Microbiological Examination of Personal Effects of Undergraduate Students in Microbiology Laboratory

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Abstract: Personal effects (PEs) including phones, laptops and bags globally are a necessary part of our everyday lives. These PEs are often carried or worn by individuals for numerous purposes, globally. However, the increasing risk of microbial contamination and the presence of antibiotic-resistant strains on these devices are of public health significance. Using standard microbiological procedures, this study examined the microbial occurrence and contamination of undergraduate students' mobile phones, laptops and bags and their resistant profile to conventional antibiotics. This cross-sectional study, carried out between April and May 2023, was performed on 65 swab samples collected from surfaces of mobile phones (n =25), laptops (n =20) and handbags (n = 20) of students attending the Microbiology Laboratory. Of the bacteria isolated, 39.2% were *Staphylococcus aureus*, *Staphylococcus epidermidis* (21.4%), *Escherichia coli* (7.1%), *Bacillus subtilis* (14.2%), *Klebsiella pnuemoniae* (7.1%), and *Pseudomonas aeruginosa* (11.0%). Fungal isolates included; *Fusarium* sp. (25.0%), *Aspergillus terreus* (25.0%), *Aspergillus flavus* (20.0%), and *Aspergillus niger* (30.0). Fifty four percent (54.0%) of the isolates produced complete hemolysis on blood agar, 7.1% showed partial hemolysis and 39.2% had no hemolysis at all. Antibiogram revealed an increased resistance of Gram positive bacteria to amoxicillin (38.1%) and levofloxacin (33.4%). Higher resistance was observed in gram negative bacteria to cephalothin (85.8%), ampicloxacilin (85.8%), augmentin (71.5%) and trimethoprim-sulphamethoxazole (71.5%). Findings demonstrated that personal effects of undergraduate students attending the Microbiology Laboratory at the university were microbially tainted with putative pathogens. This emphasizes the need for regular hand hygiene and disinfection of these items to minimize the spread of antibiotic-resistant superbugs.
Key word: Personal effects; undergraduates, microbial contamination, putative pathogens, antibiotic resistance

INTRODUCTION

The rapid advancement in technology over the past decades has led to an increased reliance on personal items such as mobile phones, laptops, and bags among the global population, including undergraduate students (Nikolopoulou and Gialamas, 2018; Olu-Taiwo *et al*., 2021). Personal effects, like fomites, are known to harbour and transmit microorganisms, including bacteria, thereby presenting public health risks (Meadow *et al*., 2014). These personal items include any inanimate object that, when contaminated with or exposed to infectious agents (such as bacteria, viruses, or fungi), can transfer the disease to a new host (Jabłońska-Trypuć *et al*., 2022). A substantial body of researches has shown that common personal items like mobile phones, laptops, and bags, often carried and used by people, are significant fomites (Auhim, 2013; Chandra *et al*., 2014; Szeto *et al*., 2015; Tusabe *et al*., 2022).

Mobile phones, for example, are near-constant companions, being handled frequently and placed on various surfaces, from dining tables to restroom counters. This contributes to the accumulation of diverse microbial populations on the device (Ulger *et al*., 2009). Laptops and phones, especially those used in healthcare settings, have been reported to harbour high levels of bacteria due to the frequent exchange between users (Bhoonderowa *et al*., 2014; Ide *et al*., 2019; Chatterjee *et al*., 2021). Bags, which are often placed on the floor or tabletops, are also prone to bacteria and other microbes' contaminations, increasing their potential as fomites (Chandra *et al*., 2014; Maharjan *et al*., 2014; Choudhury *et al*., 2022). The bacteria found on personal items can be both pathogenic (disease-causing) and non-pathogenic. Researches have shown that *Staphylococcus aureus, Escherichia coli*, and *Klebsiella pneumoniae*, among others, can be found on mobile phones, laptops, and bags (Brady *et al*., 2009; Scott *et al*., 2008; Koscova *et al*., 2018). These bacteria can cause infections ranging from minor skin infections to

serious conditions like pneumonia and meningitis (Blythe *et al*., 2005; Bodena *et al*., 2019). A study by Tagoe *et al*. (2011) found a significant level of bacterial contamination on mobile phones of undergraduate students, with potential pathogens isolated, suggesting a significant public health risk. Similarly, other studies have revealed that laptops and bags owned by persons also harbour diverse bacterial communities, presenting potential health risks (Anderson and Palombo, 2009; Meadow *et al*., 2014). The level and type of bacterial contamination on personal items are influenced by numerous factors. These include the frequency of use and cleaning of the items, the environment in which these items are used, and the hand hygiene practices of the individuals (Bloomfield *et al*., 2007; de Kraker *et al*., 2022; Koscova *et al*., 2018; Gaube *et al*., 2021). For example, a study conducted by Kilic *et al*. (2012) demonstrated that the frequency of mobile phone use significantly affected the extent of bacterial contamination.

Furthermore, undergraduate students, being a diverse population from various backgrounds, are known to exhibit a wide range of hygienic practices, which could influence the level of bacterial contamination on their personal items. What is more, research on bacterial contamination of personal items in non-clinical locales, like school settings, remains scarce. Therefore, this study aimed to isolate and identify microorganisms and their antimicrobial susceptibility profile from personal items of undergraduate students attending Microbiology Laboratory in the University of Uyo, Nigeria.

MATERIALS AND METHODS

Study Area and Sample Collection: The study area is Located in Uyo, the capital city of Akwa Ibom State, Nigeria. The University of Uyo, main campus lies between longitude 5.0281° N and latitude 7.9788° E. The main campus of the university houses five faculties namely; Engineering, Agriculture, Law and Environmental Studies, and Science, with the Microbiology Laboratory sited within the Faculty of Science. This cross-sectional study was conducted from April to May 2023 at the Microbiology Laboratory within the Department of Microbiology, Faculty of Biological Sciences, University of Uyo, Nigeria. Sixty-five (65) samples were randomly collected, comprising mobile phones (n = 25), laptops (n = 25), and bags (n=20). The samples were collected using a sterile cotton swab moistened in sterile peptone water, and transferred into McCartney bottle, appropriately labelled, and incubated at 37℃ for 24 hr for bacteria and 27℃ ± 2 for 5-7 days for fungi.

Isolation and characterization of microorganisms associated with the personal effects: A loopful of the cultured broth was picked using a sterile inoculating loop after 24 h of incubation. This was streaked onto the surface of a sterile solidified medium (Nutrient agar and MacConkey agar – for the isolation of heterotrophic bacteria and coliforms). The plates were incubated in an inverted position at 37℃ for 24 h. The cultured broth was also streaked on Sabouraud dextrose agar for the isolation of fungi, with the plates incubated at room temperature (27 ± 2°C) for 5 to 7 days. Pure cultures of isolates were sub-cultured and stored on appropriate agar slants, in a refrigerator at 4 °C for further characterization and identification. All bacterial isolates were Gram stained and subjected to a suite of biochemical tests described by Forbes *et al*. (2007); Cheesbrough (2010); Holt *et al*. (1994). Pure cultures of fungi were characterized morphologically and biochemically. Wet examination of fungi (using ×40 objective lens) was also performed with lactophenol in cotton blue. The colonies of fresh cultures of fungi isolates were observed for texture, colour, surface, elevation, and margin. Cellular morphology was determined by taking a portion of the yeast colony into a drop of lactophenol cotton blue on a clean glass slide. The slide was examined under

the microscope using the X40 objective (Kurtzman *et al*., 2011). Isolation and identification of yeasts were done by the use of standard morphological and physiological tests and identification keys described by Nwachukwu *et al.* (2006)

Hemolysin production and antibiotics susceptibility assay of the microbial isolates: Hemolysin production by the isolates was identified by the presence of hemolytic zones (clear – β or greenish halos - α, and no zones - γ) around the colonies on blood agar after incubation for 24 h at 37˚C (Ndubuisi-Nnaji *et al*., 2022). *In-vitro* antibiotic susceptibility of bacterial isolates was determined by the Kirby-Bauer disc diffusion method (CLSI, 2016). In summary, 10 µl of each 18-hr old bacterial isolate, carefully adjusted to 0.5 McFarland standard, was inoculated onto Mueller-Hilton agar (MHA) plate. For Gram positives, antibiotic discs: Ciprofloxacin (CPX, 10 µg), norfloxacin (NB, 10 µg), gentamycin (CN, 10 µg), amoxicillin (AML, 20 µg), streptomycin (S, 30 µg), erythromycin (E, 30 µg), ampicloxacillin (APX, 20 µg), chloramphenicol (CH, 30 µg), levofloxacin (LEV, 10 µg) and rifampin (RD, 20 µg) were placed on the surface of dry agar plates. Conversely, for Gram-negative bacteria, ciprofloxacin (CPX, 10 µg), pefloxacin (PEF, 10 µg), augmentin (AUG, 30 µg), cephalothin (CEP, 10 µg), streptomycin (S, 30 µg), nalidixic acid (NA, 30 µg), ofloxacin (OFX, 10 µg), trimethoprim-sulphamethoxazole (SXT, 30 µg) and ampicillin (PN, 30 µg) were placed on the agar plates in like manner. The discs were aseptically placed using sterile forceps, and the plates were incubated at 37°C for 18 h (Okon *et al*., 2020). Zones of inhibition observed were measured in millimeters (mm) and interpreted as sensitive, intermediate, or resistant based on the criteria outlined in CLSI (2016).

RESULTS

A total of 28 bacterial isolates and 20 fungal isolates were characterized and identified from the studied samples (bags, phones, and laptops). Five (5) bacterial genera consisting of 21 (75.0%) Gram-positive bacteria (GPB) and 7 (25.0%) Gram-negative bacteria (GNB) were encountered. Of the 28 bacterial isolates, *S. aureus* (39.3%) had the highest frequency of occurrence, followed by *S. epidermidis* (21.4%), *Bacillus subtilis* (14.2%), *P. aeruginosa* (10.7%), while least frequency of 7.1% each was recorded for *E. coli* and *K. pneumoniae* (Figure 1). Out of the 20 fungal isolates encountered, *A. niger* (30%) had the highest frequency of occurrence, followed by *Fusarium* species and *A. terreus*, each having 25%, while the least frequency of occurrence was recorded for *A. flavus* (20%) as shown in Figure 2. The hemolytic patterns as shown in Table 1 revealed that 7.1% of the 28 bacterial isolates tested, produced alpha (α) – partial hemolysis, 54 % produced beta (β) hemolysis – complete hemolysis), and 39.2% produced gamma (γ) hemolysis – no hemolysis. From the number, *S. aureus, S. epidermidis, E. coli,* and *K. pnenmoniae* did not exhibit alpha (α) hemolysis, while *E. coli* and *P. aeruginosa* did not display gamma (γ) hemolysis. However, only *B. subtilis* displayed a varied degree of hemolysin production. The varied antibiotics susceptibility profiles of GPB and GNB from students' items are presented in Tables 2 and 3. The findings of the antibiotic susceptibility pattern showed that all (100%) of the GPB were sensitive to ciprofloxacin and rifampicin. *B. subtilis* and *Staphylococcus epidermidis* were generally sensitive to all the antibiotics; with only 50% of *Bacillus subtilis* resistance to streptomycin and ampicloxacillin. Also *S. epidermidis* showed resistance (16.7%) each to (levofloxacin and norfloxacin) and 63.7% to ciprofloxacin, while *S. aureus* displayed 54. About 6% resistance to both amoxicillin and levofloxacin (Table 2).

The GNB (Table 3) displayed 100% sensitivity to ofloxacin, pefloxacin, and ciprofloxacin, while, *K. pneunomiae, P. aeruginosa,* and *E. coli,* showed 100 % resistance to 1, 2 and 4 out of the 10 tested antibiotics, respectively.

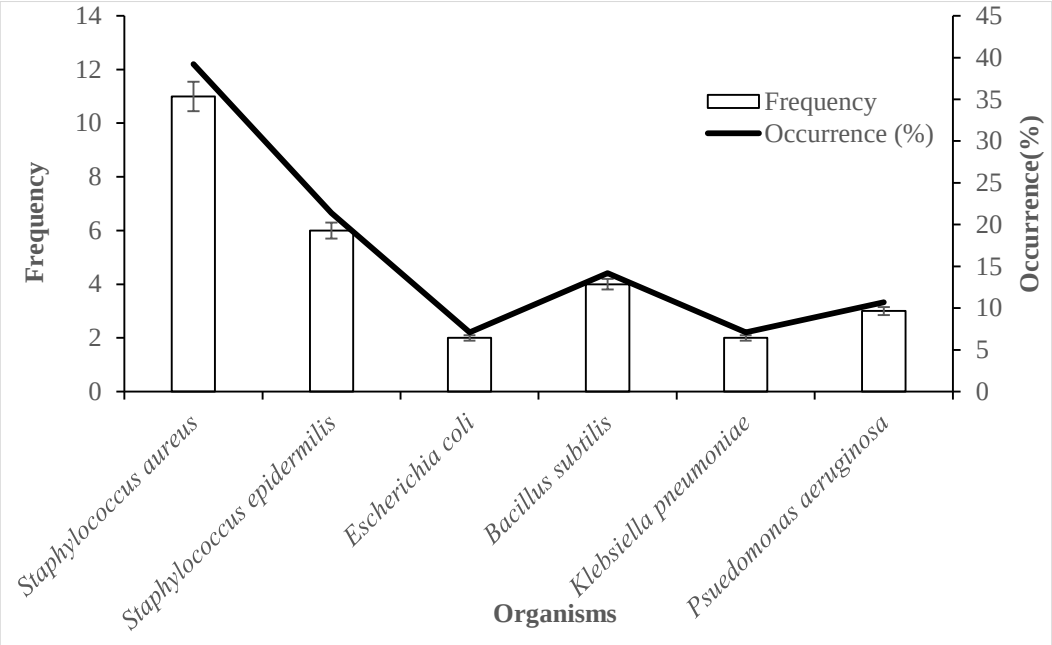

Figure 1: Occurrence of bacterial isolates in personal effects of undergraduates

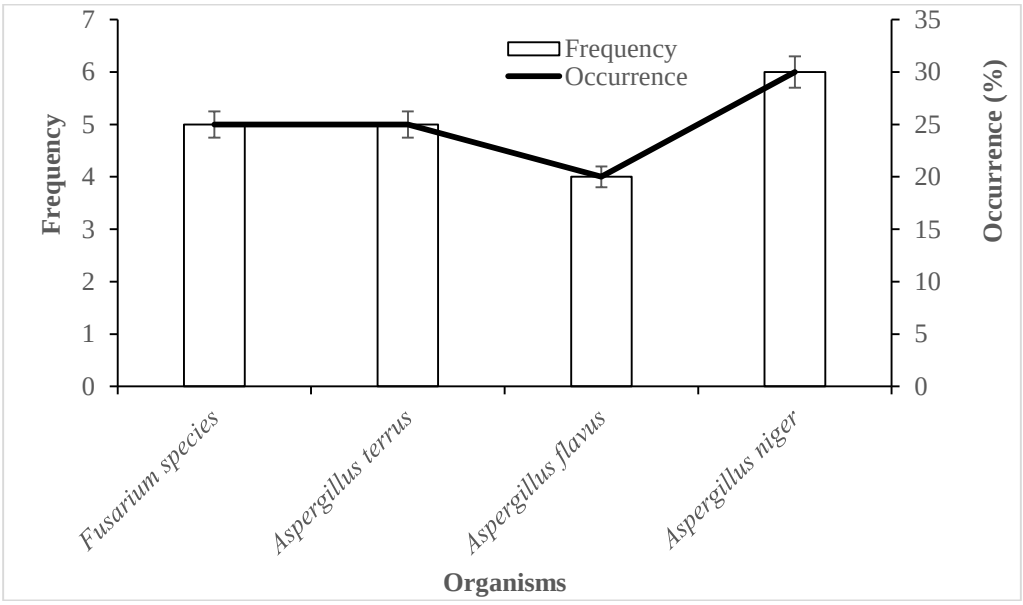

Figure 2: Occurrence of fungal isolates in personal effects of undergraduates

Table 1: Haemolytic activities of bacterial isolated from student's items

Bacterial Isolates	Hemolytic Patterns of Isolates No (%)			
	Total number tested	Alpha (α)	Beta (β)	Gamma (γ)
Staphylococcus aureus	11	0(0.0)	8(73.0)	3(27.2)
Staphylococcus epidermidis	6	0(0.0)	1(17.0)	5(83.3)
Escherichia coli	2	0(0.0)	2(100.0)	0(0.0)
Bacillus subtilis	4	1(25.0)	2(50.0)	1(25.0)
Klebsiella pneumoniae	2	0(0.0)	0(0.0)	2(100.0)
Pseudomonas aeruginosa	3	1(33.3)	2(67.0)	0(0.0)
Total	28	2(7.1)	15(54.0)	11(39.2)

Key: Values in brackets are percentages

Table 2: Antibiotic susceptibility testing of Gram-positive bacterial isolated from student's items

Bacterial Isolates	Antibiotic susceptibility profile No (%)										
	Total number tested	CPX	NB	CN	AMX	S	RD	E	CH	APX	LEV
S. aureus	11	11(100)	6(54.5)	11(100)	5(45.4)	10(90.9)	11(100)	9(81.8)	10(90.9)	9(81.8)	5(45.4)
S. epidermidis	6	6(100)	5(83.3)	4(36.3)	6(100)	6(100)	6(100)	6(100)	6(100)	6(100)	5(83.3)
Bacillus subtilis	4	4(100)	4(100)	4(100)	4(100)	2(50.0)	4(100)	4(100)	4(100)	2(50)	4(100)
TOTAL	21	21(100)	15(71.4)	19(90.4)	13(61.9)	18(85.7)	21(100)	19(90.4)	20(95.2)	17(80.9)	14(66.6)

Key: CPX=Ciprofloxacin; NB=Norfloxacin; CN=Gentamycin; AMX=Amoxicillin; S=Streptomycin; RD=Rifampicin; E=Erythromycin; CH=Chloramphenicol; APX=Ampicloxacillin; LEV=Levofloxacin.

Table 3: Antibiotic susceptibility testing of Gram-negative bacterial isolates

Bacterial Isolates	Antibiotic susceptibility profile No (%)										
	Total number tested	OFX	PEF	CPX	AU	CN	S	CEP	NA	SXT	PN
Escherichia coli	2	2(100)	2(100)	2(100)	0	2(100)	2(100)	0	1(50.0)	0	0
K. pneumoniae	2	2(100)	2(100)	2(100)	1(50.0)	2(100)	0	1(50.0)	2(100)	1(50.0)	1(50.0)
P. aeruginosa	3	3(100)	3(100)	3(100)	1(33.3)	1(50.0)	3(100)	0	1(33.3)	1(33.3)	0
Total	7	7(100)	7(100)	7(100)	2(28.5)	5(71.4)	5(71.4)	1(14.2)	4(57.1)	2(28.5)	1(14.2)

Keys: OFX=Ofloxacin; PEF= Pefloxacin; CPX=Ciprofloxacin; AU=Augmentin; CN=Gentamycin; S=Streptomycin; CEP=Cephalothin; NA=Nalidixic acid; SXT=Trimethoprim-Sulphamethoxazole; PN=Ampicloxacilin

DISCUSSION

Practically, the ubiquitous nature of microorganisms makes it difficult to have a universe devoid of microbial invasion, hence it is crucial to adhere strictly to microbial safety standards and hygienic practices that ensure a safe and healthy life. This investigation revealed that personal items are highly contaminated with microorganisms of health importance. This was in agreement with the report of Tagoe *et al*. (2011) who submitted that mobile phones screened were contaminated with varied numbers of bacteria. Bacterial (*Staphylococcus aureus*, *Staphylococcus epidermidis*, *Escherichia coli*, *Bacillus subtilis*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa*) and fungal (*Fusarium* sp., *Aspergillus terreus*, *Aspergillus flavus*, and *Aspergillus niger*) contaminants encountered in phones, bags and laptops of undergraduate students attending Microbiology laboratory in the University of Uyo, Nigeria were examined, identified and reported in this study. These organisms may likely have contaminated the fomites through direct skin and hand-to-hand contact. This may result from the fact that the isolated bacteria are a subsection of the normal skin microbiota as advanced by Amira and Abdalllahi (2010). The presence of *Escherichia coli*, *Pseudomonas aeruginosa*, and *Klebsiella pneumonia* from our study substantiates earlier report by Selim and Abaza (2015) who isolated similar organisms from mobile phones. The occurrence of *Escherichia coli*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae* (which are notable pathogens) in the personal items of students is capable of causing school-acquired infections (SAIs) (Sikora and Zahra, 2022). These items may as well serve as sources for nosocomial infection transmission. For instance, sepsis is most frequently caused by Gram-negative *Escherichia coli*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa*. The isolation of *Bacillus subtilis*, a common soil bacterium, and laboratory contaminant may contaminate food if prepared or eaten with infected hands (Jay, 2000). Susheela *et al*. (2015) from findings discovered that bags

from the community carries potential pathogens as 95.2% of the bags from community settings were colonized by bacteria. From this study, S*taphylococcus aureus* was the most predominant bacterium which was in accordance with reports from other researchers (Kokate *et al*., 2012; Tambe and Pai, 2012; Rana *et al*., 2013; Bhoonderowa *et al*., 2014; Raghavendra *et al*., 2014). *Staphylococcus aureus* causes wide-ranging infections like pimples, boils, pneumonia, and meningitis. The pathogen also pose serious health concerns owing to its virulence, ability to cause far-reaching and life-threatening infections, and its capacity to survive in a different environment (Lowy, 1998). In warm environments such as those found in cell phones, *S. aureus* and coagulase-negative staphylococci (CoNS) have been established to survive desiccation and thus could endure and rapidly undergo cell division (Trivedi *et al*., 2011). A total of 28 bacterial isolates were encountered and the hemolytic activities were observed as follows; 7.1% for alpha (α), 54% for beta (β), and 39.2% for gamma (γ) hemolysis. *Staphylococcus aureus* showed the highest percentage for beta (β) hemolysis as the blood cells were completely lysed. This type of hemolysis could be caused by the streptolysin enzyme produced by bacteria. The isolation of bacteria with varied hemolysis profiles is consistent with other studies by Rutala *et al*. (2006) and Akinjogunla *et al*. (2016); who independently examined laptops, mice, and keypads for microbial contaminants.

The Gram positive bacteria (GPB), *Staphylococcus aureus* and *Staphylococcus epidermidis* were highly susceptible (100%) to Ciprofloxacin from our findings. This observation corroborated Akinjogunla and his co-workers, who reported >70% susceptibility of these organisms isolated from surfaces of computer mice, keyboard and automated teller machines (ATMs) (Akinjogunla *et al*., 2016). Resistance to other antibiotics was also observed, conspicuously with 55% resistance by *Staphylococcus aureus* to amoxicillin and levofloxacin, respectively. *Staphylococcus epidermis* exhibited the highest resistance of 63.7 % to gentamycin while *Bacillus subtilis* demonstrated 100 susceptibilities to 8 of the 10 tested antibiotics. The Gram negative bacteria (GNB), *Escherichia coli,* and *Pseudomonas aeruginosa* were highly resistant (100%) to ampicloxacilin which was in contrast with the report of Akinjogunla *et al*. (2016). The authors reported <50 % resistance of these organisms in samples from computer mice, keyboards, and ATMs. However, 100% resistance to each of augmentin, ciprofloxacin, trimethoprim-sulphamethoxazole, and ampicloxacilin was observed for *Escherichia coli.* Conversely, *Klebsiella pneumoniae* was resistant to Streptomycin while *Pseudomonas aeruginosa* was resistant to ciprofloxacin and ampicloxacilin. The susceptibility outcome varied with bacterial isolates revealing that antibiotics use is commonplace. The diverse resistance level displayed by these encountered bacteria (*Staphyloccocus aureus, Staphylococcus epidermidis, Bacillus subtilis, Escherichia coli, Klebsiella pneumoniae,* and *Pseudomonas aeruginosa)* in phones, laptops, and bags have public health consequences (Tagoe *et al*., 2011). Furthermore, the common misapplication of these antibiotics in chemotherapy especially could also explain these observations as earlier reported by Kumurya *et al.* (2010). Elsewhere, some researchers found that 95% of phones were tainted with multidrug resistant superbugs (Clean, 2013). By examining the study group hands, the author concluded that a substantial number of germs were also isolated from their hands from which transferred are to their phones, and vice versa. About 30% of the bacteria on the phones ended up in the owner's hands (Clean, 2013). In addition to the isolation and identification of some bacteria, fungi such as *Fusarium* species, *Aspergillus terreus*, *Aspergillus flavus*, and *Aspergillus niger* were also isolated from the personal items examined. The isolation of fungi

especially *Aspergillus niger* from students' items like phones validates another study by Kokate *et al*. (2012). These isolates are spore-forming organisms and are associated with severe health effects such as asthma, rhinitis, and other illnesses including allergic bronchopulmonary mycoses, allergic fungal sinusitis, and hypersensitivity pneumonitis (Sachin *et al*., 2016). Most of these fungal isolates affect the hair, nail, and skin, causing mycoses: ringworm, athletes' foot, rashes, and other skin conditions (Hay, 2016).

CONCLUSION

This study revealed that the personal items of undergraduate students were principally tainted with epidemiologically-important skin and soil microflora. The study also presents that mobile phones, laptops, and bags could serve as potential vectors for infectious agent transmission from person to person. Most of these organisms are known to be harmful and may cause morbidity and mortality to humans. Hence, water, sanitation and hygiene (WASH) measures essentially including thorough cleaning and decontamination should be performed by in-persons after laboratory sessions.

REFERENCES

Akinjogunla, O. J., Fatunla, O. K. and Udofia E, S. (2016). Phenotypic detection of virulence markers, antibiotic and disinfectant susceptibility of bacterial isolates from automated teller machine keypads, computer keyboards and mice in Uyo. Nigeria, *British Biotechnology Journal*, 15(3): 1 – 15.

Amira H, A, and Abdalllahi (2010). Isolation and identification of microbes associated with mobile phones in Damman in Eastern Saudi Arabia. *Journal of Family and Community*, 17: 11-14.

Anderson, G. and Palombo, E. A. (2009). Microbial contamination of computer keyboards in a university setting. *American Journal of Infection Control*, 37(6): 507-509.

Auhim, H. S. (2013). Bacterial contamination of personal mobile phones in Iraq. *Journal of Chemical, Biological and Physical Sciences (JCBPS)*, 3(4): 2652.

Bhoonderowa, A., Gookool, S. and Biranjia-Hurdoyal, S. D. (2014). The importance of mobile phones in the possible transmission of bacterial infections in the community. *Journal of Community Health*, 39(5): 965-967.

Bloomfield, S. F., Aiello, A. E., Cookson, B., O'Boyle, C. and Larson, E. L. (2007). The effectiveness of hand hygiene procedures in reducing the risks of infections in home and community settings including handwashing and alcohol-based hand sanitizers. *American Journal of Infection Control*, 35(10): S27-S64.

Blythe, D. G., Routh, J. and Lakin, A. (2005). Methicillin-resistant Staphylococcus aureus infection in a college football team: risk factors outside the locker room and playing field. *The Journal of Pediatrics*, 146(5): 702.

Bodena, D., Teklemariam, Z., Balakrishnan, S. and Tesfa, T. (2019). Bacterial contamination of mobile phones of health professionals in Eastern Ethiopia: antimicrobial susceptibility and associated factors. *Tropical Medicine and Health*, 47: 1-10.

Brady, R. R., Verran, J., Damani, N. N. and Gibb, A. P. (2009). Review of mobile communication devices as potential reservoirs of nosocomial pathogens. *Journal of Hospital Infection*, 71(4), 295-300.

Bures, S., Fishbian, J. T., Uyehara, C. F. T., Parker, J. M. and Berg, B. W. (2000). Computer Keyboards and faucet handles as reservoirs of nosocomial pathogens in the intensive care unit.

American Journal of Infection Control, 28: 463-417.

Chandra, J. T., Sowndarya, A. J., Sirisha, I. and Sharma, Y. V. (2014). How Safe Ladies Hand Bags Are: A Microbiological View. *Biology and Medicine*, 6(3): 1.

Cheesbrough, M., (2010). District Laboratory Practice in Tropical Countries Manual. UK, Cambridge University Press: 146 - 157.

Chatterjee, S., Saigal, S., Bhargava, A., Shankar, D., Khan, A. M. and Khan, S. F. (2021). Hidden reservoirs of pathogens in dental settings. *Bioinformation*, 17(1): 73.

Choudhury, M., Bindra, H. S., Singh, K., Singh, A. K. and Nayak, R. (2022). Antimicrobial polymeric composites in consumer goods and healthcare sector: A healthier way to prevent infection. *Polymers for Advanced Technologies*, *33*(7): 1997-2024.

Clean link. (2013). Study: Public toilet is cleaner than the average cell phone. 2013 Jul 18 [cited 2014 May 20]. Available from: http://www.cleanlink.com/news/article/Study-Public-Toilet-Is-Cleaner-Than-The-Average-Cell-Phone--15844#sthash.QlwJarRw.dpuf

Clinical and Laboratory Standards Institute. (2016). Performance standards for antimicrobial disk susceptibility testing (26th edn), Wayne, Pennsylvania, U.S.A.

de Kraker, M. E., Tartari, E., Tomczyk, S., Twyman, A., Francioli, L. C., Cassini, A. and Pittet, D. (2022). Implementation of hand hygiene in health-care facilities: results from the WHO Hand Hygiene Self-Assessment Framework global survey 2019. *The Lancet Infectious Diseases*, *22*(6): 835-844.

Forbes, B. A., Sahm, D. F and Weissfeld, A. S. (2007). Bailey and Scott's diagnostic microbiology. 12th ed. St Louis: Mosby.

Gaube, S., Fischer, P. and Lermer, E. (2021). Hand hygiene insights: Applying three theoretical models to investigate hospital patients' and visitors' hand hygiene behavior. *PloS One*, *16*(1): e0245543.

Hay, R. J. (2016). Fungal infections of the skin. *Antibiotic and Antifungal Therapies in Dermatology*, 157-186.

Holt, J. G., Krieg, N. R., Sneath, P. H. A., Stately, J. T. and Williams, S. T. (1994). St. Bergeys Manual of Determinative Bacteriology (9th Edition). Baltimore, Williams and Wilkins.

Ide, N., Frogner, B. K., LeRouge, C. M., Vigil, P. and Thompson, M. (2019). What's on your keyboard? A systematic review of the contamination of peripheral computer devices in healthcare settings. *BMJ Open*, 9(3), e026437.

Jabłońska-Trypuć, A., Makuła, M., Włodarczyk-Makuła, M., Wołejko, E., Wydro, U., Serra-Majem, L. and Wiater, J. (2022). Inanimate surfaces as a source of hospital infections caused by fungi, bacteria and viruses with particular emphasis on SARS-CoV-2. *International Journal of Environmental Research and Public Health*, *19*(13): 8121.

Jay, M. J. (2000). *Modern Food Microbiology*. 6th ed. Berkhire: Van Nostrand Reinhold Pub. Co.

Kilic, I. H., Ozaslan, M., Karagoz, I. D., Zer, Y. and Davutoglu, V. (2012). The microbial colonisation of mobile phone used by healthcare staffs. *Pakistan Journal of Biological Sciences*, 15(5), 244-248.

Kokate, S. B., More, S. R., Gujar, V., Mundhe, S. and Zahiruddin, Q. S. (2012). Microbiological flora of mobile phones of resident doctors. *Journal of Biomedical Science and Engineering*. 5:696–698.

Koscova, J., Hurnikova, Z. and Pistl, J. (2018). Degree of bacterial contamination of mobile phone and

computer keyboard surfaces and efficacy of disinfection with chlorhexidine digluconate and triclosan to its reduction. *International Journal of Environmental Research and Public Health*, 15(10): 2238.

Kumurya, A. S., Kawo, A. H. and Uba, A. (2010). Prevalence and *in-vitro* susceptibility studies of bacteria isolated from hospital patients presenting with otitis media in Kano, Nigeria. *Biological and Environmental Sciences Journal for the Tropics*, 7(1): 37-39.

Kurtzman, C., Fell, J. W., Boekhout, T. and Robert, V. (2011): Methods for isolation, Phenotypic characterization and maintenance. *Researchgate (Elsevir BV)*: 87 – 110.

Lowy, F. D. (1998). *Staphylococcus aureus* infections. *The New England journal of medicine,* 339(8):520-532.

Maharjan, U., Rajbanshi, L., Gurung, G., Gautam, R. and Nepal, H. P. (2014). Are personal accessories safe in hospital settings? *Journal of Chitwan Medical College*, 4(2): 29-31.

Meadow, J. F., Altrichter, A. E., Bateman, A. C., Stenson, J., Brown, G. Z., Green, J. L. and Bohannan, B. J. (2014). Humans differ in their personal microbial cloud. *The Journal of Life & Environmental Sciences,* 3: e1258.

Ndubuisi-Nnaji, U.U., Ofon, U. A., Okon, M. U., Ekong, A. N. and Benson, E.E. (2022). Detection of virulence determinants and antibiogram of bacteria isolated from semi-batch digester treating animal manure, *Nigerian Journal of Microbiology*, 35(1): 6013 - 6023.

Nikolopoulou, K. and Gialamas, V. (2018). Mobile phone dependence: Secondary school pupils' attitudes. *Education and Information Technologies*, 23(6): 2821-2839.

Nwachukwu, I. N., Ibekwe, V. I., Nwabueze, R. N. and Anyanwu B. N. (2006): Characterization of palm wine yeast isolates for Industrial utilization. *African Journal of Biotechnology*. 5(19): 1725 – 1728.

Okon, M. U., Inyang, C. U. and Akinjogunla, O. J. (2020). Bacterial isolates from bivalve clams (*Galatea paradoxa*, Born 1778): occurence, multi-drug resistance, location of antibiotic resistance marker and plasmid profiles, *South Asian Journal of Research in Microbiology*,7(3): 35-46.

Olu-Taiwo, M., Laryea, C. A., Kweku Mykels, D. and Forson, A. O. (2021). Multidrug-resistant bacteria on the mobile phones and computer keyboards of healthcare university students in Ghana. *Canadian Journal of Infectious Diseases and Medical Microbiology*, 2021.

Raghavendra, M. P., Shruthi, K. C and Shivalingaiah, B. (2014). Bacteriological screening of hands and mobile phones of healthcare workers and its management. *International Journal of Recent Trends in Science and Technology*, 10(1): 92 - 97.

Rana, R., Joshi, K. and Kaur, S. (2013). Cell phones-homes for microbes. *Journal of Biological and Medical Research*, 4(3): 3402-3405.

Sachin, N. Baxi, Jay M. Portnoy, Desiree, Wanda. (2016). Exposure and health effects of fungi on humans. *The Journal of Allergy and Clinical Immunology Practice*, 4(3): 396-404.

Scott, E., Bloomfield, S. F. and Barlow, C. G. (2008). An investigation of microbial contamination in the home. *Journal of Hygiene*, 85(1): 61-68.

Selim, H. S. and Abaza, A. F. (2015). Microbial contamination of mobile phones in a health care setting in Alexandria, Egypt. *GMS Hygiene and Infection Control*; 10: 1-9.

Sikora, A and Zahra, F. (2022). Nosocomial infections. In: StatPearl (internet).

Treasure Island (FL): StatPearls Publishing. 1-10.

Sushella, D.B., Shailendra, D. and Krishna,P (2015). A study to investigate the importance of purses as formites. *Advanced Biomedical Research*, 4: 102.

Szeto, J., Sidhu, B. and Shaw, F. (2015). Increased organic contamination found on mobile phones after touching it while using the toilet. *BCIT Environmental Public Health Journal*.45-53.

Tagoe, D. N., Gyande, V. K. and Ansha, E. O. (2011). Bacterial contamination of mobile phones: when your mobile phone could transmit more than just a call. *Journal of Web-medical Central Microbiology*, 2(10): 2294.

Tambe, N. N and Pai, C. (2012). A Study of microbial flora and MRSA harboured by mobile phones of health care personnel. *International Journal of Recent Trends in Science and Technology*,. 4(1):14-18.

Trivedi, H.R., Desai, K. J., Trivedi, L. P., Malek,. S. S. and Javdekar, T. B. (2011). Role of mobile phone in spreading hospital acquired infection. A study in different group of health care workers. *National Journal of Integrated Research in Medicine*, 2(3): 61- 66.

Tusabe, F., Kesande, M., Amir, A., Iannone, O., Ayebare, R. R. and Nanyondo, J. (2022). Bacterial contamination of healthcare worker's mobile phones: a case study at two referral hospitals in Uganda. *Global Security: Health, Science and Policy*, 7(1): 1-6.

Ulger, F., Dilek, A., Esen, S., Sunbul, M. and Leblebicioglu, H. (2009). Are healthcare workers' mobile phones a potential source of nosocomial infections? *Journal of Occupational and Environmental Hygiene*, 6(11): 722-725.