MICROBIOLOGICAL EXAMINATION OF PERSONAL EFFECTS OF STUDENTS IN LECTURE THEATRERS

BY

PRECIOUS OMOIKHEFE OKHUOYA

LSC2103990

DEPARTMENT OF MICROBIOLOGY,

FACULTY OF LIFE SCIENCES,

UNIVERSITY OF BENIN,

BENIN CITY

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

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CERTIFICATION

I hereby certify that this project was carried out by OKHUOYA Precious Omoikhefe with matriculation number LSC2103990 of the Department of Microbiology, Faculty of Life sciences under the supervision of Dr. C.U. Ajuzie, University of Benin.

_________________ _________________

Dr. C.U. AJUZIE Date
(Project supervisor).

_________________ _________________

Prof. E.O. IGBINOSA Date
(Head of Department)

DEDICATION

This project is dedicated to God Almighty who saw me through everything and whose guidance and blessing have been my strength and inspiration. I also extend my heartfelt gratitude to my parents, siblings and amazing friends whose unwavering support, love and encouragement have been instrumental in my journey. Thank you for believing in me and for being my constant pillars of strength.

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ABSTRACT

This study investigated the microbial contamination of personal effects belonging to undergraduate students in lecture theaters at the University of Benin, Edo State, Nigeria. The aim was to isolate, identify, and characterize bacteria and fungi present on frequently handled items such as mobile phones, bags, laptops, wristwatches, earbuds, and power banks, as well as to assess their antibiotic susceptibility profiles. Samples were collected using sterile swabs moistened with saline and cultured on Nutrient Agar, MacConkey Agar, *Salmonella-Shigella* Agar, and Potato Dextrose Agar following standard microbiological procedures. Bacterial isolates were characterized using Gram staining and biochemical tests, while fungal isolates were identified based on macroscopic and microscopic features. The total heterotrophic bacterial count ranged from 0.85×10^4 to 4.75×10^4 CFU/m², and the total fungal count ranged from 4.0×10^3 to 9.0×10^3 CFU/m², with higher microbial loads observed on items from female students. Five bacterial species were identified: *Enterobacter cloacae*, *Salmonella* spp., *Bacillus* spp., *Escherichia coli*, and *Staphylococcus aureus* alongside fungal isolates including *Aspergillus niger*, *Aspergillus* spp., *Penicillium* spp., *Mucor* spp., and Yeast. Antibiotic susceptibility testing revealed high sensitivity to ciprofloxacin and gentamicin but resistance to tetracycline, metronidazole, and colistin, indicating the presence of multidrug-resistant strains. The findings demonstrate that students' personal items serve as potential fomites capable of harboring and transmitting pathogenic and antibiotic-resistant microorganisms within academic environments. This highlights the need for improved hygiene practices, regular disinfection of personal effects, and health education to minimize fomite-mediated infections and safeguard public health.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of study

Microorganisms are ubiquitous and exist in a variety of environments, including those considered non-clinical, such as lecture theaters. These microorganisms include bacteria, fungi, and viruses, many of which are capable of surviving on surfaces for extended periods (Kramer *et al.,* 2006). Personal effects such as bags, mobile phones, notebooks, and clothing serve as fomites, i.e., inanimate objects capable of carrying and transferring infectious agents (Weber and Rutala, 2013).

Lecture theaters, especially those that are frequently packed and have inadequate ventilation are ideal the growth and spread of microorganisms. Students commonly place their personal belongings on floors, tables, and shared surfaces, increasing the risk of cross-contamination. Additionally, these items are rarely cleaned, promoting the survival and spread of pathogenic or opportunistic microorganisms.

Technological advancements over recent decades have significantly increased dependence on personal belongings such as mobile phones, bags, and laptops, particularly among university students (Nikolopoulou and Gialamas, 2018; Olu-Taiwo *et al.*, 2021). These everyday items can serve as fomites capable of carrying infectious agents such as bacteria posing a potential threat to public health (Meadow *et al.*, 2014). Several studies have revealed that microorganism from the environments can be carried and hosted by inanimate items, (i.e., phones, wristwatch, laptops) and then be transferred to other substrates including the human body (Domenico et al., 2020). Extensive research has identified commonly used items like mobile phones, bags, and laptops as significant reservoirs of microbial life (Chandra *et al.*, 2014).

Mobile phones are constantly in use and often come into contact with contaminated surfaces such as tables, restroom sinks, or floors, creating ideal conditions for microbial buildup (Ulger *et al.*, 2009). Similarly, laptops and mobile devices used in medical or public spaces tend to harbor high bacterial loads due to frequent user contact (Bhoonderowa *et al.*, 2014; Ide *et al.*, 2019;). Bags are also frequently placed on unhygienic surfaces like floors or public benches, further increasing their likelihood of microbial contamination (Chandra *et al.*, 2014; Maharjan *et al.*, 2014).

These contaminated items may contain both harmless and harmful microorganisms. Research has shown that pathogens such as *Staphylococcus aureus*, *Escherichia coli*, and *Klebsiella pneumoniae* are frequently isolated from these objects (Koscova *et al.*, 2018). These bacteria are capable of causing health issues ranging from simple skin infections to more severe illnesses such as pneumonia and meningitis (Bodena *et al.*, 2019). For example, Tagoe *et al.* (2011) reported high levels of bacterial contamination on mobile phones used by undergraduates, including strains known to cause disease highlighting a significant health concern. Other investigations similarly found that laptops and bags belonging to individuals are frequently contaminated with diverse microbial species (Meadow *et al.*, 2014).

Several factors affect the microbial load found on these personal effects. These include how often the items are used or cleaned, the specific environments in which they are used, and the hygiene habits of the users (Koscova *et al.*, 2018). Kilic *et al.* (2012), for instance, demonstrated a direct relationship between the frequency of mobile phone use and bacterial contamination levels. Given the wide variation in personal hygiene practices among undergraduates from different backgrounds, the degree of contamination on their personal effects is likely to vary as well. Despite these findings, there is still a limited amount of research focusing on microbial contamination of personal items in non-medical settings like academic institutions.

1.2 Aims and Objectives

The aim of this study is to isolate and identify microbial contaminants present in personal effects of undergraduate students in lecture theatres.

1.3 Specific Objectives are to:

1. determine the bacterial and fungal load of the personal effects like bags, laptops, phones.
2. isolate and identify the bacteria and fungi present
3. determine the antibiotics susceptibility pattern of the isolates.
4. determine the Multiple Antibiotics Resistance (MAR) index of bacteria isolates.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Overview of microbial contamination of personal effects

Microorganisms are tiny life forms that cannot be seen without magnification and require a microscope for observation. These include bacteria, fungi, viruses, and others. They have the ability to survive and remain on surfaces for extended periods, making it possible for them to contaminate both the human body and the surrounding environment either directly or indirectly (Koca *et al.*, 2012).

The term microbial contamination of personal effects describes the presence and proliferation of microorganisms such as bacteria, viruses, and fungi on commonly handled personal items. In student populations, particularly within academic environments like lecture theaters and laboratories, objects such as mobile phones, bags, notebooks, laptops, and clothing are continually at risk of microbial contamination due to frequent handling, contact with shared surfaces, and lack of regular disinfection (Kramer *et al.*, 2006; Cicciarella *et al.*, 2020).

It is widely accepted that non-living objects can act as carriers of microorganisms from their immediate surroundings. These microorganisms possess what is referred to as bio-transfer potential that is, the ability to relocate to a new surface where they can potentially grow and multiply (Verran, 2012).

Hand contact plays a major role in the transmission of infections, with approximately 80% of cases linked to direct or indirect hand contact. Bacteria are known to exist virtually everywhere in air, soil, water, food, plants, animals, and the human body. Inanimate surfaces are no exception, often becoming carriers of environmental microbes. Frequently, Gram-positive cocci such as *Staphylococcus* and *Micrococcus* species, as well as spore-forming bacilli like *Bacillus spp.*, and certain Gram-negative bacteria, are found on items like mobile devices and computer keyboards. These microorganisms can then be transferred to food or human skin, where they may continue to thrive. Additionally, the formation of biofilms by some bacteria may enhance the survival chances of other pathogenic species on the same surface. Without proper cleaning or sterilization, many of these pathogens are capable of remaining infectious on surfaces for days or even weeks, depending on environmental conditions (Jana *et al.*, 2018).

2.2. Bacterial Hazards on Fomite Surfaces

Fomites consist are non-living objects that can become contaminated with pathogenic microorganisms and serve as vehicles in transmission, especially in high-contact environments such as lecture theaters. Undergraduate students frequently handle personal items such as mobile phones, wristwatches, bags, and earphones, which have been identified as potential fomites capable of harboring potentially pathogenic bacteria and resistant bacteria.

Fomite surfaces, especially those frequently touched or shared, can serve as significant reservoirs of potentially pathogenic bacteria. These surfaces become hazardous when contaminated by human contact, body fluids, or environmental exposure, and can contribute to the indirect transmission of infectious diseases. Several studies have shown high rates of bacterial contamination on students' personal effects, emphasizing the public health risks associated with their improper handling. Because people in industrialized countries spend approximately 90% of their time indoors, the most important fomites for contamination and transmission tend to be those found in the built environment and those that humans frequently come into direct contact with such as mobile phones, laptops, bags. Each of these objects is host to an entire community composed of a wide variety of bacterial, organisms, including potential pathogens and microbial metabolic products harmful to humans (Stephens *et al.,* 2019). Fomites become contaminated with bacteria by direct contact with body secretions or fluids, contact with soiled hands, talking, sneezing, coughing (Boone and Gerba, 2019). In buildings, we shed bacteria directly to the indoor air and onto building surfaces, bacteria are transported indoors from outdoors, and we also acquire bacteria from our surroundings.

2.2.1. Potentially Pathogenic Bacteria

Personal effects such as pens, phones, and ID cards used by students have been found to harbor *Staphylococcus aureus*, *Pseudomonas* spp., and *Escherichia coli*, which are known to cause hospital and community-acquired infections (Amadi *et al.,* 2013). These items often serve as reservoirs of bacteria and can contribute to the indirect transmission of infectious diseases when proper hygiene is neglected.

Bags used by students have also been reported to carry high levels of bacterial contamination, particularly with *Staphylococcus* species. Studies have isolated *Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, and Bacillus* spp. from bag surfaces (Chandra *et al.*, 2014). Because these bags are placed on various surfaces including the ground and lecture benches they are easily contaminated and since bags often come into close contact with clothing and hands, they can facilitate the spread of skin and gastrointestinal pathogens. Fecal contaminants like *E. coli* may indicate poor hygiene and pose a risk of foodborne illnesses when transferred to food items or utensils.

Purses are used not only for the storage of money, but also to store keys, credit cards, mobiles phones and receipts etc. Thus, purses come in regular contact with the hands and a variety of other articles and surfaces. Moreover, majority of purses hardly get washed and are only discarded after years of use. In the healthcare settings, purses and handbags of medical staff have been found to be colonized with bacteria as they are often kept in the environment laden with microorganisms such as patients side tables, ICU counter tops, restroom counters and laboratory shelves etc. (Feldman *et al.,* 2012). Therefore, purses can be easily contaminated with infectious agents and may serve as vehicles of transmission of microorganisms from one place to another. The increase in bacterial load on purses is probably contributed by storage of various articles inside them. Currency notes, mobile phones, and playground equipment from the community, and computers, keyboards, and medical equipment from healthcare settings have been reported to be colonized with opportunistic bacteria (Michal *et al*., 2013; Biranjia-Hurdoyal *et al*., 2015). Commensals as well as opportunistic pathogenic organisms have been isolated from fomites, which have included mostly *Staphylococcus* spp., *Enterococcus* spp., *Escherichia coli, Pseudomonas* spp., and *Micrococcus* spp. Coagulase negative *Staphylococci* which have been isolated most frequently from the purses is a constituent of normal skin microflora (Messina *et al.,* 2013). *Bacillus* and *Micrococcus* spp. also contaminate the purses of both men and women as they are ubiquitous in nature and can settle anywhere (Biranjia-Hurdoyal *et al.,* 2015). At times all the above-mentioned organisms can act as opportunistic pathogens in immunocompromised individuals.

Mobile phones have become indispensable accessories in today's life. However, they might act as fomites as they have travelled with their owner to places such as toilets, hospitals and kitchens which are loaded with microorganisms (Bhoonderowa *et al.,* 2014). Mobiles phones have a high frequency of use, are often in contact with our hands and faces, and while in operation, can often heat up to temperatures that favor the survival and possibly growth of microorganisms. Combined with the fact that cleaning and disinfection of mobile phones is not a common practice with up to 72% of mobile phone users never washing their devices. It is likely that they constitute a suitable fomite, meaning an inanimate platform with microbial contamination. The frequent handling of billions of mobile phones worldwide, which are often microbially contaminated, provides the potential for them to enable disease infection transmission globally (Olsen *et al.,* 2020). Several bacterial species have been identified on surfaces of mobile phones used in both clinical and non-clinical community settings. The most common health risk carrying bacteria isolated from mobile phone surfaces are *Staphylococcus aureus*, coagulase-negative *Staphylococcus* (CoNS), *Micrococcus* spp., *Pseudomonas* spp., and *Escherichia coli* (Brady *et al.,* 2011).

Computers have been commonly used in daily life and at hospitals by medical staff. Computers have been found to be colonized by coagulase-negative *staphylococci*, *bacillus* spp., diphtheroids and *Micrococcus* spp. (Rutala *et al.,* 2006).

Power banks, though less directly exposed to skin than other personal items, are frequently handled with bare hands, placed on tables, beds, and public surfaces. Swab studies have isolated *Enterobacter* spp., *Klebsiella* spp., *Staphylococcus* spp., and *Pseudomonas* spp. from such electronic devices. The combination of dust accumulation, warmth from the battery, and frequent handling creates a conducive environment for microbial colonization (Ide *et al.,* 2019). These bacteria may pose a risk when transferred to mucous membranes or food surfaces. Computer keyboards and mobile phone screens, commonly used by students during lectures, have also shown contamination with *Enterococcus faecalis*, *Pseudomonas aeruginosa*, and methicillin-resistant *Staphylococcus aureus* (MRSA) (Koscova *et al.,* 2018). The grooves between keys are ideal for bacterial colonization, and infrequent cleaning worsens the risk. These pathogens pose a health risk in environments where frequent contact and poor disinfection practices prevail. Infections associated with these pathogens include skin infections, wound infections, and respiratory tract infections particularly concerning in immunocompromised individuals. The study further showed that surface disinfection with agents such as chlorhexidine digluconate significantly reduces microbial load.

Wristwatches, although often ignored, have been identified as fomites that can contribute to bacterial transmission. When worn continuously, especially without regular cleaning, they harbor bacteria such as coagulase-negative *Staphylococci* and *S. aureus*, particularly among individuals with poor hand hygiene practices (Jeans *et al.,* 2010). As students often wear wristwatches during lectures and other academic activities, the risk of contamination is amplified in lecture halls. The wrist area is also often overlooked during hand hygiene routines, increasing the risk of bacterial persistence and transfer. These bacteria can cause skin infections, especially in individuals with abrasions or dermatitis.

Earbuds, commonly used by students for music and online learning, are also sources of potentially harmful bacteria. Isolated organisms from these devices include *Staphylococcus aureus*, *Pseudomonas* spp., and *Micrococcus luteus* (Mukhopadhyay *et al.,* 2008). These findings are especially concerning as many students share earphones or use them for extended periods without cleaning. These microbes can cause otitis externa (ear infections), skin irritation, or even systemic infections if introduced into open wounds. Shared earbuds pose an even greater risk of cross-contamination between users.

The accumulation of these pathogens on personal items highlights the significance of fomites in the transmission of disease among student populations. The high-contact nature of lecture theaters, coupled with limited hygiene practices, creates a suitable environment for the spread of bacterial infections. Encouraging proper sanitation of personal items and hand hygiene can significantly reduce the microbial load on fomites and lower the risk of infection.

2.2.2 Antibiotic-Resistant Bacteria

Antibiotic-resistant bacteria (ARB) have become a global public health threat due to their ability to survive common antimicrobial treatments and persist in various environments. Fomite surfaces particularly personal items handled regularly by students can act as reservoirs and transmission routes for these resistant strains. The frequent contact between hands, personal devices, and shared surfaces creates an ideal pathway for the spread of multidrug-resistant organisms.

Mobile phones are one of the most contaminated personal items and have been found to harbor antibiotic-resistant bacteria such as methicillin-resistant *Staphylococcus aureus* (MRSA), extended-spectrum beta-lactamase (ESBL) producing *E. coli*, and vancomycin-resistant enterococci (VRE) (Ulger *et al.,* 2009; Bhoonderowa *et al.*, 2014). Because phones are used in nearly all environments including restrooms, classrooms, and cafeterias without routine disinfection, they provide a stable environment for resistant bacteria. These pathogens can cause skin, respiratory, and bloodstream infections that are difficult to treat.

Bags frequently touch contaminated floors and public surfaces, especially in schools, hospitals, and buses. Studies have reported that bags can carry carbapenem-resistant *Klebsiella pneumoniae*, methicillin-resistant Staphylococcus aureus (MRSA), and drug-resistant *Acinetobacter* spp., *Escherichia coli*, and *klebsiella* spp. (Lawal *et al.,* 2024). The potential for cross-contamination is high as bags are transferred between locations and come in contact with clothing, hands, and sometimes food item.

Laptops particularly the keyboard and touchpad are touched constantly and cleaned infrequently. Research has found multidrug-resistant *Pseudomonas aeruginosa* and MRSA on laptop surfaces used in both educational and healthcare settings (Koscova *et al.*, 2018). These surfaces act as hotspots for antibiotic-resistant bacteria, especially when used in group settings, libraries, or classrooms where multiple individuals may share devices or workspaces.

Earbuds, when shared or poorly cleaned, can host resistant microbes like MRSA, ESBL-producing *Proteus* spp., and even multidrug-resistant *Staphylococcus epidermidis* (Mukhopadhyay *et al*., 2008). Their proximity to the skin and ear canal provides a warm, moist environment ideal for microbial survival. Prolonged use and storage in unclean pockets or bags further increase contamination risks.

Wristwatches remain in constant contact with the skin and are rarely disinfected. Studies have identified MRSA, Coagulase-negative *Staphylococcus* spp. (some of which are methicillin-resistant), and resistant *Corynebacterium* spp. on watch surfaces (Jeans *et al.,* 2010). Since watches are often worn during handwashing but not cleaned themselves, they act as neglected fomite surfaces that can transfer ARB back onto the skin post-washing.

Power banks are handled frequently and placed on various surfaces like desks, chairs, or beds. Though not often considered high-risk, swabs have detected resistant strains of *Enterobacter* spp. and *Klebsiella* spp**.**, particularly in communal or academic settings where devices are often shared (Ide *et al.*, 2019). The warmth produced during use and close handling makes them another viable habitat for resistant microbes.

2.3. Fungal Hazards on Fomite Surfaces

Fomites are not only reservoirs for bacteria but also for fungi, many of which are opportunistic pathogens capable of causing infections, especially in immunocompromised individuals. Fungal spores are ubiquitous in the environment and can easily settle on inanimate objects handled by students such as mobile phones, laptops, bags, earbuds, wristwatches, and power banks. These surfaces can provide favorable conditions for fungal persistence, particularly when moisture, organic residues, or dust are present

Mobile phones are among the most handled personal items and serve as reservoirs for both bacteria and fungi. The warmth generated by phone usage, combined with constant skin contact and exposure to respiratory droplets, provides favorable conditions for fungal survival. Studies have reported the isolation of fungi such as *Aspergillus niger, Penicillium chrysogenum, Candida parapsilosis, Candida krusei, Candida glabrata, Aspergillus flavus, Aspergillus fumigatus, Rhodotorula* spp.*, Cladosporium* spp.*, Alternaria alternata, Mucor* spp.*, and Fusarium oxysporum*. Students with fungal contamination of their mobile phones significantly more often use mobile phones, hold their phones in pockets at university, and keep their mobile phones in random places at home. Also, students with fungal contamination of their mobile phones significantly less often clean their phones compared to students negative for mobile phones' fungal contamination (Dubljanin *et al.,* 2022).

Currently, there is an increase in the use of earphones among young adults and a high rate of sharing among students. Wearing headphones or earplugs has been suggested as a possible predisposing factor for external ear canal infection since their use can increase the temperature and humidity of the canal, create the potential for skin abrasion and provide a vehicle for the introduction of organisms into the canal skin. Common fungal isolates are *Aspergillus* spp., *Rhizopus* spp., and *Mucor* spp., with higher occurrence in frequent users (Ukaegbu-Obi *et al.,* 2019).

Laptop surfaces, especially keyboards and touchpads, are high-contact zones that can harbor fungal spores due to infrequent cleaning and shared usage in classrooms. Fungi such as *Candida* spp., *Aspergillus* spp., *Cryptococcus* spp., and *Aureobasidium* spp. have been isolated from computer keyboards (Koscova *et al.,* 2018). The presence of these fungi poses risks of allergic responses and respiratory complications in users, especially when spores become aerosolized during keyboard use.

In today's technologically driven society, the use of smart watches is fast becoming as ubiquitous as mobile phones. The health and fitness applications available on these smart watches have increased their popularity in recent years as individuals strive towards attaining a healthy lifestyle. Similar to mobile phones, these smart watches are devices used for communication and also represent high touch surfaces. Furthermore, as they are wearable devices, they are in close contact with the skin thus interacting with the skin microbiome and are always carried from place to place as the wearer moves around (Boucherabine *et al.,* 2022). The fungal isolates included *Aspergillus* spp., *Penicillium* spp., Yeast, *Trichophyton* spp., and *Microsporum* spp. ((Ukaegbu-Obi *et al.,* 2019).

Although power banks are not directly worn on the body, they are handled frequently and often placed on contaminated surfaces such as desks or floors. Their outer casing can accumulate dust and organic matter, which supports fungal growth. Studies have suggested that fungi such as *Aspergillus* spp., *Penicillium* spp., and *Candida* spp. can persist on power banks, especially when exposed to humid environments (Ide *et al.,* 2019). Though not as heavily contaminated as mobile phones, power banks may still act as fomites for fungal spores capable of indirect transmission.

2.4. Mechanism Of Transmission Between Fomites and Humans

Fomites consist of both porous and nonporous surfaces or objects that can become contaminated with pathogenic microorganisms and serve as vehicles in transmission. The transmission of bacteria and fungi via fomites represents a critical pathway for microbial dissemination, particularly in high-traffic environments such as lecture theaters. This process involves the deposition of pathogens onto surfaces, their persistence under varying conditions, and subsequent transfer to humans through direct contact. While bacterial transmission often aligns with contact-based mechanisms facilitated by human behavior, fungal transmission frequently incorporates airborne deposition and moisture-dependent persistence.

2.4.1 Mechanisms of Bacterial Transmission via Fomites

Bacterial transmission via fomites occurs primarily through indirect contact, where pathogens are deposited onto surfaces by infected individuals and later acquired by others. Key steps include:

Deposition: Bacteria are introduced to fomites via human activities, such as skin shedding, respiratory droplets, or contaminated hands. For instance, skin-associated bacteria like *Staphylococcus aureus* and *Streptococcus* species are commonly transferred through frequent touching of surfaces, including desks, keyboards, and personal items in lecture theaters

(Stephens *et al.,* 2019). In educational environments, this is intensified by high occupancy, leading to contamination of shared objects like door handles and chairs.

Persistence: Bacteria can survive on inanimate surfaces for extended periods, influenced by surface material and environmental factors. Non-porous materials such as stainless steel and plastic support longer viability; for example, *Pseudomonas aeruginosa* persists for up to 6.75 hours on stainless steel, while *Acinetobacter baumannii* survives on glass for over 100 days. Biofilm formation enhances persistence, as seen with *Streptococcus pyogenes*, which can remain viable on musical instruments or clarinets for 24 hours, relevant to shared educational tools (Wißmann *et al.,* 2021).

Transfer and Acquisition: Transmission to humans occurs when individuals touch contaminated fomites and then self-inoculate by contacting mucous membranes (e.g., eyes, nose, or mouth). Transfer efficiency varies, with studies indicating rates of approximately 24% for *Acinetobacter baumannii* from non-porous surfaces to ungloved hands (Stephens *et al.,* 2019). In lecture theaters, frequent hand-to-surface interactions, such as adjusting laptops or bags, facilitate this process, potentially leading to cross-transmission of antibiotic-resistant strains like methicillin-resistant *Staphylococcus aureus* (MRSA) (Jaradat *et al.,* 2020).

2.4.2. Mechanisms of Fungal Transmission via Fomites

Fungal transmission via fomites shares similarities with bacterial pathways but often emphasizes airborne spore deposition and environmental moisture as key facilitators.

Deposition: Fungi, primarily from outdoor sources, settle onto fomites through bioaerosols or direct contact. In indoor settings like lecture theaters, genera such as *Aspergillus* and *Penicillium* are transported via air currents and accumulate on surfaces, particularly in areas with poor ventilation. Human activities, including placement of personal items like bags or earbuds, can introduce fungal spores from external environments (Stephens *et al.,* 2019).

Persistence: Fungal spores exhibit resilience on dry surfaces but thrive in moist conditions. For example, *Aspergillus fumigatus* and *Aspergillus niger* can persist on cloths and plastics for up to 30 days, with *Candida auris* surviving over 14 days on plastics through biofilm formation tools (Wißmann *et al.,* 2021). In educational settings, damp areas such as floors or walls in lecture theaters may support prolonged fungal viability, increasing transmission potential (Stephens *et al.,* 2019).

Transfer and Acquisition: Transmission occurs via direct contact with contaminated fomites, followed by transfer to skin or inhalation if spores are disturbed. Transfer efficiency is influenced by moisture, with higher humidity enhancing spore adhesion and viability. In lecture theaters, touching shared surfaces like desks contaminated with *Candida* species can lead to skin or mucosal infections, particularly among immunocompromised individuals. Fomite-mediated fungal spread is also linked to respiratory issues, as spores from surfaces like carpets or walls can become airborne upon disturbance (Stephens *et al.,* 2019).

2.5. Factors Influencing Bacterial and Fungal Transmission via Fomites

The transmission of bacteria and fungi through fomites depends on a multifaceted interplay of biological, environmental, and behavioral elements. These factors determine the likelihood of pathogen deposition, persistence, and subsequent transfer to humans, particularly in high-occupancy settings such as lecture theaters. The following analysis delineates the primary influences, drawing upon established microbiological principles and empirical evidence.

2.5.1 Pathogen-Specific Factors

Characteristics inherent to the microorganisms significantly affect their transmission potential. For bacteria, species such as *Staphylococcus aureus* or *Pseudomonas aeruginosa* exhibit varying virulence and biofilm-forming capabilities, which enhance adherence and survival on surfaces (Olsen *et al.,* 2020). Fungal pathogens, including *Aspergillus* species or *Candida auris*, often form resilient spores that resist desiccation, thereby prolonging viability (Kramer *et al.,* 2024). The initial inoculum size, or quantity of microbes deposited, is crucial; higher loads increase the probability of successful transmission, as does the infectious dose required to cause illness. Additionally, the presence of organic matter, such as proteins or soil, can protect pathogens from environmental stressors, amplifying their persistence (Kramer *et al.,* 2024).

2.5.2 Environmental Factors

Ambient conditions play a pivotal role in microbial survival and transfer efficiency. Temperature and relative humidity are paramount; for instance, moderate temperatures (20–25°C) and high humidity favor fungal spore germination and bacterial viability, while extreme conditions may inactivate certain strains. Ultraviolet light exposure, particularly from sunlight, reduces pathogen longevity by damaging DNA, though this effect is diminished indoors. Indoor air quality, including ventilation rates, influences airborne deposition of fungal spores onto fomites, potentially exacerbating transmission in enclosed spaces like lecture halls (Bonadonna *et al.,* 2021). Suspension media, such as respiratory secretions or moisture, further modulate stability, with wet environments promoting fungal proliferation (Boone and Gerba, 2007).

2.5.3 Fomite Properties

The physical attributes of the surface directly impact pathogen adherence and transfer. Non-porous materials, such as plastics or metals found on mobile phones or desks, facilitate higher transfer rates to hands compared to porous ones like fabrics in bags, which may trap microbes but reduce immediate dissemination (Kramer *et al.,* 2024). Surface contamination levels and the presence of biofilms enhance bacterial and fungal persistence, as seen in hospital environments where fomites harbor multidrug-resistant strains (Bonadonna *et al.,* 2021).

2.5.4 Human and Behavioral Factors

Human interactions with fomites are critical determinants of transmission. The frequency of contact increases exposure opportunities, thereby elevating risks. Hygiene practices, including handwashing and surface disinfection, mitigate transfer, with ineffective routines allowing sustained pathogen reservoirs (Olsen *et al.,* 2020). Host susceptibility, modulated by immune status, age, or underlying conditions, affects infection outcomes upon exposure. Behavioral patterns, such as sharing personal effects or poor ventilation management, further amplify transmission in educational contexts (Stephens *et al.,* 2019).

2.6. Diseases Associated with Bacterial Contamination of Fomite in Human

Bacterial pathogens can persist on inanimate surfaces, such as desks, mobile phones, and shared equipment, facilitating indirect transmission through contact with contaminated fomites followed by self-inoculation or entry via mucous membranes.

The following outlines key diseases, associated pathogens, and transmission contexts, based on established microbiological evidence.

2.6.1 Skin and Soft Tissue Infections: Commonly caused by *Staphylococcus aureus* (including methicillin-resistant strains, MRSA), which survives on surfaces like plastics and fabrics for days to months. These infections may manifest as abscesses, cellulitis, or impetigo, particularly in community and healthcare settings where fomites such as door handles or personal items contribute to spread (Wißmann *et al.,* 2021).

2.6.2 Respiratory Infections: Associated with *Streptococcus pneumoniae* and *Streptococcus pyogenes*, persisting on materials like glass and plastic for up to a month. Diseases include pneumonia, pharyngitis (strep throat), and whooping cough from *Bordetella pertussis*, which survives on dust and fabrics for days. Fomites in educational or public environments amplify transmission (Wißmann *et al.,* 2021; Stephens *et al.,* 2019).

2.6.3 Gastrointestinal Infections: Linked to pathogens such as *Salmonella enterica*, *Escherichia coli* (including O157 strains), *Shigella dysenteriae*, *Clostridioides difficile*, and

Campylobacter jejuni, which endure on stainless steel, plastics, and wood for hours to years. These cause salmonellosis, hemolytic-uremic syndrome, shigellosis, diarrhea, colitis, and gastroenteritis, often via contaminated food-contact surfaces or household items (Aakriti Guleria, 2024).

2.6.4 Urinary Tract Infections (UTIs) and Bacteremia: Caused by *Enterococcus* species (including vancomycin-resistant Enterococcus, VRE), *Proteus mirabilis*, and *Klebsiella pneumoniae*, persisting on fabrics and plastics for weeks. These infections may progress to endocarditis or sepsis, especially in nosocomial settings involving contaminated medical equipment (Wißmann *et al.,* 2021; Stephens *et al.,* 2019).

2.6.5 Nosocomial and Opportunistic Infections: Associated with *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and *Stenotrophomonas maltophilia*, surviving on ceramics and plastics for weeks. These lead to pneumonia, wound infections, and bloodstream infections, particularly in immunocompromised individuals exposed to hospital fomites (Wißmann *et al.,* 2021; Stephens *et al.,* 2019).

2.6.6 Other Infections Include listeriosis from *Listeria monocytogenes* (central nervous system involvement), tularemia from *Francisella tularensis*, gonorrhea from *Neisseria gonorrhoeae*, and chlamydial infections (*Chlamydia pneumoniae* and *trachomatis*), all with documented persistence on surfaces like paper and plastics for hours to days (Wißmann *et al.,* 2021).

2.7. Diseases Associated with Fungal Contamination of Fomites in Humans

Fungal pathogens, often forming resilient spores or biofilms, can contaminate fomites in moist or indoor environments, leading to infections through direct contact or inhalation of disturbed spores. Transmission is less frequent than bacterial but significant in vulnerable populations.

2.7.1 Candidiasis: Caused by *Candida* species (e.g., *C. albicans*, *C. auris*, *C. glabrata*, *C. parapsilosis*), persisting on fabrics, plastics, and stainless steel for days to months. This manifests as oral thrush, vaginal infections, or invasive candidiasis (e.g., bloodstream infections) with high mortality in hospitalized patients, often via contaminated medical devices or surfaces (Wißmann *et al.,* 2021).

2.7.2 Aspergillosis: Associated with *Aspergillus* species (e.g., *A. fumigatus*, *A. niger*, *A. flavus*), surviving on copper, cardboard, and fabrics for hours to days. T2his causes noninvasive allergic forms or invasive pulmonary infections, particularly in immunocompromised individuals exposed to contaminated indoor surfaces (Wißmann *et al.,* 2021).

2.7.3 Dermatophyte Infections (Tinea): Caused by species like those responsible for ringworm, athlete's foot, and onychomycosis (fungal nail infections), transmitted via fomites such as upholstery, hairbrushes, or shared clothing. These superficial skin, hair, and nail infections spread through direct contact with contaminated objects (Baumgardner, 2017).

2.7.4 Cryptococcosis: Linked to *Cryptococcus neoformans*, persisting on fabrics for at least a month. This respiratory infection can progress to meningitis, primarily affecting those with weakened immune systems through inhalation from contaminated environments (Wißmann *et al.,* 2021).

2.7.5 Other Opportunistic Infections: Include those from *Penicillium* species (respiratory issues), *Geotrichum candidum* (rare systemic infections), and *Saccharomyces cerevisiae* (opportunistic in immunocompromised hosts), with persistence on aluminum, copper, and fabrics for hours to days (Wißmann *et al.,* 2021).

2.8. Prevention Of Fomite Contamination In Humans

Fomite contamination, wherein infectious agents such as bacteria, viruses, and fungi are transferred via inanimate objects or surfaces, poses a significant risk for pathogen transmission in humans. Effective prevention strategies are essential to interrupt this pathway, particularly in high-occupancy environments like healthcare facilities, educational institutions, and public spaces. These measures encompass hygiene practices, environmental controls, and behavioral modifications, as supported by epidemiological and infection control research.

2.8.1 Hand Hygiene

Hand hygiene represents a cornerstone of fomite prevention, as contaminated hands frequently serve as vectors for pathogen transfer from surfaces to mucous membranes. Regular handwashing with soap and water, or the use of alcohol-based sanitizers when soap is unavailable, effectively reduces microbial loads. Washing hands after contact with potentially contaminated surfaces and before touching the face or eating is important. In indoor settings, pairing hand hygiene with surface cleaning has been shown to control fomite-mediated transmission, with quantitative models indicating that frequent handwashing can significantly lower infection risks (Lei *et al.,* 2020). Additionally, changing gloves during patient care to avoid moving contaminants from soiled to clean body sites is advised in clinical contexts (Siegel *et al.,* 2007).

2.8.2 Surface Cleaning and Disinfection

Routine cleaning and disinfection of high-touch surfaces mitigate the persistence of pathogens on fomites. Strategies should consider the frequency of contact and potential for patient exposure, employing Environmental Protection Agency (EPA)-registered disinfectants effective against a broad spectrum of microbes. For instance, in healthcare-associated outbreaks linked to medical equipment, enhanced disinfection protocols have proven effective in reducing transmission (Kanamori *et al.,* 2017). Regular surface disinfection combined with proper hand hygiene is critical for preventing respiratory virus transmission through fomites (Lei et al., 2020). Quantitative hygiene criteria suggest establishing minimum frequencies for disinfection to control fomite spread indoors. In non-critical medical devices, comprehensive infection prevention programs addressing cross-contamination are recommended (Association for Professionals in Infection Control and Epidemiology, 2021).

2.8.3 Behavioral and Educational Interventions

Controlling human behaviors that facilitate fomite transmission is critical. This includes minimizing unnecessary touching of surfaces and promoting awareness through education on hygiene rules. Interventions such as restricting the sharing of items like bedding, toys, or clothing in animal care or communal settings prevent direct contact transmission. Public health campaigns emphasizing personal hygiene, such as avoiding contact with bodily fluids on surfaces, are vital for broader prevention (Abney *et al.,* 2025).

2.8.4 Environmental and Structural Controls

Improving environmental conditions disrupts fomite viability. Enhanced ventilation reduces aerosol deposition on surfaces, while the use of antimicrobial materials or coatings on high-touch objects limits pathogen survival (Barron, 2023). In settings prone to respiratory virus spread, a multifaceted approach, including protections against all transmission sources is advocated. For fomites contaminated by bodily fluids, immediate isolation and disinfection are essential to prevent further dissemination (Phan *et al.,* 2019).

2.8.5 Responsible Antibiotic Use

In relation to the prevention of fomite contamination in humans, responsible antibiotic use plays an indirect yet critical role by curbing the proliferation and dissemination of antibiotic-resistant bacteria, which can persist on inanimate surfaces and facilitate transmission (Abney *et al.,* 2025). Fomites, such as door handles, mobile devices, or shared equipment, serve as reservoirs for pathogens like methicillin-resistant *Staphylococcus aureus* (MRSA) or vancomycin-resistant *Enterococcus*, which exhibit prolonged viability on surfaces and contribute to healthcare-associated infections. Overuse or misuse of antibiotics accelerates the development of these resistant strains in clinical and community settings, increasing the risk that contaminated fomites will harbor difficult-to-treat organisms. By adhering to stewardship principles, such as reducing unnecessary prescriptions and promoting alternatives like hand hygiene or vaccination healthcare providers and individuals can lower the overall burden of resistant bacteria in the environment, thereby diminishing the potential for fomite-mediated spread (Maillard *et al.,* 2020). This integrated approach complements direct fomite prevention strategies, such as surface disinfection and antimicrobial materials, to safeguard public health against resistant infections.

2.9. Relevance of Fomite Contamination to Public Health

Fomite contamination, defined as the presence of infectious agents on inanimate objects or surfaces capable of transmitting pathogens to humans, holds substantial relevance to public health. This mechanism facilitates the indirect spread of diseases, particularly in high-traffic environments such as healthcare facilities, educational institutions, and public transportation hubs, thereby contributing to outbreaks and increased morbidity (stephens *et al.,* 2019). By serving as reservoirs for bacteria, viruses, and fungi, fomites amplify transmission risks, especially for vulnerable populations including the elderly, immunocompromised individuals, and children.

From an epidemiological perspective, fomites play a key role in the dissemination of respiratory and enteric infections, such as influenza, norovirus, and COVID-19, where contaminated surfaces enable pathogen persistence and subsequent human acquisition through hand-to-mucosa contact (Boone and Gerba, 2007). In healthcare settings, fomites like medical equipment or patient care items are implicated in nosocomial infections, exacerbating antimicrobial resistance and prolonging hospital stays. In educational settings, such as lecture theaters, the high turnover of individuals and frequent contact with shared objects like desks or personal effects can lead to rapid dissemination, contributing to absenteeism and reduced productivity. Moreover, the emergence of antimicrobial-resistant strains on fomites poses a long-term threat, as these resistant organisms can persist on surfaces, complicating treatment and increasing mortality rates in affected communities. Moreover, the emergence of antimicrobial-resistant strains on fomites poses a long-term threat, as these resistant organisms can persist on surfaces, complicating treatment and increasing mortality rates in affected communities (Lei *et al.,* 2017).

Economic and societal implications also warrant attention. Fomite-associated outbreaks incur substantial costs related to medical treatment, lost workdays, and infection control measures. For example, in hotel or transportation hubs, contaminated surfaces have been modeled to create "hotspots" that accelerate pathogen spread, necessitating resource-intensive interventions (Spitzer *et al.,* 2025; Zhuang *et al.,* 2023). Public health strategies must therefore integrate surveillance of fomite contamination, as evidenced by workshop recommendations emphasizing the need for enhanced monitoring in built environments to prevent viral exposures (Abney *et al.,* 2025). Overuse of disinfectants in response to fomite risks, however, raises environmental concerns, including potential ecological harm and the promotion of resistance, highlighting the need for balanced, evidence-based approaches.

Public health implications extend to community environments, including schools and offices, where high-touch surfaces act as hotspots for microbial exchange, potentially sustaining endemic transmission.

The relevance is further underscored by the potential for fomite-mediated outbreaks in densely populated areas, such as airports or public restrooms, where insufficient hygiene protocols can lead to widespread dissemination of pathogens. Effective public health interventions, including enhanced surface disinfection, hand hygiene promotion, and environmental monitoring, are essential to mitigate these risks, as evidenced by reductions in infection rates following targeted cleaning strategies. Moreover, addressing fomite contamination aligns with broader public health goals, such as preventing the overuse of disinfectants that may cause environmental harm or contribute to resistance.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was carried out in the Department of microbiology laboratory, University of Benin, Edo State, Nigeria. Samples were collected from lecture theaters with high student traffic and representative usage patterns. These lecture halls are characterized by high population density, prolonged usage, and shared surfaces that create favorable conditions for microbial transmission. The target population comprises undergraduate students actively attending lectures, with inclusion criteria encompassing individuals who consented to participation and regularly carry personal effects such as mobile phones, bags, wristwatches, laptops, earbuds, and power-banks.

3.2 Sample Collection

Sterile cotton swabs moistened with sterile normal saline were used for sampling. For each personal effect: Mobile phones and laptops were swabbed across the screen and keyboard surfaces, bags were swabbed outer fabric, wristwatches were swabbed across the straps and back surface, earbuds were swabbed on the outer casing and power banks were swabbed on their surfaces.

Each swab was placed into a labeled swab stick containing 5 mL of sterile peptone water and transported to the microbiology laboratory within 1 hour for analysis.

3.3 Preparation And Sterilization Of Materials

Materials such as measuring cylinders, test tubes, beakers, conical flasks and micropipette tips were soaked in detergent, rinsed with distilled water, and sterilized by autoclaving at 121^0c for 15 minutes.

3.3.1 Preparation Of Nutrient Agar

Twenty-eight grams (28g) of nutrient agar was weighed and dissolved in 1000 ml of distilled water in a conical flask corked with cotton wool and foil paper. The medium was placed in an autoclave and sterilized at 121^0c for 15 minutes.

3.3.2 Preparation Of Citrate Agar

Twenty-four point twenty-eight (24.28) grams of agar was dissolved in 1000 ml distilled water and heated to boiling, to dissolve the medium completely. It was then mixed properly and distributed in conical flasks. The medium was sterilized by autoclaving at 121°C for 15 mins and then left to cool before dispension on sterile petri dishes.

2.3.3 Preparation of Triple Sugar Iron agar

Sixty-four point six (64.6) g of powder was dissolved in 1liter of distilled water and then heated to properly dissolve the mixture. The mixture was autoclaved to sterilize the agar before it is dispensed into tubes and sterilized again at 121°C for 15 mins. The agar was then left to solidify with short slant and good butts.

2.3.4 Preparation of Potato Dextrose agar

Thirty-nine (39) grams of agar was dissolved in 1000 ml distilled water and heated to boiling, to dissolve the medium completely. It was then mixed properly and distributed in conical flasks. The medium was sterilized by autoclaving at 121°C for 15 mins and then left to cool before dispension on sterile petri dishes.

2.3.5 Preparation Of Mueller Hinton Agar

Thirty-eight (38) grams of the dehydrated Mueller Hinton Agar powder using an analytical balance, added to **1 liter** of distilled/deionized water in a clean conical flask and then heated gently with constant stirring until the powder is completely dissolved. The medium was sterilized by autoclaving at **121°C for 15 minutes, allowed to cool and dispensed into sterile petri dishes.**

3.4 Identification Of Bacteria And Fungi

Bacterial isolates were identified based on colonial morphological characteristics such as: shapes, size, elevation, optical activity, margination and pigmentation on the agar. KOH and biochemical test were also carried out to further identify the bacterial Isolates.

Fungal isolates were identified by their macroscopic features (color, texture, surface, and reverse colony appearance on PDA) and microscopic examination was done using Lactophenol Cotton Blue (LPCB) mounts to observe spore structure and hyphae.

3.4.1 Bacteria And Fungi Enumeration

Following the air sampling exercise, all exposed nutrient agar plates were transported aseptically to the microbiology laboratory for incubation. The plates were incubated at a temperature of 37°C for 24 to 48 hours to allow for optimal bacterial growth and the plate containing the PDA was incubated at 25–28 °C for 5–7 days. After incubation, distinct bacterial and fungal colonies on each plate were visually enumerated.

3.4.2 Potassium Hydroxide (KOH) test

Two drops of 3% solution of KOH were applied on a clean glass slide and a loopful of pure bacterial growth was stained in a circular motion on the slide. The loop was occasionally raised and observed for the presence of a string of the mixture. The solution was observed to be of a viscous and mucoid consistency indicating a Gram-negative bacterium. No reaction (absence of stringing) indicates a Gram-positive bacterium (Roberts and Sandle, 2008).

3.5 Biochemical Test

3.5.1 Catalase Test

This is a test to detect the presence or absence of catalase enzyme. The catalase enzyme catalyses the breakdown of hydrogen peroxide to release free oxygen gas and the formation of water. A few drops of freshly prepared 3% hydrogen peroxide were added onto the bacterial isolates smeared on a slide. The production of gas bubble indicated catalase enzyme positive.

3.5.2 Oxidase Test

A piece of filter paper was wet with a few drops of the dilute (1%) solution of oxidase reagent (tetramethyl-phenylenediamine-dihydrochloride) which was prepared by standard procedure. A bit of growth from the nutrient agar slant was obtained using sterilized platinum wire loop and smeared on the wet piece of paper. Development of an intense purple color by the cells within 30 seconds indicates a positive oxidase test.

3.5.3 Citrate Utilization Test

This test is based on the ability of some organisms to utilize citrate as a sole source of carbon. This was carried out by inoculating the test organism in test tube containing Simon's citrate medium and this was incubated at 37°C for 24 - 48 hr. The development of deep blue colour after incubation indicates a positive result.

3.5.4 Indole Test

Indole test is performed to determine the ability of the organism to split tryptophan molecule into indole. This test is performed to help differentiate species of the family *Enterobacteriaceae*. Kovac's reagent which contains hydrochloric acid, dimethyl-amino benzaldehyde and amyl alcohol is used. The broth was inoculated with the test organism and incubated for 18 hours at 37°C. 5ml of Kovac's reagent was then added down the inner wall of the tube. Development of bright red colour at the interface of the reagent and the broth within seconds after adding the reagent was indicative of the presence of indole and a positive result.

3.5.5 Triple sugar iron (TSI) agar test

The Triple Sugar Iron (TSI) test is an ability to test an organism's capability to ferment sugars and to produce hydrogen sulphide (H_2S) or gas (O_2), 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 TST 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_2S, gas and a change in colour 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_2S production. Bubbles, cracks, or bottom-raised space in the slanted agar indicated gas production (formation of CO_2, and H_2).

3.6 Antibiotic Susceptibility Testing

Antibiotic susceptibility of bacterial isolates was determined using the Kirby-Bauer disk diffusion method on Mueller-Hinton agar. Discs impregnated with antibiotics such as Ampicillin, Ciprofloxacin, Gentamicin, Tetracycline, and Erythromycin were used. Plates were incubated at 37 °C for 24 hours, and zones of inhibition were measured and interpreted according to Clinical and Laboratory Standards Institute (CLSI) guidelines.

CHAPTER FOUR

4.0 RESULT

The results for the investigation are shown as follows:

Table 4.1 shows the total heterotrophic bacterial counts obtained from swab samples of various personal effects such as mobile phones, bags, laptops, wristwatches, earbuds, and power banks.

Table 4.2 presents the fungal counts obtained from the same set of samples. Fungal load was relatively lower than bacterial counts but still significant.

Table 4.3 summarizes the colonial morphology and Gram staining characteristics of the bacterial isolates.

Table 4.4 shows the macroscopic and microscopic features of fungal isolates.

Table 4.5 presents the antibiotic susceptibility pattern of the bacterial isolates.

Table 4.1: Total heterotrophic bacteria count

Table 1: heterotrophic bacteria count (cfu/m^2)

SAMPLE CODE	HETEROTROPHIC BACTERIA COUNT
Physical science 1000LT	$1.8 \pm 1.0 X 10^4$
Physics MSC class	$1.6 \pm 1.0 X 10^4$
300L Physics lab	$1.95 \pm 4.5 X 10^4$
MCB twin LT	$0.85 \pm 1.5 X 10^4$
Physics PD lab B	$2.7 \pm 2.0 X 10^4$
Physics PD lab A	$2.6 \pm 2.0 X 10^4$

Table 4.2: Total heterotrophic fungi count

SAMPLE CODE	HETEROTROPHIC FUNGI COUNT (CFU/M^2)
Physical science 1000LT	$4\pm0.0X10^3$
Physics MSC class	$4.5\pm2.5X10^3$
300L Physics lab	$7.0\pm1.0X10^3$
MCB twin LT	$9.0\pm0.0X10^3$
Physics PD lab B	$8.0\pm4.0X10^3$
Physics PD lab A	$6.5\pm1.5X10^3$
Physical science 1000LT	$7.5\pm1.5X10^3$

Table 4.3: Cultural And Morphological Characteristic Of Isolates

Morphological					
Elevation	Flat	Raised	Flat	Flat	Flat
Margin	Undulate	Entire	Undulate	Undulate	Undulate
Color	Cream	Cream	Cream	Cream	Cream
Shape	Irregular	Circular	Irregular	Irregular	Irregular
Size	Large	Medium	large	Large	Large
Gr. diff. agar	EMB	SSA	BCA	EMB	Mannitol
Colour	Purple	Black	Straw	Green	Straw
Staining					
Gram stain	-	-	+	-	+
Cell type	Rod	Rod	Rod	Rod	Cocci
Arrangement	Disperse	Pair/Chains	Disperse	Disperse	Disperse
Color	Pink	Pink	Purple	Pink	Purple
Spore Staining	-	-	+	-	-
Biochemical					
KOH test	+	+	-	+	-
Catalase	+	+	+	+	+

Indole	-	-	-	+	-
Citrate	+	-	+	-	+
Oxidase	-	-	-	-	-
Urease	-	-	-	-	Variable
Glucose	+	+	+	+	+
Sucrose	-	-	+	+	+
Lactose	-	-	+	+	+
Mannitol	-	-	+	-	+
Gas formation	+	+	-	+	+
H_2S formation	-	+	-	-	+
Identity	*Enterobacter cloacae*	*Salmonella* sp.	*Bacillus* sp.	*E. coli*	*Staphylococcus aureus*

KEY
+ = POSITIVE
- = NEGATIVE
EMB = Eosin methylene blue
SSA = *Salmonella-shigella* agar
BAC = Blood culture agar
MSA = Mannitol salt agar

Table 4.4: Cultural And Morphological Characteristics Of Fungi Isolates

PARAMETERS	1	2	3	4	5
Colour of mycelium on agar plate	Dark colored growth	Cream front color	Green, woolly with profuse growth	White	Lemon woolly front colour
Colour of plate Culture reverse	Dark	Dark cream	Dark	Darkish	Yellowish
Microscopic characteristics					
Nature of hyphae	Septate	Septate	Septate	Non- septate	Septate
Type of Spore	Conidiospore	Ascospore	Conidiospore	Conidiospore	Sporangiospore
Conidia	Present	Present	present	Present	Present

Rhizoids	Absent	Absent	Absent	Absent	Absent
Spore colour	Absent	Absent	Absent	Absent	Black
Appearance of special structure	Dark	Fruiting heads	Dark	Dark	Black
Class of fungi	Ascomycetes	Ascomycetes	Ascomycetes	Ascomycetes	Ascomycetes
Possible Identity	*Aspergillus niger*	*Yeast*	*Penicillium* sp.	*Mucor* sp.	*Aspergillus* sp.

Table 4.5: Antibiotic Sensitivity Test

ISOLATES	CS	CIP	GEN	E	TE	M	CD	AG
Enterobacter sp.	10(R)	45(S)	27(S)	15(S)	0(R)	0(R)	31(S)	12(I)
Salmonella sp.	0(R)	35(S)	31(S)	8(R)	16(S)	0(R)	0(R)	14(S)
Bacillus sp.	0(R)	51(S)	35(S)	17(S)	17(S)	0(R)	27(S)	29(S)
Staphylococcus sp.	15(S)	47(S)	0(R)	18(S)	20(S)	28(S)	21(S)	20(S)
E. coli	14(S)	55(S)	29(S)	21(S)	0(R)	35(S)	0(R)	36(S)

KEY

CS: COLLISTIN

CIP: CIPROFLOXACIN

GEN: GENTAMYCIN

E: ERYTHROMYCIN

TE: TETRACYCLIN

M: METRONIDAZOLE

CD: CLINDAMYCIN

AG: AUGMENTIN

S: SUSCEPTIBLE

R: RESISTANT

CHAPTER FIVE

5.0 DISCUSSION

The heterotrophic bacterial counts from swab samples of students' personal effects and classroom surfaces ranged from 0.85 ± 1.5 × 10^4 CFU/m^2 in the microbiology twin lecture theatre to 2.7 ± 2.0 × 10^4 CFU/m^2 in the physics postgraduate laboratory B. These values indicate moderate microbial contamination, which can be attributed to frequent human contact, poor ventilation, and inadequate surface disinfection in shared learning environments. The fungal counts were comparatively lower, ranging from 4.0 ± 0.0 × 10^3 CFU/m^2 in the physical science 1000-level lecture theatre to 9.0 ± 0.0 × 10^3 CFU/m^2 in the microbiology twin lecture theatre. This pattern is consistent with indoor microbial ecology, where bacteria dominate high-touch surfaces through skin shedding and transient moisture, while fungi rely on airborne spore deposition and high humidity for survival (Samson *et al*., 2019).

Samples from the physics postgraduate laboratory B exhibited the highest bacterial load ($2.7 \pm 2.0 \times 10^4$ CFU/m^2), significantly exceeding those from the microbiology twin lecture theatre ($0.85 \pm 1.5 \times 10^4$ CFU/m^2). This disparity may reflect variations in occupancy density, ventilation, and cleaning frequency between the laboratory and lecture environments. Laboratories typically experience prolonged human interaction with surfaces and personal devices, which facilitates microbial transfer (Enebe and Babalola, 2018). In contrast, the relatively uniform fungal counts ($4.0–9.0 \times 10^3$ CFU/m^2) across sampling sites suggest that airborne spore dispersal, rather than surface activity, influenced fungal contamination levels likely modulated by tropical humidity.

Five bacterial genera were identified based on cultural, morphological, and biochemical characteristics: *Enterobacter cloacae*, *Salmonella* sp., *Bacillus* sp., *Escherichia coli*, and *Staphylococcus aureus*. The detection of *E. coli* and *S. aureus* indicates fecal and skin contamination respectively, likely arising from inadequate hand hygiene after restroom use or direct skin contact with personal items. *Enterobacter cloacae* and *Salmonella* sp. points to environmental contamination, possibly through dust or food handling, while *Bacillus* sp. reflects the presence of soil-derived spores capable of surviving harsh, dry surfaces. These results agree with findings by Oluduro *et al.* (2019), who reported similar bacterial contaminants on students' personal effects and classroom fomites in Nigerian universities.

Fungal isolates included *Aspergillus niger*, *Aspergillus* sp., *Penicillium* sp., *Mucor* sp., and yeast (*Candida* sp.). The predominance of *Aspergillus* species corresponds to their widespread distribution in tropical environments and association with airborne dust and organic matter (Odebode *et al*., 2020). The green, woolly growth of *Penicillium* sp. and the dark-pigmented colonies of *A. niger* are characteristic of saprophytic molds thriving on skin flakes and fabric fibers. The detection of *Mucor* sp. is noteworthy due to its rapid growth under humid conditions and its role in mucor mycosis among immunocompromised individuals (Samson *et al*., 2019).

Antibiotic susceptibility testing revealed varying levels of resistance among bacterial isolates. *E. coli* and *S. aureus* were sensitive to ciprofloxacin but resistant to tetracycline and metronidazole which are antibiotics that are frequently misused in the community. *Enterobacter cloacae* showed resistance to colistin but remained sensitive to ciprofloxacin, gentamicin, erythromycin, and clindamycin. *Salmonella* sp. exhibited resistance to colistin, erythromycin, metronidazole, and clindamycin, while *Bacillus* sp. was generally sensitive except to colistin and metronidazole. These findings align with reports by Adeshina *et al*. (2020), which highlighted the persistence of resistance to older antibiotic classes while fluoroquinolones and aminoglycosides remain effective against most environmental isolates. The emergence of colistin-resistant *Enterobacter* and *Salmonella* species is particularly concerning, as colistin is considered a last-resort antibiotic. The presence of such resistance in non-clinical environments suggests environmental dissemination of resistant strains, potentially through agricultural or healthcare waste, thereby increasing the risk of untreatable infections via fomite transmission (World Health Organization, 2023). The widespread metronidazole resistance observed among Gram-negative isolates further underscores the misuse of this agent beyond its intended anaerobic spectrum.

The coexistence of enteric pathogens (*E. coli*, *Salmonella* sp.), skin flora (*S. aureus*), and environmental organisms (*Enterobacter*, *Bacillus*, *Aspergillus*, *Mucor*) on personal effects underscores their role as potential fomites in infection transmission. Poor hand hygiene, shared device usage, and inadequate cleaning practices contribute to persistent contamination cycles. These findings are consistent with reports by Ezeonu *et al*. (2021), who observed similar hygiene lapses and microbial persistence in Nigerian educational institutions.

CONCLUSION

This study confirms that students' personal effects can harbour diverse microorganisms, including potentially pathogenic and antibiotic-resistant strains. The findings are consistent with previous studies and reinforce the need for improved sanitation, hygiene education, and infection prevention programs in schools. Preventive measures such as regular handwashing, disinfection of personal and classroom materials, and awareness campaigns on responsible antibiotic use are critical to reducing microbial transmission and safeguarding public health.

RECOMMENDATIONS

1. Promote regular hand hygiene: Regular handwashing with way and water, of the wwe of alcohol-based sanitizers when soap is unavailable, should be encouraged. Washing hanh aer

contact with potentially contaminated surfaces and before touching the face of eating in also important

2. Encourage Routine Cleaning of Personal Belongings: Items such as mobile phones, hap laptops, wristwatches, and earbuds should be disinfected using 70% alcohol wipes or approved disinfectants. Awareness campaigns can help students understand the importance of cleaning these frequently used items.

Surface Cleaning and Disinfection: Routine cleaning and disinfection of high-touch surfaces

mitigate the persistence of pathogens on fomites. Strategies should consider the frequency of contact and potential for patient exposure, employing Environmental Protection Agency (EPA)-registered disinfectants effective against a broad spectrum of microbes.

4. Improve Cleaning and Disinfection of Lecture Theatres: University management should implement scheduled cleaning routines targeting high-touch surfaces such as desks, chairs, door handles, and podiums. Proper disinfectants effective against bacteria and fungi should be used.

CONTRIBUTION TO KNOWLEDGE

I contributes to knowledge by providing scientific evidence that personal belongings of students harbor potentially pathogenic and antibiotic resistant bacteria and fungi. It also adds to local data to support public health awareness on fomite contamination in Nigeria universities and encourage the adoption of regular cleaning and hand hygien3.5e among students.

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