



UNIVERSITI
MALAYSIA
KELANTAN

**MOBILE PHONES AS POTENTIAL SOURCES OF SPREADING
MULTI-DRUG-RESISTANT BACTERIA**

By

NURUL ATIKAH BINTI AZMAN
(D21A0135)

A RESEARCH PAPER SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF
VETERINARY MEDICINE

Faculty of Veterinary Medicine
UNIVERSITI MALAYSIA KELANTAN

2025

CERTIFICATION

This is to certify that we have read the research paper entitled “**Mobile Phones as Potential Sources of Spreading Multi-Drug Resistant Bacteria**” by Nurul Atikah binti Azman, and in our opinion, it is satisfactory in terms of scope, quality, and presentation as partial fulfillment of the requirement for the course DVT55204 - Research Project.

Prof. Madya Dr. Erkihun Aklilu Woldegioris

DVM (Universiti Putra Malaysia), MVSc (Universiti Putra Malaysia)

PhD (Universiti Sains Malaysia)

Senior Lecturer

Faculty of Veterinary Medicine

Universiti Malaysia Kelantan

(Supervisor)

Dr. Muhammad Ali Imran bin Mohamed Kamil

DVM (Universiti Putra Malaysia), MVSc (Universiti Malaysia Kelantan)

Lecturer

Faculty of Veterinary Medicine

Universiti Malaysia Kelantan

(Co-Supervisor)

UNIVERSITI
MALAYSIA
KELANTAN

ORIGINAL LITERARY WORK DECLARATION

I hereby certify that the work embodied in this thesis is the result of the original research and has not been submitted for a higher degree to any other University or Institution.

	OPEN ACCESS	I agree that my thesis is to be made immediately available as hardcopy or online open access (full text).
	EMBARGOES	I agree that my thesis is to be made available as hardcopy or online (full text) for a period approved by the Post Graduate Committee. Dated from _____ until _____.
	CONFIDENTIAL	(Contains confidential information under the Official Secret Act 1972)*
	RESTRICTED	(Contains restricted information as specified by the organization where research was done)*

I acknowledge that Universiti Malaysia Kelantan reserves the right as follows.

1. The thesis is the property of Universiti Malaysia Kelantan
2. The library of Universiti Malaysia Kelantan has the right to make copies for the purpose of research only.
3. The library has the right to make copies of the thesis for academic exchange.

SIGNATURE OF CANDIDATE

SIGNATURE OF SUPERVISOR

NRIC/PASSPORT NO.

NAME OF SUPERVISOR

DATE:

DATE:



MOBILE PHONES AS POTENTIAL SOURCES OF SPREADING MULTIDRUG-RESISTANT BACTERIA

ABSTRACT

As mobile phones have become such an important role in our daily lives, it is not questionable to assume that they are exposed to what we are exposed to and carry what we do not even notice carrying. There are already studies on mobile phones' roles as reservoirs for pathogenic bacteria especially in clinical settings. This study is aimed to determine the bacterial contamination on veterinary students' phones across different years of study and level of exposure as well as to assess the antimicrobial susceptibility profiles of the isolates. A total of 74 samples were collected from the veterinary students of University Malaysia Kelantan using sterile swabs. Bacterial identification was performed using bacterial staining, colony morphology, and a series of biochemical tests along with supplemental selective media. Lastly, antibiotic susceptibility was tested using the disk diffusion method according to European Committee on Antimicrobial Susceptibility Testing (EUCAST) and Clinical and Laboratory Standards Institute (CLSI) guidelines. A total of 75 isolates were recovered dominated by coagulase-negative staphylococci (CoNS) (16%, n=12). The highest resistance was observed against Penicillin G, while most isolates remained susceptible to Enrofloxacin. Students also completed a short questionnaire assessing personal phone hygiene habits, mobile phones pattern and bacterial contamination awareness. The findings indicate that mobile phones harbor clinically significant bacteria with varying resistance patterns, highlighting importance of regular device disinfection and improved hygiene practices.

Keywords: Antimicrobial susceptibility, contamination, mobile phones, veterinary

MOBILE PHONES AS POTENTIAL SOURCES OF SPREADING MULTI DRUG RESISTANT BACTERIA

ABSTRAK

Telefon bimbit kini memainkan peranan penting dalam kehidupan seharian dan secara tidak langsung terdedah kepada pelbagai mikroorganisma yang mungkin tidak kita sedari dibawa. Beberapa kajian telah dijalankan yang menunjukkan bahawa telefon bimbit boleh bertindak sebagai reservoir bagi bakteria patogen, terutamanya dalam persekitaran klinikal. Kajian ini bertujuan untuk menentukan tahap pencemaran bakteria pada telefon bimbit pelajar veterinar di Universiti Malaysia Kelantan mengikut tahun pengajian dan tahap pendedahan, serta menilai profil kepekaan antibiotik bagi isolat yang diperolehi. Sebanyak 74 sampel dikumpul menggunakan swab steril dan dikultur pada media nutrient agar. Pengenalpastian bakteria dijalankan melalui Gram stain, morfologi koloni, dan siri ujian biokimia, termasuk media selektif tambahan. Kepekaan antibiotik diuji menggunakan kaedah disk diffusion mengikut garis panduan EUCAST dan CLSI. Sebanyak 75 isolat diperolehi, dengan 'coagulase-negative staphylococci' (CoNS) mendominasi (16%, n=12). Rintangan tertinggi dicatatkan terhadap Penicillin G, manakala kebanyakan isolat masih sensitif terhadap Enrofloxacin. Pelajar turut menjawab soal selidik ringkas mengenai tabiat kebersihan telefon bimbit, pola penggunaan, dan kesedaran terhadap pencemaran bakteria. Hasil kajian menunjukkan bahawa telefon bimbit boleh membawa bakteria klinikal yang signifikan dengan corak rintangan antibiotik yang berbeza-beza, menekankan kepentingan pembersihan peranti secara berkala dan amalan kebersihan yang lebih baik.

Kata kunci: Telefon bimbit, pencemaran bakteria, kepekaan antibiotik, veterinar

ACKNOWLEDGEMENTS

Special thanks to those who have given their support, guidance, advice, and aid for the completion of this project paper:

Prof. Madya Dr. Erkihun Aklilu Woldegiorsis

Dr. Muhammad Ali Imran bin Mohamed Kamil

Ar. Azman bin Ismail

Wan Noor Wahida binti Mohd Mokhtar

Hassan, Fathini, Imad, Mustaqim, Aliyah, Hannah

Ahmad Ashraf bin Amalludin

Jenny

Ain Syahira

DVM 5 (2026)

Thank You

UNIVERSITI

MALAYSIA

KELANTAN

DEDICATIONS

First and foremost, I want to extend my deepest gratitude towards my loving parents, Ar. Azman bin Ismail and Wan Noor Wahida binti Mohd Mokhtar, who supported me and gave me the strength to finish the project. My siblings, Hassan, Fathini, Imad, Mustaqim, Aliyah and Hannah who inspired me to be a better person.

Next, I would also like to dedicate this dissertation to my supervisor, Prof. Madya Dr. Erkihun Aklilu Woldegiorsis and my co-supervisor, Dr. Muhammad Ali Imran bin Mohamed Kamil, for their continuous support and guidance. I would also like to dedicate this work to the Bacteriology Laboratory particularly, the laboratory assistant of FPV UMK, Puan Norsyamimi Farhana Binti Mat Kamir, for her patience and support throughout my project.

I would also like to acknowledge the support of my partner, Ahmad Ashraf bin Amalludin, for providing much needed support and for always being there for me. Not to forget, my classmate, housemate and former rotation groupmate, Ain Syahira, for assisting me with the labwork. Lastly, special thanks to all of the veterinary students who volunteered and gave great interest in my project.

TABLE OF CONTENT

ORIGINAL LITERARY WORK DECLARATION	3
ABSTRACT	5
ABSTRAK	6
ACKNOWLEDGEMENTS	7
LIST OF TABLES	11
LIST OF SYMBOLS	12
CHAPTER 1 : INTRODUCTION	13
1.1 Problem Statement	15
1.2 Research questions	16
1.3 Research Hypothesis	16
1.4 Research Objectives	16
CHAPTER 2 : LITERATURE REVIEW	17
2.1 Mobile Phones	17
2.2 Multidrug-Resistant Organisms	17
2.3 Mobile Phones as Potential Source of Bacterial Contamination	18
CHAPTER 3 : METHODOLOGY	19
3.1 Study Area	19
3.2 Study Design	19
3.3 Study Population	20
3.4 Selection Criteria	20
3.4.1 Inclusion Criteria	20
3.4.2 Exclusion Criteria	21
3.5 Study Questionnaire	21
3.5.1 Details of the questionnaire	22
3.6 Materials and Methods	22
3.7 Data Analysis	26
CHAPTER 4 : RESULT	27
4.1 Sample Overview	27
4.2 Questionnaire Result	27
4.3 Colony Characteristics and Gram Reaction	30

4.4 Bacteria Isolated	32
4.4 Antimicrobial Susceptibility Results	36
CHAPTER 5 : DISCUSSION	40
CHAPTER 6 : CONCLUSION AND RECOMMENDATION	46
CHAPTER 7 : APPENDIX	48
REFERENCES	50



UNIVERSITI
MALAYSIA
KELANTAN

LIST OF TABLES

NO		PAGE
Table 3.6.4	List of Antibiotics	25
Table 4.3	Gram Staining Result of Each Batch	31
Table 4.4.1 - 4.4.5	Bacterial Identification	32 - 35
Table 4.5.1 - 4.5.5	Measurement of Inhibition Zones of Antimicrobial Susceptibility (AST)	36 - 38
Table 4.5.6	Total Number of Resistant Samples of Each Antibiotic	39
Table 5.1	Percentage of Genus of the Isolates	41

LIST OF ABBREVIATIONS

AST	Antibiotic Susceptibility Testing
AMR	Antimicrobial Resistance
MDR	Multidrug Resistant
EUCAST	European Committee on Antimicrobial Susceptibility Testing
CLSI	Clinical and Laboratory Standards Institute

LIST OF SYMBOLS

%	Percentage
>	Greater Than
<	Less Than
\geq	Greater Than or Equal To
\leq	Less Than or Equal To

CHAPTER 1 : INTRODUCTION

Multidrug-resistant organisms (MDROs) are microorganisms, particularly bacteria, that exhibit resistance to one or more classes of antibiotics (Centers for Disease Control and Prevention, 2022). The evolution and mutation of bacteria, driven by various factors such as antibiotic misuse and environmental pressures, have led to the emergence of different resistant strains.

A well-known example of an MDRO is Methicillin-Resistant *Staphylococcus aureus* (MRSA), first identified in 1960. Remarkably, *S. aureus* developed resistance to penicillin just a few years after penicillin's introduction. Subsequently, MRSA was detected only two years after methicillin was introduced as a treatment. Despite widespread awareness of antimicrobial resistance (AMR), MRSA remains a significant global health challenge.

According to a 2019 study published in *The Lancet*, an estimated 4.95 million deaths were associated with AMR worldwide. The most commonly isolated bacteria in these cases included *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Streptococcus pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa*.

This study aims to investigate the prevalence of bacterial contamination on mobile phones belonging to veterinary students and compare these findings with samples from 'unexposed' students who have had minimal contact with clinical or

field environments. Additionally, antimicrobial susceptibility testing (AST) will be performed to identify the presence of MDROs and determine which antibiotics show the highest resistance rates.

Mobile phones are often overlooked as potential vectors for microbial transmission. Frequent exposure to various pathogens, especially in veterinary settings, may facilitate the introduction and spread of MDROs. This concern is particularly relevant for veterinary students who are regularly exposed to zoonotic pathogens, which can be inadvertently transmitted to the general public.

The study will involve collecting swab samples from approximately 30% of students' mobile phones from each academic year, totaling an estimated 72 samples. Samples will be processed using standard bacterial isolation and identification techniques, including biochemical tests and differential agar media. AST will be conducted using 5 to 6 commonly used antimicrobials. Data will be recorded and managed using online software such as Google Sheets. To manage workload, sample collection and processing will be conducted in phases—for example, starting with first-year students over the first two weeks before proceeding to subsequent batches.

Following approval of the research proposal, a detailed schedule will be developed, and coordination with the Bacteriology and Mycology Laboratory will be arranged to ensure availability of agar plates, biochemical test kits, and antimicrobial discs for AST.

1.1 Problem Statement

There are already several studies on bacteria isolated from medical settings. In fact, there seems to be research on similar topics almost every year worldwide. In Malaysia, a study was conducted on 126 students and 37 staff of Universiti Teknologi MARA (UITM), specifically from the Faculty of Health Sciences (Hikmah & Anuar, 2020). The most recent studies were done in Portugal (da Silva et al, 2025) and Puerto Rico (Scharbaai-Vázquez et al, 2025). In Puerto Rico, 83 samples were taken from healthcare workers for hospital-acquired infections (HAIs) meanwhile in Portugal the research was centering around veterinary practitioners.

Thus, this study is proposed to address the research gap concerning bacterial contamination of mobile phones among veterinary medicine students in Universiti Malaysia Kelantan. Currently, only one study in Malaysia has investigated this topic, but it focused on non-veterinary personnel (Hikmah & Anuar, 2020). Existing studies on veterinary students have been conducted overseas, and it is important to fill this gap because the bacterial profiles found in Malaysia may differ from those observed internationally due to variations in environment, hygiene practices, and local microbial flora.

Furthermore, this study will include first-year veterinary students who have not yet been exposed to fieldwork or laboratory activities. This allows us to establish a baseline or 'control' group representing unexposed individuals. By comparing their mobile phone bacterial contamination with that of fourth and fifth-year students, who

have had extensive exposure to various pathogens during clinical and farm visits, we may observe potential differences in bacterial profiles and contamination levels related to exposure.

1.2 Research questions

- What are the common bacteria to be isolated from mobile phones of veterinary students?
- Are there multidrug-resistant bacterial isolates among those from the mobile phones of veterinary students?
- Are there differences in diversity and resistance profiles of bacterial isolates from mobile phones of different batches veterinary medicine students?

1.3 Research Hypothesis

- Null Hypothesis (H₀): There is no presence of multidrug-resistant organisms (MDRO) from swab cultures of veterinary students' mobile phones
- Alternative Hypothesis (H_A): Mobile phones of veterinary students serve as a reservoir for multidrug-resistant organisms (MDRO)

1.4 Research Objectives

- To isolate and identify common bacteria from the surfaces of the mobile phones of veterinary students
- To identify the multidrug-resistant bacteria species
- To compare the diversity and resistance profiles of bacterial isolates from mobile phones of different batches veterinary medicine students.

CHAPTER 2 : LITERATURE REVIEW

2.1 Mobile Phones

Mobile phones have become an extra appendage for every person. According to a study conducted in Kuala Lumpur and Selangor; Malaysia's most populous states, 99.9% and 99.5% of the respondents have their own personal mobile phones (DataReportal, 2025). It has gotten impossible to do even any basic daily life task without it. With everything within a fingertip reach, mobile phones are used everyday, especially by students. From looking up information, to recording photos or videos and as a medium of communication, it is undeniable that phones might be the most used and contaminated object we use.

2.2 Multidrug-Resistant Organisms

Multidrug Resistant Organism (MDRO), is the general term that refers to any organism (particularly bacteria) that has developed resistance to one or more antimicrobial classes (Centers for Disease Control and Prevention, 2006). The main cause of the progression of resistance to current antimicrobials is the lax use and prescription of antibiotics. One of the most recent concerning issues of MDRO is the discovery of *mcr-1* gene in *E.coli*, where the bacteria strain has developed resistance against colistin, a last resort antibiotic (Gu et al., 2016). This is concerning as *mcr-1* gene can be transmitted horizontally and has been detected in human, animal, and environmental samples, making it a One Health issue.

2.3 Mobile Phones as Potential Source of Bacterial Contamination

Multiple research has been conducted to prove that mobile phones do act as potential sources of bacterial contamination. A study performed by a group of researchers on mobile phones of veterinary undergraduates had concerningly produced eleven bacterial species (Viveka, 2017). Across much research done on this topic, the 3 most common bacterial species isolated were *E.coli*, *S. aureus* and *P. aeruginosa*. These 3 bacteria can infect humans as well as animals ,thus making it a veterinary and public health concern.

CHAPTER 3 : METHODOLOGY

3.1 Study Area

This research was conducted at the Faculty of Veterinary Medicine, Universiti Malaysia Kelantan (UMK). The bacteriology laboratory is equipped with the necessary facilities and resources for bacterial isolation, identification, and antimicrobial susceptibility testing. Additionally, the target population, i.e., veterinary students, were readily accessible within the faculty, facilitating efficient sample collection and study implementation.

3.2 Study Design

This research uses a cross-sectional observational design to assess bacterial contamination and multidrug-resistant organisms (MDROs) on mobile phones of veterinary students at a single point in time. It allows for comparison between different groups of students with different degrees of possible exposures, particularly from veterinary clinics and farms. Accordingly, the study included students from the relatively 'unexposed' (first-year) to relatively more 'exposed' (final-year) students without manipulating variables.

Data were collected through swab sampling and analyzed quantitatively to identify bacterial species and resistance patterns. This design is appropriate for establishing associations between clinical exposure and contamination levels, aligning with the One Health concept linking human, animal, and environmental health.

3.3 Study Population

The study population will consist of veterinary students enrolled at the Faculty of Veterinary Medicine, Universiti Malaysia Kelantan (UMK). The faculty admits approximately 50 new students annually. Students range from first-year entrants, who have minimal exposure to clinical or field environments, to final-year students who have undergone extensive practical training involving contact with various animal species and potential pathogens.

Participants will be selected from all academic years to allow comparison between ‘unexposed’ students (e.g., first-year students) and those with significant exposure (e.g., fifth-year students). The estimated total sample size is around 72 mobile phone swab samples, representing approximately 30% of students from each year cohort.

This population is appropriate for the study as veterinary students are regularly exposed to zoonotic and other microbial agents during their training, making them a relevant group for investigating bacterial contamination and multidrug-resistant organisms on personal devices.

3.4 Selection Criteria

This section is divided into :

3.4.1 Inclusion Criteria

- Veterinary students currently enrolled at the Faculty of Veterinary Medicine, Universiti Malaysia Kelantan.
- Students who own and regularly use a mobile phone as a personal device.

- Students from all academic years are included to allow comparison between ‘unexposed’ (e.g., first-year) and ‘exposed’ (e.g., final-year) groups.
- Participants who provide informed consent to participate in the study.
- Samples collected during the study period and processed according to standard bacterial isolation and antimicrobial susceptibility testing protocols.

3.4.2 Exclusion Criteria

- Students who do not own or regularly use a mobile phone, as sampling requires access to the device.
- Students who have recently (within the past week) disinfected or cleaned their mobile phones extensively may affect bacterial contamination results.
- Students currently taking antibiotics or who have used antibiotics within the last two weeks before the date of sampling, as this may influence bacterial flora on their phones.
- Students who decline to give informed consent or are unwilling to participate in the study.

3.5 Study Questionnaire

A questionnaire was done titled “Questionnaire on Mobile Phones Usage & Hygiene Practices”. The purpose of this questionnaire was to gather brief information about students’ phone usage and cleaning habits before bacterial sampling was done. The responses will help in understanding possible factors contributing to bacterial

contamination. The questionnaire is done on a Google Form and is strictly confidential and anonymous.

3.5.1 Details of the questionnaire

In the first section, the first question was the year of study with options to choose from DVM1 to DVM5. In the next section, the mobile phones usage related questions were asked. The first question is about the average daily phone use from 3 hours to more than 12 hours daily. This section also focuses on the frequency of phone cleaning, ranging from daily, weekly and monthly to rarely or never. The method of phone cleaning was also asked with multiple options allowed. The said options were alcohol wipes, disinfectant, soap, and/or just water. Also the respondent was asked if they were aware that their phones may contain harmful pathogens. The last section is about personal hygiene. The first question is if the respondent uses disinfectant daily and the last question is specific to whether they changed their gloves/disinfect their gloves before using their mobile phone during farm or laboratory activities. (see Appendix 1)

3.6 Materials and Methods

3.6.1 Ethical Consideration

Human ethics application was required for this study, as access to a person's personal belongings was needed. The application had been approved by the FPV Animal Ethics Committee. The approval code is UMK/FPV/HUMAN/EXT/0006/2025.

3.6.2 Sample Collection and Preparation

A total of 74 samples were collected, and approximately 14 to 15 samples were taken from each batch of students. Samples were taken on different days as the availability of both students and researchers needs to be considered. Proper attire and equipment

were worn, such as wearing a mask, glove and labcoat for the researcher. The phone was swabbed thoroughly on all surfaces and in every crevice, and making sure to cover all the surfaces multiple times for maximum collection. The samples were collected in an Amies Transport Medium Swab; each labeled with student name, batch number and a serial number. Example of serial number is 'D5001', D5 indicating year 5 students and '001' indicating the sample number. Once collected, they were stored in a plastic bag for transport as no ice box with ice was needed. The samples were stored within the same day in a chiller at the bacteriology lab.

3.6.3 Bacterial Culture and Identification

Primary culture was done on a Nutrient Agar plate and incubated 18 - 24 hours at 35 to 39 C in the incubator. The agar plate was labelled with a serial number and the date of incubation. After incubation, the colony morphology was observed and recorded, and a secondary culture was done.

Secondary culture was done by selecting colonies that had emerged on the primary plate and reculture on a Nutrient agar plate. The secondary plates were incubated for 18 to 24 hours at 39 - 41 C as well. The colonies that had grown from the secondary plates were first stained using Gram stain and observed under compound light microscope. After determining the Gram and morphology of isolates, further identification will be done.

Selective media such as Eosin Methylene Blue (EMB) agar plate and Mannitol Salt Agar (MSA) plate were prepared. Gram negative bacteria were cultured onto the EMB plate, and Gram-positive bacteria were cultured on the MSA plate. Eosin

Methylene Blue (EMB) agar was used for the isolation of Gram-negative bacteria and for the differentiation of lactose fermenters. Mannitol Salt Agar (MSA) was used for the selective isolation of staphylococci and to differentiate mannitol-fermenting species.

Biochemical tests were performed on each isolate as well. To save time and resources, the isolates were separated according to their Gram staining result, and using a workflow from Bergey’s Manual, the following selected biochemical tests were conducted.

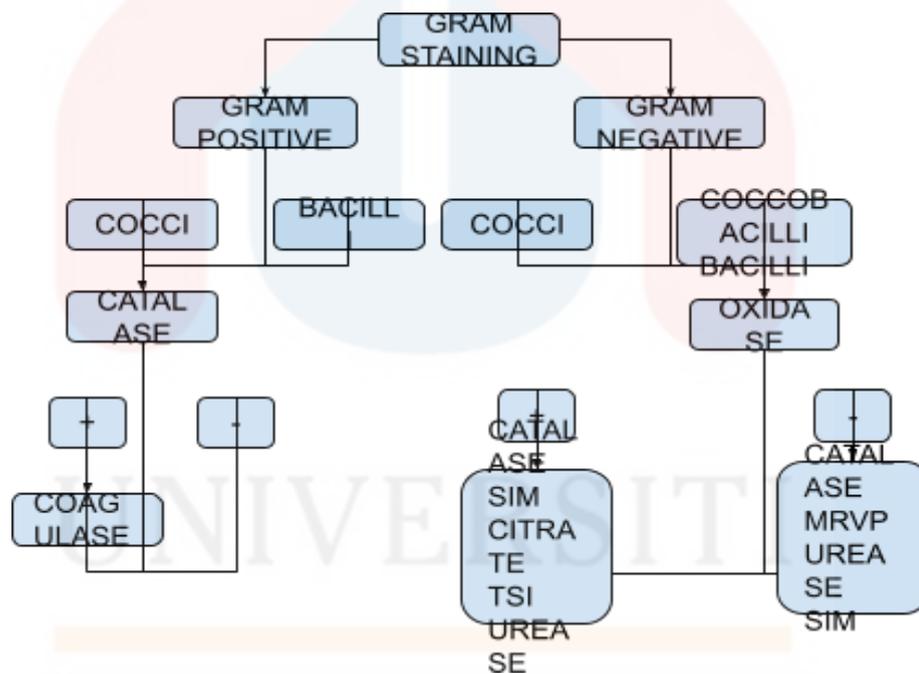


Figure 3.6.3 : Biochemical tests workflow

All results were recorded in a Google Sheet that is accessible to only the researcher and the supervisors. Due to limitations of available tests and time constraints, bacterial identification can only be done up to genus unless a specific test can be performed to confirm the species. The genus is determined by colony morphology on agar plates, Gram staining, and biochemical tests. When an isolate exhibited two or

more key characteristics consistent with a particular species, it was provisionally identified as that species.

3.6.4 Antimicrobial Susceptibility Testing (AST)

As mentioned, due to time and resource constraints, only 50 samples were able to be used for antimicrobial susceptibility testing. Mueller-Hilton Agar (MHA) was prepared, and 5 antibiotics were chosen beforehand. The rationale of picking these antibiotics was that these antibiotics are commonly used in both human and animal medicine and the antibiotic discs are available in the bacteriology lab.

Antibiotic Name	Label
Oxytetracycline	OTC30
Amoxicillin + Clavulanic Acid	AMC30
Enrofloxacin	ENR 5
Gentamicin	CN30
Penicillin G	P10

Table 3.6.4 Antibiotics used in the study

Ten samples of abundant colonies were chosen from each batch. To ensure diversity, the balance of both Gram-negative and Gram-positive bacteria was considered. Using the Kirby-Bauer disk diffusion method and both Clinical and Laboratory Standards Institute (CLSI) and European Committee on Antimicrobial Susceptibility Testing (EUCAST) standards, the routine procedure was done on Mueller-Hilton Agar. The agar plates were incubated for 18 to 24 hours, and the inhibition zones were measured with a standard ruler using millimeters (mm). The results were recorded in the same Google sheet.

3.7 Data Analysis

3.7.1 Calculation and Data Analysis

The total number of bacteria isolates recovered from the phone swabs was recorded for each genus. The percentage for each bacterial genus was calculated using the formula :

$$\text{Percentage of Isolates} = \frac{\text{Number of isolates of the genus}}{\text{Total number of isolates}} \times 100$$

Antimicrobial susceptibility of selected isolates was interpreted using the EUCAST guidelines for human-relevant antibiotics and CLSI veterinary breakpoints (VET01/VET08) for veterinary-specific antibiotics. Due to research gaps in these guidelines, there will be samples with no verified breakpoints for the selected antibiotics thus cannot be categorized as either Susceptible (S) or Resistant (R). These isolates were labelled with their zones of inhibition measurements.

MALAYSIA

KELANTAN

CHAPTER 4 : RESULT

4.1 Sample Overview

There were 74 samples collected from the students, 16 samples from year five students, 14 samples each from year 3 and year 4 students, and 15 samples from year one and year two students. A total of 79 isolates were identified, including two samples that were undetermined and four samples contaminated with fungi.

4.2 Questionnaire Result

A total of 30 responses were recorded from the Google Form. Second year students had the highest number of respondents (33.3%), followed by fifth year students while the least responses was by the first year students.

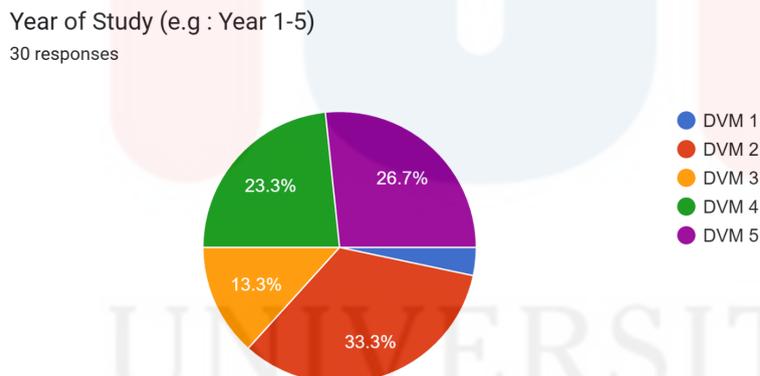


Figure 4.2.1 : Pie chart showing the percentage of respondents based on year of study

The average daily duration of mobile phone usage was between 6 to 12 hours for the majority of the respondents (66.7%). Only 6.6% of the respondents uses phones for less than 5 hours daily.

Average daily phone use
30 responses

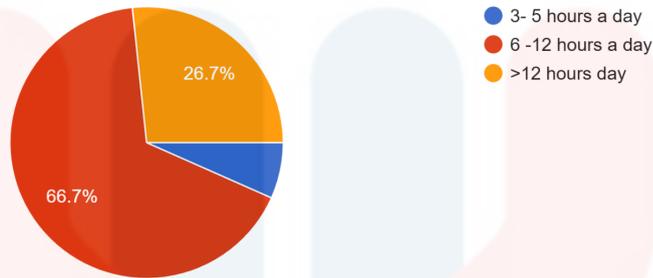


Figure 4.2.2 : Pie chart showing average daily phone usage

Half of the respondents cleaned their phones at least once a week , 26.7% of them rarely cleaned their phones and only 6.6% cleaned their phones daily.

How frequent do you clean your phone?
30 responses

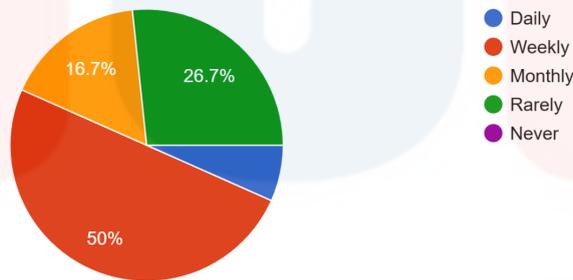


Figure 4.2.3 : Pie chart showing frequency of mobile phones cleaning

As for the method of cleaning, 70% of the respondents disinfect their phones using alcohol wipes, 23.3% used other disinfectant, 6.7% with soap and 30% with just water.

How do you clean your phone?
30 responses

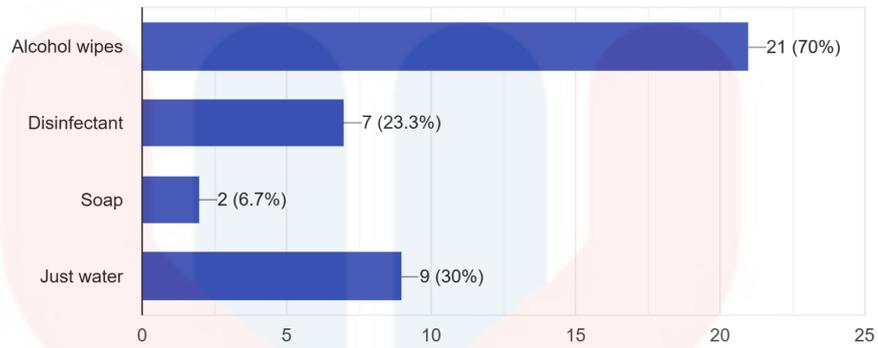


Figure 4.2.4 : Horizontal column chart showing methods of phone cleaning

93.3% of the respondents are aware that their phones may contain harmful pathogens and may act as reservoirs or fomites for disease transmission.

Do you believe that your mobile phone may contain harmful pathogens?
30 responses

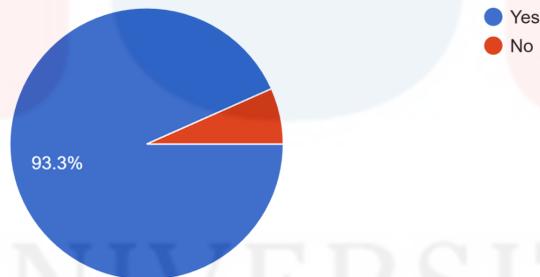


Figure 4.2.5 : Pie chart showing students awareness of mobile phones as reservoir

In the personal hygiene question, 70% of the students do not disinfect their hands. Disinfection in this context is using at least 70% alcohol or soaps with antibacterial properties. Only 30% of respondents disinfect their hands daily.

Do you use disinfectant on your hands daily?
30 responses

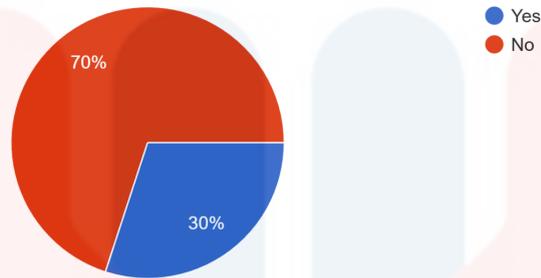


Figure 4.2.6 : Pie chart showing the percentage of students who disinfect their hands daily

For the last question, 70% of the respondents do change their dirty gloves prior to handling their phones in farm or laboratory settings.

When you need to use your mobile phone during farm or laboratory activities, do you usually change your gloves first, or use your phone with the same gloves?
30 responses

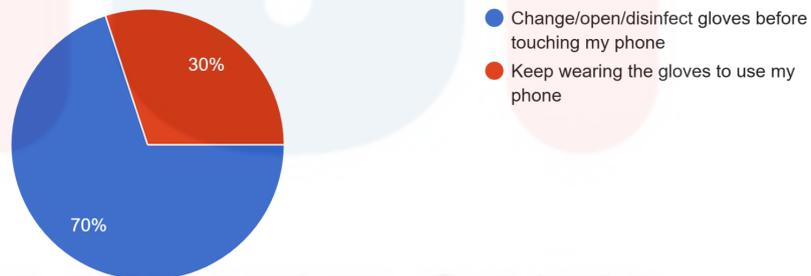


Figure 4.2.7 : Pie chart showing the percentage of students who changed their gloves prior to handling phones while in the farm or laboratory

4.3 Colony Characteristics and Gram Reaction

From the 79 colonies isolated from the secondary cultures, there were 48 Gram-positive bacteria and 31 Gram-negative bacteria. Four samples were contaminated with fungi; however, they were still included in the respective Gram staining result.

Sample Batch	Gram Positive	Gram Negative	Remarks
D5	8	9	
D4	10	8*	*1 sample is contaminated with fungi
D3	11	3	
D2	12	3	
D1	7*	8**	*1 sample was contaminated with fungi **2 samples were contaminated with fungi

Table 4.3 : Gram staining result of each batch with remarks

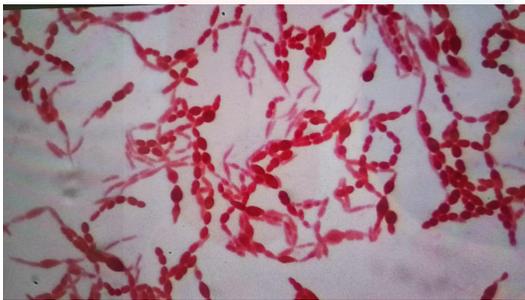


Figure 4.3.1 : Sample contaminated with yeast (suggestive) with Gram-positive rods in the background

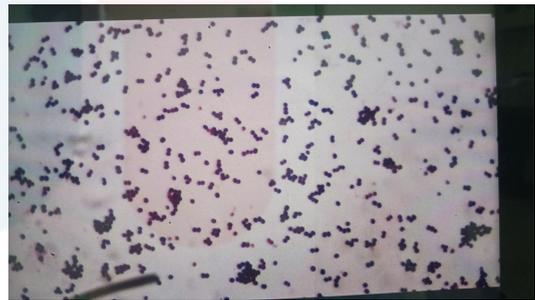


Figure 4.3.2 : Gram-positive cocci in clusters



Figure 4.3.3 : Gram-positive rods



Figure 4.3.4 : Gram-negative coccobacilli

4.4 Bacteria Isolated

According to the bacterial culture and identification done, these are the results of bacteria findings of all the batches. There are 73 total isolates found from the 74 samples.

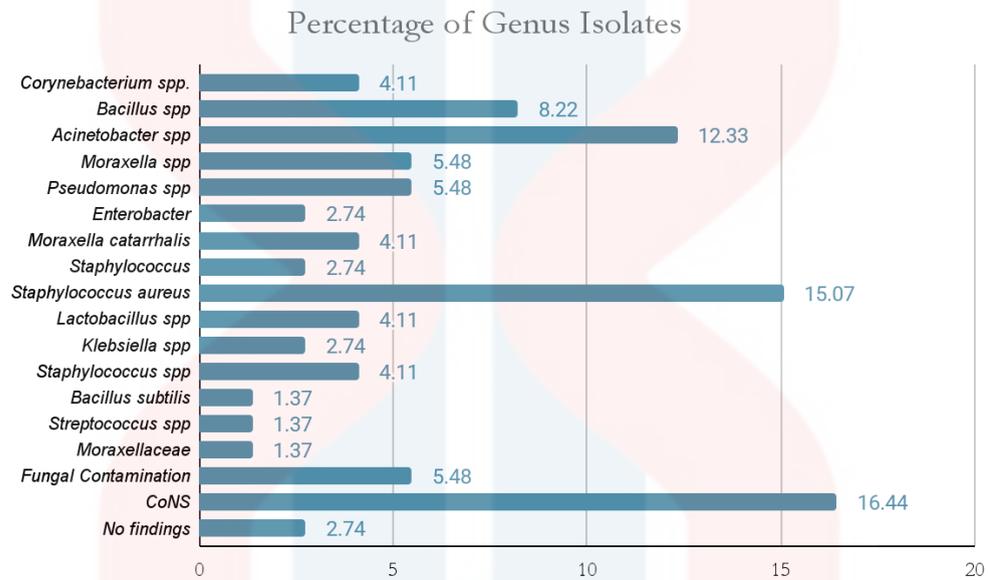


Figure 4.4 : Percentage of Total Genus Isolates

The highest percentage of genus isolates was Coagulase-Negative *Staphylococcus* spp. (16.44%). Followed by general *Staphylococcus aureus* (15.07%) and *Acinetobacter* spp (12.33%). *Bacillus subtilis*, *Streptococcus* spp. and general *Moracellaceae* spp were the lowest isolates (1.37%).

The following is the total isolates based on different batches :

D1

Bacteria	Total	Percentage (%)
<i>Corynebacterium</i> spp.	1	6.67
<i>Bacillus</i> spp.	1	6.67
<i>Acinetobacter</i> spp.	3	20.00

<i>Moraxella</i> spp.	2	13.33
<i>Pseudomonas</i> spp.	2	13.33
<i>Enterobacter</i> spp.	1	6.67
Contam with fungi	3	20.00
CoNS	2	13.33
Total	15	100.00

Table 4.4.1

Fifteen different isolates were identified from samples collected from first-year students' handphones. Unfortunately, three samples were contaminated with fungi. *Acinetobacter* spp. is the predominant bacteria found in the samples.

D2

Bacteria	Total	Percentage (%)
<i>Moraxella catarrhalis</i>	1	6.67
<i>Corynebacterium</i> spp.	2	13.33
<i>S. epidermidis</i>	1	6.67
<i>S. aureus</i>	2	13.33
<i>Lactobacillus</i> spp.	1	6.67
<i>Bacillus</i> spp	3	20.00
<i>Acinetobacter</i> spp.	2	13.33
CoNS	3	20.00
Total	15	100.00

Table 4.4.2

Second year students' swab handphone samples also had 15 isolates. The most predominant bacteria were Coagulase-Negative *Staphylococcus* species (CoNS).

D3

Bacteria	Total	Percentage (%)
<i>Klebsiella</i> spp.	1	7.14
<i>Staphylococcus</i> spp.	2	14.29
<i>Bacillus</i> spp.	1	7.14
<i>S. aureus</i>	1	7.14
<i>S. epidermidis</i>	1	7.14
<i>Bacillus subtilis</i>	1	7.14
<i>Acinetobacter</i> spp	1	7.14
CoNS	6	42.86
Total	14	100.00

Table 4.4.3

The isolates identified from the handphones of the third batch DVM students were 14 isolates, with almost half (42.86%) of the bacterial findings suggestive of Coagulase-Negative *Staphylococcus* species.

D4

Bacteria	Total	Percentage (%)
<i>Klebsiella</i> spp	1	6.67
<i>Enterobacter</i> spp	1	6.67
<i>Streptococcus</i> spp.	1	6.67
<i>S. aureus</i>	5	33.33
<i>Moraxella</i> spp.	1	6.67
<i>Bacillus</i> spp.	1	6.67
<i>Acinetobacter</i> spp.	2	13.33
CoNS	1	6.67
No findings	1	6.67
Contam with fungi	1	6.67
Total	15	100.00

Table 4.4.4

The isolates identified from the handphones of the year 4 students had were 14 samples yet, there are 15 colonies isolated. *Staphylococcus aureus* was the most commonly detected bacteria (33.33%). There was a sample with an undetermined genus, and 1 sample that had been contaminated with fungi.

D5

Bacteria	Total	Percentage (%)
<i>Acinetobacter</i> spp	2	11.76
<i>Staphylococcus</i> spp	1	5.88
<i>Bacillus</i> spp	1	5.88
<i>Moraxella</i> spp.	1	5.88
<i>S.aureus</i>	3	17.65
<i>Lactobacillus</i> spp	2	11.76
<i>Pseudomonas</i> spp.	2	11.76
<i>Moraxella catarrhalis</i>	2	11.76
Moraxellaceae	1	5.88
No findings	2	11.76
Total	17	100.00

Table 4.4.5

The largest number of isolates, 17 isolates from 16 samples collected from the handphones of final year students' were detected. The predominant bacteria was *Staphylococcus aureus* as well.

4.5 Antimicrobial Susceptibility Results

As many of the isolates do not have a valid breakpoint according to either EUCAST or CLSI, these bacteria will be described by its measurement in millimeters (mm). Oxytetracycline does not have a Below are the results of antimicrobial susceptibility testing for each batch of students with sample numbers.

(R)	Resistant
(I)	Intermediate
(S)	Susceptible
	Invalid

D5					
SAMPLE	OTC 30	AMC 30	ENR 5	CN30	P10
1	30 (S)	35 (S)	30 (S)	32 (S)	30 (I)
2	29 (S)	33 (S)	35 (S)	30 (S)	28 (I)
4	31 (S)	30 (S)	35 (S)	26 (S)	0 (R)
5					
6					
6(3)	29 (S)	24 (S)	31 (S)	26 (S)	11 (R)
7					
10	30 (S)	35 (S)	25 (S)	25 (S)	36 (S)
13	33 (S)	30 (S)	30 (S)	35 (S)	0 (R)
16					

Table 4.5.1

For year 5 students, 4 samples had invalid results due to insufficient growth. Penicillin G had the most resistant bacteria result.

D4					
SAMPLE	OTC 30	AMC 30	ENR 5	CN30	P10
14	30 (S)	24 (S)	31 (S)	25 (S)	0 (R)
10	35 (S)	40 (S)	22 (I)	30 (S)	32 (S)
11	12 (R)	36 (S)	36 (S)	35 (S)	30 (I)
3	27 (S)	30 (S)	27 (S)	23 (S)	26 (R)
12	33 (S)	24 (S)	40 (S)	35 (S)	0 (R)
7	35 (S)	40 (S)	20 (I)	35 (S)	30 (I)
13					
1					
4					
8					

Table 4.5.2

For year 4 students, 4 samples were invalid due to insufficient growth as well.

Oxytetracycline and penicillin G were the two antibiotics with resistant results.

D3					
SAMPLE	OTC 30	AMC 30	ENR 5	CN30	P10
1	20 (S)	20 (S)	32 (S)	16	0 (R)
4					
12	24 (S)	19 (S)	25 (S)	21 (S)	0 (R)
6	34 (S)	34 (S)	19 (I)	25 (S)	29 (I)
11	35 (S)	38 (S)	22 (I)	25 (S)	32 (S)
10	31 (S)	30 (S)	30 (S)	24 (S)	11 (R)
13	34 (S)	30 (S)	34 (S)	27 (S)	19 (R)
2	36 (S)	33 (S)	36 (S)	26 (S)	20 (R)
7					
5	31 (S)	37 (S)	30 (S)	23 (S)	40 (S)

Table 4.5.3

For year 3 students, 2 samples had insufficient growth as well. Penicillin G is still the one with the most resistant result.

D2					
SAMPLE	OTC 30	AMC 30	ENR 5	CN30	P10
15					
14	36 (S)	20 (S)	26 (S)	28 (S)	0 (R)
7	30 (S)	21 (S)	30 (S)	22 (S)	18 (R)
12	36 (S)	38 (S)	21 (I)	27 (S)	32 (S)
3	34 (S)	31 (S)	22 (I)	29 (S)	28 (I)
1	35 (S)	29 (S)	30 (S)	31 (S)	0 (R)
10(1)	32 (S)	28 (S)	31 (S)	34 (S)	14 (R)
11	31 (S)	20 (S)	25 (S)	28 (S)	0 (R)
6	0 (R)	31 (S)	31 (S)	26 (S)	20 (R)
10(2)	30 (S)	30 (S)	30 (S)	32 (S)	14 (R)

Table 4.5.4

For year 2 students, only 1 sample was invalid. Here, there is a presence of a multidrug resistant bacteria sample; which is sample six with resistance towards Penicillin G and Oxytetracycline.

D1					
SAMPLE	OTC 30	AMC 30	ENR 5	CN30	P10
15	30 (S)	35 (S)	25 (S)	29 (S)	0 (R)
10	26 (S)	30 (S)	32 (S)	34 (S)	40 (S)
5					
13(2)	30 (S)	26 (S)	27 (S)	29 (S)	0 (S)
3	30 (S)	30 (S)	29 (S)	22 (S)	0 (S)
4	20 (S)	0 (R)	32 (S)	16 (S)	0 (S)
6	26 (S)	20 (S)	32 (S)	25 (S)	0 (S)
8	30 (S)	26 (S)	30 (S)	22 (S)	0 (S)
13	35(S)	22 (S)	29 (S)	35 (S)	0 (S)
7					

Table 4.5.5

For first year students, 2 samples were invalid. There is also a multidrug resistant sample. Sample 4 was resistant to amoxicillin + clavulanic acid, gentamicin and

penicillin G. This batch also had the highest number of resistant isolates ; mostly against penicillin G.

Among the 50 plates of Mueller-Hilton Agar plates incubated, only 37 plates had valid results. Hence, further discussion will be included in the next section.

Number of Resistant Sample				
OTC30	AMC30	ENR5	CN30	P10
1	1	0	1	25

Table 4.5.6

CHAPTER 5 : DISCUSSION

Mobile phones are an item that we frequently handle throughout our daily lives, hence it tends to be contaminated with our own commensal microflora as well as what we are exposed to. The most commonly isolated bacteria from healthcare worker in a human hospital include coagulase-negative staphylococci (CoNS), *Staphylococcus aureus*, *Bacillus* species, *Acinetobacter* spp., *Pseudomonas* spp., *Klebsiella* spp. and *Escherichia coli* (Morubugal et al., 2017; Kaden et al., 2020). These are the common bacteria isolated as they are non-fastidious and resistant to variable environments. They are also commensal or ubiquitous, thus finding these on phone surfaces is not a cause of concern necessarily. Coagulase-negative staphylococci (CoNS) commonly colonize the skin and nares without causing disease in healthy individuals. Examples of CoNS, such as *S.epidermidis*, *S.haemolyticus* and *S.saprophyticus*, form part of normal mucous membranes or skin microbiota.

The findings in Figure 4.4 have similar results with other studies similar to this. In the proposed hypothesis, the fifth year student will have the most variable bacterial findings in comparison to first year students, and there will be more findings of multidrug resistant bacteria from the D5 batch. This is somehow proven by the total number of isolates from D5; which was 17, surpassing other batches. D5 also had a more stable growth on agar, with colony-forming unit (CFU) of 2+ to 3+, from the majority of the samples. On the other hand, D1 had the most number of resistant samples during the antimicrobial susceptibility testing (AST). Although this could be explained by the greater number of valid samples of D1. The greater sample size increases the likelihood of detecting resistant bacteria. Thus the differing growth

densities introduce sampling bias, making direct comparisons between D1 and D5 less reliable.

In comparison to other studies conducted overseas on veterinary students as well, this study had the same result especially with *Staphylococcus* spp. leading the percentage. Although it may be overrepresented as many *Staphylococcus* species is a skin normal flora that will naturally colonize phone surfaces. Pal and Juyal (2017) reported that after *Staphylococcus* spp, *Bacillus* spp is the next commonly isolated species, along with *Pseudomonas* spp. This differs from our findings as *Bacillus* spp was only 9.59% and *Pseudomonas* spp. was only 5.48% of the samples. There were also no findings of *E.coli*, *Proteus* spp., *Citrobacter* spp. and *Flavobacterium* spp. but these may be due to insufficient tests done and variable hygiene level of students.

Genus	Percentage (%)
<i>Staphylococcus</i> spp.	38.36%
<i>Acinetobacter</i> spp.	12.33%
Moraxellaceae	10.96%
<i>Bacillus</i> spp.	9.59%
<i>Pseudomonas</i> spp.	5.48%
<i>Corynebacterium</i> spp.	4.11%
<i>Klebsiella</i> spp.	2.74%
<i>Lactobacillus</i> spp.	4.11%
<i>Enterobacter</i> spp.	2.74%
<i>Streptococcus</i> spp.	1.37%

Table 5.1 : Genus Percentage

Nutrient agar is the main media used to culture the samples from primary to secondary culture. It is chosen as it is a non-selective media with basic nutrition, enough to cultivate and prolong the survival of cultures whilst lowering risk of overgrowth due to its minimum nutritional value. The disadvantages of using this medium as primary culture media is it is not sufficient for culturing fastidious microorganisms, especially pathogenic bacteria. For example, *Neisseria* spp. And *Haemophilus* spp. require chocolate agar. *Streptococcus* spp. grows poorly on nutrient agar and prefers blood agar. But for isolating normal microflora that can easily grow on phone surfaces, nutrient agar is sufficient. MacConkey agar was prepared but due to preparation error, the plates were unset and could not be used. Thus only EMB and MSA plates were used as selective media. This influences which genera that can be detected.

All samples had varied bacterial load, due to variation of different phone habits. For example, *Lactobacillus* spp. is a normal gastrointestinal tract and vaginal flora. It is not abundant on hands or phone surfaces, and usually successfully isolated due to recent contact with gut flora or transient contamination instead of permanent colonization. *Enterobacter* spp. is also found mainly in the gastrointestinal tract and also in soil, water and hospital environments (NICD, 2023). Poor hand hygiene after using the toilet can contribute to this contamination.

There is an issue of undergrowth during the antimicrobial resistance testing (AST). During suspension preparation, 0.5 MacFarland was the measurement to ensure adequate growth and uniformity yet some samples failed to grow sufficiently to be measured, leading to invalid results. There are several factors affecting the growth;

inoculum size, rate of growth, medium formulation and pH (MicrobeNotes, n.d.). Manipulation of these factors may help in troubleshooting the issue.

During AST, there is a slight methodology issue that we had missed which is the antibiotic selection. During the proposal stage, 5 antibiotics were chosen that are commonly used in both human and animal medicine as well as stock availability in the laboratory. Instead, the antibiotic disk selection should be done after the bacterial identification and 5 antibiotics should be chosen based on the bacteria genus and inhibition zone range availability in either EUCAST or CLSI. Due to this error, the majority of the samples could not be interpreted as susceptible or resistant. Additionally, some samples were contaminated with fungi, which explains why it did not grow.

Regardless, there are still some findings of multi-antibiotic resistant bacteria. In table (), sample 6 from batch D2, the coagulase-negative Staphylococci (CoNS) showed resistance to Oxytetracycline and Penicillin G. CoNS commonly produces beta-lactamase thus is also commonly resistant to Penicillin G but oxytetracycline is from tetracycline class, and this sample is resistant to it. In table () sample 4 from batch D1, the *Moraxella* spp. is resistant to amoxicillin+clavulanic acid, gentamicin and penicillin G. *Moraxella* spp. commonly produce beta-lactamase as well thus usually resistant to Penicillin but despite beta-lactamase inhibitor action of amoxicillin+clavulanic acid (AMC30), the sample is still resistant. It is considered as a Multi-drug Resistant (MDR) antibiotic if it is not susceptible to at least one agent in 3 or more antimicrobial classes (Magiorakos et al., 2012); thus this sample can be classified as MDR.

Multi-drug resistant (MDR) bacteria is a growing concern especially in the clinical environment as the exposure is much higher. Several studies have shown that mobile phones do act as fomites in transporting concerning pathogens. While most are just normal skin flora, some such as coagulase-positive *Staphylococcus aureus* has more pathogenicity than CoNS, and can act as opportunistic pathogens. Presence of bacteria originating from gut microbiome is also concerning because it indicates the level of hygiene for a veterinary student. In this study, there is a higher MDR in D1, which might be due to better bacterial recovery or just better knowledge of Antimicrobial Resistance (AMR) and zoonotic potential, which has led fifth year students to be more hygienic.

It is worth mentioning that while *Acinetobacter* spp. is a common environmental bacteria and can be found in normal skin flora (Towner 2006; Seifert et al. 1997), it is an ongoing concern especially in clinical settings. It is an opportunistic pathogen and a common nosocomial infection causing illnesses such as hospital-acquired pneumonia, bacteremia, wound and soft tissue infections. Additionally, *Acinetobacter* spp. especially *A.baumannii*, has the ability to cause severe, multidrug-resistant (MDR) healthcare-associated (HAIs) that are difficult to treat and associated with high mortality rates, especially in immunocompromised patients. Some strains have developed into pandrug-resistant (PDR), as they are resistant to nearly all available antibiotics. (Mark F. et al, 2023). They also persist on dry surfaces for weeks, thus phones can act as fomites. Presence of coagulase-positive staphylococci such as *Staphylococcus aureus* might not be concerning but it also can be an opportunistic

pathogen and due to its coagulation capability, is more pathogenic than the coagulase-negative staphylococci (Quinn, et al, 2011).

The fungal contamination was only reported and not further investigated due to insufficient time and resources. The source of contamination is unknown as the fungal could have been from the phone samples themselves or contamination during culture preparation as the workspace and storage area are shared with other students working on their rotation labworks. The morphology of the colony under the microscope suggests *Candida* spp. but further laboratory testing using Saboroud-Dextrose Agar (SDA) and lactophenol blue staining should be done.

CHAPTER 6 : CONCLUSION AND RECOMMENDATION

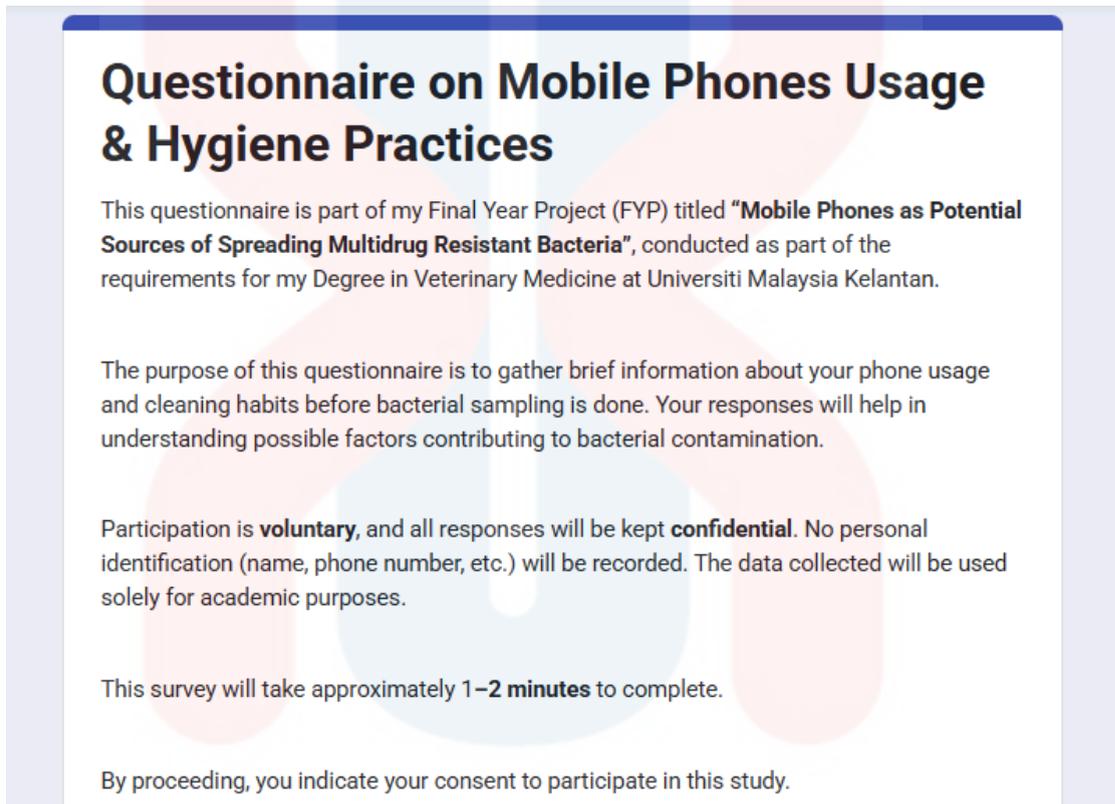
In conclusion, the mobile phones used by the students showed measurable bacterial contamination, indicating that phones do act as potential fomites for environmental and opportunistic bacteria. The most commonly isolated organisms were coagulase-negative staphylococci (CoNS), *Staphylococcus aureus*, *Acinetobacter* spp., and *Bacillus* spp, which are generally part of skin or environmental flora but may cause infections in immunocompromised individuals. Antimicrobial susceptibility (AST) revealed varying resistance patterns. The antibiotic used was amoxicillin-clavulanic acid, gentamicin, enrofloxacin, penicillin G and oxytetracycline. One sample was resistant to 3 antibiotics, amoxicillin-clavulanic acid, gentamicin and penicillin G. Another sample was resistant to penicillin G and gentamicin. Only two samples had the multi-antibiotic resistant results because certain antibiotics, such as veterinary or non-standard agents such as enrofloxacin ; no CLSI or EUCAST breakpoints were available for many organism-drug combinations. Therefore, only raw zone diameters could be reported without Susceptible (S) / Intermediate (I) / Resistance (R) interpretation. Overall, the presence of bacteria with resistant traits on everyday personal devices demonstrates the importance of good hand hygiene, proper clean devices and awareness of environmental contamination.

For recommendation for future similar study, the sample size should be increased. Using the sample size formula, 200 students should have 132 samples but in this study, the sample size was chosen to suit the timeline and feasibility. Students had also suggested swabbing their other devices such as tablets and laptops because in the younger generation, they tend to use tablets more even for recording or taking notes.

Next, inclusion of more bacterial or fungal tests can be considered. This study did not focus on the fungal contamination findings as time constraint and resources prevent additional testing more than proposed workflow. Furthermore, future study should follow the EUCAST or CLSI guidelines and choose antibiotics after identifying the isolates and looking up available antibiotics against said isolate to prevent unavailable breakpoints thus making determination of susceptibility difficult. Lastly, an inclusion of an efficient method of disinfection via laboratory confirmation can be done. For example, swabbing a phone prior and after disinfecting with alcohol to see the efficacy of the method of phone cleaning. This finding can encourage the students to clean their phones more often.

CHAPTER 7 : APPENDIX

Appendix 1 : The google form questionnaire can be accessed via this link : <https://forms.gle/EvpUdLCZ3sqALghA6>



Questionnaire on Mobile Phones Usage & Hygiene Practices

This questionnaire is part of my Final Year Project (FYP) titled "**Mobile Phones as Potential Sources of Spreading Multidrug Resistant Bacteria**", conducted as part of the requirements for my Degree in Veterinary Medicine at Universiti Malaysia Kelantan.

The purpose of this questionnaire is to gather brief information about your phone usage and cleaning habits before bacterial sampling is done. Your responses will help in understanding possible factors contributing to bacterial contamination.

Participation is **voluntary**, and all responses will be kept **confidential**. No personal identification (name, phone number, etc.) will be recorded. The data collected will be used solely for academic purposes.

This survey will take approximately **1-2 minutes** to complete.

By proceeding, you indicate your consent to participate in this study.

Figure 1. 1 : A screenshot of the questionnaire given to the students

REFERENCES

- Cotter, G., & Adley, C. C. (2001). *Comparison and evaluation of antimicrobial susceptibility testing of Enterococci performed in accordance with six national committee standardized disk diffusion procedures*. *Journal of Clinical Microbiology*, 39(10), 3753–3756. <https://doi.org/10.1128/JCM.39.10.3753-3756>
- Hindler, J. A., Humphries, R. M., Richter, S. S., Jorgensen, J. H., Bernard, K., Killian, S. B., ... Castanheira, M. (2016). *Methods for antimicrobial dilution and disk susceptibility testing of infrequently isolated or fastidious bacteria; approved guideline (CLSI Document M45, 3rd ed.)*. Clinical and Laboratory Standards Institute.
- The European Committee on Antimicrobial Susceptibility Testing. (2021). *Breakpoint tables for interpretation of MICs and zone diameters*. EUCAST. (latest version)
- Menzies School of Health Research. (2022). *Melioidosis Manual 2022 — Part II: Laboratory methods (disk diffusion & MIC testing)*. Menzies School of Health Research.
- Böhme, L., et al. (2013). *Standardisation of disk diffusion results for antibiotic susceptibility testing using the Sirscan automated zone reader*. *BMC Microbiology*, 13, 225. <https://doi.org/10.1186/1471-2180-13-225>
- Yang, X., Wang, D., Zhou, Q., Dai, Y., Sun, Y., & Zhao, H. (2019). *Antimicrobial susceptibility testing of Enterobacteriaceae: determination of disk content and Kirby-Bauer breakpoint for ceftazidime/avibactam*. *BMC Microbiology*, 19, 240. <https://doi.org/10.1186/s12866-019-1613-5>
- Concepção, N., Rodrigues, W. F., de Oliveira, K. L. P., et al. (2020). *Beta-lactams susceptibility testing of penicillin-resistant, ampicillin-susceptible Enterococcus faecalis isolates: a comparative*

assessment of Etest and disk diffusion methods against broth dilution. Annals of Clinical Microbiology and Antimicrobials, 19, 43. <https://doi.org/10.1186/s12941-020-00386-8>

Lee, J. Y. H., Bushell, R., Howden, B. P. (2023). *Antimicrobial susceptibility testing for Enterococci: current standards and recommendations*. *Journal of Medical Microbiology*. (Review)

EUCAST. (2014). *Development of the EUCAST disk diffusion antimicrobial susceptibility testing method and its implementation in routine microbiology laboratories*. *Clinical Microbiology and Infection*, 20(11), 1254–1260. <https://doi.org/10.1111/1469-0691.12651>

Hasan, H., et al. (2020). *Rapid disc diffusion antibiotic susceptibility testing for Pseudomonas aeruginosa, Acinetobacter baumannii and Enterococcus spp.* *Journal of Microbiological Methods*.

Chopra, I., & Roberts, M. (2001). *Tetracycline antibiotics: mode of action, applications, molecular biology, and epidemiology of bacterial resistance*. *Microbiology and Molecular Biology Reviews*, 65(2), 232–260.

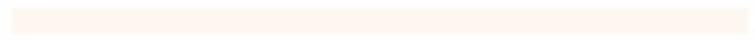
Paterson, D. L., & Bonomo, R. A. (2005). *Extended-spectrum beta-lactamases: a clinical update*. *Clinical Microbiology Reviews*, 18(4), 657–686.

13 DePalma, G., & Craig, B. A. (2018). *Bayesian monotonic errors-in-variables models with applications to pathogen susceptibility testing*. *arXiv preprint*. <https://arxiv.org/abs/1806.06974>

Zhang, M., Abutaleb, N. S., Li, J., Dong, P.-T., Zong, C., Wang, P., Seleem, M. N., & Cheng, J.-X. (2020). *Rapid determination of antimicrobial susceptibility by stimulated Raman scattering imaging of D₂O metabolic incorporation in a single bacterium*. *arXiv preprint*. <https://arxiv.org/abs/2004.10748>



UNIVERSITI



MALAYSIA



KELANTAN

FYP FPV