BACTERIOLOGICAL ASSESSMENT OF INDOOR AIR OF ROOMS IN CALEB UNIVERSITY FEMALE HOSTELS

BY

OLORUNFUNMI MORIAMO OLORUNKEMI

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DECLARATION

I, OLORUNFUNMI MORIAMO OLORUNKEMI hereby declare that this project is entirely my work and composition. The work in this project has not been submitted in candidature for any degree and is not concurrently being submitted for any other degree. All references made to works of other persons have been duly acknowledged.

CERTIFICATION

This is to certify this project titled Bacteriological Assessment of Indoor Air of Rooms in Caleb University Female Hostels was carried out by Olorunfunmi Moriamo Olorunkemi with the matriculation number 18/5005 under supervision in the department of Biological sciences and biotechnology, Caleb University for the award of Bachelor of Science (Bsc) degree in Microbiology.

T.C. BAYO-OLAJIDE ----------

(Project Supervisor). Signature & Date

DR. C.C. EZEANYA-BAKPA ----------

(Head of Department). Signature & Date

EXTERNAL SUPERVISOR ----------

Signature & Date

DEDICATION

This work is dedicated to almighty God and my family.

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ABSTRACT

Indoor air quality refers to the air quality within and around buildings, particularly as it relates to the health and comfort of residents. Poor indoor air quality may lead to sick building syndrome which causes mucous membrane irritation, poor physical conditions, exhaustion, headache and a decline in memory and intellectual activity. This study was aimed at isolating, enumerating, identifying and determining the antibiotics sensitivity profile of bacteria isolated from indoor air of two Caleb University female hostels. Eighteen samples were collected from two female hostels in Caleb University Imota, Lagos. Standard microbiological procedures were employed in the process of the study. Bacteriological analysis of the samples were carried out and the bacteria isolated were identified using morphology characteristics and biochemical characteristics. Colony counts of hall A ranged from $2.09xl0^2$to $1.57xl0^3$ CFU/m^3 and that of hall B ranged from $4.71xl0^2$ to 1.1 xlO^3 CFU/m^3. The organisms isolated from the air samples included *Staphylococcus* spp., *Bacillus* sp., *Klebsiella* sp., *Proteus* sp., *Corynebacterium* sp. and *Escherichia coli.* The presence of these bacteria can be attributable to dust, leakage, occupants, building conditions, weather condition and ventilation systems. One hundred percent (100%) of isolates showed resistance to Augmentin, 97.1% were resistant to Ceftriaxone and 85.7% were resistant to Erythromycin. Ninety two percent (92%) of *Staphylococcus* spp. isolated were resistant to Oxacillin while 8% were susceptible which points to the Methicillin Resistant *Staphylococci.* The high prevalence of multi drug resistant bacterial in indoor air may lead to prolonged respiratory infections in occupants. Also, high cost of treatment could be a consequence of the presence of resistant bacteria strains isolated from indoor air. Proper ventilation, low population and good sanitation practices can help in reducing the risk of occupants getting infected by bacteria.

CHAPTER ONE

INTRODUCTION

1.1 STUDY BACKGROUND

Indoor air quality refers to the air quality within and around buildings, particularly as it relates to the health and comfort of residents (United States Environmental Protection Agency, 2021). For more than a century, from the beginning of the hygienic revolution in 1850 through the 1960s, indoor air was thought to be a major environmental element. According to the World Health Organization (2009), 4.3 million people die each year as a result of poor indoor air quality.

There is ample evidence, according to the World Health Organization (2009), that a wet indoor environment has a wide variety of impacts on respiratory health, including respiratory infections, asthma development, cough, wheeze and dyspnea. Asthmatic pupils' conditions deteriorate when they are housed in rooms with poor air quality. In addition, a low air exchange rate, poor room design, and inadequate ventilation encourage microorganism growth and reproduction in the interior environment. Poor indoor air quality can have a negative impact on one's health, productivity and school attendance. Bacteria, molds and yeasts are the most common sources of biological contamination in indoor air.

Bio aerosols are airborne particles that are living or originate from living organisms (KiHyun *et al*., 2017). Microorganisms can be deadly as pathogenic live cells, but they can also produce harmful chemicals. Bioaerosols consist of aerosols originated biologically which could be metabolites, toxins, or fragments of microorganisms that are present ubiquitously (Ki-Hyun *et al*., 2017). Poor indoor air quality may lead to sick building syndrome, which causes mucous membrane irritation, poor physical conditions, exhaustion, headaches, and a decline in memory and intellectual activity.

1.2 STATEMENT OF PROBLEM

Bacteria isolated from indoor air are community acquired pathogens. Organisms like *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Proteus mirabilis* and *Escherichia coli* have been isolated by previous studies done on bacteriological assessment of indoor air (Mohammed *et al*., 2020). Studies have shown the prevalence of antibiotic resistant strain among the isolates. In a study by Adekunle *et al.* (2019) majority of the isolates were resistant; this pattern shown by the organisms may lead to severity of illnesses and endangering more lives.

1.3 AIM AND OBJECTIVES

The aim of this study is to determine the bacteriological quality of the indoor air in Caleb University's female dorms.

The objectives of the study are

i. To isolate and enumerate microorganisms found in the indoor air of Caleb University's female dorms.
ii. To determine the multiple antibiotics sensitivity pattern of microorganisms isolated from indoor air.

1.4 JUSTIFICATION FOR STUDY

This research will lead to enumeration, identification of the microorganisms present in indoor air of rooms in Caleb University female hostels. Also, the antibiotics susceptibility of the identified microorganisms will be done. This research could also aid in improving indoor air quality by identifying microbiological contaminants and devising control strategies.

CHAPTER TWO

LITERATURE REVIEW

2.1 INDOOR AIR QUALITY

Indoor air quality is the state of the air inside and around buildings and structures, with a focus on the health and comfort of building occupants (EPA, 2021). The term "good indoor air quality" refers to a scenario in which the air in an indoor setting is free of microbiological contamination or has a low level of contamination. In 2009, the World Health Organization organized a working group to develop indoor air quality guidelines. The group met to identify the key health risks related with microbial growth, excess wetness, and contamination of indoor spaces, and to produce guidelines by reviewing scientific data utilizing the meeting's background materials. Sufficient epidemiological evidence from studies conducted in different countries under different climate conditions has provided clinical evidence that exposure to mold and other dampness-related microbial agents increases the risk of negative health conditions (WHO, 2010). Toxicological evidence obtained and increased prevalence of asthma and allergies in countries where most people are susceptible to dampness are all part of the background material used. In addition, the recommendations were developed using the feedback obtained during the review (WHO, 2009).

Avoiding persistent dampness on interior surfaces and in building structures was one of the guidelines developed during the review. Building owners were told to ensure that buildings were properly constructed and well maintained to ensure proper ventilation and restriction of excessive moisture and microbial growth indoors, as well as the prevention of water leakage or penetration into the indoor environment (WHO, 2009).

2.2 SOURCES OF INDOOR AIR MICROBIOLOGICAL CONTAMINATION

2.2.1 HUMANS AS A SOURCE OF AIRBORNE MICROORGANISMS

In the environment, humans might be the greatest source of germs. Humans carry germs on their epidermis and the daily shedding of millions of skin cells adds to the production of bioaerosols in the interior environment. Talking, coughing, and sneezing are examples of human behaviors that release air under pressure. Microorganisms from the upper respiratory tract are ejected into the air during this procedure. Sneezing is the most active of the activities, producing up to one million droplets in 0.1 micrometers (Bispasha *et al*., 2015). The most prevalent species detected in the air of a building were *Staphylococcus* spp., *Streptococcus* spp., *Micrococcus* spp. and *Streptomyces* spp. These bacteria are normal human flora, implying that human habitation influences the bacterial communities in indoor air to an extent (Prussin *et al*., 2015).

When skin sheds, certain fungi species associated with human skin can be discharged as bioaerosols. Yeasts associated with the skin such as *Candida*, *Rhodotorula* and *Cryptococcus* have been identified from indoor air, demonstrating that human skin shedding has a significant impact on the fungal concentration in the air (Prussin *et al*., 2015).

With the invention of polymerase chain reaction, researchers were able to investigate individual viruses in the air. The researchers discovered that huge amounts of influenza virus can remain airborne for hours (Prussin *et al*., 2015). This establishes that when a person afflicted with influenza coughs, the virus is likely to remain suspended, and that a healthy person inhaling the same air can acquire influenza injected into their system (Prussin *et al*., 2015).

2.2.2 PETS

Keeping pets indoors can be a significant source of air pollution and this has been connected to the presence of indoor endotoxins (Moldoveanu, 2015). Dogs produce bio-aerosols, which aid in the development of the indoor microbiota. *Porphyromonas* spp*., Moraxella* spp*., Blautia* spp*., Arthrobacter* spp., *Bacteriodes* spp. were shown to be related with dogs indoors, while cats were found to be associated with *Moraxella* spp*., Prevotella* spp. and *Bifidobacterium* spp. (Prussin,2015).

2.2.3 PLUMBING SYSTEMS

Bio-aerosols are abundant in plumbing systems. After flushing, bacteria and viruses have been identified on bathroom surfaces studied, including the toilet wall, toilet seat, flush handle, bathtub, toilet rim, sink, flush handle and cabinet. This meant that microbes released by a toilet flush stayed airborne and alive long enough to spread throughout the bathroom and settle on surfaces (Purssin, 2015). Leakage in plumbing systems, on the other hand, increases the moisture content of indoor air, which is a primary predictor of mold growth (Stetzenbach e*t al*., 2021).

2.2.4 DEBRIS

Dust accounts for up to 60% of total particulate matter in indoor air. Sweeping floors, making beds, dusting clothes, and cleaning furniture can all produce dust. Microorganisms are more likely to be linked with larger carrier particles and as a result of their higher settling velocities, they may be enriched in dust (Prussin, 2015). *Staphylococcus, Corynebacterium, Lactococcus, Firmicutes* and *Actinobacteria* are the most common bacteria discovered in indoor dust. Fungal species found indoors may include outdoor fungi. *Cladosporium* spp*., Saccharomyces* spp*., Aspergillus* spp*., and Penicillium* spp. are among the fungi found indoors

2.2.5 OUTDOOR AIR

Particulate matter can effectively permeate the inside environment from the outside air. Infiltration and natural ventilation bring bio-aerosols indoors. Outdoor air infiltrates the internal environment through holes, seams, and cracks in the walls, ceiling, and flooring. Air travels through opened windows and doors in natural ventilation (EPA, 2021). Because most organisms found outdoors may also be found indoors, microbial communities detected in indoor air were closely similar to those found in outdoor air. *Pseudomonas* spp., *Burkholderiales* spp., *Flavobacteriales* spp. which are normally categorized as outdoor associated microbes, are found in high quantity indoors (Prussin, 2015).

2.2.6 HVAC SYSTEM (HEATING, VENTILATION AND AIR CONDITIONING)

Due to contamination from both indoor and outside air, HVAC systems can be a source of airborne germs. The growth of *Penicillium* spp. is aided by poor HVAC system maintenance. It was also discovered that a legionnaires' disease epidemic was triggered by a *Legionella pneumophila*-infected air conditioning cooling tower (Prussin, 2015).

2.2.7 WATER DAMAGED MATERIALS

Homes that have been flooded have been linked to major respiratory problems. Indoor environments with water damaged materials have a high amount of *Stachybotrys chartarum* a toxigenic mold species (Prussin, 2015).

2.3 MICROORGANISMS ISOLATED FROM INDOOR AIR

Bacteria, mold and yeast are the most common sources of biological contamination in indoor air. They can be toxic as pathogenic live cells, but they can also secrete harmful compounds (Sekulska, 2007). In rare circumstances, viruses have been found to be indoor air pollutants.

The presence of bacteria, fungi, and viruses in the air is due to dispersion from the colonization site (Bertrand, 2015).

2.3.1 BACTERIA ISOLATED FROM INDOOR AIR

Gram positive and negative bacteria have been isolated from indoor air from previous studies. Various genera like *Bacillus, Staphylococcus, Proteus, Corynebacterium, Klebsiella* and *Escherichia coli* are among the bacteria recovered from indoor air (Siebielec *et al*., 2020).

2.3.1.1 *Staphylococcus* spp.

Staphylococci are facultative anaerobic, non-spore-forming, Gram-positive, catalase-positive or negative, non-motile, tiny, spherical bacteria that grow in clusters from pairs to grapes. They're commonly connected with human skin and mucosa, implying that the majority of bacterial contamination in the indoor air comes from people (Hayleeyesus, 2014). Staphylococcus causes infections of the skin, wounds, soft tissues, as well as blood infections, pneumonia, septic, sepsis, arthritis, endocarditis, and osteomyelitis (Kozajda *et al*., 2019).

In a study by Kunwar *et al.* (2019), *Staphylococcus aureus* was found in 47.18 percent of the isolates from indoor air samples. Agwaranze *et al*. (2020) found that 100% of the isolates were *Staphylococcus aureus* and 33% were *Staphylococcus epidermidis*.

2.3.1.2 *Klebsiella* spp.

Klebsiella species are gram negative rods, non-motile, aerobic and facultative anaerobes. They cause human nosocomial infections. In a study by Ayepola *et al.* (2015), on the indoor air of a university health center in Nigeria 15.7% of *Klebsiella* spp. was isolated. In a study the microbiological assessment of indoor air of hospitals were carried out in Dutse, *Klebsiella* species were among the bacteria frequently isolated.

2.3.1.3 *Bacillus*

Bacillus species are endospore-forming, Gram-positive, rod-shaped bacteria found all over the world. *Paenibacillus*, *Brevibacillus*, *Geobacillus* and *Lysinibacillus* are only a few of the *Bacillus* species that have been assigned to other genera. Meningitis, endocarditis, osteomyelitis, and bacteremia are all illnesses caused by *Bacillus* (Tuazon, 2017).

A larger part of these bacteria present in the environment and can be found in dust, soil, garbage and air Most of the time, these microbes predominate in occupied buildings' indoor air since they are widespread in cleanroom microflora. In addition, they can be found in the dust and on any surface. Stress can cause endospores to grow in both plants and animals, which can be extremely hardy and resilient. Hayleeyesus *et al.* (2014) found that *Bacillus* species were among the most common bacteria found in indoor air samples.

2.3.1.4 *Proteus* species

Proteus species are gram negative, rod shaped and facultative anaerobes. They cause infection from the colonized and oral mucosa. They produce endotoxins when invading blood stream, thereby triggering additional host inflammatory response which can result in sepsis (Jamil *et al*., 2022). In a study carried out on the indoor air of banks by Adekunle *et al*. (2019), Proteus species were among the pathogenic bacteria isolated.

2.3.1.5 *Corynebacterium*

Corynebacterium are gram positive, non-spore forming, rod shape and in a study carried out by Aydogdu *et al.* (2005) on the indoor air of primary schools 20.4% of *Corynebacterium* species were detected and it occurred in all the months the study was done. Also a study by Prussin *et al*. (2015) showed high occurrence of *Corynebacterium* in indoor air

2.3.2 FUNGI ISOLATED FROM INDOOR AIR

Aspergillus, penicillium, Alternaria, and *Cladosporium* are among the fungi having a high incidence in indoor air. Many volatile chemicals produced by fungal metabolism can cause sensory discomfort in the eyes and upper respiratory.

2.3.2.1 *Aspergillus*

Aspergillus is a type of filamentous fungus that thrives as a saprophyte in soil, rotting vegetation, seeds, and grains. Respiratory problems have been connected to microbial growth in moisture-damaged buildings and the presence of the mycotoxin-producing fungus Aspergillus (Mousavi, 2016). *Aspergillus fumigatus, Aspergillus versicolor,* and *Aspergillus flavus* are *Aspergillus* species that can thrive indoors and cause allergic broncho-pulmonary aspergillosis (ABPA), nosocomial infections and sinusitis. Aspergillus species produces the aflatoxins which is associated with toxicity and carcinogenicity in humans. Aflatoxin consumption causes aflatoxicoses (Kumar *et al*., 2015).

According to Verde *et al.* (2015), *Aspergillus* isolates comprised about 24% of the isolates. In another investigation, 86.2 % of *Aspergillus* was identified from an indoor air sample by Shittu *et al.* (2019).

2.3.2.2 *Cladosporium*

Cladosporium is a fungus genus that includes a number of common indoor and outdoor molds. The species has dark mycelia that ranges in hue from brown to blackish-brown to gray-green (Sandoval-Denis, 2015). Skin rashes, keratitis, onychomycosis, sinusitis, and pulmonary infections are all caused by *Cladosporium* species. Segers *et al.* (2015) isolated 44.7 % of *Cladosporium sphaerospermum* species, 33.3% of *Cladosporium cladosporioides* species,

and 22.0 % of *Cladosporium herbarum* species in a study on the predominance of *Cladosporium* species on interior surfaces.

2.3.2.3 *Alternaria*

Carpets, wallpaper, fabrics, window frames, and air conditioning systems all contain *Alternaria* spp. The Pleosporaceae family includes the *Alternaria* genus, which is one of the most important allergenic fungi. *Alternaria* species produce spores that are club-shaped, multicellular, septate, and produced in single or branched chains on conidiophores that are typically short and erect. *Alternaria* exposure has been identified as a risk factor for the onset, persistence, and severity of asthma (Grewling, 2019). Salon *et al.* (2007) found that houses in the United States of America were exposed to *Alternaria* with 4.3ug/g of *Alternaria* present.

2.3.2.4 *Penicillium*

The most prevalent mold found in homes is *Penicillium* (Reboux,2019). *Penicillium* is a large genus of ascomycetous fungi that contains over 350 species. Even though the relative humidity is low, there is a chance that *Penicillium* will grow if there is enough moisture available on a specific surface inside. It produces ochratoxin, a mycotoxin that damages the kidneys and is also carcinogenic. In a study by Teaf *et al.* (2012), it was discovered that the majority of *Penicillium* growth occurred indoors.

2.3.3 VIRUSES DETECTED IN INDOOR AIR

Viruses are spread via air droplets, aerosols, and fomites that come into contact with the conjunctival and nasal epithelium. Parainfluenza viruses 1, 2, 3, and 4, Influenza viruses A and B, rhinoviruses/enteroviruses, adenovirus and respiratory syncytial virus are among the etiological viral agents implicated (Paba *et al*., 2014). Respiratory syncytial virus, rhinovirus, metapneumovirus, influenza and parainfluenza viruses, and human enterovirus infections

have all been linked to virus-induced asthma, which can progress to diseases like pneumonia, according to studies. Adenovirus was the first virus isolated from indoor aerosol in 1966, when samples were collected from the quarters of military recruits suffering from Acute Respiratory Disease (type 4) (Ronald, 2007).

2.3.3.1 Rhinovirus

Rhinovirus (RV) is a Picornaviridae virus, which means it's a tiny RNA virus. More than 100 immunologically different serotypes have been identified, with more being discovered all the time. This virus causes more than half of all instances of the common cold and has the highest morbidity rate among respiratory viruses. Bronchitis is caused by the rhinovirus in youngsters (Ronald, 2007). Human rhinovirus was discovered in the indoor air of a room utilizing an MD8 air scan in a recent investigation.

2.3.3.2 Respiratory syncytial virus

The respiratory syncytial virus (RSV) is a single-stranded RNA virus that belongs to the Paramixoviridae family of viruses. RSV infections is present worldwide, and outbreaks are widespread in temperate climates during the cold season and in tropical settings during the rainy season. Is one of the most prevalent viruses, capable of causing a type of potentially fatal pneumonia in the elderly and a major source of respiratory illness in youngsters (Tsukagoshi *et al*., 2013). It is spread through the inhalation of droplets produced by sneezing or coughing.

2.3.3.3 Influenza virus

Three antigenic serotypes of influenza A, B, and C are RNA viruses that belong to the Orthomyxoviridae family. An acute fever with symptoms ranging from mild exhaustion to respiratory failure and death can be caused by it (Ronald, 2007). While coughing and

sneezing can spread the flu virus, airborne droplet nuclei can do the same (La Rosa *et al*., 2013).

2.4 FACTORS INFLUENCING THE PRESENCE OF INDOOR AIR CONTAMINANTS

The situations that lead to the presence of indoor air contaminants in the indoor environment are referred to as factors. The elements are listed below:

2.4.1 OCCUPANCY

This refers to the number of people who live in an interior setting, as well as the type and intensity of their activities. Human actions such as sweeping, making beds, cleaning furniture, and dusting clothes produce particle pollutants (Tsakas *et al*., 2011).

2.4.2 VENTILATION

Appropriate indoor air quality and a healthy indoor environment are created by proper ventilation. Providing oxygen and fresh air for human respiration, creating correct air distribution, and encouraging a healthy and comfortable environment are all advantages of ventilation in a building. Mechanical and natural ventilation systems can be used to ventilate the indoor environment. Fans and air conditioning systems are examples of mechanical ventilation in the indoor environment, whereas natural ventilation is the process of exchanging indoor and outdoor air without the need of mechanical equipment (Vinh *et al*., 2020).

2.4.3 WEATHER CONDITION

Weather conditions determine whether people keep windows open or closed in their homes, as well as whether they use air conditioners, humidifiers, or heaters (EPA, 2021). The ability

of microorganisms to be airborne is determined by weather factors such as relative humidity and temperature. The presence of mold signifies a high relative humidity level in the indoor environment (Srikanth *et al*., 2008). Humidity was found to be the most important factor determining the variety of airborne bacteria and dangerous bacteria in a study (Siebielec *et al*., 2020).

2.4.4 BUILDING STRUCTURE

The foundations, floors, walls, roofs, claddings, and sheathing make up the building structure. Building height is important because it enhances the stack effect, or updraught, and exposes the building to higher speed of wind, which increases the rate of infiltration in the inside environment (Tsakas *et al*., 2011).

2.4.5 LEAKAGES

The rate of infiltration is increased by leakage gaps in buildings such as walls, windows and doors, sill plates, electric outlets, and plumbing systems (Tsakas *et al*.,2011). Leakage increases the amount of moisture in the indoor environment. Moisture is the primary predictor of mold growth indoors, and a lack of effective maintenance practices in the interior environment can lead to moisture buildups, which can lead to increased levels of bio aerosols if left unattended. Structures that are more prone to water intrusion are the result of a lack of understanding of moisture dynamics and negligent building design and construction (Stetzenbach, 2021).

2.5 THE HEALTH CONSEQUENCES OF INDOOR AIR POLLUTION

In humans, poor indoor air quality can have negative consequences that might be long-term or minor. The following are some of the negative impacts of indoor air pollution on human health.

2.5.1 THE EFFECTS OF INDOOR AIR CONTAMINATION TO HUMAN HEALTH

Building-related illnesses are illnesses that are caused directly by air quality issues and a poor indoor environment (Johnson, 2019). Various symptoms and illnesses have been linked to poor indoor air quality in buildings and homes over the years. Building-related illness is any ailment induced by indoor environmental conditions (WHO, 2010). Building related illness and Sick building syndrome are the common types of illnesses associated with buildings.

2.5.1.1 SICK BUILDING SYNDROME

The term "sick building syndrome" refers to a condition in which the residents of a building suffer from acute health problems that appear to be linked to their time spent there (Sumedha, 2008). Mucous membrane irritation, such as throat and nose irritation, and neurotoxic consequences, such as irritability, headaches, and exhaustion, are sick building symptoms produced by indoor air pollution. Asthma and asthma-like symptoms, skin irritation and dryness, and gastrointestinal issues such as diarrhea are some of the other symptoms (Vinh *et al*., 2020). Sick building syndrome lowers productivity and raises absenteeism.

2.5.1.2 BUILDING-RELATED DISEASES

Building-related sickness refers to illnesses and symptoms that have a known causal factor and are linked to poor indoor air quality (Vinh *et al*., 2020). Cough, chest pain, nosebleeds shortness of breath with light effort, cough, palpitations, oedema, and pregnancy issues are all symptoms of building-related disorders. Legionnaire's disease, extrinsic allergic alveolitis, pneumonia and humidifier fever, are all possible side effects (WHO,2010). Humidifier fever is caused by inhaling droplets of water infected with bacteria from humidifiers. Legionnaire's disease is caused by legionella organisms contaminating cooling towers. Pontiac fever, which affects young, healthy adults, is also caused by Legionella (Sumedha, 2008).

2.5.2 RESPIRATORY INFECTION (ACUTE)

Most indoor air contaminants target the upper respiratory system because toxins enter the human body through inhalation. Upper respiratory infections are infections of the upper respiratory tract that cause symptoms such as cough, sinusitis, and otitis media, and are usually mild (Vinh *et al*., 2020). The majority of respiratory infections are caused by viruses, with *Haemophilus influenzae* type b being the most common cause of severe cases. *Streptococcus pyogenes*, which causes bacterial pharyngitis, enters the respiratory tract through inhalation of droplets and invades the mucosa (Dasaraju, 2021).

2.5.3 PULMONARY INFECTIONS

Bio aerosols generate significant inflammatory reactions, immunological dysfunction, and chronic inflammation, all of which contribute to chronic obstructive pulmonary disease (COPD) (Vinh *et al*., 2020). Aspergillosis, a mold-borne infection, causes both minor and severe lung infections, as well as underlying lung disorders (Mayoclinic,2022).

2.6 ANTIBIOTICS RESISTANCE OF MICROORGANISMS ISOLATED FROM INDOOR AIR

Antibiotics resistance occurs when a drug does not have any effect on the growth or metabolism of bacteria. Resistance in bacteria can be caused by various factors like production of enzymes, impermeability of drug into bacteria membrane, efflux system, mutation, and acquired resistance (Douglas, 2017). The development of resistance to many antibiotics by *S. aureus* has involved acquisition of determinants by horizontal gene transfer of mobile genetic elements. According to studies, penicillins and cephalosporins are among the regularly prescribed antibiotics. The case of prescribing the drugs often had led to increased resistance of bacteria to these antibiotics (Azuonwu *et al*., 2019). High level of

antibiotic resistance has been made possible through means like acquisition of plasmids. Acquired resistance is a type of plasmid-mediated resistance. Through plasmid-mediated transduction, transformation, and insertion of drug-resistant genes, excessive β-lactamase can be produced, leading to bacteria resistance. The mechanism of MRSA resistance is mainly because plasmids, or drug-resistant gene transmission mediated by plasmids, which can expand the genome and resistance genes can be transferred between *Staphylococcus aureus* and other bacteria (Lin *et al*., 2015). For example, MRSA can obtain drug-resistant plasmids from *Enterococcus*, further expanding and enhancing its resistance. Approximately 20% of *Klebsiella pneumoniae* infections in intensive care units in the United States now involve strains not susceptible to third-generation cephalosporins. Such resistance in *Klebsiella pneumoniae* to third-generation cephalosporins is typically caused by the acquisition of plasmids containing genes that encode for extended-spectrum beta-lactamases and these plasmids often carry other resistance genes as well. ESBL-producing *Klebsiella pneumoniae* and *Escherichia coli* are now relatively common in healthcare settings and often exhibit multidrug resistance (Schmidt *et al.,* 2015).

CHAPTER THREE

MATERIALS AND METHODS

3.1 EQUIPMENT AND APPARATUS USED

Materials used in this study include cotton wool, polythene bags, petri-dishes, foil paper, glass slides, permanent marker, hand gloves, filter paper, masking tape and sensitivity disc (Abtek Biological Ltd England, June 2023).

Equipment and apparatus used includes autoclave, incubator, water bath, weighing balance, beaker, conical flasks, spirit lamp, conical flasks, beaker, wire loop, glass slide, measuring cylinder, test tubes, measuring cylinder, wire loop, spirit lamp, beaker, and microscope.

3.2 MICROBIOLOGICAL MEDIA

The media employed in this study were Nutrient agar (HiMedia Laboratories Pvt Ltd, February 2025), Mannitol salt agar (HiMedia Laboratories Pvt Ltd, December 2025), citrate agar (HiMedia Laboratories Pvt Ltd, August 2023), urease agar (HiMedia Laboratories Pvt Ltd, February 2025) and Mueller-Hinton agar (HiMedia Laboratories Pvt Ltd, September 2024).

3.3 REAGENTS AND CHEMICALS

In this study, the following chemicals were used Gram iodine, crystal violet, phenyl red, glucose, sucrose, galactose, maltose, Safranin, blood plasma, peptone water, acetone-alcohol, hydrogen peroxide, normal saline and Potassium hydroxide.

3.4 STUDY AREA

The study area is Caleb University, Lagos. It is located at Itoikin-Imota Lagos, Nigeria. The study was carried out in rooms in the female hostels. The two hostels are located close to

each other. There are two floors at hall A and hall B, air samples were taken from nine rooms of each hall. The samples from hall A were gathered from room A1, A8, A6, A9, A3, A5, A7, A4 and A10 and samples were taken from room B1, B3, B5, B9, B7, B4, B8, B2 and B3.

3.5 SAMPLE COLLECTION

Indoor air samples were taken using the settle plate technique with petri dishes containing various culture conditions. This method was used in previous study done by (Adekunle *et al*., 2018). In each room, the Petri dishes with solidified media were held up for fifteen minutes and thereafter closed.

3.6 BACTERIAL ISOLATION AND IDENTIFICATION

The exposed plates were brought to Caleb University microbiology laboratory and incubated for 24 hours in an inverted position at 37°C, according to Kunwar *et al*. (2019). Distinct colonies on plates were collected and streaked on freshly prepared sterile nutrient agar after 24 hours of incubation. According to Williams *et al*. (2019) this was done to obtain pure bacterial isolates.

3.6.1 IDENTIFICATION OF ISOLATES

Bacterial colonies were identified using morphological, cultural, biochemical and microscopic studies. The results were compared according to Bergey's Manual of Systematic Bacteriology as described by Adekunle *et al*., (2018).

3.6.1.1 MORPHOLOGICAL CHARACTERIZATION

The shape, color, texture, elevation, and colony margin were among the morphological features utilized for identification.

3.6.1.2 Gram Staining

Gram's staining is performed on bacterial isolates in order to determine their gram type. Twenty-four hours old isolates were being smeared over a clean, grease-free slide and heat fixed. After being saturated with crystal violet for one minute and rinsed with distilled water twice more, iodine was added as a mordant and washed off after 30 secs. They were decolorized with acetone for 15 seconds before being rinsed with distilled water. Finally, safranin was administered for a minute before being rinsed and properly dried. A drop of oil immersion was placed on a glass slide, and the slide was studied under a light microscope with an x100 magnification objective lens. Gram reaction and cell shape were established by utilizing a purple hue to represent Gram positive organisms and a pink or red color to represent Gram negative organisms.

3.6.1.3 Biochemical Test

Following Gram staining of the colonies, biochemical tests such as sugar fermentation test, urease test, potassium hydroxide test, catalase, citrate and motility tests were carried out on the microorganisms.

3.6.1.3.1 Catalase Test

This test is used to demonstrate the presence of catalase, an enzyme that causes the release of oxygen form hydrogen peroxide. It differentiates catalase enzyme producing bacteria from non-catalase producing bacteria. A small colony of bacteria was placed on a glass slide and

3% of hydrogen peroxide was added. Formation of bubbles indicated catalase positive organisms and the absence of bubbles indicates catalase negative organisms.

3.6.1.3.2 KOH Test

The KOH test relies on organism's differential resistance to 3% potassium hydroxide and this test differentiates gram positive from gram negative organisms. A drop of 3% potassium hydroxide was placed on a clean glass slide, colonies from a pure isolate were dropped on the KOH solution and stirred for about a minute. The formation of a thick, stingy long strands organisms within the first 30 seconds indicates gram negative organisms while the absence indicates gram positive organism.

3.6.1.3.3 Coagulase Test

Coagulase test is used to differentiate *Staphylococcus aureus* strains from *Staphylococcus epidermidis*. *Staphylococcus aureus* strains are capable of coagulating plasma in test tubes and produce clumps in the slide test. The slide test was done in this study. The pure bacteria cell was mixed into a drop of EDTA treated human plasma on a glass slide. Positive results were indicated by agglutination/clumping.

3.6.1.3.4 Urease Test

The urease test identifies those organisms that are capable of hydrolyzing urea to produce ammonia and carbon dioxide. Christensen's urea agar was prepared and dispensed in a sterile Bijou bottle which was made to slant. Pure bacteria colonies were then picked and inoculated on the slant. Urease production was indicated by a bright pink (fuchsia) color on the slant after 1-6 hours of incubation.

3.6.1.3.5 Citrate Test

The citrate test screens bacteria isolates for the ability to utilize citrate as its carbon and energy source. The citrate medium was prepared following the manufacturer's directions.

Pure colony of bacteria isolate was picked and streaked on the media with a sterile inoculating needle. After inoculation, the tubes were incubated at 35 ^{0}C for 48 hours. Positive results showed color change from green to blue.

3.6.1.3.6 Motility Test

This is to test for the ability of bacteria to move. Half strength nutrient agar was prepared in sterile test tubes. A sterile needle was used to pick a pure colony and stab the medium to within 1cm of the bottom of the tube. This was done carefully by making sure the needle is removed in the same line as it entered. After inoculation, the tubes were incubated at 35 ^{0}C for 24hours - 48hours. A positive result showed turbidity from the line of inoculation.

3.6.1.3.7 Sugar Fermentation Test

The sugar fermentation test was done to identify bacteria based on the ability to utilize sugars. In this study maltose, galactose, glucose, sucrose where the sugars used. For glucose the sugar medium was prepared and dispensed in sterile tubes, Durham tubes were then placed in an inverted position. Pure colonies of isolate were picked and inoculated into the tubes and incubated for 24 hours at 35 ^{0}C. For the glucose test, gas production and color change were observed for positive results. Positive results showed color change of the media.

3.6.1.4 ANTIMICROBIAL SUSCEPTIBILITY TEST

This study employed the disc diffusion approach according to Williams *et al*. (2020) whereby pure colonies of bacterial isolates were selected and put in test tubes containing 4 ml of sterile distilled water, which were then incubated overnight. It was necessary to standardize the turbidity of bacterial isolates by utilizing the McFarland standard that had already been produced. Muller-Hinton agar plates were made and swabbed horizontally and vertically with standardized bacterial isolates in duplicates on their surfaces. The plates were allowed to sit

for 5 mins after which discs containing antibiotics were applied to the surface of Muller-Hinton agar plates using sterile forceps. Incubation was carried out for 18-24 hours at 37 ^{0}C. A ruler graduated in millimeters (mm) was used to measure the observable zones of inhibition, which were then categorized as resistant, intermediate, and susceptible. The antibiotics used were Erythromycin (15 ug), Gentamicin (15ug), Augmentin (30ug), Ofloxacin (5ug), Cefuroxime (30ug), Ceftriaxone (30ug) and Oxacillin (5ug).

CHAPTER FOUR

RESULTS

This study was carried out to determine the indoor air quality of rooms in female hostels in Caleb University. The results of this study are presented using tables and figures.

Microbial CFU/M3 of indoor air of the rooms sampled in Hall A. Room A3 had the highest microbial CFU/M3 of indoor air which is $1.73x10^3$ microbial CFU/M^3 of indoor air. Room A7 had the lowest microbial CFU/M3 of indoor air which is $2.09x10^2$ microbial CFU/M^3 of indoor air (Table 4.1).

Microbial CFU/M^3 of indoor air of the rooms sampled in hall B. Room B3 had the highest microbial CFU/M^3 of indoor air which is $1.1\ x10^3$ microbial CFU/M^3 of indoor air. Room B8, B5 and B7 had the lowest microbial CFU/M^3 of indoor air which is $4.71x10^2$ microbial CFU/M^3 of indoor air (Table 4.2).

Colonial morphology such as shape, size, colour, texture, margin, transparency of the isolates from nutrient agar (Table 4.3).

Biochemical characteristics of the isolated bacteria collected on nutrient agar from indoor air of the rooms in Caleb university female hostel. The biochemical test in the table includes the catalase test, glucose, sucrose, maltose, galactose fermentation test, KOH test, urease test, citrate test and motility test (Table 4.4).

Colonial morphology and biochemical characteristics of the isolated bacteria collected on mannitol salt agar from indoor air of the rooms in Caleb university female hostel (Table 4.5).

Antibiotics susceptibility of the bacteria isolates of nutrient agar in each room. The antibiotics used were Erythromycin 15 µg, Gentamicin 15µg, Aµgmentin 30µg, Ofloxacin 5µg, Cefuroxime 30µg, Ceftriaxone 30µg (Table 4.6).

Percentage of isolates susceptible, intermediate or resistant to a particular antibiotic. 100% of the isolates were resistant to Augmentin. 14.3% of the isolates were intermediate to erythromycin while 85.7% were resistant. 88.6% of the isolates were sensitive to ofloxacin while 11.4% were intermediate. 20% of the isolates were resistant to gentamicin, 25.7% were susceptible while 54.3% were intermediate. 100% of the isolates were resistant to cefuroxime. 2.9% of the isolates were intermediate to Ceftriaxone while 97.1% were resistant (Table 4.7).

Antibiotics susceptibility of the bacteria isolates of mannitol salt agar. Oxacillin antibiotic disc were used for the isolates on the mannitol salt agar (Table 4.8).

Table 4.1: Colony forming units of rooms in hall A

Hall A rooms	Microbial CFU/M^3 of indoor air
A1	$1.048x10^3$
A8	$1.31x10^3$
A6	$1.1x10^3$
A9	$8.9x10^2$
A3	$1.73x10^3$
A5	$1.57x10^3$
A7	$2.09x10^2$
A4	$1.15x10^3$
A10	$6.29x10^2$

Table 4.2: Colony forming units of rooms in hall B

Hall B rooms	Microbial CFU/M^3 of indoor air
B1	$7.34x10^2$
B3	$1.1\ x10^3$
B5	$4.71x10^2$
B9	$7.34x10^2$
B7	$4.71x10^2$
B4	$8.91x10^2$
B8	$4.71x10^2$
B2	$6.81x10^2$
B3	$6.81x10^2$

TABLE 4.3: COLONIAL MORPHOLOGY OF ISOLATES FROM NUTRIENT AGAR

SHAPE	SIZE	COLOUR	Texture	MARGIN	TRANSPARENCY	PROBALE ORGANISMS
Flat	Medium	White	Dry	Irregular	Opaque	*Bacillus* sp.
Round	Small	White /Golden yellow	Moist	Entire	Opaque	*Staphylococcus* sp.
Round	Large	White	Moist	Entire	Opaque	*Escherichia coli*
Irregular	Medium	White	Dry	Wavy	Opaque	*Proteus* sp.
Round	Small	Grey white	Mucoid	Entire	Opaque	Klebsiella sp.
Round	Small	Grey	Dry	Wavy	Opaque	*Corynebacterium* sp.

Table 4.4: Biochemical characteristics of the isolates from Nutrient agar

Gram staining	Catalase	KOH	Urease	Citrate	Motility	Galactose	Glucose	Sucrose	maltose	Probable organisms
+Rod	+	-	-	+	+	-	+	+	+	*Bacillus* sp.
+Rod	+	-	-	-	-	+	+	-	+	*Corynebacterium* sp.
-Rod	+	+	+	+	+	+	+	-	+	*Proteus* sp.
-Rod	+	+	-	-	+	+	+	+	+	*Escherichia coli*
-Rod	+	+	+	+	-	+	+	+	+	*Klebsiella* sp.

Table 4.5: Colonial morphology and biochemical characteristics of isolates on mannitol salt agar

Isolate code	Colony morphology	Gram stain	Catalase	Urease	Citrate	Motility	KOH	Glucose	Sucrose	Maltose	Galactose	Probable organism
R8A	Small, mucoid, golden yellow, convex, round, entire, opaque	+ Cocci	+	+	+	-	-	+	+	+	+	*Staphylococcus aureus*
R8B	Small, pink, mucoid, convex, round, entire, opaque	+ Cocci	+	+	-	-	-	+	+	+	+	*Staphylococcus epidermidis*
R9A	Small, mucoid, golden yellow,convex,round,entire,opaque	+ Cocci	+	+	+	-	-	+	+	+	+	*Staphylococcus aureus*
R9B	Small,pink, mucoid, convex, round, entire,opaque	+ Cocci	+	+	-	-	-	+	+	+	+	*Staphylococcus epidermidis*
M10A	Small,mucoid,golden yellow,convex,round,entire,opaque	+ Cocci	+	+	+	-	-	+	+	+	+	*Staphylococcus aureus*

M10B	Small,pink, mucoid, convex, round, entire,opaque	+ Cocci	+	+	-	-	-	+	+	+	+	*Staphylococcus epidermidis*
M4A	Small,mucoid,golden yellow,convex,round,entire,opaque	+ Cocci	+	+	+	-	-	+	+	+	+	*Staphylococcus aureus*
M4B	Small,pink, mucoid, convex, round, entire,opaque	+ Cocci	+	+	-	-	-	+	+	+	+	*Staphylococcus epidermidis*
R2A	Small,mucoid,golden yellow,convex,round,entire,opaque	+ Cocci	+	+	+	-	-	+	+	+	+	*Staphylococcus aureus*
R2B	Small,pink, mucoid, convex, round, entire,opaque	+ Cocci	+	+	-	-	-	+	+	+	+	*Staphylococcus epidermidis*
R3A	Small,mucoid,golden	+	+	+	+	-	-	+	+	+	+	*Staphylococc*

	yellow,convex,round,entire,opaque	Cocci											*us aureus*
R3B	Small,pink, mucoid, convex, round, entire,opaque	+ Cocci	+	+	-	-	-	+	+	+	+		*Staphylococcus epidermidis*
M7A	Small,mucoid,golden yellow,convex,round,entire,opaque	+ Cocci	+	+	+	-	-	+	+	+	+		*Staphylococcus aureus*

Table 4.6: Antibiotics susceptibility of isolates on nutrient agar

ISOLATE CODE	AUGMENTIN	ERYTHROMYCIN	OFLOXACIN	GENTAMICIN	CEFUROXIME	CEFTRIAXONE	ORGANISMS
M5B	Resistant	Intermediate	Interme diate	Resistant	Resistant	Resistant	*Staphyloc ocus epidermid is*
R1D	Resistant	Resistant	susceptible	Resistant	Resistant	Resistant	*Bacillus* spp.
R1B	Resistant	Resistant	susceptible	Resistant	Resistant	Resistant	*Proteus* spp.
R3A	Resistant	Resistant	susceptible	Resistant	Resistant	Resistant	*Esherichi a coli*
R3B	Resistant	Resistant	susceptible	Resistant	Resistant	Resistant	*Klebsiella* spp.
R3C	Resistant	Intermediate	susceptible	susceptible	Resistant	Intermediate	*Bacillus* spp.
M8B	Resistant	Resistant	susceptible	Intermediate	Resistant	Resistant	*Bacillus* spp.
M1A	Resistant	Resistant	suscepti	Intermed	Resistant	Resistant	*Escherich*

			ble	iate			*ia coli*
M3A	Resistant	Resistant	suscepti ble	susceptib le	Resistant	Resistant	*Staphyloc occus aureus*
M3B	Resistant	Intermediat e	Interme diate	susceptib le	Resistant		*Escherich ia coli*
M8A	Resistant	Resistant	suscepti ble	Resistant	Resistant	Resistant	*Klebsiella* spp.
M9B	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Coryneba cterium* spp.
R4A	Resistant	Resistant	suscepti ble	susceptib le	Resistant	Resistant	*Bacillus* spp.
M6B	Resistant	Resistant	suscepti ble	susceptib le	Resistant	Resistant	*Bacillus* spp.
M1C	Resistant	Resistant	Interme diate	susceptib le	Resistant	Resistant	*Bacilluus* spp.
M9A	Resistant	Intermediat e	suscepti ble	susceptib le	Resistant	Resistant	*Klebsiiell a* spp.

M1B	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Klebsiella* spp.
M1D	Resistant	Intermediat e	suscepti ble	Intermed iate	Resistant	Resistant	*Staphyloc occus aureus*
M3C	Resistant	Resistant	suscepti ble	Resistant	Resistant	Resistant	*Bacillus* spp.
M5C	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Bacillus* spp.
R5C	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Escherich ia coli*
M9C	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Escherich ia coli*
R4D	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Escherich ia coli*
M6C	Resistant	Resistant	suscepti ble	susceptib	Resistant	Resistant	*Escherich*

				le			*ia coli*
R5C	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Escherich ia coli*
R1C	Resistant	Resistant	suscepti ble	susceptib le	Resistant	Resistant	*Escherich ia coli*
M5D	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Escherich ia coli*
R4C	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Klebsiella* spp.
R7A	Resistant	Resistant	Susc eptible	Intermed iate	Resistant	Resistant	*Klebsiella* spp.
R7B	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Coryneba cterium* spp.
M6A	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Coryneba cterium* spp.
R9C	Resistant	Resistant	suscepti ble	Intermed	Resistant	Resistant	*Coryneba*

				iate			*cterium* spp.
R5B	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	Proteus spp.
R9B	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Proteus* spp.
M5E	Resistant	Resistant	suscepti ble	Intermed iate	Resistant	Resistant	*Proteus* spp.

Table 4.7: Percentage of isolates susceptible, intermediate and resistant to antibiotics

Antibiotics	Susceptible	Intermediate	Resistant
Augmentin	0%	0%	100%
Erythromycin	0%	14.3%	85.7%
Ofloxacin	88.6%	11.4%	0%
Gentamicin	25.7%	54.3%	20%
Cefuroxime	0%	0%	100%
Ceftriaxone	0%	2.9%	97.1%

Table 4.8: Antibiotic susceptibility of isolates mannitol agar

ISOLATE LABEL	SUSCEEPTIBLE/RESISTANT
R8A	Resistant
R8B	Susceptible
R9A	Resistant
M10B	Resistant
R2A	Resistant
R3B	Resistant
M10A	Resistant
M7	Resistant
M4A	Resistant
R9B	Resistant
R3A	Resistant
R2B	Resistant
M4B	Resistant

Percentage of each bacteria isolates on plate Nutrient agar from different rooms of the female hostel where sample collection took place. Room R5 had the highest percentage of *Escherichia coli* which is 77.8% and room M8 and R7 had no *Escherichia coli* growth. Room M6 had the highest percentage of *Bacillus* species which is 38.1% and room M9, R7, R5, R9 had no *Bacillus* species growth. Room R1 had the highest percentage of *Proteus* species which is 57.2% and room M1, M8, R3 had no *Proteus* species growth. Room R7 had the highest percentage of *Corynebacterium* species which is 22.2% and room M1, M8, R1, R5, R4, M3, M5, R3 had no *Corynebacterium* species growth. Room M8 had the highest percentage of *Klebsiella* species which is 80% and room R1, R5, R4, M3, M5, R9 had no *Klebsiella* species growth. Room M1 and M3 had the highest growth of *Staphylococcus aureus* which is 35% and 30.3% respectively while the remaining rooms had no *Staphylococcus aureus* growth. Room M5 had the highest growth of *Staphylococcus epidermidis* which is 33.3% while the remaining rooms had no *Staphylococcus epidermidis* growth (Figure 4.1).

Percentage of bacteria isolates on Nutrient agar in the whole study. *Escherichia coli* percentage in the study was 37%, *Klebsiella* species percentage in the study was 19%, *Bacillus* species was 18%, *Proteus* species was 10%, *Corynebacterium* species was 5%, *Staphylococcus aureus* was 7% and *Staphylococcus epidermidis* was 4% (Figure 4.2).

Room R3 had *Staphylococcus aureus* 84.6% and *Staphylococcus epidermidis* 15.4%. Room M7 had *Staphylococcus aureus* 100% and *Staphylococcus epidermidis* 0% Room R2 had *Staphylococcus aureus* 69.2% and *Staphylococcus epidermidis* 30.8%. Room M4 had *Staphylococcus aureus* 45.5% and *Staphylococcus epidermidis* 54.5%.. Room M1 ;0 had *Staphylococcus aureus* 83.3% and *Staphylococcus epidermidis* 16.7%. Room R9 had *Staphylococcus aureus* 77.8% and *Staphylococcus epidermidis* 22.2%. Room R8 had *Staphylococcus aureus* 55.6% and *Staphylococcus epidermidis* 44.4%. Room M7 had the

highest percentage of *Staphylococcus aureus* which is 100% and room M4 had the lowest percentage which is 45.5%. Room M4 has the highest percentage of *Staphylococcus epidermidis* which is 54.5% and room R3 had the lowest percentage which is 15.4% (Figure 4.3).

Staphylococcus aureus had 64% in the study while *Staphylococcus epidermidis* had 36.6% (Figure 4.4).

The percentage of isolates susceptible, intermediate and resistant to augmentin, erythromycin, ofloxacin, gentamicin, cefuroxime and ceftriaxone are shown in (Figure 4.5).

Percentage of the isolates on mannitol salt agar susceptible or resistant to oxacillin records 92.3% of the isolates were resistant to oxacillin while 7.7% of the isolates were susceptible to oxacillin (Figure 4.6)

Questionnaire responses from room occupants on the number of students in the room is shown. 66.7% of the responses were 6 students in a room, 11.1% responses were 4 in a room and 11.1% of the responses were 7 students in a room ((Figure 4.7) .

Age range of room occupants. 66.7% of room occupants ranged from age 19-21, 11.1% were above 21, 22.2% were 16 -18 (Figure 4.8)

Rooms condition. 5.6% of rooms had septic smell, 38.9% had mould odour, 11.1% had dryness, 44.4% had crowding, 55.6% had noise, 16.7% had dust, 55.6% had stuffy air, 88.9% had hot temperature (Figure 4.9).

The use of chemicals, contact lens and smoking activity of room occupants. 88.9% do not use chemicals, contact lens or smoke. 11.1% make use of contact lens (Figure 4.10) .

Health conditions diagnosed with since occupancy of the hostels room. 16.7% were diagnosed with asthma, 83.3% were diagnosed with other health conditions (Figure 4.11) .

Symptoms experienced by occupants since stay in room. 11.1% experienced no symptoms, 72.2% experienced headache, 16.7% sore throat, 16.7% shortness of breath, 33.3% nasal congestion, 38.9% migraines, 11.1% wheezing, 44.4% irritated eyes, 39.9% sneezing (Figure 4.12).

Responses if symptoms disappear after 1 hour of leaving the room. 50% of the occupant said no, 27.8% said yes and 22.2% did not respond (Figure 4.13).

Responses gotten if there is evidence of leakage or moisture in the room (Figure 4.14) .

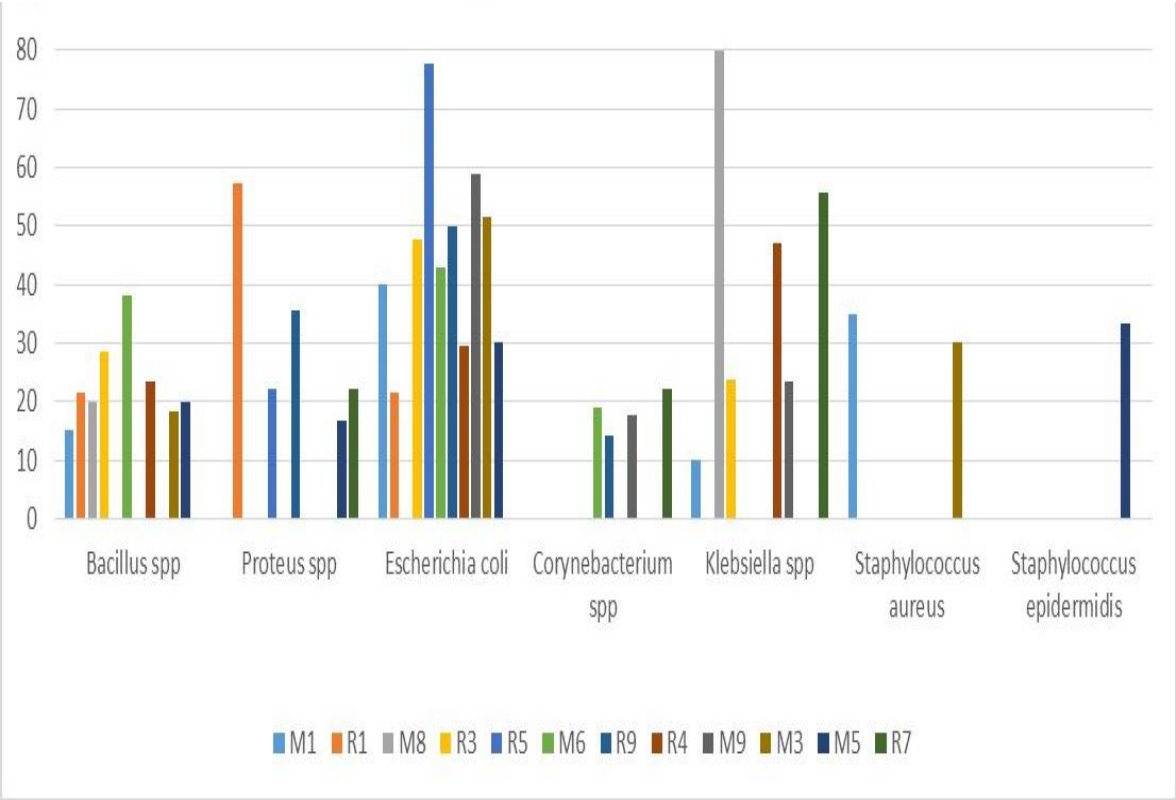

Figure 4.1 Percentage of isolates on Nutrient agar of each room.

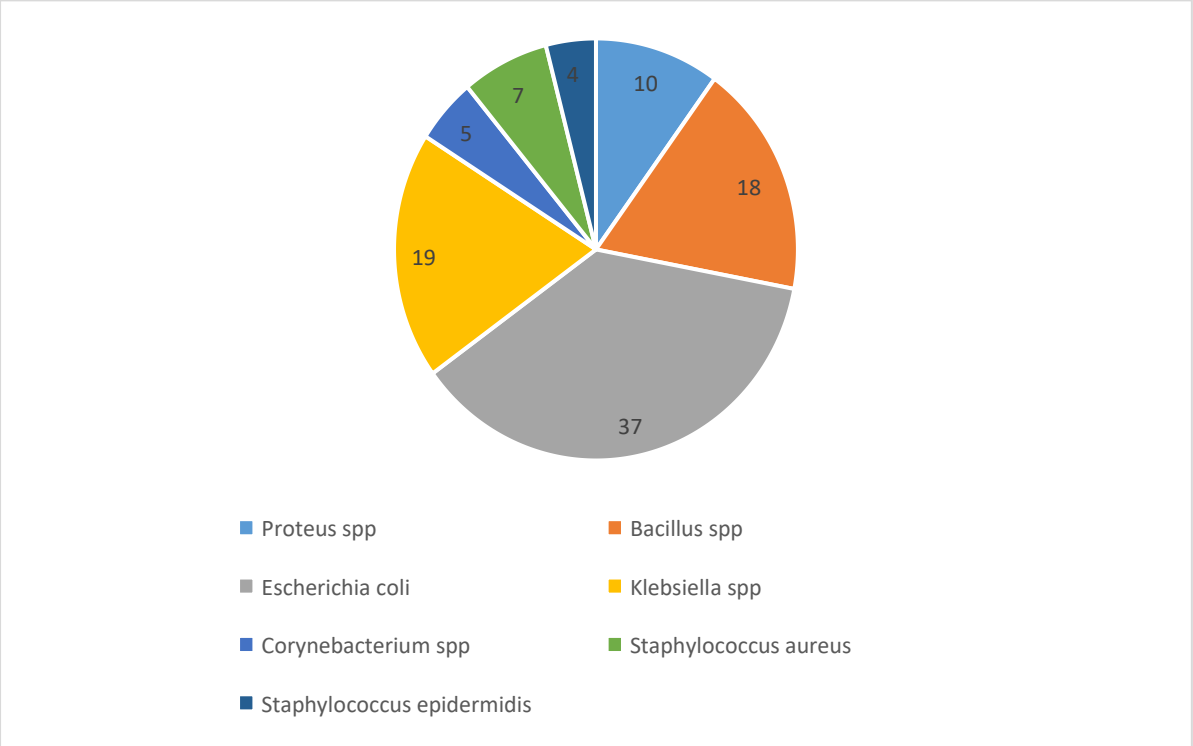

Figure 4.2: Percentage of bacteria isolates on Nutrient agar in the study.

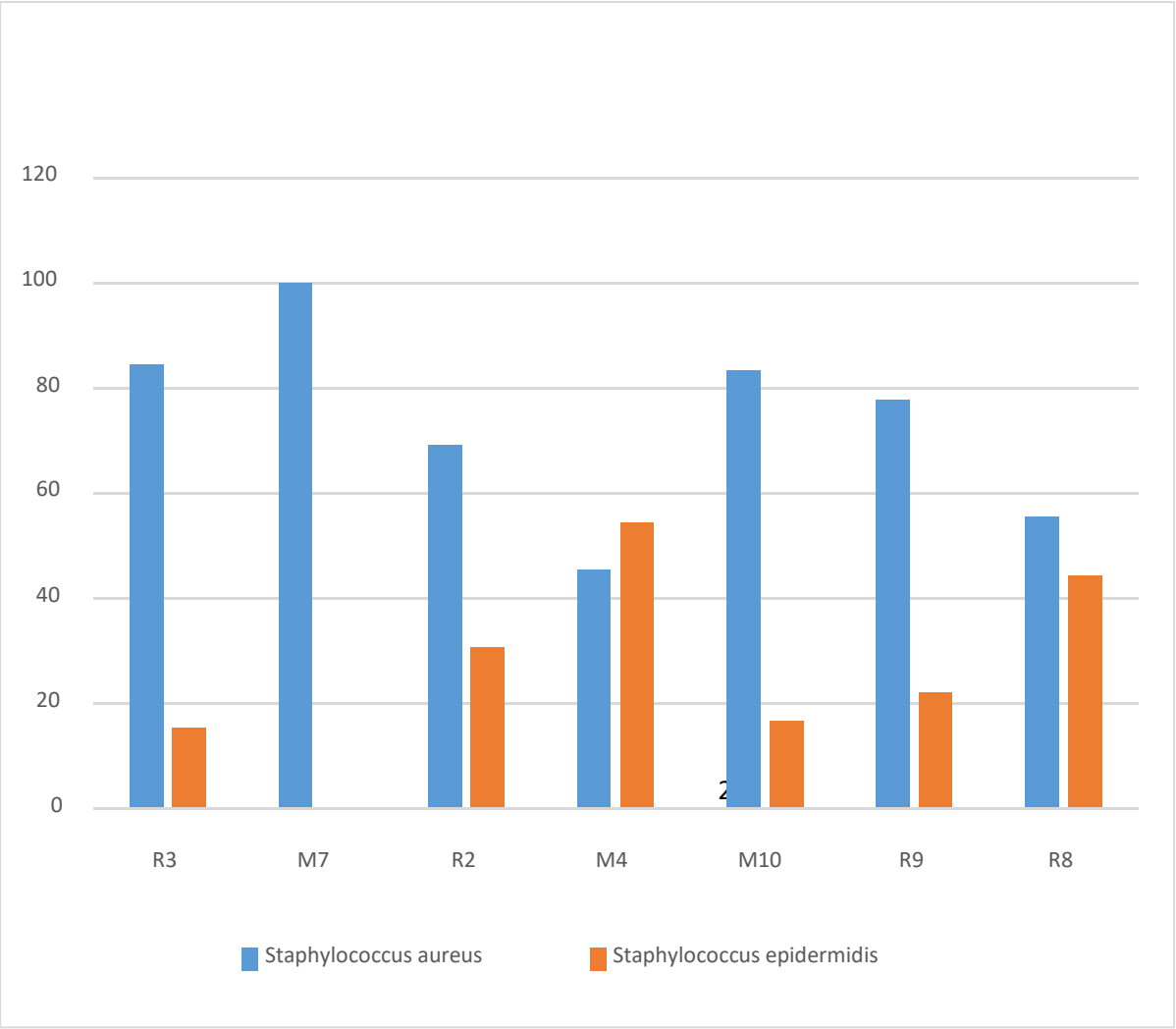

Figure 4.3 Percentage of bacteria isolates on mannitol salt agar in each room.

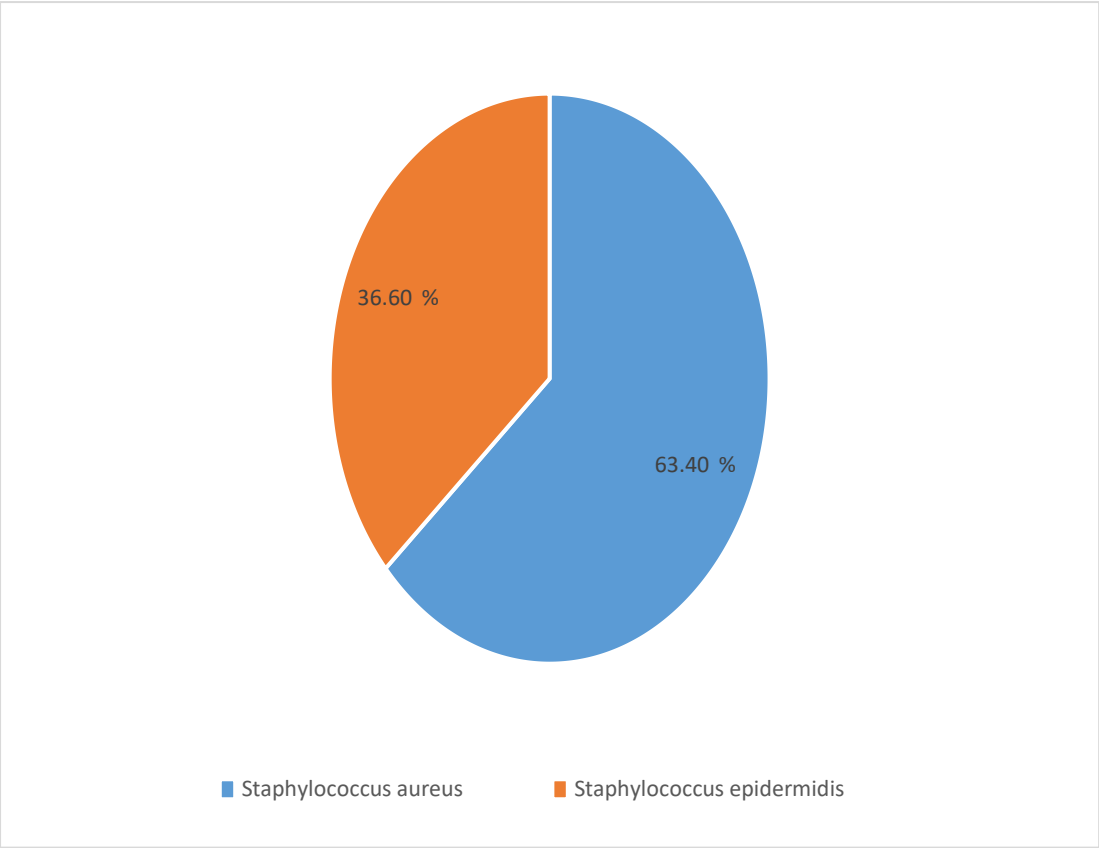

Figure 4.4 Percentage of bacteria isolates on mannitol salt agar plates of the study.

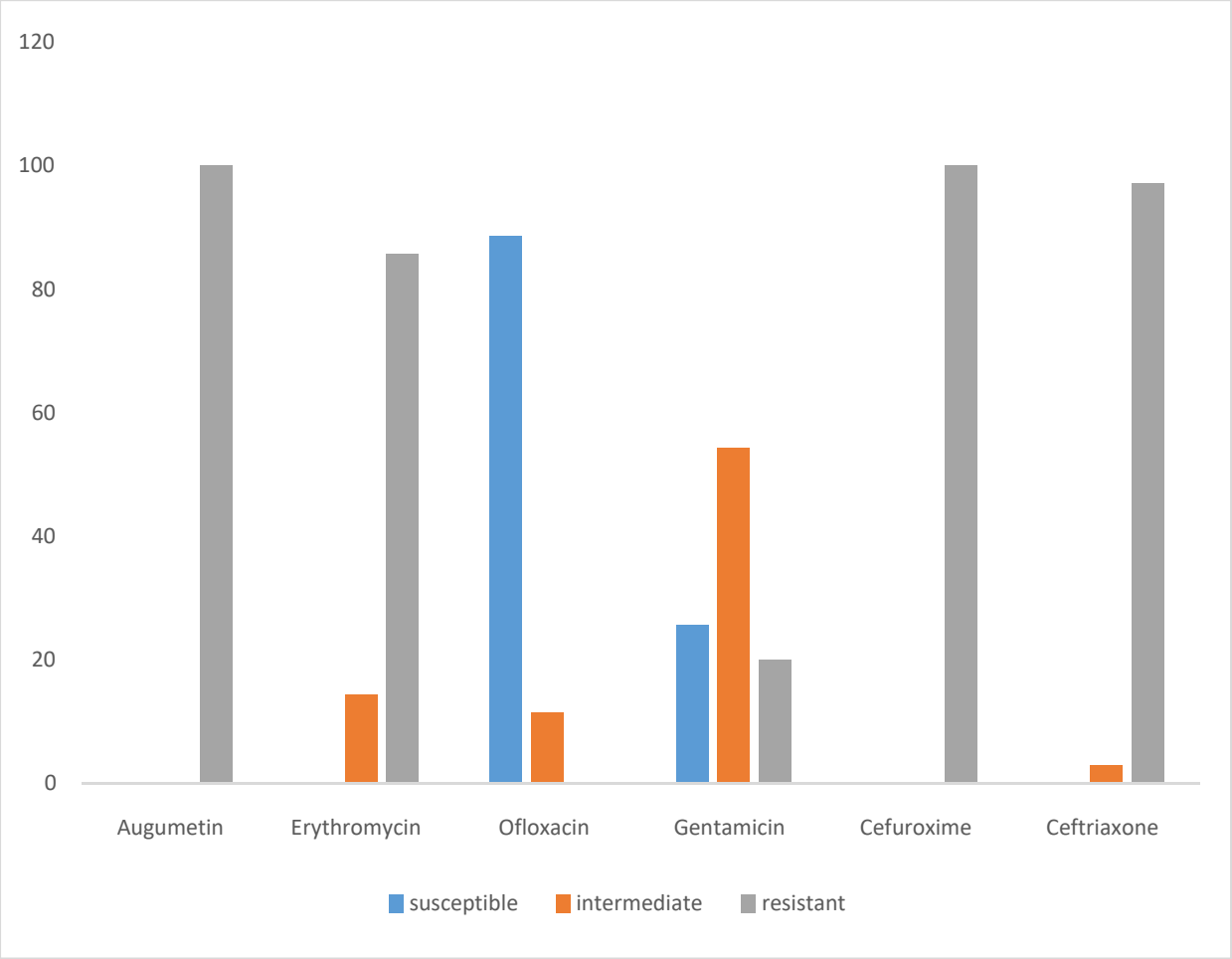

Figure 4.5 percentage of isolate susceptible, intermediate, resistant to antibiotics

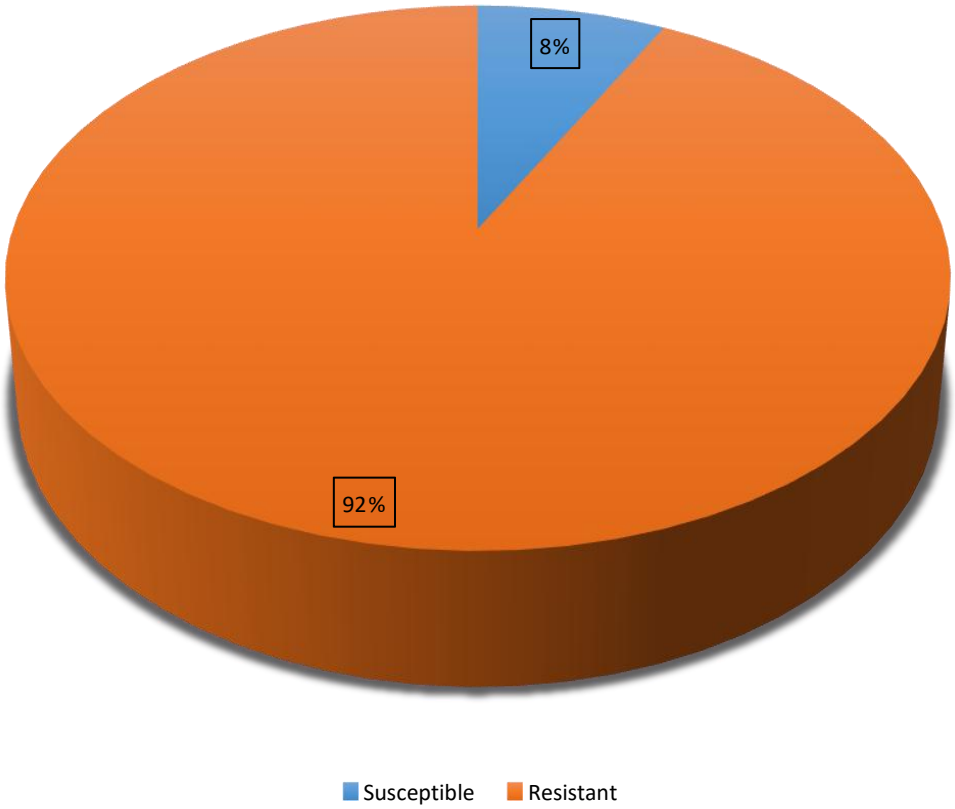

Figure 4.6: Percentage of Isolates Susceptible to Oxacillin

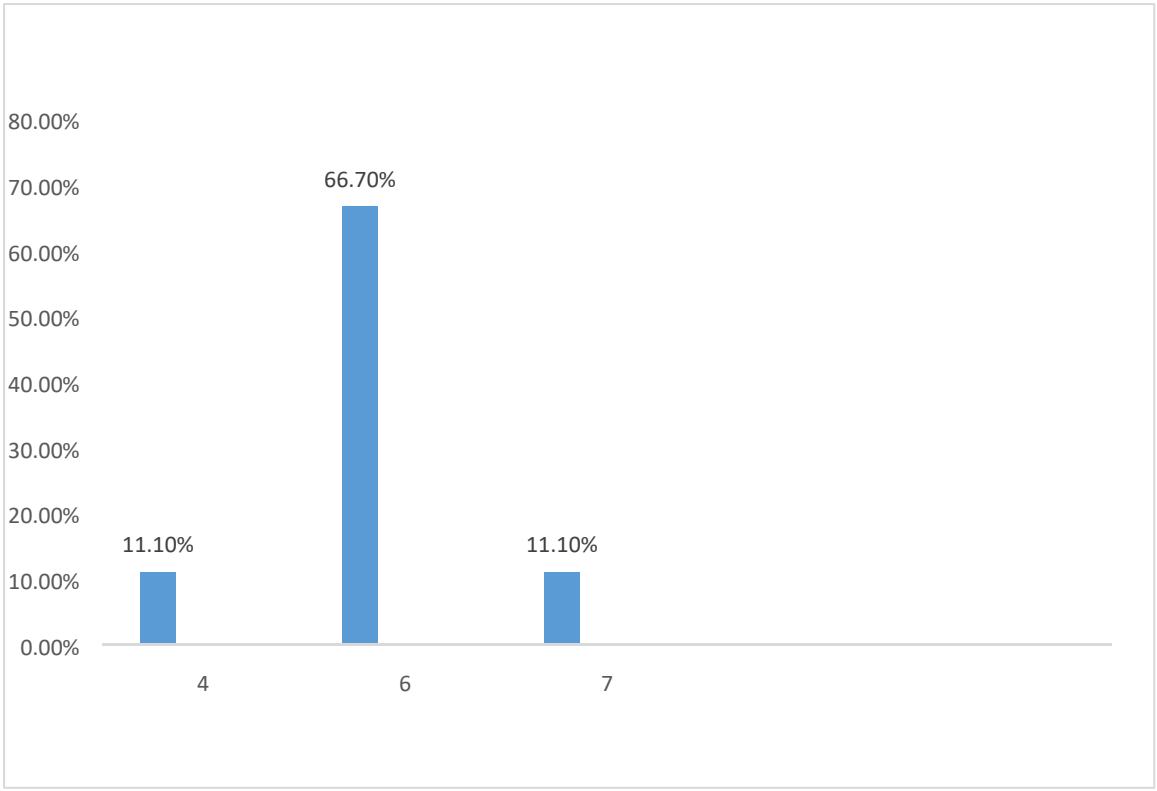

Figure 4.7 Questionnaire responses on the population of students in rooms of the two hostels

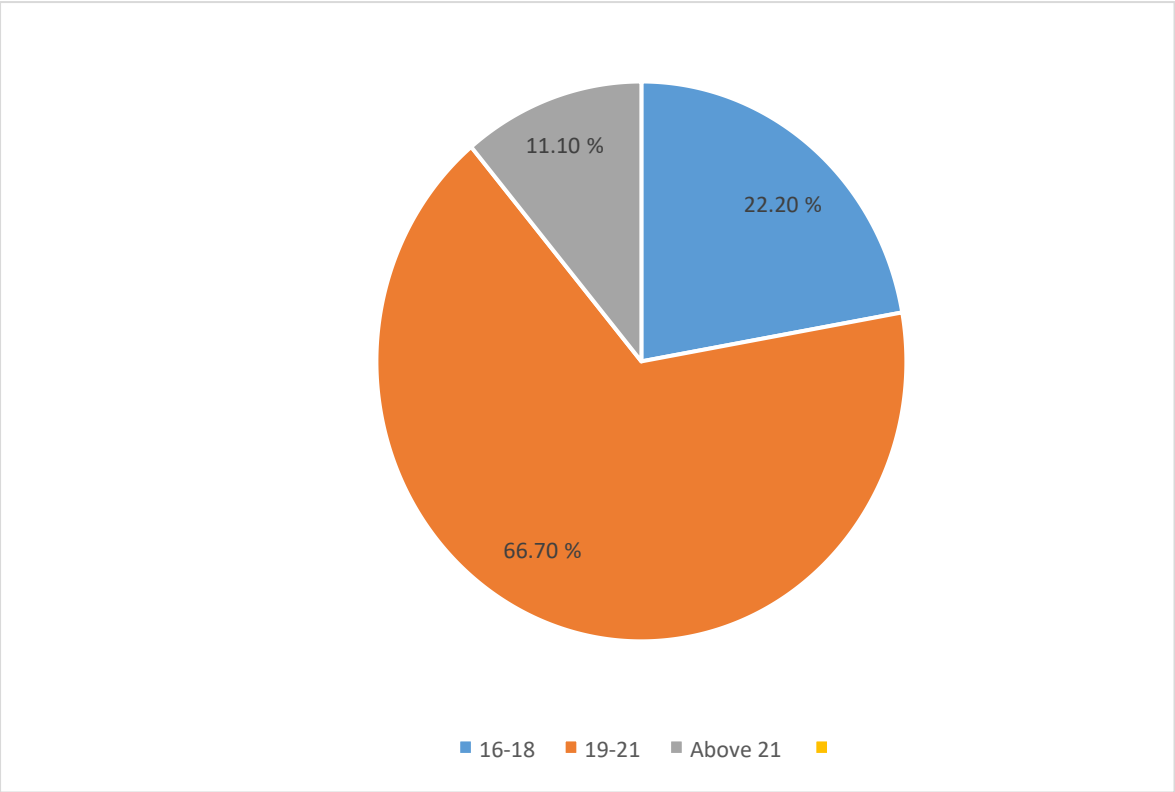

Figure 4.8 Age range of room occupants

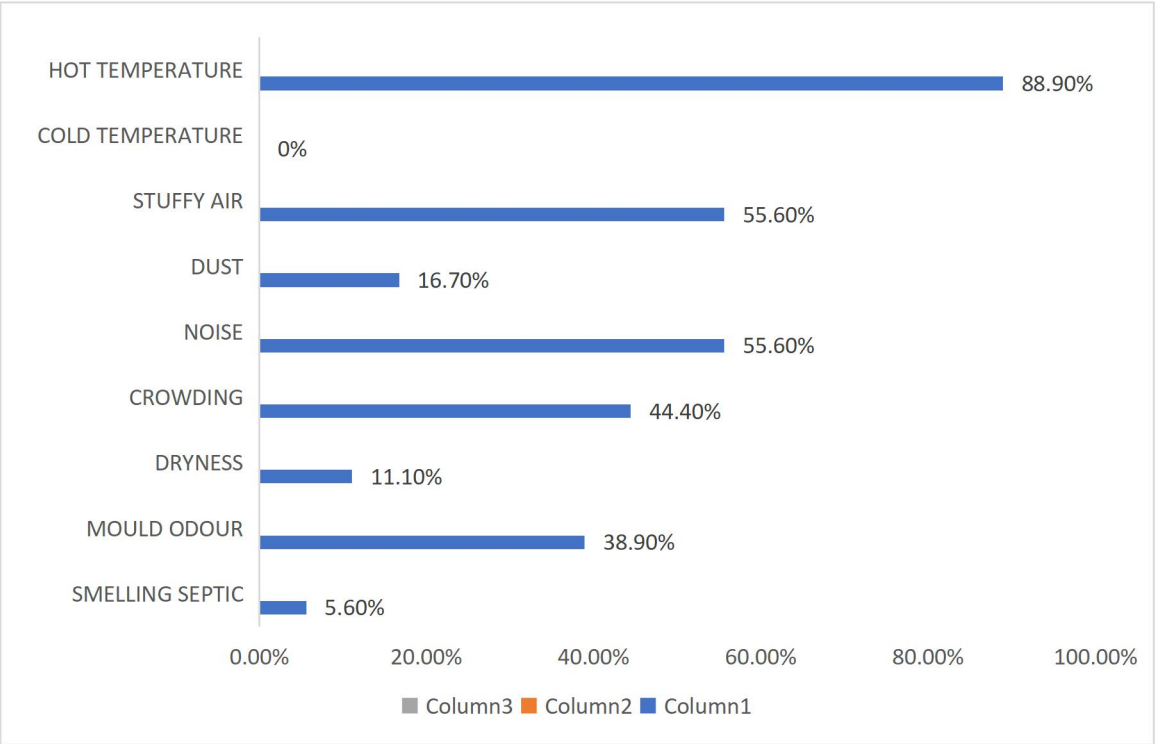

Figure 4.9 Hostel rooms condition

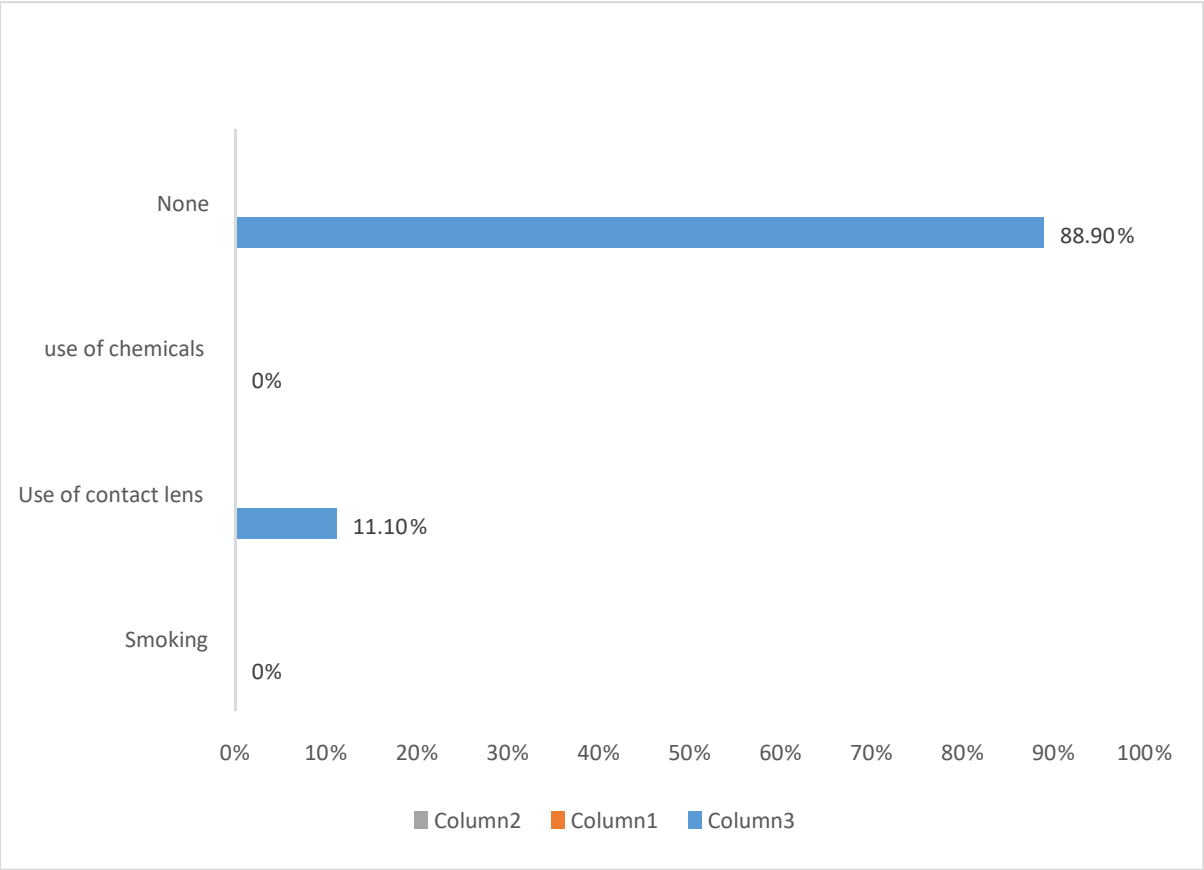

Figure 4.10 Use of chemicals, contact lens and smoking activity of room occupants

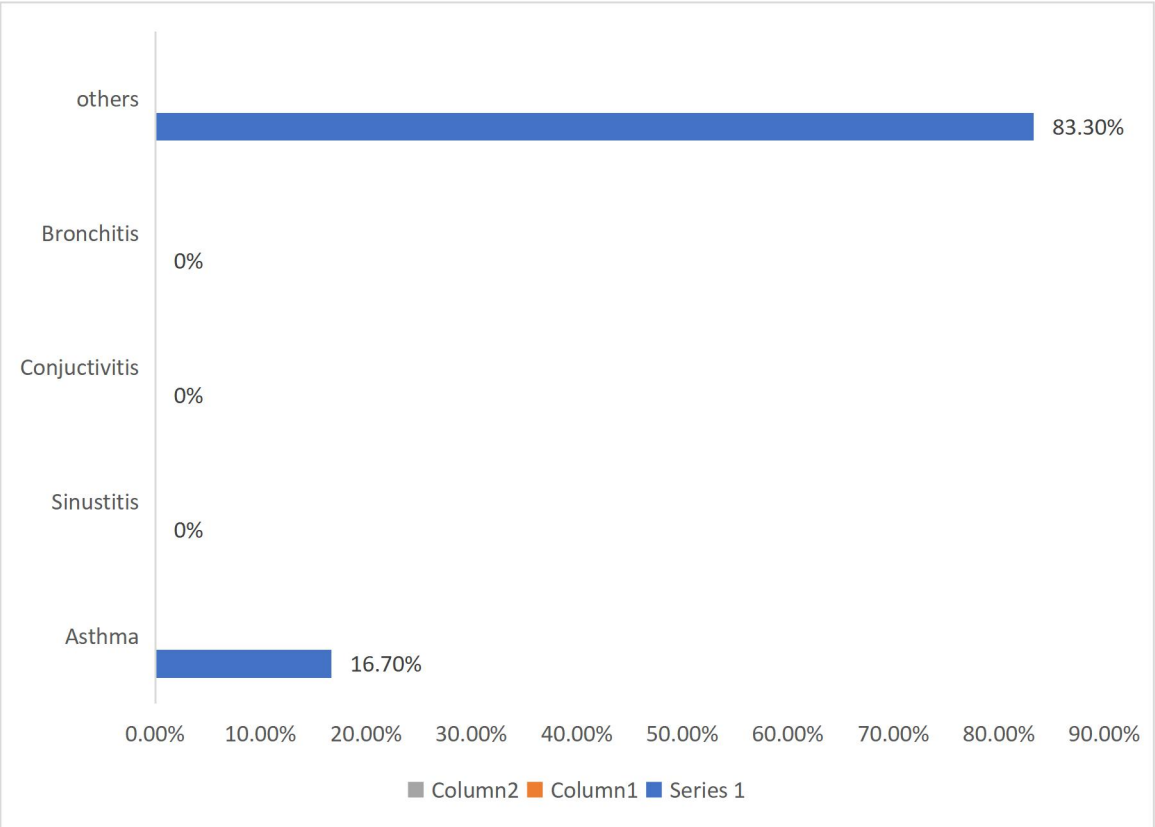

Figure 4.11 Health conditions diagnosed with since occupancy of the hostels room.

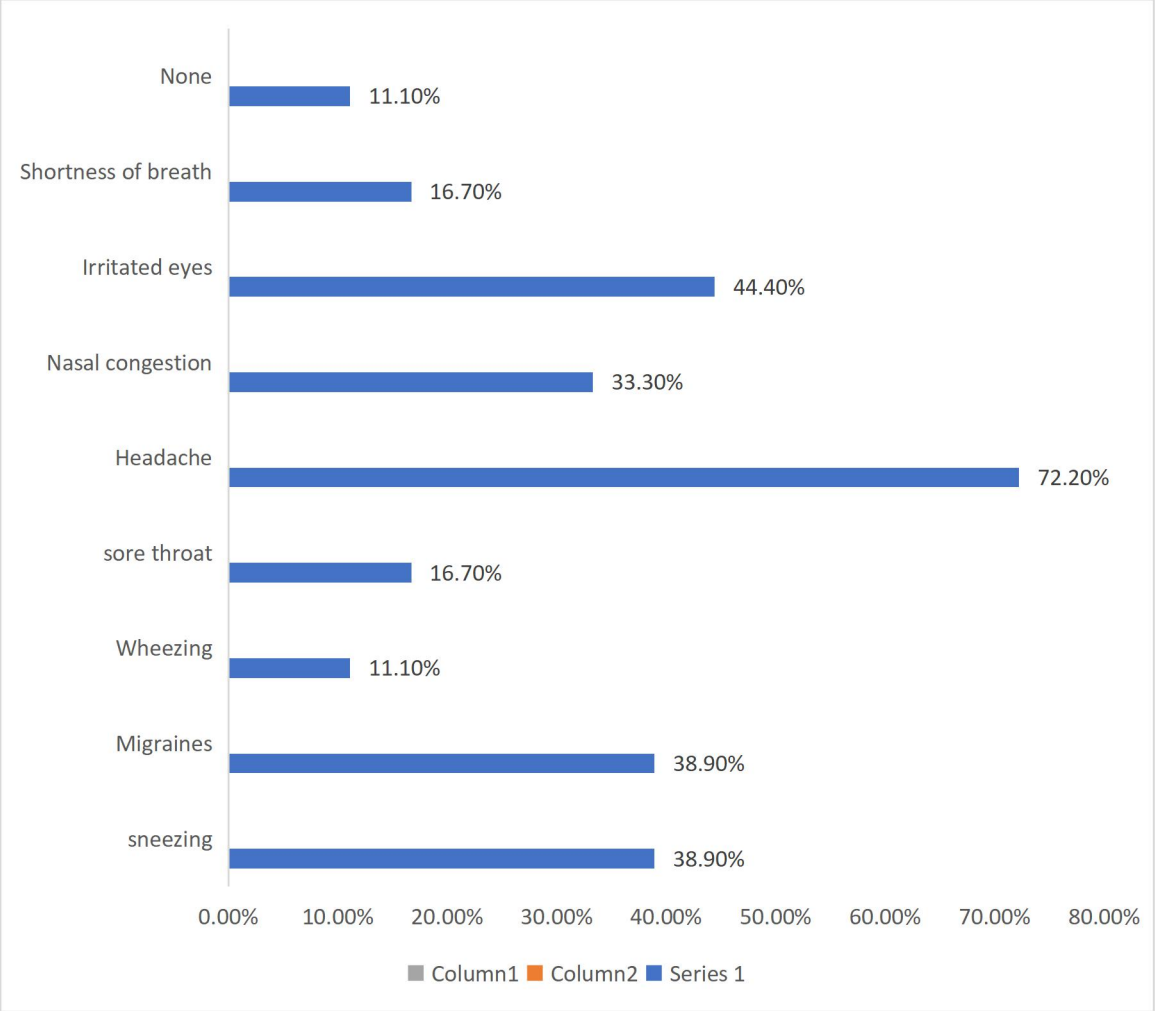

Figure 4.12 Symptoms experienced by occupants since stay in room.

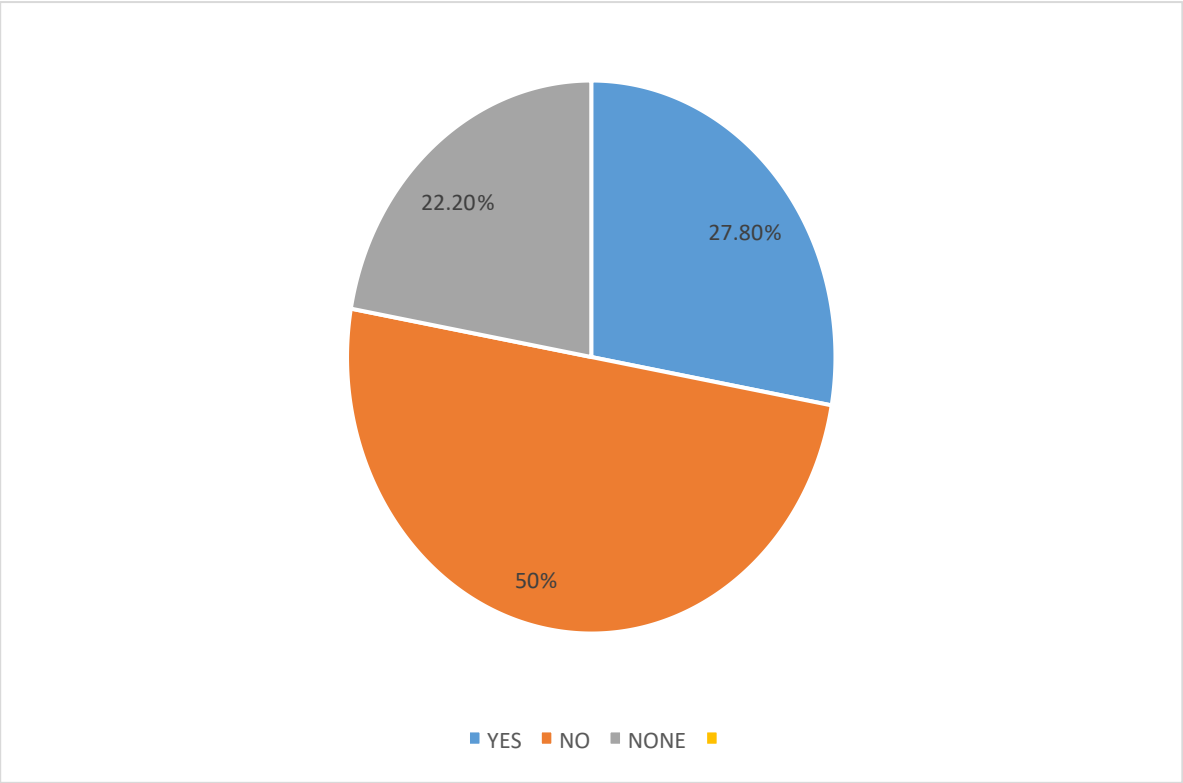

Figure 4.13 response gotten from symptoms disappearing after 1hour of leaving the room.

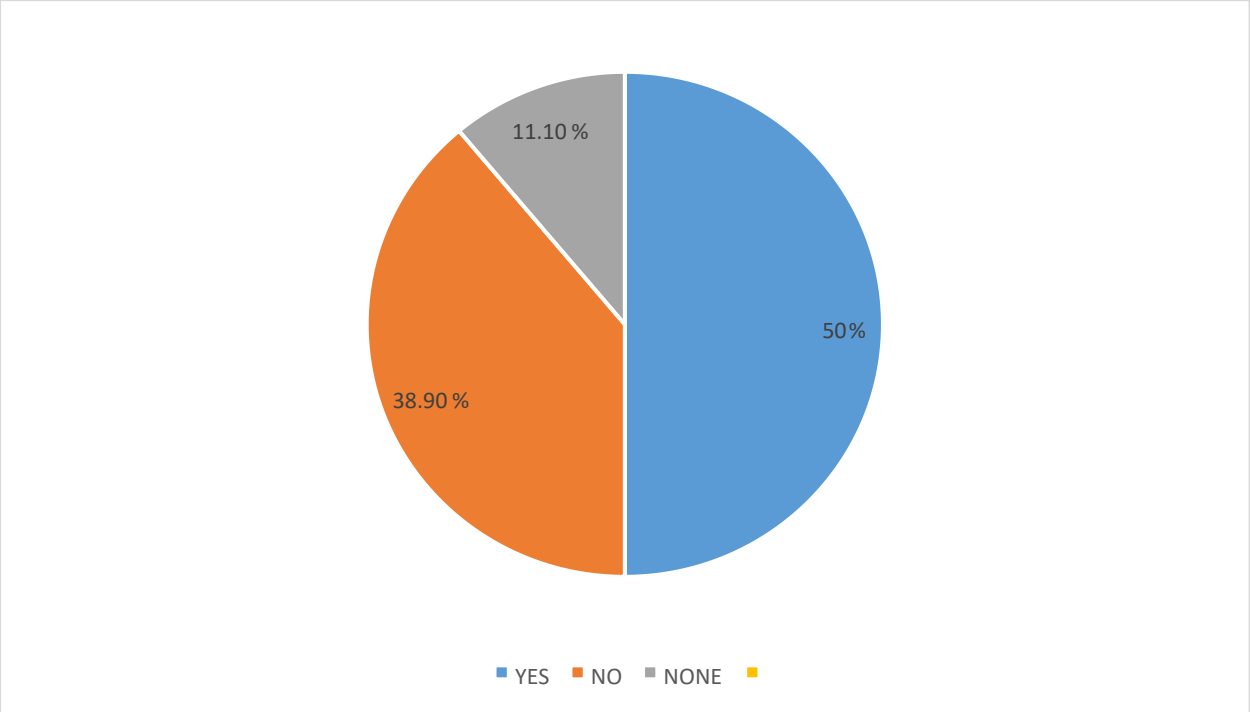

Figure 4.14 Evidence of leakage or moisture in the room

CHAPTER FIVE

DISCUSSION, CONCLUSION, RECOMMENDATION.

5.1 Discussion

Microbiological quality assessment of indoor air study is a great method to determine the microbial indoor air pollution. The indoor microbial contamination of airborne bacteria is important to estimate the health hazard and create standards for indoor air quality control. The concentrations of bacterial aerosol in the indoor environment of Caleb university female hostels, estimated with the use of settle plate method ranged between $1.73x10^3$ cfu/m^3 to $2.09x10^2$ cfu/m^3 in Hall A and $1.1\ x10^3$ cfu/m^3 to $4.71x10^2$ cfu/m^3 in Hall B.

Enumeration of the isolates in the hostels showed variation. The difference in counts of the hostels may be linked to the ventilation conditions, density of occupant during sampling and cleanliness of the rooms. In hall A the highest count which was $1.73x10^3$ cfu/m^3 could be due to the number of occupants during the assessment, while the lowest concentration was $2.09x10^2$ microbial cfu/m^3 of indoor air. In this study *Bacillus* sp., *Corynebacterium* sp., *Proteus* sp., *Klebsiella* sp., *Escherichia coli, Staphylococcus aureus* were the bacteria isolated. This is similar to that isolated by Adekunle *et al*. (2019) who isolated similar organisms from indoor air of banks and hospital in Ile Ife.

The sensitivity pattern of *Staphylococcus* sp. showed resistance to Augmentin, erythromycin, but susceptible to Ofloxacin. Also 8% of *Staphylococcus* sp. showed susceptibility to oxacillin while 92% were resistant to Oxacillin. *Bacillus* sp. were susceptible to ofloxacin, some strains were susceptible to gentamicin but resistant to cefuroxime, ceftriaxone, Augmentin, erythromycin. *Klebsiella* species showed resistance to ceftriaxone, cefuroxime, erythromycin, Augmentin and susceptibility to ofloxacin. *Corynebacterium* sp. were susceptible to ofloxacin, and resistant to Augmentin, erythromycin, cefuroxime, ceftriaxone.

Proteus sp. showed susceptibility to ofloxacin, intermediate to gentamicin, resistance to Augmentin, erythromycin, cefuroxime, ceftriaxone. Majority of the isolates showed resistance to ceftriaxone, cefuroxime, Augmentin which is in accordance with the study by Adekunle *et al*. (2019).

This study shows that some antibiotics are becoming less effective to the pathogens in indoor air. Cohabitation where resistant gene are transferred to other organisms in the same niche could be the reason for high resistance. This statement is in accordance with (Wemedo *et al*., 2018). Moreover, the antibiotic resistance pattern observed in this study could be linked to acquisition of plasmids (Azuonwu *et al.,*2019).

5.2 Conclusion

World health organization standards for bacteria count in indoor air is 500 CFU/M^3, some rooms in this study surpassed the standard count showing that the room indoor air quality is poor. The organisms isolated from the rooms are pathogenic and could lead to adverse health effects. The level of microbial population in the rooms could be caused by the ventilation system and activities of the occupants of the rooms. The antibiotic susceptibility pattern shows that Ofloxacin had high effect, therefore it should be considered as the drug choice for the infections caused by the microorganisms isolated from the rooms.

5.3 Recommendation

Based on this study, it is recommended that the indoor air quality of the rooms should be improved so as to prevent prolonged occurrence of Nosocomial or respiratory infections. This can be improved by providing proper ventilation system, reducing the population of occupants of each room in the two hostels sampled and proper room sanitation practices should be encouraged.

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Appendices

Appendix 1 Colony count obtained from room samples

ROOMS	COLONY COUNTS
A1	20
B1	14
A8	25
B3	21
B5	9
A6	21
B9	14
B4	17
A9	17
A3	33
A5	30
B7	9
A7	4
B3	13
A4	22
B2	13
B9	9
B8	9
A10	12

Appendix 2 Antibiotic susceptibility pattern of isolates

ISOLATE CODE	AUGMENTIN	ERYTHROMYCIN	OFLOXACIN	GENTAMICIN	CEFUROXIME	CEFTRIA CEFTRIAXONE	PROBABLE ORGANISMS
M5B	R	14	12	R	R	R	*Staphylococcus epidermidis*
R1D	R	R	19	11	R	R	*Bacillus* spp.
R1B	R	R	20	11	R	R	*Proteus* spp.
R3A	R	R	25	11	R	R	*Esherichia coli*
R3B	R	R	25	11	R	R	*Klebsiella* spp.
R3C	12	14	16	18	R	15	*Bacillus* spp.
M8B	R	R	19	13	R	R	*Bacillus* spp.
M1A	R	R	22	12	R	R	*Escherichi*

							a coli
M3A	R	10	25	17	R	R	*Staphyloc occus aureus*
M3B	R	13	15	16	R	14	*Escherichi a coli*
M8A	R	R	20	10	R	R	*Klebsiella* spp.
M9B	R	R	26	15	R	R	*Coryneba cterium* spp.
R4A	R	R	25	17	R	R	*Bacillus* spp.
M6B	R	R	16	18	R	R	*Bacillus* spp.
M1C	R	R	13	17	R	R	*Bacilluus* spp.
M9A	R	12	25	17	R	R	*Klebsiiella* spp.
M1B	R	R	20	13	R	R	*Klebsiella* spp.
M1D	R	12	26	15	R	R	*Staphyloc occus aureus*

M3C	R	R	18	10	R	R	*Bacillus* spp.
M5C	R	R	20	12	R	R	*Bacillus* spp.
R5C	R	R	16	14	R	R	*Escherichia coli*
M9C	R	R	20	14	R	R	*Escherichia coli*
R4D	R	R	18	12	R	R	*Escherichia coli*
M6C	R	R	21	16	R	R	*Escherichia coli*
R5C	R	R	23	12	R	R	*Escherichia coli*
R1C	R	R	17	17	R	R	*Escherichia coli*
M5D	R	R	16	11	R	R	*Escherichia coli*
R4C	R	R	17	13	R	R	*Klebsiella* spp.
R7A	R	R	20	15	R	R	*Klebsiella* spp.
R7B	R	R	20	12	R	R	*Corynebacterium*

							spp.
M6A	R	R	18	13	R	R	*Coryneba cterium* spp.
R9C	R	R	20	12	R	R	*Coryneba cterium* spp.
R5B	R	R	18	13	R	R	Proteus spp.
R9B	R	R	22	13	R	R	*Proteus* spp.
M5E	R	R	15	11	R	R	*Proteus* spp.

Appendix 3 Antibiotic susceptibility of the bacteria isolates of mannitol salt agar. Oxacillin antibiotic disc were used for the isolates on the mannitol salt agar.

ISOLATE LABEL	SENSITIVE/RESISTANCE
R8A	6.5 mm
R8B	7mm
R9A	13mm
M10B	R
R2A	13.5mm
R3B	18mm
M10A	14mm
M7	13mm
M4A	R
R9B	R
R3A	17mm
R2B	11.5mm
M4B	R