole, citrate utilization, oxidase, urease, methyl red, Voges-Proskauer (VP), and Triple Sugar Iron (TSI) tests were used to identify the bacterial isolates. The predominant isolates were *Escherichia coli, Staphylococcus* spp*., Klebsiella* spp*.,* and *Pseudomonas* spp

Table 3: Present the frequency of occurrence of the bacterial isolates and based on the confirmed identities of the isolates, the frequency of occurrence of each bacterial species was accessed across all sampling locations.

Among the 56 isolates obtained from indoor and outdoor air samples, *Staphylococcus* spp. was the most frequently detected organism, accounting for 42.85% of the total isolates, followed by *Escherichia. Coli* (26.79%), *Klebsiella* spp. (17.86%), and *Pseudomonas* spp. (12.5%). Table 4.3 shows how often each species appeared, and whether they were more common in indoor or outdoor air.

Table 4 and 5: Presents the Antibiotic Susceptibility Profile of the Bacterial Isolates with a total of 56 bacterial isolates obtained from indoor and outdoor air samples were subjected to antibiotic susceptibility testing using the Kirby-Bauer disk diffusion method according to CLSI (2023) guidelines. The isolates included *Staphylococcus spp., Escherichia coli, Klebsiella spp.,* and *Pseudomonas spp*. The susceptibility

results, expressed as percentages of sensitive, intermediate, and resistant isolates, are presented below.

The antibiotic susceptibility patterns of Gram-negative bacterial isolates (*E. coli, Klebsiella* spp*., Pseudomonas* spp.) is shown in Table 4 below and the susceptibility pattern of the Gram-positive bacterial isolates (*Staphylococcus spp.*) is presented in Table 5.

DISCUSSION

The results of this study indicate a significant presence of airborne bacterial contaminants in both indoor and outdoor environments of the Federal University Gusau Clinic. A total of 56 bacterial isolates were recovered from 30 air samples using the settle plate method. The most frequently isolated organism was *Staphylococcus spp*. (42.9%), followed by *Escherichia coli* (26.8%), *Klebsiella spp*. (17.9%), and *Pseudomonas spp*. (12.5%). These organisms are consistent with common hospital airborne pathogens reported in similar Nigerian studies (Umeh *et al.,* 2021; Okonkwo *et al.,* 2020). The predominance of *Staphylococcus spp*. in indoor air aligns with the fact that it is commonly shed from human skin and mucosa, especially in crowded clinical areas. The distribution of isolates across the five sampled locations showed that the indoor area had the highest prevalence of *Staphylococcus spp*. (66.6%), with waiting room constituting 50%, while *Pseudomonas spp*. was more prevalent near outdoor areas such as the window and entrance, likely due to its environmental ubiquity. The presence of *E. coli* and *Klebsiella spp*. in the indoor environment, both of which are enteric bacteria, may be attributed to poor ventilation, surface contamination, or patient-related shedding, corroborating findings from Suleiman *et al*. (2020) in northern Nigeria. Biochemical and morphological characterization confirmed the identity of isolates. *Staphylococcus spp*. were Gram-positive cocci in clusters, catalase-positive, and coagulasepositive in most cases, consistent with typical *S. aureus* characteristics. *E. coli, Klebsiella spp.,* and *Pseudomonas spp*. were Gram-negative rods with varying biochemical reactions. *E. coli* showed indole-positive and citrate-negative results, while *Klebsiellaspp*. were indole-negative but citrate-positive. *Pseudomonas spp*. were oxidase-positive and nonlactose fermenters, confirming their identity. These biochemical profiles support similar findings in studies by Adekunle and Abubakar (2021) and Ibrahim *etal*. (2023). Antibiotic susceptibility testing revealed varying degrees of resistance. *Staphylococcus spp.* showed high resistance to Amoxicillin (54.2%) and Erythromycin (50.0%) but retained sensitivity to Gentamicin (70.8%) and Ciprofloxacin (79.2%). This aligns with the increasing trend of beta-lactam resistance among Gram-positive pathogens as reported by Lawal *etal*. (2021). *E. coli* and *Klebsiella spp*. were highly resistant to Augmentin and Amoxicillin but moderately sensitive to Sparfloxacin and Ciprofloxacin, consistent with patterns reported by Olayemi*etal*. (2022) in hospital air isolates. *Pseudomonas spp*. exhibited multidrug resistance with poor sensitivity to most tested antibiotics, which poses serious public health concerns due to its opportunistic pathogenicity and environmental persistence (Adeniran *et al.,* 2023). Overall, the presence of potentially pathogenic and drug-resistant airborne bacteria in clinic environments suggests a need for enhanced infection control measures. The findings emphasize the importance of indoor air quality monitoring and proper ventilation, especially in waiting areas and treatment zones where human traffic is highest.

Conclusion

This study demonstrated that the indoor air of Federal University Gusau Clinic harbors a high load of airborne bacteria, with *Staphylococcus spp., E. coli, Klebsiella spp.,* and *Pseudomonas spp.* being the predominant isolates. The highest bacteria isolated were observed in the waiting room, while the lowest occurrence was found in the window area. The findings of this study revealed a prevalence of 42.9%, 26.8%, 17.9%, and 12.5% were obtained for *Staphylococcus* spp., *E. coli, Klebsiella* spp*.,* and *Pseudomonas* spp. respectively. *Staphylococcus* spp*.* showed high resistance to Amoxicillin (54.2%) and Erythromycin (50.0%) but retained sensitive to Gentamicin (70.8%) and Ciprofloxacin (79.2%). *E.coli* and *Klebsiella spp*. were highly resistant to Augmentin (40% respectively) and Amoxicillin (40% and 50% respectively) but moderately sensitive to Sparfloxacin (86%, 90%) and Ciprofloxacin (80%) respectively.Public health may be ensured from this pathogenic agent by improving the ventilation system in the hospital setting.

Recommendations

1. Since the indoor and outdoor air are home of many harmful microorganism, proper policy should be put in place for those who work and visit the hospital to safeguard their lives.
2. Regular microbiological surveillance of both indoor and outdoor air at the FUG Clinic should be conducted. This is important for the early detection of airborne bacterial pathogens and helps to evaluate the effectiveness of infection control measures.
3. Installation of mechanical ventilation systems or High-Efficiency Particulate Air (HEPA) filters should be considered, particularly in enclosed areas such as waiting rooms and treatment areas. This would help reduce airborne bacterial load, especially where high concentrations of bacteria were observed indoors.

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