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Original Article

A study of microbial distribution and cell phone hygiene awareness at Universiti Malaysia Kelantan, Jeli Campus

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Abstract

Cell phones are an essential device for today's people. The warm environment on the cell phone may cause continuous growth of bacteria which can include harmful pathogens. This research aimed to determine if there is a relationship between gender and the daily routine environment with the bacteria count on the cell phone. The data were analysed using the chi-square test and the results showed no relationship ($P>0.05$). In addition, a survey questionnaire was conducted to study the common habits that are conducive to a microbial distribution pattern on a cell phone. Some of the common habits were using the cell phones while in the washroom and improper cell phone cleaning methods. The behavior of using the cell phone while dining and the microbial distribution pattern were found to be independent. This study aimed to provide awareness on the importance of keeping cell phones clean to minimize microbial contamination.

Keywords: cell phone, microbial distribution, common habits, survey, chi-square

1. Introduction

A cell phone is a portable, usually cordless, telephone for use in a cellular system. It has emerged as an important gadget in today's society as there are almost as many cell phones as there are people on earth (Meadow, Altrichter, & Green 2014). Cell phones have become a necessity part of modern society because of their advanced capabilities in browsing the net, taking high quality pictures, and storing data. This device has evolved from just a talking medium to a multipurpose device. The features of the cell phone were expanded by integrating different types of technologies into this device (Ray, 2015). The use of satellites and wireless services has significantly enhanced the perception of cell phones and has made the use much simpler and more convenient.

However, there is little awareness of the possible hazards of cell phones which may carry microorganisms as well as important data. Boshell (2013) noted that cell phones are filthy things that humans come in contact with every day since each square inch of a cell phone screen contains approximately 25,000 germs. The most common bacterial species found on the screen of a cell phone was *Staphylococcus aureus* (Famurewa & David, 2009). This is the number one pathogen that causes hospital-acquired infections worldwide (Ratthawongjiraku & Thongkerd, 2016). In addition, cell phones were confirmed to harbor ten times more microorganisms than a toilet seat because they are carried around to many different places causing them to be easily contaminated with microorganisms (Abrams, 2017).

Many studies have focused on investigating the microbial communities, in particular the isolation of indicator organisms from cell phones or devices used in hospitals

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(Chawla, Mukhopadhayay, Gurung, Bhate, & Bairy, 2009). Nonetheless, there is a lack of information on the microbial distribution on cell phones within common university areas, specifically in the Universiti Malaysia Kelantan Jeli Campus (UMKJC). Therefore, this study aimed to investigate whether there is an association between the environment and gender with the microbial growth pattern. Furthermore, this study also investigated common habits that contributed to the microbial growth pattern on cell phones.

2. Methods

2.1 Sample study area and sample size selection

The study was conducted at UMKJC from August to November 2017. Indoor samples are defined as respondents who were inside buildings in an enclosed environment. In contrast, outdoor samples are defined as respondents who were outside of buildings in open areas. The samples were collected based on gender, and daily routine environment.

Meanwhile, 30 UMKJC respondents were chosen randomly for pilot testing. After the questionnaire was tested to be reliable, 100 respondents were chosen to conduct the actual research study for the swab test analysis and also for the survey questionnaire based on common habits that contribute to the microbial distribution pattern on cell phones.

2.2 Questionnaire development

The questionnaire was developed to examine common habits that lead to the microbial growth patterns on a cell phone in terms of the respondents. The questionnaire consisted of four parts: personal information, cell phone usage information, hygiene information, and microbial growth on cell phone awareness information.

2.3 Pilot testing

Pilot testing was done to validate the reliability of the questionnaire. The test involved 30 UMKJC respondents: 15 outdoor and 15 indoor respondents. The data were analysed using Cronbach's alpha test. The alpha (α) value was 0.62. An α value more than 0.5 was considered adequate for an exploratory study (Wong, 2013).

2.4 Sample collection for microbial analysis

A randomised visit was made to different areas of UMKJC for the collection of data from respondents. The samples were collected from 50 outdoor and 50 indoor respondents with 25 males and 25 females from each of the two different environments. Sterile cotton swabs moistened with sterile distilled water were used to swab the cell phone surfaces. The cotton swabs were rolled over all the exposed outer surface of the respondents' cell phones (Elmanama, Hassona, Marouf, Alshaer, & Ghanima, 2015). The swabs were then placed into a capped test tube containing 1 mL of sterile distilled water to maintain the viability of the microorganisms. The collected samples were sent to the UMK Physics Laboratory. The survey questionnaire booklets were also distributed to the respondents.

2.5 Determination of microbial count from different sample collections

Initially, the cotton swabs were streaked onto nutrient agar plates and sealed with parafilm to minimize cross contamination. The plates were labelled accordingly and incubated at 37 ºC for 24 h. Bacteria from the cell phones and the hands of the users are similar because the bacteria originate from the user and grow best at human body temperature (37 ºC) (Jalalmanesh, Darvishi, Rahimi, & Akhlaghdoust, 2017). Therefore, the same temperature was used in this study. Furthermore, this research was conducted in Malaysia where the environmental temperature is around 30 to 37 ºC. After incubation, the colonies were counted. The results were tabulated according to the ranged that was set at the beginning of the experiment which were 1–15 colonies, 16–30 colonies, and over 30 colonies.

2.6 Statistical analysis

The data were recorded into SPSS version 22.0. Chi-square tests were performed in terms of gender against the number of microbial colonies formed, as well as the environment against the number of microbial colonies formed at a 0.05 confidence level.

3. Results and Discussion

3.1 Swab test analysis

Figure 1 exhibits the microbial count based on the number of microbial colonies present for each swab test conducted on cell phones of 100 respondents for different daily routine environments. The colonies formed were categorized into three categories and the data were analysed using the chi-square test of independence. The P-value obtained was 0.249 which was more than the 0.05 level of significance. This implied no relationship between the daily routine environment and the microbial distribution pattern.

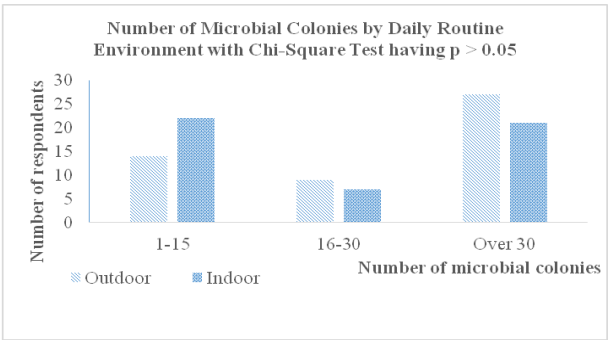


Figure 1. Number of microbial colonies by daily routine environment with the chi-square test having P>0.05.

Yassin and Almouqatea (2010) revealed that outdoors had higher bacterial concentration over indoors due to the higher temperature, humidity, and abundant nutrients available for the microbes to grow. The results of this study indicated that microbial growth was greater indoors which

contradicted previous findings. Since the indoors is a highly protected environment, the growth of bacteria can also occur on cell phones. Indoor and outdoor air is very similar regardless of the presence of ventilation indoor buildings (Bohannan, 2014).

The microbial count based on the number of microbial colonies for each swab test conducted on 100 respondents based on gender is illustrated in Figure 2. Using the chi-square test, it was found that gender and the microbial distribution pattern were independent (P>0.05).

Tiwari, Ankola, Mishra, and Kakkar (2016) studied the bacterial contamination on cellular phones from dental professionals and their findings showed no significant difference in terms of cell phone bacterial contamination based on gender. This was because both males and females spent the same amount of time using cell phones during working hours at the dental clinic.

Another study by Matini *et al.* (2016), which focused on the bacterial contamination on cell phones in Iran, also gave a result in which bacterial contamination had no relationship with gender. Thus, the perception that the cell phones of males always have more bacteria on their cell phones compared to females was proven unacceptable. Based on this research, both males and females should clean their cell phones more frequently and practice better cell phone hygiene since both males and females are susceptible to microbial contamination on cell phones.

Figure 3 delineates the relationship between the behavior of respondents in using cell phones while dining with the number of microbial colonies. The use of cell phones while dining was considered in this study because the highest levels of microbial contamination were found on non-food contact surfaces such as booth seats and table chairs in restaurants (Patel, Stansell, Jaimes, Ferris, & Webb, 2016). However, it was found through the chi-square test that the behaviour using the cell phone while dining and the microbial distribution pattern were independent (P>0.05).

Table 1 shows the number of microbial colonies present on the nutrient agar plates after 24 h of incubation at 37 ºC. The colonies counted were categorized as 1–15 colonies, 16–30 colonies, and over 30 colonies. The microbial colonies on the nutrient agar plate had a smooth circular form with a greyish-white color which is the characteristic of *Escherichia coli* (Gillespie, 2018). *E. coli* was frequently isolated from cell phones and therefore cell phones can now be used as a device to study the presence of *E. coli* (Brewerton, 2012; Gonzales, Solorzano, Diaz, Montario, & Cardenase, 2017).

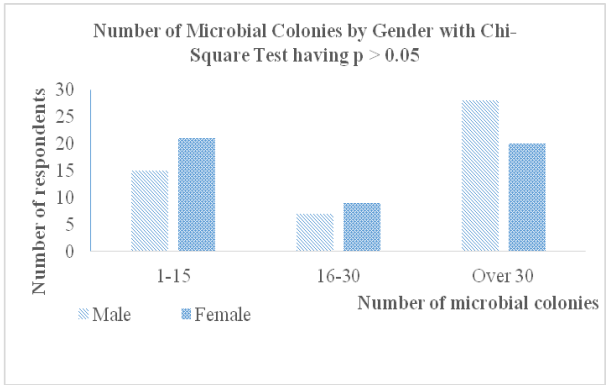


Figure 2. Number of microbial colonies by gender with the chi-square test having P>0.05.

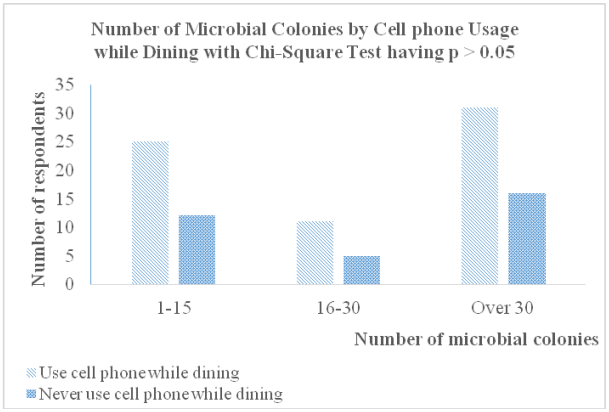
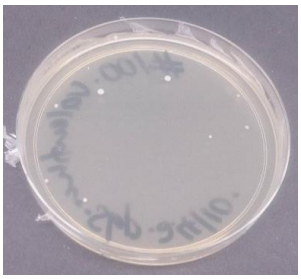
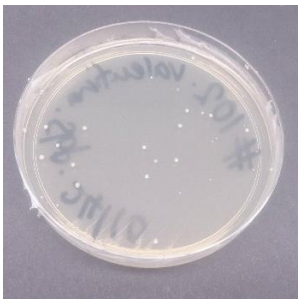
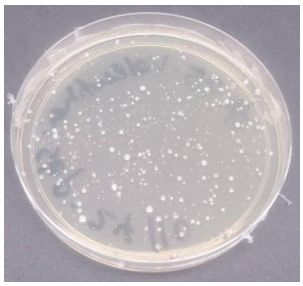


Figure 3. Number of microbial colonies by cell phone use while dining with the chi-square test having P>0.05.

Table 1. Number of microbial colonies present on nutrient agar plates.

Number of microbial colonies	Culture plates
1−15	
16−30	
Over 30	

3.2 Questionnaire analysis

Descriptive statistics were performed to study the habits of respondents that result in the microbial growth pattern on cell phones. The questionnaire analysis consisted of categorical data questions that focused on personal information, cell phone information, hygiene information, and awareness related to microbial growth on cell phones.

3.2.1 Personal information

In the personal information section, the questionnaire consisted of questions concerning gender, environment, age group, and occupation of the residents at UMKJC. An equal number of males (50 respondents), and females (50 respondents) were needed for the ease of the swab test and is in line with past studies done by Ovca, Rednak, Torkar, Jensyik, and Bauer (2012), Pal, Chatterjee, Sen, and Adhya (2015), and Anuradha, Arunkumar, Mekhanayakee, Shyen, and Arwintharao (2016). Likewise, respondents were equally divided between indoor and outdoor environments, numbering 50 for each environment.

The highest number of respondents was in the 18–24 age group since UMK is dominated by students of these ages (Table 2). This can be related with the highest number of students for the occupation questions. Technological gadgets like cell phones are usually popular among the youth. The number of respondents decreased as the age group increased. The reason is because when the survey was conducted, it could be seen that many of the students were with their cell phones compared to the other age groups.

3.2.2 Cell phone usage information

For the cell phone information section, "Other" cell phone brands were the most popular among the UMKJC residents (Table 3). Most respondents had used their cell phones for almost 2 years. Consumers customarily purchase their cell phone based on brand (Sasitharan, 2015). However, the popularity of other brands among UMKJC residents may be due to the price factor since most participants were students and were not yet employed.

Most respondents are now using smartphones compared to non-smartphone cell phones (Table 3). This may be largely due to the multi-function ability of smartphones over the non-smartphone cell phones. Smartphones are able to surf the internet and share data. Hence, a smartphone is more of an entertainment device compared to a non-smartphone. The work of Koroglu, Gunal, Yildiz, and Altindis' (2015) reported an insignificant difference between the types of cell phones with microbial contamination. Yet, touch screen cell phones are inclined to harbor a higher number of microbial colonies since their screens are larger compared to a normal keypad non-smartphone. Therefore, smartphone users are advised to clean their cell phones regularly to prevent microbial contamination on their cell phones.

There were 69 respondents who liked to keep their cell phone in the pocket of their trousers. The area in which a cell phone is kept also contributes to the microbial growth. While the cell phone by itself provides a warm habitat which is suitable for microbes to grow, dark places like pockets and handbags can increase bacterial growth.

Long hours spent with cell phones can contribute to the growth of microbes due to constant handling (Chaka, Misgana, Feye, & Kassa, 2016; Lee & Heng, 2014). Most of the respondents spent 6–10 hours a day using their cell phones (Table 4). This signified that their hands were constantly coming in contact with their cell phones. This has inflated the change for bacteria growth on cell phones.

Table 2. Number of respondents according to age group and occupation.

Age group	Number of respondents
18–24	80
25–34	13
35–49	6
Above 50	1
Occupation	Number of Respondents
Lecturer	3
Administration staff	2
Laboratory staff	3
Student	84
Others	8

Table 3. Number of respondents according to cell phone brand, cell phone period of use, cell phone type, and cell phone storing position.

Cell phone brand	Number of respondents
Samsung	24
iPhone	16
Nokia	2
Others	58
Cell phone period of use	Number of Respondents
Less than a month	2
A month but less than a year	23
A year but less than 2 years	40
More than 2 years	35
Cell phone type	Number of Respondents
Smartphone	99
Non-smartphone	1
Cell phone storing position	Number of Respondents
Handbag	16
Pocket of trousers	69
Shoulder bag	10
Jacket/Shirt pocket	3
Others	2

Table 4. Number of respondents according to time spent using a cell phone per day, using a cell phone in the washroom, and using a cell phone while dining.

Time spent using a cell phone per day	Number of respondents
Less than an hour	3
1–5 hours	34
6–10 hours	40
More than 10 hours	23
Using a cell phone in the washroom	Number of Respondents
Yes	22
No	78
Using a cell phone while dining	Number of Respondents
Yes	67
No	33

Over 20% of the respondents liked to take their cell phone with them to the washroom (Table 4). Contamination of cell phones by fecal bacteria is common, especially in the washroom (Mills, 2016). Taking a cell phone into a public washroom induces more harm as germs are active inside the washroom.

Sixty-seven of the respondents indicated they habitually used a cell phone while dining. This habit is likely to lead to microbial growth on cell phones. Dining tables and menu cards are the main breeding areas for microbes. Swab tests conducted on items on restaurant tables, specifically the menu cards, had the highest number of microorganisms, which was about 185,000 bacteria (Myers, 2014). Cell phones are no doubt a form of entertainment during dining but it is always presumed that limiting usage will minimize these microbial growths. Nonetheless, this study found that the use of cell phones while dining did not show any relationship with the microbial growth pattern.

3.3.3 Hygiene information

In this study, most respondents do not like to use antibacterial wet tissues to clean their cell phones (Table 5). Antibacterial wipes contain chemicals like alcohol which can kill microbes on the surface by denaturing the protein structure (Oxford, 2015). Instead, they preferred to rub the phone with the clothes they were wearing or just using tissue paper. This method is unsuitable for removing the microbes growing on cell phones. This is due to the misconception that antibacterial wipes have the ability to damage cell phones (Moss, 2015). Nonetheless, there are antibacterial wipes which are specifically meant to clean electronics.

Nearly 50% of respondents like to clean their cell phone daily by rubbing it with their clothes. To reduce the growth of microorganisms, cell phones should be regularly cleaned. For daily cleaning, dry lint-free cloth can be used, as recommended by Apple (Kee, 2016). A majority of the respondents (68 respondents) liked to wash their hands 1–10 times daily and only a minority (7 respondents) have the habit of washing their hands more than 20 times per day (Table 5). Although washing the hands is a simple procedure, many studies routinely reported intolerably low hand washing rates (Hart & Opara, 2001). Hand washing is important for removing dirt and microorganisms from the hands, and it is basic for minimizing infections. Microorganisms on the skin are short-lived and are less adherent (Wong *et al.,* 2014). Therefore, the existence of microorganisms on the skin can be eliminated easily by proper hand washing.

Table 6 elucidates the number of respondents according to the use of antibacterial hand washing soap, frequency of cell phone sharing habits, and sneezing habits while scrolling on cell phones. The respondents in this survey did not like to use antibacterial soap when washing their hands. They liked to use normal hand wash just to clean their hands but not to reduce bacteria on their palms. Antibacterial products can reduce microorganisms present on the skin because these products are formulated with active ingredients including benzethonium chloride and tea tree oil which are more effective in reducing microorganisms compared to normal hand wash soap. Some antibacterial hand wash soaps also contain essential oils which have antibacterial activities (Mahboubi, Kazempour, & Taghizadeh, 2014). Essential oils are normally obtained from medicinal plants like *Boesenbergia kigii,* which have proven to have antibacterial properties (Sudsai *et al.,* 2017). Washing the hands with a non-antimicrobial hand wash is not effective in removing bacteria found on the hands (Lucet *et al.,* 2002). Antibacterial hand wash such as Dettol has the ability to abate microorganisms present on hands. Therefore, fewer microbes are transmitted from hands to cell phones.

Table 5. Number of respondents according to the cell phone cleaning method, cell phone cleaning period, and daily hand washing habits.

Cleaning method	Number of respondents
By rubbing with the clothes you are wearing	47
Using a handkerchief/tissue paper	46
Using wet antibacterial tissue	5
Others	2
Cell phone cleaning period	Number of Respondents
Daily	29
Weekly	34
Monthly	37
Daily hand washing habits	Number of respondents
1–10 times	68
11–20 times	25
More than 20 times	7

Table 6. Number of respondents according to the use of antibacterial handwash soap, habit of frequently sharing cell phones, and sneezing habits while scrolling on a cell phone.

Use of Antibacterial Handwash Soap	Number of Respondents
Yes	48
No	52
Frequently share cell phones	Number of Respondents
Yes	38
No	62
Sneezing habits while scrolling Through cell phone	Number of Respondents
I randomly sneeze onto my phone	8
I sneeze onto my hands and wipe on shirt/pants then continue scrolling	27
I sneeze onto my hands and wash my hands before continue scrolling	25
I always sneeze onto a tissue or handkerchief	30

The respondents also have a habit of sharing their cell phones with others. Basol *et al.* (2014) highlighted that healthcare associated infectious diseases are easily spread when cell phones are shared with others. Everyone has their own microbiome in the body. When the cell phones are shared with others, a whole new ecosystem of germs is introduced to the cell phone and is transferred into parts of the ears, nose, and mouth.

Sneezing while scrolling on cell phones also causes microbial growth. Sneezing and then wiping the cell phones with the clothes they are wearing can actually cause easy contamination. By exercising proper hygienic practices, microbial contamination on cell phones can be reduced.

Infectious diseases can spread through sneezing and consequently, after sneezing or after shaking hands with a person who has a common cold. It is crucial to wash the hands immediately before using the cell phone (Wu, 2014). To avoid contamination of cell phones, it is better to sneeze onto a tissue instead of directly sneezing on the cell phone.

3.3.4 Microbial growth on cell phone awareness information

Based on the survey, most respondents were aware that microbes are able to grow on cell phones because most of the respondents are students who study microbiology (Table 7). Notwithstanding this, many respondents were unaware that their poor hygiene habits can lead to microbial growth.

The danger of microbial growth to health was also known by a majority of the respondents. Seventy-seven respondents were aware that microorganisms can jeopardize health (Table 8). Previous research confirmed that microbes isolated from the cell phones of health care workers (Gunaydin, 2011; Osman *et al.*, 2015) included pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA), while the cell phones of non-health care workers also carried multidrug resistant pathogens which can impose a danger to health. MRSA is known as the main bacteria which can cause nosocomial infections (Chuangchot, Tattawasart, Sripanidkulchai, Junlatat, & Fangkrathok, 2017). Future studies should be conducted to determine if these pathogens are also present on the cell phones of UMKJC personnel because many types of microbes were found on the phones.

Most respondents agreed that constantly holding their cell phones makes a cell phone a breeding ground for microbial growth. Studies have shown that humans share their own bacterial communities, especially from their skin (Altricher, 2014). Constant holding can cause easy transfer of bacteria, especially from the skin since the skin is constantly in contact with a wide variety of materials. Hence, many of the respondents agreed that human skin and hands are the main possible sources of microbial contamination on their cell phones.

The skin is the part of the body which always has contact with microorganisms and certain microbial species readily colonize on the skin. Elkholy and Ewees (2010) mentioned that cell phones come into very close contact with the body, especially with the hands, when talking on the phone. Consequently, the hands and skin are the main sources of microbial contamination to a cell phone and having frequent contact between the hands and cell phones will result in the spread of infectious diseases (Kilic, Ozaslan, Karagoz, Zer, & Davutoglu, 2009). Lastly, many respondents agreed that this survey was an eye-opener for them in terms of keeping their cell phones clean. This is because many did not realise that common habits can lead to microbial growth on cell phones.

4. Conclusions

Daily routine environment and gender had no relationship with the microbial growth pattern and likewise between using the cell phone while dining. This was discovered by performing the chi-square test with P-values greater than the 0.05. Many habits were identified from the UMKJC respondents through the questionnaire survey. Some of the common habits were use of the cell phones while in the washroom and also while dining. Future studies should be performed to identify and characterize the microbes present on the cell phone either as pathogenic or non-pathogenic types.

Table 7. Number of respondents according to awareness of microbial growth on cell phone, personal hygiene for reduction of microbial growth, and awareness these microorganisms can endanger health.

Awareness of microbial growth on cell phone	Number of respondents
Yes	72
No	28
Personal hygiene for reduction of microbial growth	Number of Respondents
Yes	80
No	20
Awareness these microorganisms can endanger health	Number of Respondents
Yes	77
No	23

Table 8. Number of respondents according to constantly holding the cell phone is a breeding ground for microbes, possible microbial contamination source, and the importance of cell phone cleanliness.

Constant Holding the Cell Phone is a Breeding Ground for Microbes	Number of Respondents
Yes	64
No	36
Possible microbial contamination source	Number of Respondents
human skin or hands	45
Dust	10
Environment	31
Transmission from contaminated material	14
Importance of cell phone cleanliness	Number of Respondents
Yes	98
No	2

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References

Abrams, A. (2017). Time health: Your cell phone is 10 times dirtier than a toilet seat. Here's what to do about it. Retrieved from http://time.com/4908654/cell-phone-bacteria/

Alex-Hart, B., & Opara, P. (2011). Hand washing practices amongst health workers in a teaching hospital. *American Journal of Infectious Disease*, *7*(1), 8-15.

Altricher, A. E. (2014). Mobile phones carry the personal microbiome of their owners. *Peer Journal*, *3*(2), 144-147.

Anuradha, S. N., Arunkumar, S., Mekhanayakee, Shyen, W. Y., & Arwintharao (2016). Study awareness on microbial contamination through mobile phones. *Asian Paciffic Journal of Health Science*, *3*(4), 313-323.

Basol, R., Becket, J., Glisdorf, J. Reischi, S., Schimnich, M., & Skillings, K. (2014). Bacteria on shared mobile phone can lead to infections, *Journal of Nursing*, *9*(4), 5-7.

Bohannan, M. (2014). Indoor airborne bacterial communities are influenced by ventilation, occupancy and outdoor air source. *International Journal of Indoor Environment and Health*, *24*(1), 41-48.

Boshell, P. (2013). Your phone is dirtier than you think. Retrieved from http://info.degroup.com/blog/bid/290652/your-mobile-phone-is-dirtier-than-you-think.

Brewerton, H. (2012). Picturing bacteria on your phone. Retrieved from https://www.chemistryworld.com/newspicturing-bacteria-on-your-phone article.

Chaka, T. E., Misgana, G. M., Feye, B. W. & Kassa, R. T. (2016). Bacterial isolates from cell phones and hands of health care workers: A cross sectional study in Pediatric wards at Black Lion Hospital, Addis Ababa, Ethiopia. *Journal of Bacteriology and Parasitology*, *7*(4), 1-6.

Chawla, K., Mukhopadhayay, C., Gurung, B., Bhate, P., & Bairy, I. (2009). Do cell phones carry potential pathogens? *Online Journal of Health and Allied Sciences*, *8*(1), 1-5.

Chuangchot, C., Tattawasart, U., Sripanidkulchai, B., Junlatat, J., & Fangkrathok, N. (2017). Antibacterial and antioxidant activity of *Rafflesia kerrii* extract against multidrug-resistant bacteria. *Songklanakarin Journal of Science and Technology*, *39*(2), 163-170.

Elmanama, A., Hassona, I., Marouf, A., Alshaer, G., & Ghanima, E. A. (2015). Microbial load of touch screen mobile phones used by university students and healthcare staff. *Journal of the Arab American University*, *1*(1), 1–21.

Elkholy, M., & Ewees, I. (2010). Mobile phone contamination with nosocomial pathogens in intensive care units. *The Medical Journal of Cairo University*, *2*, 1-5.

Famurewa, O., & David, O. M. (2009). Cell Phone: A medium of transmission of bacterial pathogens. *World Rural Observations*, *1*(2), 69 - 72.

Gillespie, C. (2018). Colony characteristics of *E. coli*. Retrieved from https://sciencing.com/colony-characteristics-ecoli-8507841.html.

Gonzales, M., Solorzano, F., Diaz, C., Montario, P., & Cardenase, M. (2017). Microbial contamination on cell phones used by undergraduate students. *Journal of Annals of Clinical Microbiology and Antimicrobial*, *32*(4), 121-132.

Gunaiydin, M. (2011). Are we aware how contaminated our mobile phones with nosocomial pathogens?

Jalalmanesh, S., Darvishi, M., Rahimi, M., & Akhlaghdoust, M. (2017). Contamination of senior medical students' cell phones by nosocomial infections: A survey in a University-Affiliated hospital in Tehran. *Shiraz E- Medical Journal*, *18*(4), 1-5.

Kee, C. (2016). Here's how to actually clean your disgusting phone. Retrieved from https://www.buzzfeed.com/carolinekee/get-those-germs-off-your-phone-for-real?utm_term=sy9QDP9av#.jlW93GZMJ.

Kilic, I., Ozaslan, M., Karagoz, I., Zer, Y., & Davutoglu, V. (2009). The microbial colonisation of mobile phone used by healthcare staffs. *Pakistan Journal of Biological Sciences*, *12*(11), 882-884.

Koroglu, M., Gunal, S., Yildiz, F., & Altindis, M. (2015). Comparison of keypads and touch-screen mobile phones/devices as potential risk for microbial contamination. *The Journal of Infection in Developing Countries*, *9*(12), 1308-1314.

Lee, C. W., & Heng, P. L. (2014). Investigating culturable gram positive cocci from the surface of mobile phones with different form factors. *Malaysian Journal of Science*, *33*(2), 112-117.

Lucet, J. C., Rigaud, M. P., Mentre, F., Kassis, N., Deblangy, C. Andremont, A., & Bouvet, E. (2002). Hand contamination before and after different hand hygiene techniques: A randomized clinical trial. *Journal Hospital Infection*, *50*, 276-280.

Mahboubi, M., Kazempour, N., & Taghizadeh, M. (2014). The antibacterial activity of some essential oil against clinical isolates of *Acinetobacter Baumannii*. *Songklanakarin Journal of Science and Technology*, *36*(5), 513-519.

Matini, E., Shayeghi, F., Nematian, J., Shayeghi, H., Iazemi, V., Ghahroud, R. R., . . . Barjin, Z.B. (2016). Frequency survey of bacterial contamination of mobile cell phones in general population in Tehran, Iran. *Galen Medical Journal*, *5*(2), 70-74.

Meadow, J. F., Altrichter, A. E., & Green, J. L. (2014). Mobile phone carry the personal microbiome of their owners. *PeerJ*, *2*, e447. doi:10.7717/peerj.447

Mills, J. (2016). Here's Why you should never take your phone into the toilet with you. Retrieved from http://metro.co.uk/2016/03/28/heres-why-you-should-never-take-your-phone-into-the-toilet-with-you-

Moss, G. (2015). How dirty is your phone and how can you keep it clean? Retrieved from http://www.bustle.com/articles/81417-how-dirty-is-your-phone-and-how-canyou-keep-it-clean-here-are-the

Myers, D. (2014). These are the dirtiest things in every restaurant. Retrieved from http://www.foxnews.com/food-drink/2014/08/20/these-are-dirtiest-things-in-every-restaurant.html.

Osman, M. R., Azid, A., Yunus, M., Mustafa, A. D., Amran, M. A., Azaman, F., . . . Bakar, Y. A. (2015). Assessment of bacteria in heavy metal bioremediation. *Malaysian Journal of Analytical Science*, *19*(6), 1405-1414.

Ovca, A., Rednak, B., Torkar, K, Jensvik, M., & Bauer, M. (2012). Student's mobile phones- how clean are they? *International Journal of Sanitary Engineering Research*, *6*, 7-18.

Oxford, J. (2015). How cleaning with wipes may actually spread deadly bacteria, including MRSA. Retrieved from http://www.dailymail.co.uk/health/article-3209458/How-cleaning-wipes-actually-spread-deadly-bacteria-including-MRSA.htm.

Pal, K., Chatterjee, M., Sen, P., & Adhya, S. (2015). Cell phones of health care professionals: a silent source

of bacteria. *National Journal of Laboratory Medicine*, *4*(4), 33-38.

Patel, D., Stansell, J., Jaimes, M., Ferris, K., & Webb, G. (2016). A survey of microbial contamination on restaurant nonfood-contact surfaces. *Journal of Food Safety*, *37*(1), 39-51.

Ratthawongjirakul, P., & Thongkerd, V. (2016). Fresh garlic extract inhibits Staphylococcus aureus biofilm formation under chemopreventive and chemotherapeutic conditions. *Songklanakarin Journal of Science and Technology*, *38*(4), 381-389.

Ray, A. (2015). The history and evolution of cell phones. Retrieved from https://www.artinstitutes.edu/about/blog/the-history-and-evolution-of-cell-phones.

Sasitharan, D. (2015). What factor persuade malaysians consumer to purchase smartphone? *Journal of Technology and Operations Management*, *10*(2), 38-50.

Sudsai, T., Leajae, S., Dangmanee, N., Chatgat, W., Chaniad, P., & Tewtrakul, S. (2017). Antibacterial and anti-HIV-1 integrase properties of isolated compounds from *Boesenbergia kingie*. *Songklanakarin Journal of Science and Technology*, *39*(1), 131-135.

Tiwari, A., Ankola, A.V., Mishra, H., & Kakkar, M. (2016). Assessment of bacterial contamination in cellular phones of dental professionals working in a Dental Institution in Belgaum City-A cross sectional study. *Medical Research Chronicles*, *3*(3), 266-273.

Wang, J. (2013). Management science, logistics, and operations research. Dauphin, PA: IGI Global.

Wong, J. L., Azrin, S. A. H., Narizan, M. I., Norliah, Y., Noraida, M., Amanina, A., & Habsah, H. (2014). Back to basic: Bio-burden on hands of health care personnel in tertiary teaching hospital in Malaysia. *Tropical Biomedicine*, *31*(3), 534-539.

Wu, J. Y. (2014). Hand-Washing global. *Open Journal of Philosophy*, *4*, 404-408.

Yassin, M. F., & Almouqatea, S. (2010). Assessment of airborne bacteria and fungi in an indoor and outdoor environment. *International Journal of Environmental Science and Technology*, *7*(3), 535-544.