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Isolation and Characterization of Bacterial Strains Contaminating the Metallic Keyboards of Automated Teller Machines (ATMs) of Commercial Banks in Akure Metropolis

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Abstract

Background. Automated Teller Machine (ATM) contamination occurs indiscriminately in cities. ATMs have become a medium for transmitting infectious diseases; hence, this study was carried out to examine the level of bacterial contamination on ATM keyboards. **Methods**. Samples were collected from the metallic keyboards of ATMs at nine different commercial banks using moistened commercial sterile swab sticks and sterilized peptone water. After collection, samples were plated on different agar forms using the pour-plating method and incubated at 37°C for 24 hours. The bacterial isolates were culturally identified and molecularly characterized using 16s rRNA Polymerase Chain Reaction (PCR), DNA gene extraction, and sequence blasting. **Results**. The bacterial isolates identified include *Escherichia coli, Pseudomonas aeruginosa, Shigella dysenteriae, Salmonella typhi,* and *Staphylococcus aureus*, among others. 16s rRNA sequencing confirmed the presence of *Escherichia coli* strain NBRC 102203, *Pseudomonas aeruginosa* DSM 50071, *Salmonella typhi* SKST, *Shigella dysenteriae* ATCC 13313, and *Staphylococcus aureus* S33R. **Conclusion**. ATM keyboards are contaminated with various bacterial genera, with Staphylococcus aureus being the most prominent bacterium found. Therefore, adequate measures to ensure safety when using ATMs are necessary.

Key word: antibiotics, contamination, culture, infections, inhibition.

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Introduction

Information and Communication Technology (ICT) is a significant driver of improved quality of life, economic growth, and development in countries worldwide. It is indisputable that ICT has the potential to continue driving growth for the foreseeable future. Anwana (1) believes that electronic banking (e-banking) is an offshoot of ICT, providing both classic and modern banking means. E-banking systems have evolved technologies such as automated teller machines (ATMs), point of sales terminals (POS), electronic funds transfer, and telebanking. Among these technologies, ATMs have the most significant impact on the common person (2).

ATMs, also known as cash point machines, cash machines, or cavities in a wall, are computer-supported telecommunication equipment that helps clients of financial institutions perform banking transactions from almost anywhere in the world where an ATM is present (3). People who perform bank transactions (bank workers and customers) significantly influence the introduction of microorganisms onto ATM keypads due to their unhygienic habits, such as sneezing, coughing, and inadequate hand sanitation before and after using the machine (4). These devices have become a medium for transmitting infectious diseases; once the keyboard is contaminated, the user may pick up these microbes after utilizing the ATM (4).

Moreover, ATMs in banks have no restrictions on who can use them and no guidelines for sanitary usage. When there is a lack of adequate cleaning practices, ATMs become exposed to microbial colonization and attack, leading to user infection (5). ATMs are located in city centers, trade environments, campuses, and health facilities where customers can easily access them (6). Contamination of environmental inanimate objects and surfaces, such as ATMs, is normal because microorganisms are ubiquitous in the environment (7).

Various studies of human environments have indicated contamination and colonization of inanimate objects like door handles, phones, money, fabrics, plastics, and other fomites by microorganisms responsible for

spreading different infections (7). For instance, inanimate objects frequently in regular contact with hands include phones, money, and ATM keypads (8). Microorganisms that contaminate fomites have been shown to persist on surfaces for extended periods and can be detected and recovered from those surfaces even after regular sterilization (9). Human hands play a crucial role in the transmission and cross-contamination of microorganisms between environmental surfaces (7, 10).

Microbial contamination of environmental objects and surfaces is a common phenomenon and a source of severe public health concern due to these objects' ability to harbor pathogenic microorganisms (11). The extensive use of electronic devices such as ATMs is not excluded as a source of bacterial contamination (12). Since microorganisms are ubiquitous, their presence on ATM keypads is inevitable and has been reported by various researchers (11, 13, 14). The tendency for these microorganisms to be picked up by humans and cause infection through oral, nasal, or eye contact with contaminated fingers is very high (14, 15). This tendency increases with the growing human population and the progressive digitization of banking systems, abandoning the traditional system (i.e., using tellers and chequebooks), which is time-consuming and exhausting for customers, making ATMs widely used across Nigeria (14, 16).

Bacteria can be transmitted using the ATM's keyboard to perform bank transactions such as cash withdrawals, checking account balances, and recharging mobile phone accounts. When the ATM card is inserted into the machine, it guides the customer to enter their security number by pressing the keyboard, potentially contaminating the user's hand with bacteria on the keypad. Given the general acceptance and extensive usage of ATMs in Nigeria, electronic technologies are considered sources of bacterial contamination due to their widespread use (17, 18).

A serious concern is that the number of bacterial strains acquiring resistance against antibiotics is increasing faster than expected. This resistance arises due to the intermittent threat to human life and the need to control the development of pathogenic microorganisms, particularly bacteria, fungi, and viruses, on non-living surfaces, which remains a fundamental global interest (19). Therefore, this research aims to carry out the molecular characterization and antibiotic susceptibility patterns of bacteria isolated from the metallic keyboards of ATMs from selected banks in Akure metropolis, Ondo State, Nigeria.

Methods

Study Location

A total of nine different commercial bank ATM metallic keyboards were used for this study. Four bank locations were considered, involving three banks on the Federal University of Technology, Akure (FUTA) campus and six banks from outside the FUTA campus, including the Oyemekun area, Oja Oba area, and Alagbaka area, all within the Akure metropolis, Ondo State, Nigeria. The banks used for this study included United Bank for Africa (UBA), Guaranty Trust Bank (GTB), and Wema Bank (FUTA branch); First Bank, Providus Bank, and GTB (Alagbaka branch); Access Bank and Sterling Bank (Oyemekun branch); and Polaris Bank (Oja Oba branch).

Samples Collection

Samples were collected using a moistened commercial sterile swab stick and sterilized peptone water, prepared according to the manufacturer's specifications. At each sampling point, the sterile swab stick was carefully used to swab the metallic keyboard of each machine. After swabbing, the sterilized McCartney bottle was opened aseptically, and the swab stick was dipped into the peptone water and gently shaken to ensure that microorganisms were dispensed into the peptone water. The peptone water was then transported to the Microbiology Laboratory of the Federal University of Technology, Akure, for bacteriological analysis.

Isolation and Identification of Bacteria

All media used in this study were prepared according to the manufacturer's instructions. The method described by Onifade and Omololu (20) was used to isolate bacteria from ready-to-eat food samples. Inoculum was standardized using the 0.5 McFarland standard, as described by Isunu *et al.* (21). Bacterial isolates were identified using cultural and molecular techniques described by Olutiola *et al.* (22) and Adeboboye *et al.* (23), respectively. All colonies were counted and expressed in colony-forming units per milliliter (cfu/ml) of the sample, and the colony-forming units were determined using the formula: [No of colonies / Volume used] × dilution factor.

Molecular characterisation

Molecular characterization was carried out following the procedure described by the manufacturer (Bioneer AccuPrep Genomic DNA Extraction Kit) for bacterial characterization involving DNA extraction, specific Polymerase Chain Reaction (PCR), and DNA amplification. Using specific primers' sequences for 16s rRNA, electrophoresis and DNA sequencing were carried out according to the manufacturer's instructions for the PCR kit (Bioneer Accupower Hotstart PCR premix). DNA bands were detected and visualized using a UV lightbox or gel imaging system (Biorad). The length of amplified products was 1500 base pairs. The sequence obtained was blasted in the National Center for Biotechnology Information (NCBI) database.

Antibiotic Susceptibility Test

The antibiotic susceptibility test was carried out following a modified Kirby-Bauer method, as described by Willey *et al.* (24). The test involved subjecting the isolated pathogenic bacteria to ten diffusion discs with antibacterial drugs to determine their antibiotic susceptibility pattern (24). The results (Table 3) were presented as resistant or sensitive, according to the National Committee for Clinical Laboratory Standards (25).

Ethical Aspects

This research was submitted to an ethical committee and authorized by the School of Sciences Research Ethics Committee (SOS-REC) of the Federal University of Technology, Akure. Consent was also obtained from the bank's management before swabbing the ATM keyboards.

Statistical Analysis

Descriptive analysis was performed using graphs and tables. Data were analyzed using GraphPad Prism 9.0 statistical software, with a level of significance set at $p<0.05$.

Results

Figure 1 illustrates the number of samples examined and the average bacteria counts obtained from metallic keyboards of ATMs at selected commercial banks in the Akure metropolis.

Type of Bacterial Isolates

Conventional microbiological methods, including Gram staining and biochemical reactions, were employed to identify all isolated bacteria. The identified isolates include *Staphylococcus epidermidis, Staphylococcus aureus, Bacillus psychrophilus, Bacillus subtilis, Streptococcus pyogenes, Bacillus coagulans, Enterococcus faecium, Pseudomonas aeruginosa, Shigella dysenteriae, Escherichia coli,* and *Salmonella typhi.*

Table 1 presents morphological and biochemical characteristics of bacterial isolates obtained from metallic keyboards of ATMs located in commercial banks within the Federal University of Technology, Akure (FUTA), and the Akure metropolis. Table 2 presents the molecular identities of bacterial isolates obtained from metallic keyboards of ATMs located in commercial banks within the FUTA, and the Akure metropolis. Based on 16s rRNA sequencing, the following bacteria were confirmed using NCBI database accession numbers: Shigella dysenteriae ATCC 13313, Staphylococcus aureus S33R, Escherichia coli strain NBRC 102203, Pseudomonas aeruginosa DSM 50071, and Salmonella typhi SKST (Figure 2).

Figure 1

Number of examined samples and Average bacterial counts of samples collected from ATMs keyboards

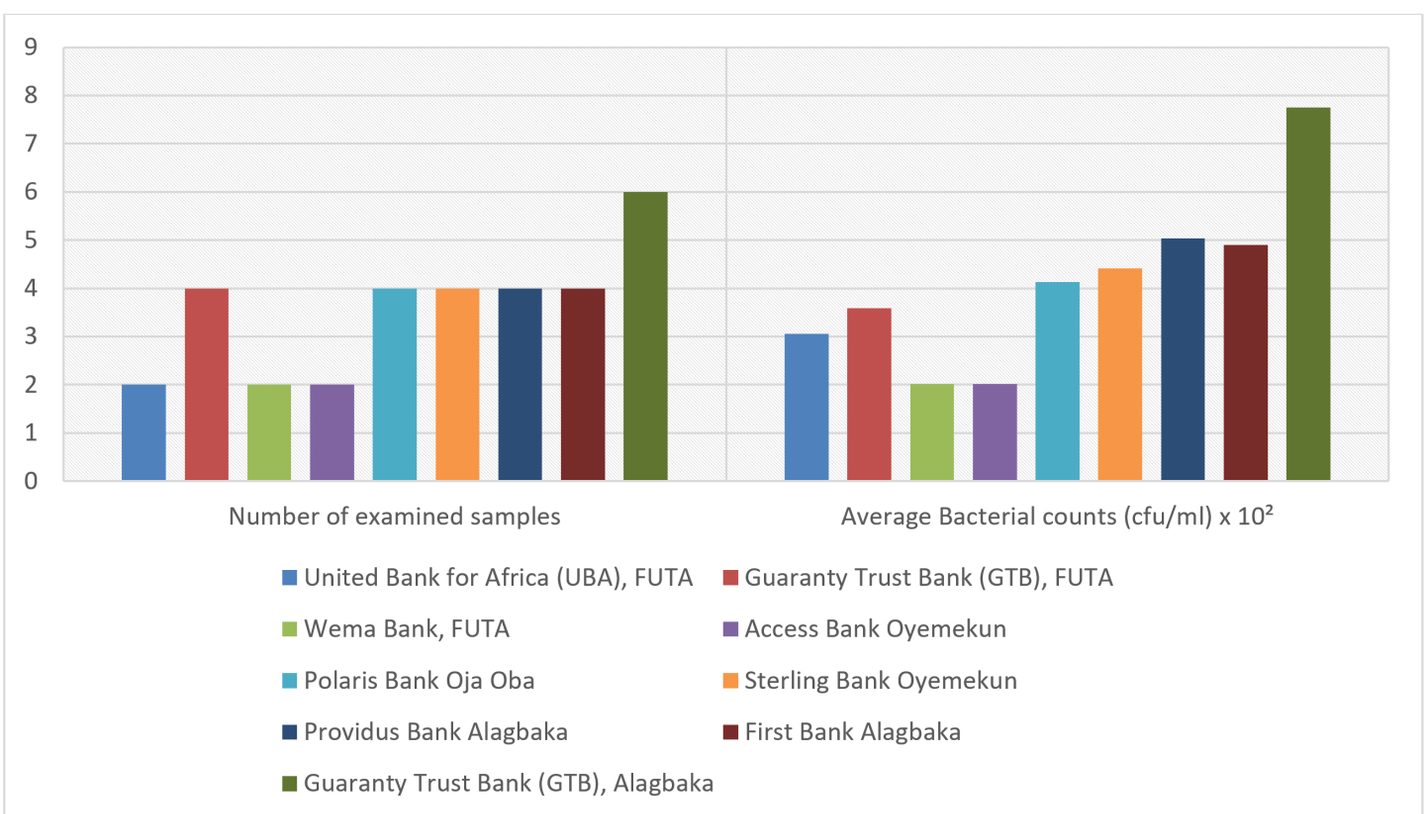


Table 1

Morphological and biochemical characteristics of bacterial isolates

S/N	Suspected Organism	Gram Stain	Cell Shape	Glucose	Sucrose	Lactose	H_2S	Gas	Oxidase	Coagulase	Catalase	Citrate	Motility	Indole	Urease	MR	VP
1	*Staphylococcus epidermidis*	+	Cocci	+	+	+	+	+	-	-	+	-	-	-	+	-	+
2	*Bacillus psychrophilus*	+	Rod	-	-	-	+	-	-	-	+	-	-	-	+	+	-
3	*Bacillus subtilis*	+	Rod	+	-	-	+	-	-	-	+	+	+	-	-	+	-
4	*Pseudomonas aeruginosa*	-	Rod	-	-	-	-	-	-	-	+	+	+	-	-	-	-
5	*Bacillus coagulans*	+	Rod	+		-	+	-	+	+	+	-	-	+	-	-	+
6	*Enterococcus faecium*	+	Cocci	+		-	-	-	-	+	-	+	-	+	+	-	-
7	*Streptococcus* pyogene	+	Cocci	+	+	+	-	-	-	+	-	-	-	-	-	+	-
8	*Escherichia coli*	-	Rod	+	+	+	-	+	-	-	+	-	+	+	-	+	-
9	*Salmonella typhi*	-	Rod	+	-	-	+	-	-	-	+	-	+	-	-	+	-
10	*Shigella dysenteriae*	-	Rod	+	-	-	-	-	-	-	+	-	-	-	-	+	-
11	*Staphylococcus aureus*	+	cocci	+	+	+	-	-	+	+	+	+	-	-	+	+	+

+ = Present; - = Not Present

Table 2

Molecular Identification of Bacterial Isolates

S/N	Conventional Identities	16s rRNA sequence identification	Max Identity	Accession number
1	*Shigella dysenteriae*	*Shigella dysenteriae* ATCC 13313	95%	NR 026332.1
2	*Salmonella typhi*	*Salmonella typhi* SKST	100%	FJ 009676.1
3	*Staphylococcus aureus*	*Staphylococcus aureus* S33R	99%	NR 037007.2
4	*Escherichia coli*	*Escherichia coli* str. NBRC 102203	94.89%	NR 114042.1
5	*Pseudomonas aeruginosa*	*Pseudomonas aeruginosa* DSM 50071	92%	NC010554.1

Table 3 shows the summary of antibiotic susceptibility pattern of bacterial isolates against antibiotics while the zone of inhibition of antibiotics for both Gram-negative and Gram-positive bacterial isolates were shown in Supplementary Table 1 and Supplementary Table 2 respectively.

Table 3

Summary of Antibiotic Susceptibility Pattern of Bacterial Isolates

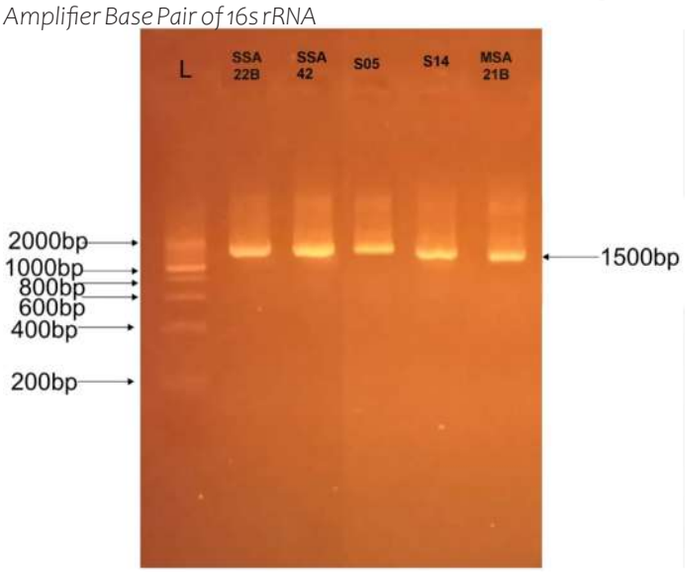
Bacterial Isolates	CPX	S	AM	APX	R	GN	SXT	E	PEF	SP	AU	CH
S. aureus	+	+	+	+	+	×	×	×	×	-	-	-
B. subtilis	+	+	×	×	×	+	×	×	×	-	-	-
B. coagulan	+	×	×	+	×	+	×	×	×	-	-	-
B. psychrophilus	+	+	+	+	×	+	×	×	×	-	-	-
E. faecium	+	+	×	×	+	+	×	×	+	-	-	-
S. pyogene	+	×	×	+	+	+	×	+	×	-	-	-
P. aeruginosa	+	+	×	+	+	+	×	+	+	-	-	-
S. dysenteriae	+	+	×	-	-	×	×	-	+	+	×	×
E. coli	+	+	×	-	-	+	×	-	+	+	×	×
S. typhi	+	+	×	-	-	×	×	-	+	+	×	×

+: Sensitive; ×: Resistant; -: Not tested

CPX= Ciprofloxacin, S = Streptomycin, AM=Amoxicillin, APX= Ampiclox, R= Rocephin, GN= Gentamycin, SXT= Septrin, E= Erythromycin, PEF = Pefloxacin, SP= Sparfloxacin, AU= Augmentin, CH = Chloramphenicol.

Figure 2

Gel Electrophoresis Plate of the Bacterial Isolates Using 1500 Amplifier Base Pair of 16s rRNA



L = Molecular weight marker
SSA 22B = *Pseudomonas aeruginosa* DSM 50071
SSA 42 = *Shigella dysenteriae* ATCC 13313
SO5 = *Salmonella typhi* SKST
S14 = *Escherichia coli* str. NBRC 102203
MSA 21B = *Staphylococcus aureus* S33R

Discussion

Studies have consistently identified electronic technologies, such as bank ATMs, as potential sources of bacterial contamination due to their widespread public usage (17, 18, 26). This research focused on the molecular characterization and antibiotic susceptibility patterns of bacteria isolated from the metallic keyboards of ATMs in selected banks across the Akure metropolis.

The study found a higher occurrence of Gram-positive bacteria (63.64%) compared to Gram-negative bacteria (36.36%). This elevated bacterial presence may be attributed to the frequent use of ATM keyboards by a diverse range of users.

Our findings revealed significant levels of bacterial contamination on the electronic hardware interfaces, specifically the ATM keyboards, examined within the Federal University of Technology Akure (FUTA) and surrounding areas. The structural design and extensive surface area of ATMs likely contribute to their heightened susceptibility to contamination, exacerbated by their exposure to environmental elements such as wind and rain (27). Earlier studies, including pioneering work by Oluduro *et al.* (26), have laid the groundwork for understanding bacterial contamination associated with ATMs.

The bacteria isolated and identified from the ATM keyboards of commercial banks in our study include Staphylococcus aureus, *Staphylococcus epidermidis, Bacillus psychrophilus, Bacillus subtilis, Bacillus coagulans, Enterococcus faecium, Streptococcus pyogenes, Escherichia coli, Salmonella typhi, Shigella dysenteriae*, and *Pseudomonas aeruginosa*. These findings are consistent with those reported by Nworie et al. (27). Some of these bacteria, particularly those from the Enterobacteriaceae family, have the potential to cause hand-to-mouth infections if proper hand hygiene practices are not observed after ATM use. Additionally, there is a risk of nosocomial infections if medical personnel fail to sanitize their hands adequately after using ATMs in hospital settings, where they may inadvertently transmit pathogens (28).

Given that users frequently touch ATM interfaces and may inadvertently introduce pathogens like S. aureus during use, coupled with the potential airborne transmission through handshakes (27), the study underscores the importance of stringent hygiene practices. Despite recording lower bacterial counts on some ATM keyboards, the presence of *E. coli, S. typhi*, and *S. dysenteriae* indicates a significant risk of infection if users do not adhere to proper handwashing practices.

The bacterial load on a surface also influences the survival of microorganisms; higher concentrations increase their longevity, thereby enhancing the likelihood of transmission (9, 29). Moreover, studies have shown that microorganisms can persist longer on plastic surfaces, prevalent in ATM interfaces, compared to other materials like fabric or steel (30). This resilience suggests that plastic interfaces could serve as reservoirs for microbial transfer. Rutala and Weber (31) similarly observed bacterial colonization on keyboards within a university healthcare system, highlighting the potential for user hands to serve as major vectors of contamination due to their frequent contact with various surfaces, substances, and body fluids.

Bacterial contamination has also been linked to currency notes, further emphasizing the hygiene challenges associated with financial transactions (32-35). Despite variations in bacterial counts, the types and quality of microorganisms present on surfaces play a crucial role in determining infection risks. Our study confirms the presence of both Gram-positive and Gram-negative bacteria on the examined ATM interfaces.

A total of eleven bacterial species were recovered from ATM keyboard interfaces in this study, including skin commensal (*Staphylococcus aureus*), environmental bacterium (*Pseudomonas aeruginosa*), and enteric bacteria (*Salmonella typhi and Shigella dysenteriae*). This finding is consistent with studies by Barbosa *et al.* (36) and Aquino *et al.* (37), which also reported a similar range of bacteria associated with multidrug resistance. The health risks associated with most of these bacteria are well documented (38). The enteric bacteria identified in this study are opportunistic human pathogens known to cause nosocomial infections (39,40). The bacterial contaminants cultured from electronic hardware user interfaces mirror those recovered from both hospital and non-hospital surfaces and objects. Similar findings have been reported with mobile phones, environmental devices (41, 42), currency notes (43), day care centers (44), stethoscope covers (45), and computer keyboard and mouse interfaces (46-48).

Staphylococcus aureus was found to be the most

prevalent bacterial contaminant on ATMs, consistent with the findings of Anderson and Palombo (46), who reported *S. aureus as* the most common isolate contaminating keyboards in a university setting. Staphylococcus aureus is a major component of the skin and nasal flora, likely explaining its high prevalence as a contaminant. Its widespread dissemination can be attributed to human activities such as sneezing, talking, and contact with moist skin (49, 50). Additionally, S. aureus has been implicated in various infectious diseases and nosocomial infections (51).

Pseudomonas aeruginosa, Bacillus spp., and *Staphylococcus epidermidis* were also prominent contaminants. The prevalence of these organisms on electronic hardware user interfaces is concerning due to their potential to cause infections, particularly in hospital settings (39). Previous studies have similarly highlighted these organisms as significant contaminants or as the most prevalent pathogenic bacteria isolated (48, 52). On the other hand, *Enterococcus faecium, Streptococcus pyogenes, Brevibacillus brevis*, and *Bacillus psychrophilus* were less frequently isolated bacterial contaminants. However, both *Brevibacillus brevis* and *Bacillus psychrophilus* have been identified on environmental objects. This study recorded a high rate of bacterial contamination across all sampled interfaces, consistent with reported culture rates exceeding 70% in previous studies (47, 48, 52). Such high levels of contamination underscore the significant risk posed by interfaces exposed to environmental and human interactions (53, 54).

Various bacterial species were found to coexist on interfaces and on the hands of users. Interfaces harbor a diverse bacterial community with varying virulence and pathogenicity, thereby increasing the risk and severity of infections (55). This issue may be exacerbated by users' unhygienic practices, as hands frequently touch various surfaces and objects, potentially transferring bacteria from different fomites (32, 56, 57). Although ATMs exhibited the highest bacterial load (26, 58), the number of bacterial species detected was relatively low, likely due to users spending minimal time at the ATM. Variations in contamination levels among different occupational groups and organizations may reflect differences in hygiene practices (48), with poorer hygiene linked to higher bacterial contamination.

Furthermore, ATMs located near busy roads, such as First Bank in Alagbaka, Polaris Bank, Providus Bank, and Sterling Bank, also exhibited significant bacterial loads due to vehicle-generated dust, smoke, and airborne particles that increase microbial presence in the air (7).

Antibiotic susceptibility testing against Gram-positive isolates (Appendix 1 and Table 3) indicated that *Staphylococcus aureus* was susceptible to all Gram-positive antibiotics except gentamicin, septrin, erythromycin, and pefloxacin. *Bacillus subtilis* was susceptible to ciprofloxacin (26 mm), streptomycin (20 mm), and gentamicin (26 mm) but resistant to other antibiotics. *Bacillus coagulans* showed susceptibility to ciprofloxacin (24 mm), ampiclox (21 mm), and gentamicin (23 mm), with resistance noted against other antibiotics. *Bacillus psychrophilus* exhibited susceptibility to all Gram-positive antibiotics except septrin, erythromycin, pefloxacin, and rocephin. *Enterococcus faecium* was susceptible to all Gram-positive antibiotics except septrin, erythromycin, and amoxicillin. Similarly, *Streptococcus pyogenes* showed susceptibility to all Gram-positive antibiotics except septrin, amoxicillin, pefloxacin, and streptomycin, indicating favorable antibiotic sensitivity against the isolated organisms, consistent with the findings of Nwankwo and Offiah (4).

Similarly, antibiotic susceptibility testing against Gram-negative bacterial isolates (Appendix 2 and Table 3) revealed that *Shigella dysenteriae* was susceptible to ciprofloxacin (28 mm), sparfloxacin (24 mm), streptomycin (20 mm), and pefloxacin (24 mm), while other antibiotics (amoxicillin, augmentin, septrin, gentamicin, and chloramphenicol) showed resistance. *Escherichia coli* exhibited susceptibility to all Gram-negative antibiotics except amoxicillin, augmentin, septrin, and chloramphenicol. *Salmonella typhi* was susceptible to all Gram-negative antibiotics except amoxicillin, augmentin, gentamicin, septrin, and chloramphenicol. *Pseudomonas aeruginosa* demonstrated susceptibility to all Gram-negative antibiotics except amoxicillin (14 mm) and septrin (13 mm), consistent with the findings reported by Nworie *et al.* (27). Resistance against amoxicillin, erythromycin, augmentin, septrin, and chloramphenicol was also observed in the tested Gram-negative bacterial isolates in this study.

Conclusion

ATM keyboards, particularly contaminated with *Staphylococcus aureus* and other pathogens, pose a significant risk of bacterial transmission to users. Combining technological advancements with stringent hygiene practices is essential to mitigate this risk. Authorities must enforce regular cleaning protocols and promote public awareness about the importance of hand hygiene before and after ATM use. These measures are crucial for minimizing infections spread through ATMs and ensuring the safety of users.

Author Contribution Statement

Williams Adesina: Conceptualization, Data curation and Methodology. **Oluwagbenga John Ogunbiyi**: Formal analysis, Writing-Reviewing and Editing. **Adewale Ibrahim Wahab**: Writing- Original draft preparation. **Muftau Kolawole Oladunmoye**: Visualization. **Alake Aishat Omorinola**: Validation.

Ethics statement

The authors declare that the present study was conducted under the strictest ethical conditions. This research received approval from the School of Sciences Research Ethics Committee (SOS-REC) of Federal University of Technology, Akure. Consent was also obtained from the

bank's management before swabbing of the ATM keyboard.

Conflict of interest

The authors have declared no conflict of interest.

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Availability of data

The datasets generated and /or analyzed during current study available from the corresponding author on reasonable request.

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