

**BACTERIOLOGICAL ASSESSMENTS OF CURTAINS OF SOME STUDENTS  
FOUND IN HOSTELS IN THE UNIVERSITY OF BENIN, NIGERIA**

**BY**

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**DEPARTMENT OF MICROBIOLOGY  
FACULTY OF LIFE SCIENCES  
UNIVERSITY OF BENIN  
BENIN CITY**

**SEPTEMBER, 2023.**

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**A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF  
MICROBIOLOGY, FACULTY OF LIFE SCIENCES IN PARTIAL FULFILLMENT  
OF THE REQUIREMENTS FOR THE UNIVERSITY OF BENIN, BENIN CITY,  
AWARD OF BACHELOR OF SCIENCE (B.Sc HONS) DEGREE**

**SEPTEMBER, 2023.**

## **CERTIFICATION**

This is to certify that this project work was carried out by Peace EDOSA of the Department of Microbiology, Faculty of Life Science, University of Benin, under my supervision.

.....  
**Mrs. F. O. Omorotionmwan**  
(Project Supervisor)

.....  
**Date**

## APPROVAL

This project was carried out by Peace EDOSA in partial fulfilment of the award of a bachelor of science, B.sc (HONS) degree in the department of Microbiology, University of Benin.

.....  
**Prof. (Mrs.) F. I. Akinnibosun**  
(Head of Department)

.....  
**Date**

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## **DEDICATION**

This project work is dedicated to the Almighty God for his grace and mercies throughout my period of research.

## **ACKNOWLEDGEMENTS**

I sincerely thank the Almighty God for his mercy and kindness shown to me during my study years.

I want to express my sincere gratitude to my project supervisor, Mrs. F. O. Omorotionmwan, for her support and assistance in the accomplishment of this project. May the Most High God graciously bless you for your efforts.

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With a deep sense of honour, I won't forget to thank my wonderful parents, Mr. and Mrs. Clarkson Edosa, for their financial support and words of wisdom. My incredible family, who was loving and supportive in every way. My friends who have helped in some way or another to the success of the work. God bless you all.

## TABLE OF CONTENTS

<b>CERTIFICATION</b> .....	<b>iii</b>
<b>DEDICATION</b> .....	<b>v</b>
<b>ACKNOWLEDGEMENTS</b> .....	<b>vi</b>
<b>TABLE OF CONTENTS</b> .....	<b>vii</b>
<b>LIST OF TABLES</b> .....	<b>ix</b>
<b>LIST OF FIGURES</b> .....	<b>x</b>
<b>ABSTRACT</b> .....	<b>xi</b>
<b>CHAPTER ONE</b> .....	<b>1</b>
1.0 Introduction .....	1
1.1. Background .....	1
1.2. Significance of the Study .....	4
1.3. Aim and Objectives .....	5
<b>CHAPTER TWO</b> .....	<b>6</b>
2.0. Literature Review .....	6
2.1. Definition of Hostel .....	6
2.2. Environmental Health .....	8
2.3. Indoor Air Quality .....	10
2.4. Curtains as Microbial Reservoirs .....	13
2.5. Microbial Contamination in Indoor Environments .....	16
<b>CHAPTER THREE</b> .....	<b>18</b>
3.0 MATERIALS AND METHODS .....	18
3.1 Study Area .....	18
3.3 Sterilization of Materials .....	18
3.4 Preparation and Sterilization of Media .....	19
3.5 Sample Preparation, Inoculation and Incubation .....	19
3.6 Phenotypic Identification of Bacteria from Samples .....	20
3.6.1 Gram Staining Test .....	20
3.6.2 Potassium Hydroxide (KOH) test .....	20
3.6.3 Biochemical Test .....	21
3.6.4.1 Indole Test .....	21
3.6.4.2 Oxidase Test .....	21
3.6.4.3 Catalase Test .....	22
3.6.4.4 Citrate Utilization Tests .....	22
3.6.4.5 Urease test .....	23
3.6.5 Mannitol Test .....	23
3.6.6 Triple Sugar Iron (TSI) test .....	23
3.7 Growth on Differential Media .....	24

3.7.1	<i>Bacillus Cereus</i> Agar Base .....	24
3.7.2	Mannitol Salt Agar (MSA) .....	24
3.7.3	Pseudomonas Agar .....	25
3.7.4	Eosin Methylene Blue (EMB) agar .....	25
3.8	Phenotypic Virulence Test .....	25
3.8.1	Nutrient Gelatin test .....	26
3.8.2	DNase Test Agar .....	26
3.8.4	Hemolysis on Blood Agar Base .....	27
3.9	Antimicrobial Susceptibility Test .....	27
3.10	Evaluation of Multiple Antibiotics Resistance (MAR) Index .....	28
<b>CHAPTER FOUR .....</b>		<b>29</b>
4.0 RESULTS .....		29
<b>CHAPTER 5 .....</b>		<b>37</b>
5.0 DISCUSSION AND CONCLUSION .....		37
5.1 Discussion .....		37
5.2 Conclusion .....		39
<b>REFERNCES .....</b>		<b>40</b>



## **LIST OF FIGURES**

Figure 4.1. Heterotrophic bacterial counts ( $\log_{10}$  cfu/cm<sup>2</sup>) of curtains

Figure 4.2. Percentage frequency of occurrence of bacterial for surfaces of curtains

Figure 4.3 Multiple antibiotic resistance index of bacterial isolates from curtains

## ABSTRACT

Curtains give seclusion, lessen the quantity of light that enters a room, and enhance the interior design of a space. The aim of this research project is to conduct bacteriological assessments of curtains in school hostels. Before sample collection, students' consent was sought. Fifty samples (50) of curtains were collected from students in the study. Questionnaires were administered to students whose curtains were sampled for bacteriological analysis. The data obtained from this research were analyzed using statistical analysis. Antibiotic susceptibility testing was carried out as well as pathogenicity testing. Heterotrophic bacterial counts ( $\log_{10}$  Cfu/cm<sup>2</sup>) of curtains ranged from 2.59 to 2.74 Cfu/cm<sup>2</sup>. Four bacteria isolates were identified in this study; *Staphylococcus aureus* (29.41%), *Serratia marcescens* (17.65%), *Pseudomonas aeruginosa* (23.53%) and *Bacillus subtilis* (29.41%). Multiple antibiotic resistance index of bacterial isolates ranged from 0.25 to 0.50, indicating their potential public health implications as these values were above the permitted limit of 0.2. This study shows that curtains can be contaminated with bacteria. The microbiological burden on curtains can be greatly reduced by taking easy steps like routine cleaning, good ventilation, and the use of antimicrobial treatments, which will result in a better atmosphere for all inhabitants.

# CHAPTER ONE

## INTRODUCTION

### 1.1. Background of the Study

Curtains have played a significant role in human dwellings, evolving from simple functional coverings to elaborate decorative elements. In ancient Egypt, evidence suggests that curtains made of linen or animal skins were used to provide privacy and protection from the sun. These early curtains were likely simple pieces of fabric hung over doorways and windows. In Mesopotamia (modern-day Iraq), curtains made from woven reeds or palm leaves were used to shield interior spaces from the sun and dust. These early curtains were often adorned with decorative motifs, demonstrating an early appreciation for both functionality and aesthetics. In ancient China, curtains served the practical purpose of providing privacy and insulation from drafts. They were typically made of silk, a highly prized fabric in Chinese culture. Elaborate silk curtains became a symbol of wealth and status, with intricate patterns and designs reflecting the artistic skills and craftsmanship of the time. During the medieval period in Europe, curtains gained prominence as a symbol of luxury and opulence. Castles and palaces were adorned with sumptuous tapestries and heavy velvet curtains, showcasing the wealth and power of the ruling elite. These curtains not only served to enhance the aesthetics of grand halls and chambers but also provided insulation and privacy.

The Renaissance period marked a significant shift in curtain design and construction. The use of more delicate fabrics, such as damask and brocade, became popular. Curtains were often embellished with elaborate embroidery and lacework, reflecting the artistic and cultural influences of the time (Wu and Kyungsun, 2022). The Renaissance also saw the introduction of curtain rods and rings, allowing for easier manipulation and movement of curtains. The 18th and 19th centuries witnessed further advancements in curtain design and manufacturing techniques. With the Industrial Revolution, the production of textiles and curtains became

more accessible, leading to increased availability and variety. Fabrics such as chintz, calico, and muslin were widely used, with printed patterns and designs becoming more prevalent. In the Victorian era, curtains became an integral part of interior decor. Heavy, floor-length curtains in rich fabrics like velvet and brocade were favored, often adorned with tassels, fringes, and intricate trims. The curtains were designed to be grand and imposing, reflecting the ornate and lavish Victorian style.

In the 20th century, the concept of curtains evolved alongside changing architectural and interior design trends. Modernist movements embraced simplicity and minimalism, leading to the use of lighter fabrics and simpler curtain designs. Sheer curtains and blinds gained popularity, allowing for more natural light while still providing privacy.

Today, curtains continue to be an essential element in interior design. From traditional styles to contemporary designs, curtains offer both functional and aesthetic benefits. They provide privacy, control light, and contribute to the overall ambiance of a space. With advancements in textile technology and a wide range of fabric options, curtains can be customized to suit various styles and preferences. The history of curtains demonstrates their enduring presence and importance throughout different cultures and time periods. From ancient civilizations to modern-day interiors, curtains have evolved from simple coverings to intricate and versatile elements, reflecting the ever-changing needs and tastes of society. Curtains play a significant role in interior design and are commonly used as window coverings in various settings, including hostels. They serve multiple purposes, such as providing privacy, controlling light, and enhancing aesthetic appeal. However, beyond their visual and functional aspects, curtains can also harbor microorganisms, including bacteria, fungi, and allergens. This poses potential health risks to individuals, especially in environments with high occupant turnover, such as hostels. Curtains, with their fabric texture and ability to accumulate dust particles, provide an ideal environment for microorganisms to thrive. As occupants enter and exit hostel rooms,

they bring in microorganisms from the external environment. These microorganisms, along with dust particles and organic matter, settle on the surface of curtains. Over time, this accumulation creates a conducive environment for microbial growth. The presence of bacteria on curtains in hostels is a significant concern. Bacteria are microscopic organisms that can be found virtually everywhere, including in the human body and in the environment. Some bacteria are harmless or even beneficial, but others can cause illness and infections (Straub *et al.*, 2016). Pathogenic bacteria, such as *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*, have been found on curtains in various studies (Esteves *et al.*, 2016). These bacteria can survive on curtain surfaces for extended periods and may pose a risk to the health of hostel occupants. Fungi are another group of microorganisms commonly found on curtains. Fungal spores can easily become airborne and are known to cause allergies and respiratory issues in susceptible individuals. Curtains provide an ideal surface for fungi to grow, especially in environments with high humidity or inadequate ventilation. As fungal spores become airborne, occupants may inhale them, leading to adverse health effects (Khan and Karuppayil, 2012).

In addition to bacteria and fungi, curtains can also harbor allergens. Dust mites, a common allergen, thrive in environments with high humidity and dust accumulation. The fabric of curtains can trap dust particles, including dust mite allergens, exacerbating allergies and respiratory conditions in sensitized individuals. The potential health risks associated with microbial contamination on curtains are particularly concerning in hostel environments. Hostels often have high occupant turnover, with individuals from diverse backgrounds and varying hygiene practices. Curtains, being a common feature in hostel rooms, can act as a reservoir for microorganisms, facilitating their transmission from one occupant to another. To mitigate the potential health risks posed by curtains in hostels, regular cleaning and maintenance are essential. Proper cleaning methods, such as vacuuming or washing curtains

at appropriate intervals, can help remove dust particles and microorganisms (Brown and Wray, 2014). Maintaining adequate ventilation and controlling humidity levels in hostel rooms can also discourage microbial growth on curtains. Bacteriological assessments of curtains in hostels are crucial for understanding the extent of microbial contamination and assessing associated health risks. By quantifying the microbial load and identifying specific bacterial species present on curtains, it becomes possible to evaluate the potential health implications. This information can be used to develop guidelines and recommendations for effective cleaning practices and hygiene interventions specific to curtains in hostel settings.

In conclusion, while curtains serve functional and aesthetic purposes in hostels, they can also harbor microorganisms that pose potential health risks to occupants (Long, 2011). Bacteria, fungi, and allergens can accumulate on the surfaces of curtains, especially in environments with high occupant turnover. Bacteriological assessments are essential for evaluating the extent of microbial contamination and understanding the associated health risks. Through proper cleaning and maintenance practices, the potential health risks associated with curtains in hostels can be minimized, creating a healthier living environment for the occupants.

## **1.2. Significance of the Study**

The significance of this study lies in its contribution to improving hygiene practices and ensuring the well-being of hostel occupants. By conducting bacteriological assessments of curtains in hostels, the research findings will provide valuable insights into the extent of microbial contamination and associated health risks. This information can be used to raise awareness among hostel management, occupants, and relevant stakeholders about the importance of maintaining clean and hygienic curtains. The study's outcomes can also aid in the development of guidelines and recommendations for effective curtain cleaning practices

and hygiene interventions in hostels, ultimately creating a healthier living environment for the occupants.

### **1.3. Aim and Objectives**

The aim of this research project was to conduct bacteriological assessments of curtains in school hostels. The specific objectives of this study were;

1. to determine the total heterotrophic count of the curtain samples.
2. to isolate and identify bacteria present in the sampled curtains.
3. to determine the antibiotic susceptibility patterns of the bacteria isolates.
4. to determine the phenotypic virulence traits of the isolates

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1. Definition of Hostel

Kolawole and Boluwatife (2016) identify the hostel as an essential aspect of the tertiary institution as its availability is an attraction to a large number of students from different backgrounds to study in the tertiary institution. Nimako and Bondinuba (2013), further stated that hostels in tertiary institutions are so important that their adequacy is highly needed in any tertiary institution to enable students to make the most use of the educational opportunity. This agrees with what Muhammad *et al.* (2014) said about the hostel. Gichere *et al.*, (2019) defines hostel as a place where a student lives while studying a particular program at an institution which comprises of the immediate environment, health, economic, sporting and social activities that are sympathetic to academic work. Hammad *et al.* (2013) categorized students' accommodation into four, these include; Traditional on campus accommodation (TOC), Off campuses leased (OCL), On campus school managed (OSM) and Off-campus private (OP). The type of hostel that is adopted in the Federal University of Benin (UNIBEN) is the traditional on campus accommodation. Irrespective of the type of accommodation adopted, the living conditions of the spaces must be conducive. A hostel serves as a residence for students within the premises of a tertiary institution, providing them with a convenient and accessible place to live while pursuing their studies. It serves as a home away from home for students, offering them a sense of community and a supportive environment.

Hostels are not only limited to providing basic accommodation but also aim to create an atmosphere conducive to academic success. This includes factors such as the immediate environment, which should be quiet, clean, and well-maintained to facilitate concentration and productivity. The hostel should also promote good health by ensuring hygienic facilities and access to necessary amenities such as clean water, sanitation, and medical services.

Furthermore, hostels should offer economic support to students, considering their financial constraints. This can be achieved by offering affordable accommodation options and providing facilities that minimize the financial burden on students, such as shared spaces and communal amenities.

In addition to academics, hostels should also cater to students' social and sporting needs. They should provide spaces and opportunities for students to engage in social activities, interact with their peers, and develop a sense of belonging. Sporting facilities and recreational areas within the hostel can contribute to students' physical well-being and provide opportunities for relaxation and leisure activities.

It is worth noting that different tertiary institutions may adopt different models of student accommodation. The categorization mentioned by Hammad *et al.* (2013) highlights various types, including traditional on-campus accommodation, off-campus leased options, on-campus school-managed facilities, and off-campus private arrangements. Each type has its own characteristics and considerations, but regardless of the specific model, the ultimate goal is to ensure that the living conditions in hostels are conducive to student life and support their academic journey.

In summary, a hostel in the context of tertiary institutions can be defined as a residential facility that attracts students from diverse backgrounds, providing them with a suitable living environment that supports their educational pursuits. It encompasses aspects such as accommodation, the immediate environment, health services, economic considerations, sporting opportunities, and social activities, all aimed at facilitating students' academic success and overall well-being.

## **2.2. Environmental Health**

Environmental health encompasses a wide range of factors that influence human health and well-being. While hygiene and sanitation are important components, they are just a part of the larger picture. (Lukkumanul, 2019), environmental health includes not only hygiene and sanitation but also various other environmental factors that can impact health. The World Health Organization (WHO) provides a comprehensive definition of environmental health. It refers to all the physical, chemical, and biological factors that exist outside of an individual, as well as the related factors that influence behaviors. This definition highlights the broad scope of environmental health, emphasizing that it encompasses everything from air and water quality to housing conditions, workplace safety, and exposure to hazardous substances. It focuses on the assessment and control of environmental factors that have the potential to affect human health. This includes identifying and addressing risks associated with pollution, toxic substances, infectious agents, climate change, and other environmental hazards. By understanding and managing these factors, the goal of environmental health is to create and maintain environments that are conducive to good health and prevent disease and injury. Environmental health is not limited to the outdoor environment alone (Mbachu *et al.*, 2020). It also encompasses the indoor environment, which refers to the conditions within buildings and homes. Indoor environmental factors such as indoor air quality, ventilation, lighting, and the presence of allergens or contaminants can significantly impact the health and well-being of individuals. When considering environmental health in the context of a hostel, there are several factors that are relevant, including hygiene, sanitation, indoor air quality, and overall living conditions. These factors can significantly impact the health and well-being of hostel residents. Hygiene and sanitation are essential considerations in a hostel setting. Proper hygiene practices, such as regular handwashing, clean and well-maintained bathroom facilities, and adequate waste management, are crucial to prevent the spread of diseases and

maintain a healthy living environment. Regular cleaning and disinfection of shared spaces, including common areas, kitchens, and bathrooms, help reduce the risk of infectious diseases and maintain a clean and safe environment for residents. In terms of indoor air quality, it is important to ensure proper ventilation within the hostel. Good ventilation helps remove pollutants and maintain fresh air circulation, reducing the risk of respiratory problems and improving overall air quality. This is particularly important in shared spaces, such as bedrooms and common areas, where multiple individuals spend significant amounts of time. Additionally, the overall living conditions in the hostel, including the quality of furnishings and infrastructure, play a role in environmental health. For example, the presence of mold or dampness in rooms can lead to respiratory issues and allergies. Adequate lighting, comfortable bedding, and appropriate room temperature control are factors that contribute to the well-being and comfort of residents.

When it comes to specific aspects like curtains in a hostel, several considerations come into play. Curtains can accumulate dust, dirt, and allergens over time, especially in high-traffic areas. Regular cleaning and maintenance of curtains are necessary to prevent the buildup of these substances and maintain a healthy indoor environment. Additionally, if curtains are made from materials that emit volatile organic compounds (VOCs), such as certain synthetic fabrics, it is important to choose low-emission or natural fiber curtains to minimize potential health risks.

Moreover, curtains can also impact privacy and personal space for hostel residents, which can have implications for mental well-being. Adequate provision of curtains in shared dormitory rooms or other areas where privacy is desired can contribute to a more comfortable and psychologically supportive environment.

### **2.3. Indoor Air Quality**

Indoor air quality (IAQ) refers to the quality of the air inside buildings and its impact on the health and well-being of occupants (Berger *et al.*, 2022). Various factors can influence IAQ, including ventilation, pollutants, and the materials present within the indoor environment (Jung and Samanoudy, 2023). While curtains themselves may not directly affect IAQ, they can play a role in maintaining or compromising the air quality in indoor spaces. One aspect to consider is the accumulation of dust, allergens, and pollutants on curtains. Over time, curtains can attract and retain these particles, especially if they are not regularly cleaned or maintained. Dust mites, pet dander, pollen, and other allergens can settle on curtains and become airborne when disturbed (Esty *et al.*, 2019). This can pose a risk to individuals with allergies or respiratory conditions, potentially leading to discomfort and health issues.

To mitigate this risk and maintain good IAQ, it is important to clean curtains regularly. Vacuuming or shaking curtains outdoors can help remove accumulated dust and allergens. For washable curtains, laundering them according to the manufacturer's instructions can effectively eliminate pollutants and maintain a healthier indoor environment. By reducing the presence of these particles on curtains, the overall air quality in the space can be improved.

Another consideration regarding IAQ is the materials used in curtains. Some curtains may be made from synthetic materials or may contain chemicals that can emit volatile organic compounds (VOCs) into the air. VOCs are a group of organic chemicals that can have both short-term and long-term health effects, including eye and respiratory irritation, headaches, and even potential carcinogenic properties.

Choosing curtains made from low-emission or natural materials can help minimize the release of VOCs. Fabrics such as organic cotton, linen, or hemp are generally considered more environmentally friendly and have lower VOC emissions compared to synthetic materials. Additionally, selecting curtains that have been certified as low-emission or meet

specific indoor air quality standards, such as Greenguard or OEKO-TEX, can provide assurance of their reduced impact on IAQ.

Proper ventilation also plays a crucial role in maintaining good IAQ, and curtains can affect airflow within a space (Thirunagari *et al.*, 2023). If curtains are constantly closed or too heavy, they may impede the natural flow of air, leading to stagnant conditions and potential moisture buildup. Inadequate ventilation can result in increased humidity levels, which can create an environment conducive to the growth of mold and mildew (Sudarisman *et al.*, 2021). These microbial contaminants can negatively impact IAQ and pose health risks, particularly for individuals with allergies or respiratory conditions.

To ensure proper ventilation, it is important to use curtains that allow for adequate air circulation. Lightweight and breathable fabrics can promote airflow, even when the curtains are closed. Additionally, using curtain tie-backs or opting for curtains that cover only a portion of the window can help maintain a balance between privacy and proper ventilation. While curtains themselves may not directly impact IAQ, they can indirectly affect air quality in indoor spaces. Accumulated dust, allergens, and pollutants on curtains can worsen IAQ if not regularly cleaned. Choosing curtains made from low-emission or natural materials can help reduce the release of VOCs into the air. Additionally, selecting curtains that allow for proper airflow and ventilation can prevent stagnant conditions and the potential growth of mold and mildew. By considering these factors and implementing appropriate measures, curtains can contribute to maintaining a healthier indoor environment and better IAQ for occupants.

In addition to the accumulation of dust and allergens, curtains can also be a potential source of indoor air pollutants. Some curtains may contain flame retardants, formaldehyde-based adhesives, or other chemicals that can off-gas and release harmful substances into the air. These emissions can contribute to poor IAQ and may cause respiratory irritation, allergic

reactions, or other health issues, especially in individuals who are sensitive or have pre-existing respiratory conditions.

To minimize the potential impact of curtain-related pollutants on IAQ, it is important to consider the selection of curtains carefully. Opting for curtains made from natural, organic, or eco-friendly materials can help reduce the presence of potentially harmful chemicals. Look for certifications such as Global Organic Textile Standard (GOTS) or STANDARD 100 by OEKO-TEX, which ensure that the curtains meet strict criteria for ecological and health safety standards.

Furthermore, it is crucial to consider the maintenance and cleaning of curtains to prevent the buildup of pollutants and allergens. Regular vacuuming or shaking of curtains can help remove surface dust and particles, reducing the potential for these substances to become airborne. If curtains are washable, following the manufacturer's instructions for cleaning can effectively eliminate accumulated pollutants and contribute to better IAQ. It is also worth noting that curtains can interact with other factors in the indoor environment that affect IAQ. For example, curtains that obstruct windows or block airflow can hinder proper ventilation, which is essential for maintaining good IAQ. Adequate ventilation helps to dilute and remove pollutants from indoor spaces, promoting a healthier living environment. Therefore, it is important to strike a balance between using curtains for privacy or light control and ensuring proper airflow and ventilation in the room.

Additionally, curtains can also contribute to moisture-related issues if not properly maintained. Moisture buildup on curtains, particularly in areas with high humidity or condensation, can create a favorable environment for mold and mildew growth. These microbial contaminants not only deteriorate the indoor air quality but also pose risks to respiratory health. Regularly inspecting curtains for signs of moisture or mold growth and promptly addressing any issues can help prevent these problems and maintain a healthier

indoor environment. It is important to consider the overall design and placement of curtains in relation to IAQ. Curtains that are too long or touch the floor may collect dust and dirt more easily. Ensuring that curtains do not drag on the floor or come into contact with other potential pollutant sources, such as dirty carpets or pets, can help minimize the introduction of contaminants into the indoor environment. Buildings are becoming increasingly airtight in developed countries (Chan *et al.*, 2005), under moves designed to provide thermal comfort and to reduce energy consumption. Indoor environments are fundamental environmental factors capable of impacting health (Gocgeldi *et al.*, 2011). The quality of air in homes, offices, schools, daycare centres, public buildings, health care facilities, and other private and public buildings where people spend over 80% (Hoskins, 2007) of their time daily is crucial for healthy living and people's well-being (WHO, 2010). Air quality of indoor environments is one of the main factors affecting the health, well-being and productivity of people (Morakinyo *et al.*, 2015). Poor indoor air quality has been linked with a wide range of effects on respiratory health such as asthma development and exacerbation, respiratory infections and upper respiratory tract symptoms. (Emmanuel, 2006), has reported that over 1.6 million lives have been lost with over 38.5 million disabled persons in the year 2000 due to IAQ problems. Hostels are part of public buildings in Nigeria, and so far, there are few studies that focused on the air quality in this complex environment. Recently, the Nigeria Government has recognized the potential risks and problems related to indoor air pollution in public buildings and it's striving to establish IAQ guidelines for different types of indoor environments (Nnadozie *et al.*, 2017).

#### **2.4. Curtains as Microbial Reservoirs**

Curtains in hostel settings can serve as potential reservoirs for microbial growth and colonization. The texture of curtain fabric, combined with the presence of dust particles and

organic matter, creates an environment that supports the survival and proliferation of microorganisms (Peer *et al.*, 2022). Moisture can also accumulate on curtains, providing an additional factor for microbial growth.

Factors such as inadequate ventilation, high humidity levels, and infrequent cleaning can further contribute to the persistence of microorganisms on curtains (Irfeey *et al.*, 2023). In environments with limited airflow or where damp conditions are prevalent, such as in bathrooms or rooms with poor ventilation, the chances of microbial colonization on curtains increase (Yong and Calautit, 2023). This can include bacteria, fungi, and even allergenic substances like dust mites. The presence of microbial contaminants on curtains poses a potential risk to indoor air quality. As occupants interact with curtains through activities like opening and closing, the disturbance of the fabric can release the microorganisms into the surrounding air. These microorganisms may include bacteria, viruses, and fungal spores, which can become airborne and be inhaled by residents, potentially leading to respiratory issues or allergies. Regular cleaning and maintenance of curtains are crucial in minimizing the microbial load. Vacuuming curtains or washing them with appropriate detergents can help remove dust particles and organic matter that serve as nutrients for microbial growth. Ensuring that curtains are completely dry after washing is important to prevent the persistence of moisture and reduce the chances of mold or fungal growth. In some cases, using antimicrobial-treated curtains or curtains made from materials that are naturally resistant to microbial growth, such as certain types of fabrics, can be considered. However, it is essential to note that these measures should be complemented with regular cleaning practices, as antimicrobial treatments may lose effectiveness over time. Furthermore, implementing measures to improve indoor air quality, such as adequate ventilation and maintaining optimal humidity levels, can help minimize the potential impact of microbial contaminants released from curtains. One important aspect is the potential for cross-

contamination. As curtains accumulate microbial contaminants, they can serve as a source of transmission, especially when individuals come into direct contact with them. This can happen when residents touch curtains with their hands or when curtains brush against clothing or personal belongings. The transfer of microorganisms from curtains to individuals' hands or objects can facilitate the spread of pathogens and increase the risk of infections within the hostel environment.

Furthermore, certain groups of individuals, such as those with weakened immune systems or respiratory conditions, may be more susceptible to the health effects associated with microbial contaminants. For example, individuals with asthma or allergies may experience aggravated symptoms when exposed to allergens present on curtains, such as dust mites or fungal spores. Regular and thorough cleaning practices, including laundering curtains at appropriate temperatures and using disinfectants, can help mitigate the microbial load and reduce the risk of cross-contamination. It is important to follow manufacturer guidelines for curtain care and maintenance to ensure effective cleaning without damaging the fabric. Another consideration is the design and material of curtains. Some curtain fabrics may be more prone to harboring microbial contaminants or may be more difficult to clean effectively. Choosing curtains that are resistant to moisture, easy to clean, and made from materials that discourage microbial growth can be beneficial in reducing the potential for microbial colonization (Gilbert and Stephens, 2018). Additionally, implementing preventive measures such as promoting good hand hygiene among residents and frequent cleaning of high-touch surfaces in the vicinity of curtains can help minimize the transfer of microorganisms and maintain a healthier environment. Regular monitoring and inspection of curtains for signs of mold, discoloration, or visible dirt accumulation are also important (Brambilla *et al.*, 2022). If curtains show signs of damage or heavy contamination, they should be promptly replaced to prevent further risks to occupants' health. Lastly, raising awareness among hostel residents

about the potential health risks associated with microbial contaminants on curtains and promoting responsible practices, such as avoiding touching curtains unnecessarily and reporting any signs of contamination or damage, can contribute to a cleaner and safer living environment.

## **2.5. Microbial Contamination in Indoor Environments**

Indoor environments can serve as reservoirs for microbial contaminants, which can impact the air quality and occupants' health. Various factors contribute to microbial contamination, including dust, humidity, ventilation, and the presence of organic matter (Bernstein *et al.*, 2008). It is important to recognize that curtains, being exposed to external environments, can accumulate a significant amount of dust particles, airborne pollutants, and microorganisms. Over time, these contaminants settle on the surfaces of curtains, creating an environment conducive to microbial growth. Curtains offer an ideal substrate for microbial colonization and proliferation. The fabric's texture, along with the presence of dust particles and organic matter, provides nutrients and moisture necessary for microbial survival (Cuadros *et al.*, 2010). As a result, curtains can become hotspots for microbial activity and the proliferation of potentially harmful pathogens.

In addition to the accumulation of contaminants, several other factors can exacerbate the growth and persistence of microorganisms on curtains. Inadequate ventilation, high humidity, and infrequent cleaning practices contribute to the favorable conditions for microbial growth (Sharpe *et al.*, 2020). Poor ventilation limits the exchange of indoor and outdoor air, allowing microbial contaminants to accumulate and remain trapped within the indoor environment. High humidity levels further enhance microbial growth, as moisture is a critical factor for their survival. Infrequent cleaning practices lead to the accumulation of dust, debris, and organic matter on curtains, providing additional nutrients for microbial colonization.

Occupants' interaction with curtains, such as opening and closing them, can disturb the settled contaminants and make them airborne, potentially affecting the indoor air quality. Microbial contaminants, once airborne, can be inhaled by occupants and may pose health risks, especially to individuals with respiratory conditions or compromised immune systems. Given the potential health risks associated with microbial contamination on curtains, conducting bacteriological assessments becomes crucial. Bacteriology, a branch of microbiology, specifically focuses on the study of bacteria, their identification, and their roles in infectious diseases. Assessing the bacterial load, diversity, and identification on curtains in hostels, for example, can provide valuable insights into the presence of potential pathogens and the overall hygiene condition of the environment. By conducting bacteriological assessments, it is possible to identify specific bacterial species present on the curtains and determine their potential pathogenicity. This information can guide the development of effective cleaning and maintenance strategies to mitigate microbial contamination and promote a healthier indoor environment. Regular cleaning, proper ventilation, and maintaining appropriate humidity levels are essential measures to control microbial growth on curtains and improve indoor air quality.

Curtains in indoor environments can serve as reservoirs for microbial contaminants. Factors such as dust, humidity, ventilation, and the presence of organic matter contribute to microbial growth on curtains. The accumulation of contaminants on curtain surfaces, along with inadequate ventilation, high humidity, and infrequent cleaning practices, creates an environment conducive to microbial colonization and proliferation. These microorganisms can become airborne when curtains are disturbed, potentially affecting indoor air quality and occupants' health. Conducting bacteriological assessments on curtains is crucial to identify potential pathogens and assess the overall hygiene condition of the environment.

Implementing proper cleaning and maintenance practices based on these assessments can help mitigate microbial contamination and promote a healthier indoor environment.

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3.1 Study Area**

This research was carried out on the main campus of the University of Benin, Benin City, Edo state, Nigeria. The campus accommodates students in its ten university halls; Halls 1-3 for undergraduate students studying at the University of Benin. A questionnaire survey was used to obtain curtain handling practices of participants in this study.

#### **3.2 Study Design and Sample Collection**

Before sample collection, students' consent was sought. Fifty samples (50 curtains) were collected from students in the study. Questionnaires were administered to students whose curtains were sampled for bacteriological analysis. This was done to collect information on their curtains-handling practices. Samples were taken from 25 students in Halls 1-3). Students were sampled using the random sampling technique.

Surface swabbing of curtains was done by rubbing with a sterile cotton swab moistened with clean physiological saline solution and collected samples kept back in their containers. Collected samples were transported immediately to laboratory for analysis.

#### **3.3 Sterilization of Materials**

Materials such as Petri dishes, pipettes, glass containers (conical flask, round bottom flask), and bottles were drained and dried. They were wrapped with aluminum foil and sterilized in a

hot-air oven at 160°C for an hour. They were allowed to cool after sterilization before usage. An aseptic working environment was achieved using a Bunsen burner flame and the disinfection of work surfaces with alcohol.

### 3.4 Preparation and Sterilization of Media

All media used were obtained from Oxoid and were prepared according to manufacturers' instructions. The media used in this study include Plate count agar, Bacillus cereus agar (BCA), Eosin methylene blue agar (EMB), Mannitol salt agar (MSA), Pseudomonas cetrimide agar (PCA), Triple sugar iron agar (TSI), Simmons citrate agar (SCA) and Mueller Hinton agar (MHA) (Willey *et al.*, 2008).

### 3.5 Sample Preparation, Inoculation and Incubation

Examining bedsheet or curtains surfaces was swabbing a known area using a sterile swab moistened in sterile saline. This semi-quantitative approach enables the enumeration of the microorganisms per cm<sup>2</sup> and can facilitate the interpretation of the results according to the method delineated by Public Health England. Aseptically soaked with 10 ml of physiological saline, sterile swab sticks were used to swab a known area of the bedsheet or curtains which came in direct contact with the body. The swab sticks were then immediately transferred into 10 ml of nutrient broth. Public Health England (2014) states this equals 100 and gives a lower detection limit of 10 colony-forming units (CFU) per swab if 1 mL is plated.

$$\text{Bacterial count } \left( \frac{\text{cfu}}{\text{cm}^2} \right) = \left( \frac{C}{V(n_1 + 0.1 n_2)d} \right) \times n_3 \quad (1)$$

Where:

$C$  = sum of colonies on the plates counted

$V$  = volume of inoculum

$n_1$  = number of plates counted at first dilution

$n_2$  = number of plates counted at second dilution

$n_3$  = original volume of neat suspension

$d$  = dilution from which the first count was obtained

### **3.6 Phenotypic Identification of Bacteria from Samples**

Pure cultures of the bacterial isolates were obtained from the subculture of a single colony from the successful pour plate technique and were characterized using cultural, morphological and biochemical methods. Several tests, such as Gram reaction, catalase, urease, indole, oxidase, citrate utilization and respective reactions of bacteria on triple sugar iron agar, were carried out to identify bacterial isolates presumptively (Holt *et al.*, 1994).

#### **3.6.1 Gram Staining Test**

A Gram staining test was carried out to determine the presence of Gram-positive and Gram-negative isolates. Neat, grease-free, and sterile-dried microscope slides with labels were smeared using a sterilized loop, and the organism was air-dried and heat-fixed over a flaming Bunsen burner. The fixed smear was saturated with drops of crystal violet, left for one minute to react, and washed off with distilled water. Lugol's iodine, which serves as a mordant, was added, left for one minute, and washed off with distilled water. The smear was decolorized with 95% ethyl alcohol, went for 30 seconds, and washed off with distilled water. Then, the smear underwent counter staining using safranin solution for one minute and was rinsed with distilled water. Lastly, the smear was allowed to air dry, and immersion oil was added for a microscopic view on an immersion objective lens light microscope. Colours, shapes, and arrangements were used in identifying the organisms. Gram-positive organisms maintained the crystal's purple color, while Gram-negative retained the pink of safranin.

#### **3.6.2 Potassium Hydroxide (KOH) test**

The potassium hydroxide (KOH) test was used to determine or confirm Gram-negative bacteria, to quickly differentiate between Gram-negative and Gram-positive bacteria as a

complement to Gram staining. KOH breaks down the thin peptidoglycan bacterial cell walls of Gram-negative bacteria but does not affect the thick layer of Gram-positive cell walls. Disruption of bacterial cell walls lyses the cell and releases its contents, including the genetic material. A drop of 3% KOH solution was applied on a labeled clean microscope slide and smeared with pure isolated culture using a loop. It was stirred carefully and observed that the solution turned to be a viscous or dense suspension, which formed a slimy or mucoid string within 60 seconds, and the appearance of that indicated a positive result as the presence of Gram-negative isolates. While non-slimy viscous suspensions remained negative results.

### **3.6.3 Biochemical Test**

To better characterize these isolates, biochemical tests were conducted, which included:

#### **3.5.4.1 Indole Test**

An indole test was carried out to demonstrate the ability of certain bacteria that can decompose amino acid **tryptophane** to **indole**. The indole production test is essential in identifying the *Enterobacteriaceae* family that breaks down the amino acid tryptophan by releasing indole in the presence of intracellular enzymes called "tryptophanase." Several drops of Kovac's indole reagent were placed on a filter paper. A portion of a pure isolated colony picked from the TSA pure culture with an inoculating loop was smeared onto the reagent-saturated area of the filter paper. It was allowed and examined to observe for color development within 2 - 3 minutes. **In this spot test**, indole combined with the reagents in the filter paper matrix to produce a **blue-to-blue-green color change** on the bacterial smear, **and adverse** reactions remained colourless or light pink.

#### **3.6.4.2 Oxidase Test**

The oxidase test was carried out to detect the presence of a cytochrome oxidase or indophenol oxidase that will catalyze electrons between electron donors in the bacteria and a redox dye known as tetramethyl-*p*-phenylene-diamine. The dye would be reduced to deep purple colour if yielded to positive reactions.

Several reagents can be used for this study, but Kovacs oxidase reagent: 1% tetra-methyl-p-sKovacs oxidase reagent solution, and a speck of the pure culture was smeared on it with a platinum loop. It was allowed and observed for colour development within 10 - 60 seconds. The appearance of a deep purple-blue/blue colour indicated oxidase production and the negative result was when no color changed.

#### **3.6.4.3 Catalase Test**

This test was used to distinguish between bacteria that produce the catalase enzyme, such as *Staphylococci*, and bacteria that do not, such as *Streptococci*. Catalase catalyzes the breakdown of hydrogen peroxide ( $H_2O_2$ ) to oxygen ( $O_2$ ) and water ( $H_2O$ ). In this test, 2mL of hydrogen peroxide solution was poured into a test tube, and some colonies of the test organism were picked and immersed into the  $H_2O_2$  solution using a sterile glass rod. The bacteria that generated catalase (positive result) produced gas bubbles (oxygen), but those that did not possess catalase enzyme had none (negative result).

#### **3.6.4.4 Citrate Utilization Tests**

The citrate utilization test is a part of the test used to differentiate organisms on their ability to utilize citrate as the primary energy source. A citrate test was performed to differentiate members of *Enterobacteriaceae* capable of fermenting citrate in the presence of the enzyme citrate. Simon's citrate agar contained citrate as significant energy and was prepared for inoculation on Petri dishes. Well-prepared and sterilized citrate agar plates were inoculated from the pure isolated culture by streaking the surface with a sterilized loop. The plates were then incubated at 37°C for 24 hours. There were changes in color due to bacterial growth of the organisms on the medium due to citrate metabolism, which gave a positive citrate test. The shift in pH turns the bromothymol blue indicator in the medium from green to blue (positive result). A negative test was demonstrated with no growth, no color change, or the color of the medium remains green.

#### **3.6.4.5 Urease test**

The urease test is used to identify bacteria capable of producing the urease enzyme. The organisms that secrete urease can hydrolyze urea to ammonia and carbon dioxide. This test was used to distinguish urease-positive bacteria from other *Enterobacteriaceae*. The isolated pure bacteria were inoculated into well-prepared and autoclaved Christensen-modified urea broth and incubated for 24 hours at 37°C. Urease-positive cultures produced a pink color due to a change in the indicator's color in the presence of ammonia, while the negative result remains no color change or yellow-orange color.

#### **3.6.5 Mannitol Test**

The mannitol test is selective (the presence of high salt concentration; sodium chloride inhibits most Gram-negative and Gram-positive bacteria) and differential test (the ability of the organism to ferment or not the mannitol). The ability to ferment mannitol induces acidification, changing the medium's coloration from red to yellow. A well-prepared mannitol salt agar was autoclaved at 121°C for 15 minutes, cooled and plated. Inoculated with pure isolates and incubated for 24 hours at 37°C. Growths were observed with yellow zones and yellow colonies as positive results. The negative result remained red-pink color with growths.

#### **3.6.6 Triple Sugar Iron (TSI) test**

The Triple Sugar Iron (TSI) test is an ability to test an organism's capability to ferment sugars and to produce hydrogen sulfide (H<sub>2</sub>S) gas (O<sub>2</sub>), or both. The test was used primarily to differentiate members of the *Enterobacteriaceae* family based on their sugar fermentation patterns and from other Gram-negative rods. An agar slant prepared of a TSI agar was used in carrying out this test in a sterile test tube at a slanted angle. The slanted medium was inoculated with TSA pure culture using a straight inoculation needle by stabbing first through the center to the bottom of the tube and streaking the agar slant's surface. After inoculations, the test tubes were covered with foil paper and left at an ambient temperature of 36°C to

incubate for 24 hours. Reactions on test tubes were examined, and sugar fermentations were indicated by the production of H<sub>2</sub>S, gas, and a change in colors from red (alkaline) to yellow (acid). When an alkaline/acid (red top/yellow bottom) slant reaction appeared, it only indicated dextrose (glucose) fermentation. When an acid/acid (yellow top/yellow bottom) slant reaction appeared, it showed the fermentation of dextrose, lactose, and/or sucrose. The appearance of an alkaline/alkaline (red top/red bottom) slant reaction represented the absence of sugar fermentation. The blackening of the medium in the slant indicated H<sub>2</sub>S production. Bubbles, cracks, or bottom-raised space in the slanted agar indicated gas production (formation of CO<sub>2</sub> and H<sub>2</sub>).

### **3.7 Growth on Differential Media**

#### **3.7.1 *Bacillus Cereus* Agar Base**

*Bacillus cereus* agar was used to identify and isolate *Bacillus* species and pathogenic *Staphylococci* species. *Bacillus cereus* agar helps to restrict the growth of Gram-negative bacteria, and this differentiating media allows the differentiation of Gram-positive *Bacillus* species. Autoclaved dissolved *Bacillus cereus* agar at 121°C for 15 minutes; then was allowed to cool and poured into Petri dishes. Isolated pure cultures were inoculated by streaking on the medium and incubated the plates at 37°C for 24 hours. Plates were examined and observed for typical growths by colony forms, colors, and spore morphology.

#### **3.7.2 Mannitol Salt Agar (MSA)**

MSA is used in differentiating and selecting mostly *Staphylococcus* species, which was prepared and autoclaved at 121°C for 15 minutes, then was allowed to cool and poured into Petri dishes. The isolated pure cultures were inoculated by streaking on the medium, and the plates were incubated at 37°C for 24 hours. Plates were examined and observed for typical growth.

### **3.7.3 Pseudomonas Agar**

*Pseudomonas* species produce a variety of pigments, and fluorescein is commonly produced. Pseudomonas agar was used to determine pigment production by *Pseudomonas* species. Pseudomonas agar is a selective and differential medium that inhibits Gram-positive and Gram-negative bacteria other than isolating *Pseudomonas* species. Pseudomonas agar Petri dishes were prepared for inoculation after the medium was autoclaved at 121°C for 15 minutes, cooled, and poured onto plates. Plates were inoculated with the isolated pure inoculums and incubated at 37°C for 24 hours. It was then examined and observed for growths, where the positive result was cream to greenish-yellow coloration in the agar, which can fluoresce under UV lighting.

### **3.7.4 Eosin Methylene Blue (EMB) agar**

**Eosin Methylene Blue (EMB) agar** is a differential medium that inhibits the growth of Gram-positive bacteria and is used to indicate Gram-negative pathogenic enteric bacteria by distinguishing between organisms that ferment lactose and those that cannot cope with a color indication. A sterile petri plate was prepared with EMB, which was autoclaved at 121°C for 15 minutes, allowed to cool, and inoculated with pure inoculums by streaking. Inoculated plates were incubated at 37°C for 24 hours and examined plates for colonial morphological changes. Lactose fermenting bacteria produced dark colonies with green metallic sheen or pink mucoid colonies (positive result), and lactose non-fermenters were colorless (negative result).

## **3.8 Phenotypic Virulence Test**

Pure culture of the isolates was identified and characterized based on their phenotypic virulence factors, including gelatinase, deoxyribonuclease (DNase), lipase, and hemolysin.

### **3.8.1 Nutrient Gelatin test**

Nutrient gelatin was used to identify and differentiate gelatinase-producing bacteria into different groups based on their ability to hydrolyze gelatin. The gelatin liquefaction test was used to test the ability of an organism that produced gelatinase and the organism's ability to liquefy gelatin in the presence of the gelatinase enzyme secreted extracellularly. Nutrient gelatin was dissolved, dispensed 5 mL of a medium into a test tube, and covered with foil paper. The medium was autoclaved with the test tubes at 121°C for 15 minutes. The tubed medium was allowed to cool in an upright position before inoculation. The isolated pure inoculum was stabbed-inoculated into the sterilized tubes containing nutrient gelatin. The inoculated tubes were incubated at 37°C for up to 48 hours. The tubes were later immersed into an ice block and bathed for 30 minutes to confirm that gelatin liquefaction was due to gelatinase activities. For stabbed-inoculated tubes, if any gelatinase-positive bacterium was present, the secreted gelatinase will hydrolyze gelatin, resulting in the medium's liquefaction. Inoculated with a gelatinase-negative bacterium for nutrient gelatin medium remained solidified after the cold treatment (Shruthi *et al.*, 2012).

### **3.8.2 DNase Test Agar**

The deoxyribonuclease (DNase) test was used to determine the ability of an organism that produce the extracellular DNase enzyme and was also used to differentiate non-pigmented strains from most other *Enterobacteriaceae*. DNases are enzymes that hydrolyze DNA and release free nucleotides and phosphate, smaller monomers that can be easily taken into the bacterial cell. A well-prepared DNase agar was autoclaved at 121°C for 15 minutes, cooled, and poured into sterile petri plates. Agar plates were inoculated with isolated pure inoculums and incubated at 37°C for 24 hours. Based upon the DNA digested zone of cleared or transparent surrounding the colonies, strains were termed as DNase positive. The absence of a cleared zone was a negative test result (Georgescu *et al.*, 2016).

### **3.8.4 Hemolysis on Blood Agar Base**

Sheep blood agar base or Columbia agar blood base was used for isolation, identification, and antimicrobial susceptibility of fastidious and non-fastidious microorganisms and used to determine different types of hemolytic reactions; Haemolysin is an exotoxin produced by bacterial extracellular enzymes that lyse red blood cells. The medium is an enrichment culture that requires Sheep blood as the first choice to prepare the blood agar plates, followed by horse, rabbit, or goat blood. Sheep blood agar was prepared, sterilized by autoclaving at 121°C for 15 minutes, cooled, and enriched with 1% sterile Sheep blood aseptically and gently appropriately mixed. It was dispensed into Petri dishes and inoculated with isolated pure inoculums, and the following cultural characteristics were observed after incubation at 37°C for 24 hours (Shruthi *et al.*, 2012). Different types of hemolysis were described on Sheep blood agar plate's colonies as follows: Alpha hemolysis ( $\alpha$ ) – Partial hemolysis (hemoglobin to methemoglobin), which resulted in a greenish discoloration zone around the colonies. Beta hemolysis ( $\beta$ ) – Complete lysis of red blood cells resulting in a transparent and/or cleared zone around the colonies. Gamma-hemolysis ( $\gamma$ ) – No hemolysis occurred, resulting in no change in the medium when observed (Shruthi *et al.*, 2012).

### **3.9 Antimicrobial Susceptibility Test**

The Kirby-Bauer disk diffusion test technique carried out the antibiotic susceptibility test. Eight (8) antibiotic sensitivity discs corresponding to drugs commonly used in treatments of human and animal infections as recommended by the Clinical and Laboratory Standards Institute (CLSI, 2020) were tested against the bacterial isolates on Muller Hinton agar. The test isolates were susceptible to conventional antibiotics using the disc diffusion technique on Mueller-Hinton agar. Bacterial cells were standardized (0.5 McFarland turbidity standard), and 0.1 ml of standardized bacterial suspension was plated (spread plate) using sterile swabs.

The plates were allowed to dry, and antibiotic discs were aseptically placed on them. The antibiotic discs include CIP; Ciprofloxacin (5µg), CRO; Ceftriaxone (30 µg), RL; Sulfamethoxazole (1.25/23.75 µg), E; Erythromycin (15 µg), TET; tetracycline (30 µg), MEM; Meropenem (10 µg), AMC; Amoxicillin/clavulanic acid (20/10 µg), CN; Gentamicin (10 µg). The plates were incubated at 37<sup>0</sup>C, and the growth inhibition zones around the antibiotic discs were measured after 24 h. Growths were observed, and zones of inhibitions were measured and evaluated as recommended by the CLSI standard guidelines (CLSI, 2020). The information gathered was utilized to create a phenotypic drug resistance pattern among the isolated bacteria.

### **3.10 Evaluation of Multiple Antibiotics Resistance (MAR) Index**

Multiple antibiotic resistance (MAR) index was determined for the identified isolates with the formula;

$MAR\ index = \frac{y}{nx}$  where  $y$  = number of resistances scored,  $n$  = number of isolates,  $x$  = number of antibiotics

MAR index has a standard permissible limit of 0.2. Therefore, bacterial isolates evaluated beyond the allowable limits were considered resistant, implying health implications (Chitanand *et al.*, 2010; Davis and Brown, 2016; Ogofure and Igbinosa, 2021).

### **Statistical Analysis**

The data obtained from this research were analyzed in R studio using one-way ANOVA followed by Tukey HSD test, and PhyloT was used to analyze sequences obtained to draw the relatedness between bacterial isolates during the research.

## CHAPTER FOUR

### RESULTS

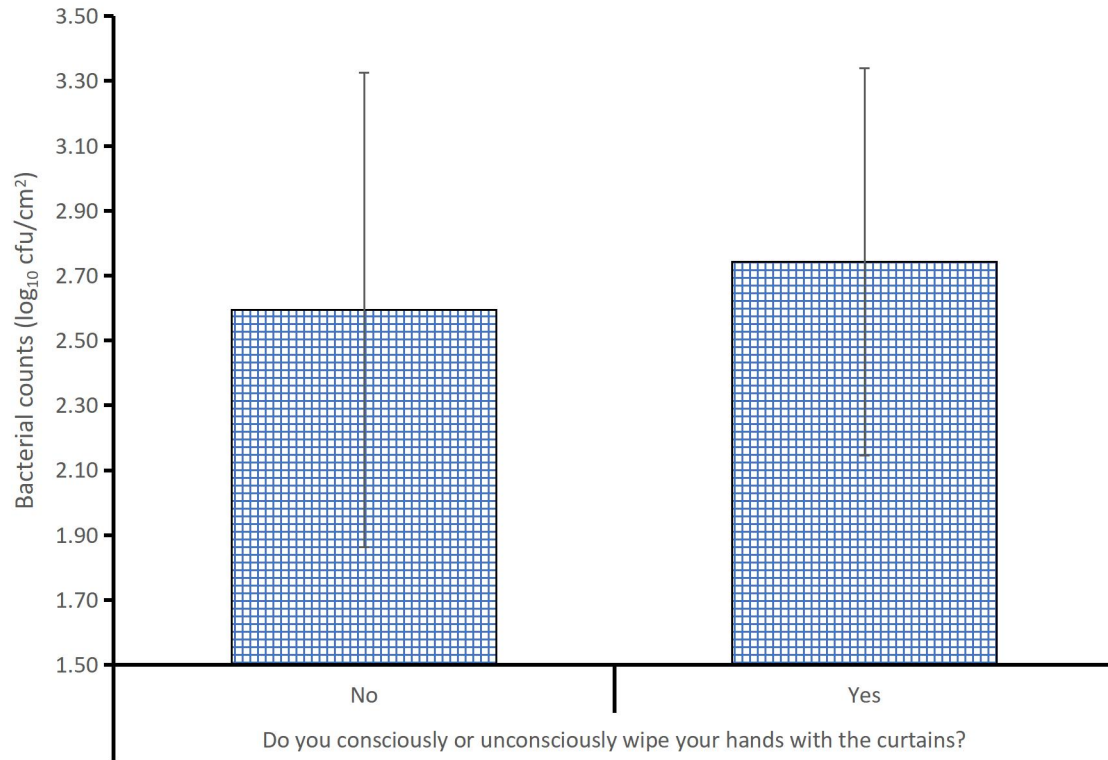
The results revealed that in Table 1. 98.9% of respondents admitted to having and using curtains in their hostels. 98.9 % did not own any pets. 84.2% admitted to frequent handwashing after using the restroom and before and after meal. 98.9% reported that they are aware that curtains need maintenance. 89.5% admitted to wiping their hands with their curtains consciously or unconsciously, those who carry out such habits occasionally were 29.5%.

Figure 4.1 shows the total heterotrophic bacteria count based on the number of participants that practice wiping their hands on their curtains. The heterotrophic bacteria counts ranged from log<sub>10</sub> cfu/cm<sup>2</sup>. Table 4.2 shows the cultural, morphological and biochemical characteristics of bacteria obtained from curtains. The characteristics observed identified bacteria isolated as *staphylococcus aureus*, *pseudomonas aeruginosa*, *bacillus subtilis* and *seratia macescens*. Figure 4.2 shows frequency of occurrence of bacterial isolates on surface of curtains. Table 4.3 shows phenotypic virulence properties of the bacterial isolates from curtain samples. Table 4.4 shows antimicrobial sensitivity of bacterial isolates obtained from curtain samples. Figure 4.5 shows multiple antibiotics resistance index of bacterial isolates from curtains samples.

The phenotypic virulence properties of the isolates showed that they were capable of hemolysin and lipase production, while *staphylococcus aureus* was positive for all three phenotypic virulence tests. All isolates were resistant to tetracyclin, colistin, metronidazole and augumetin. They were, however, sensitive to gentamicin, ciprofloxacin, and clindamycin. The isolates were above the permissible limit of 0.2 for multiple drug resistance index; thus, they are multidrug-resistant isolates of public health importance.

**Table 4.1: Curtain handling practices of respondents in the study**

<b>Variable</b>	<b>Frequency</b>	<b>Percentage</b>
<b>Do Respondents Have Curtains</b>		
Defer to Answer	1	1.1
Yes	94	98.9
<b>Do Respondents Use Curtains</b>		
No	1	1.1
Yes	94	98.9
<b>Do Respondents Have Pets</b>		
Defer to Answer	1	1.1
No	94	98.9
Yes	0	0.0
<b>Frequency of Hand Washing</b>		
After Using the restroom and before and after Meals	80	84.2
Only when visibly Dirty	10	10.5
Defer to answer	5	5.2
<b>Do You consider the condition of your curtains as a factor in maintaining hygiene?</b>		
Defer to Answer	1	1.1
Yes	94	98.9
No	0	0.0
<b>Do you consciously or unconsciously wipe your hands with the curtains?</b>		
Yes	85	89.5
No	10	10.5
Maybe	0	0
<b>If Yes, How Often?</b>		
Defer to Answer	31	32.6
Occasionally	28	29.5
Often	21	22.1
Sometimes	15	15.8



**Figure 4.1.** Heterotrophic bacterial counts (log<sub>10</sub> cfu/cm<sup>2</sup>) of curtains

**Table 4.2: Cultural morphological and biochemical characteristics of bacteria obtained from curtains**

<b>Morphological</b>				
Elevation	Raised	Raised	Flat	Raised
Margin	smooth	Entire	coarse	Entire
Color	Cream	lemon	milk white	Cream
Shape	Irregular	Circular	concave	Circular
Size	Small	Medium	large	Medium
Gr. diff. agar	MSA	PCA	BCA	EMB
Color	Yellow	green	Straw	Opaque
Staining				
Gram stain	+	-	+	-
cell type	Cocci	rod	Rod	Rod
Arrangement	clusters	disperse	disperse	Disperse
Color	purple	pink	purple	Pink
Spore staining	-	-	+	-
Biochemical				
KOH String Test	-	+	-	+
Catalase	+	+	+	+
Indole	-	-	-	-
Citrate	+	+	-	+
Oxidase	-	+	-	-
Motility	-	+	+	+
Urease	+	+	-	-
Glucose	+	-	+	+
Sucrose	+	-	-	+
Lactose	+	-	-	+
Mannitol	-	-	-	+
Gas formation	-	-	-	-
H <sub>2</sub> S formation	-	-	-	-
TSI (Slant/Butt) reaction	A/A*	K/K	A/A	(*A/A)
Esculin Hydrolysis	-	-	+	-
Identity	<i>Staphylococcus aureus</i>	<i>Pseudomonas aeruginosa</i>	<i>Bacillus subtilis</i>	<i>Serratia marcescens</i>

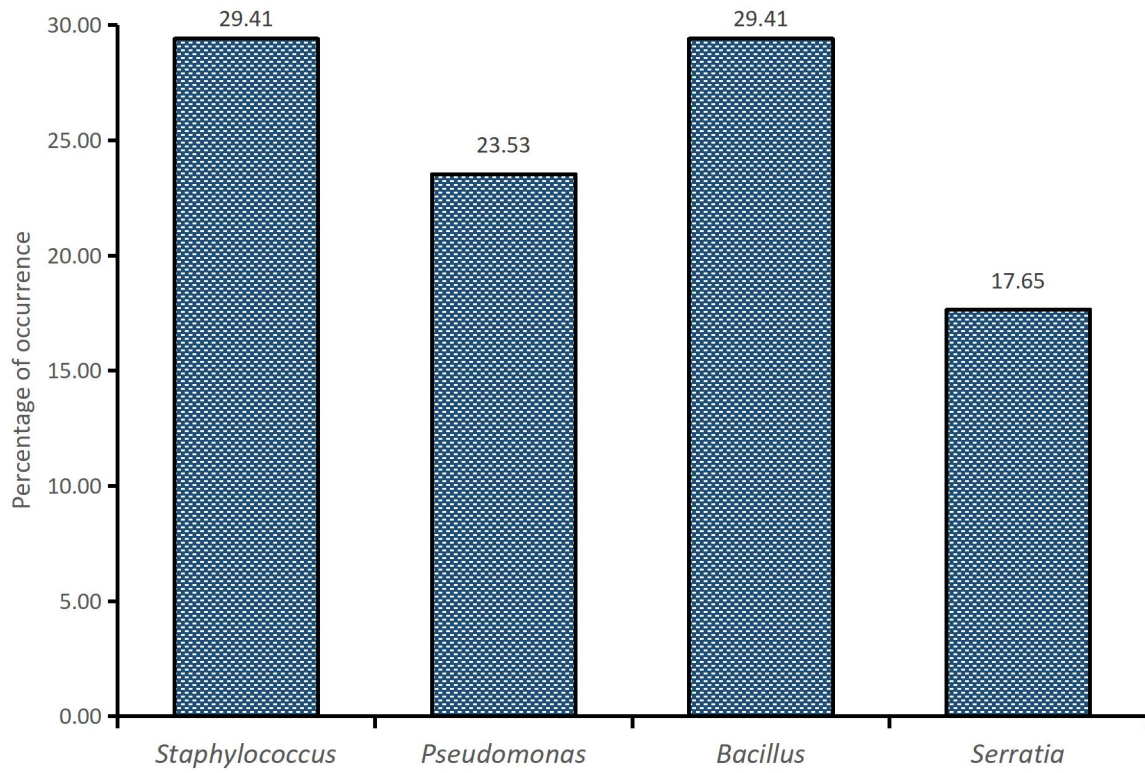


Figure 4.2. Percentage frequency of occurrence of bacterial on surfaces of curtains

**Table 4.3 Phenotypic virulence properties of the bacterial isolates from curtain samples**

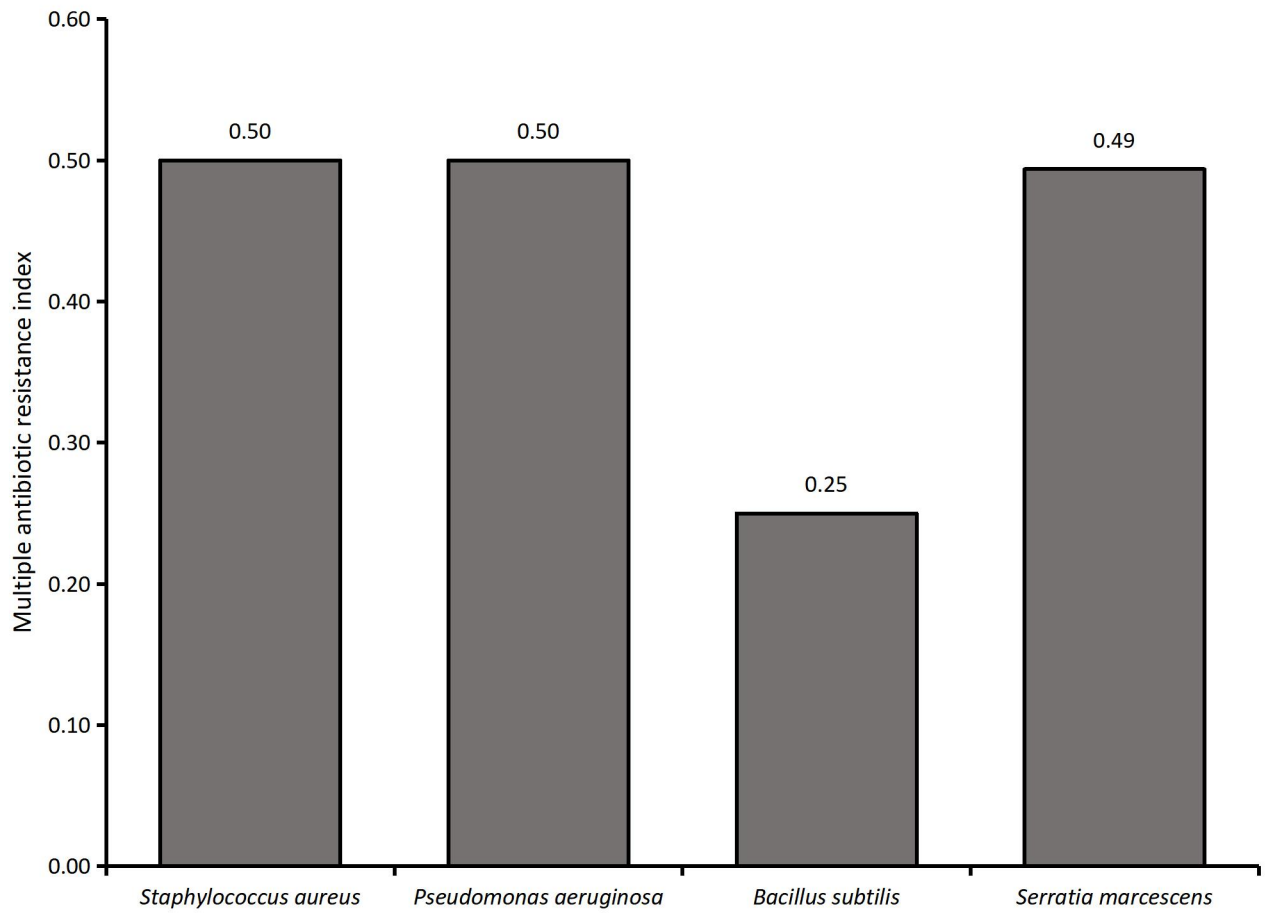
<b>Bacterial Isolates</b>	<b>Phenotypic virulence properties</b>		
	<b>DNase</b>	<b>Lipase</b>	<b>Hemolysin</b>
<i>Staphylococcus aureus</i>	+	+	$\beta$
<i>Pseudomonas aeruginosa</i>	-	+	$\beta$
<i>Bacillus subtilis</i>	-	+	$\beta$
<i>Serratia marcescens</i>	-	+	$\beta$

Key:  $\beta$  = Beta hemolysis, + = positive; - = negative

**Table 4.4: Antibacterial sensitivity of bacterial isolates obtained from curtains samples**

<b>Isolates</b>	<b>CD</b>	<b>E</b>	<b>TE</b>	<b>GEN</b>	<b>M</b>	<b>AG</b>	<b>CS</b>	<b>CB</b>
<i>Bacillus subtilis</i>	S	S	S	S	R	S	R	S
<i>Serratia marcescens</i>	S	S	S	S	R	S	R	R
<i>Staphylococcus aureus</i>	S	I	I	S	R	S	R	R
<i>Pseudomonas aeruginosa</i>	S	S	R	S	R	S	R	R

Key: AG - Amoxicillin (20+10mcg), CIP - Ciprofloxacin (5mcg), TE - Tetracycline (30mcg), GEN - Gentamycin (10mcg), CB - Cefuroxime (30mcg), E - Erythromycin (15mcg), CD - Clindamycin (2mcg), M - Metronidazole (5mcg), CS - Colistin (10mcg), S = Sensitive, R = Resistant



**Figure 4.3:** Multiple antibiotic resistance index of bacterial isolates from curtains

## CHAPTER 5

### DISCUSSION AND CONCLUSION

#### 5.1 Discussion

Curtains give seclusion, lessen the quantity of light that enters a room, and enhance the interior design of a space. However, as opposed to following direct human contact, people may be less inclined to wash or disinfect their hands after contact with inanimate objects like curtains (Trillis *et al.*, 2008). As a result, they are also a significant site of environmental contamination. As a result, microorganisms that cause illnesses could be spread by coming into contact with these high-touch surfaces (Kramer *et al.*, 2006; Mahida *et al.*, 2014; Johnstone *et al.*, 2019). Because they are constantly touched, rarely cleaned, or changed, and possibly because people are less inclined to wash their hands after coming into contact with inanimate things, curtains are at a high risk for cross-contamination (Huslage *et al.*, 2010). Curtains and the many microorganisms found on them have been the subject of investigations by various researchers (Beard-Pegler *et al.*, 1998; Shek, *et al.*, 2018; Bushey, *et al.*, 2015). This discovery is consistent with earlier studies that suggested potentially harmful bacteria may contaminate curtains, making them possible carriers of these pathogens to their unknowing users.

A questionnaire survey that was done for this research produced some fascinating findings. Interestingly, 98.9% of respondents reported having curtains in their hostels and using them. When it comes to hygiene, efforts to stop the transmission of diseases including handwashing and cleaning high-touch surfaces, are not always followed. According to the survey respondents, handwashing compliance was not 100%, and high-touch surfaces are commonly overlooked or are not regularly cleaned (Johnstone *et al.*, 2019). This is consistent with the findings of the study, which found that 84.2% of respondents wash their hands after using the restroom and before and after meals. In this survey, 89.5% of participants admitted to wiping

their hands on the curtains. 5.2% declined to respond. Though the respondents acknowledged washing their hands, there is still a chance that microbes could move to the curtains, as was also indicated in work done by Old (1998) because some bacteria can persist for a long time on fabric (Neely and Maley, 2000).

In this study, participants who consciously or unconsciously wiped their hands on their curtains had bacterial counts of up to 2.7 colony-forming units (CFU)/cm<sup>2</sup>, compared to 2.5 CFU/cm<sup>2</sup> for those who did not. A recent cross-sectional investigation discovered that 31% of the curtains examined produced methicillin-resistant *Staphylococcus aureus* (MRSA) and that the curtains were contaminated with up to 13.3 colony-forming units (CFU)/cm<sup>2</sup> of bacteria (Shek 2017). Additionally, Ohl *et al.* demonstrated that direct swabbing of curtains produced 13.2 bacterial colonies on average per cm<sup>2</sup>.

Percentage occurrence of the bacterial isolates include, 29.41% of *Bacillus subtilis* and 29.41% of *Staphylococcus aureus*. This is comparable to but greater than, isolates from a study that discovered that contamination rates ranged from 11.9 to 28.5 percent across several facilities, with 22 percent of cultures obtained from curtains testing positive for multi-drug resistance organisms (MDROs). According to Carikas and Matthew (2019), 13.8 percent of these cultures had VRE, 6.2 percent contained resistant gram-negative bacteria (R-GNB), and 4.9 percent contained MRSA.

Four bacterium isolates—*Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, and *Serratia marcescens*—were isolated in this study. It calls for concern that these isolates were resistant to antibiotics like tetracycline, gentamycin, metronidazole, colistin, and cefuroxime. According to the multiple antibiotic resistance index, this multidrug resistance ranged from 0.25 (for *Bacillus subtilis*) to 0.50 (for *Pseudomonas aeruginosa* and *Staphylococcus aureus*), indicating their potential public health implications as these values above the permitted limit of 0.2 (Davis and Brown, 2016).

It has been found that not all organisms are destroyed by washing. These discoveries are particularly important because several of the detected species have the potential to cause potentially serious infections, especially in people who have compromised immune systems (Woodland *et al.*, 2010). Other possible reasons for this discovery include the possibility that the curtains were polluted during washing handling or that they were contaminated by other materials (Sattar *et al.*, 2001).

## **5.2 Conclusion**

To assess the health implications for residents and apply practical preventive actions, it is crucial to comprehend the intricate microbial ecosystem of curtains present in our homes. To remove and clean curtains, substantial resources are needed. Little research exists to recommend cleaning schedules or frequency. The evaluation of curtains' microbiological quality offers important insights into any potential health hazards linked to these frequently disregarded objects. This study emphasizes the need for better cleanliness standards and awareness among homeowners. The microbiological burden on curtains can be greatly reduced by taking easy steps like routine cleaning, good ventilation, and the use of antimicrobial treatments, which will result in a better atmosphere for all inhabitants.

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