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# OCCURRENCE OF MULTIDRUG-RESISTANT BACTERIA ON A HIGH-TOUCH INANIMATE SURFACE (DOOR-HANDLE) IN HOSPITAL AND COMMUNITY SETTINGS AT OKADA, EDO STATE, NIGERIA

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**ABSTRACT:** *Door handles in high-contact areas pose significant risk for bacterial transmission, as highlighted by a cross-sectional study at hospital and community settings in Okada from May to July 2025. This study assessed bacterial contamination on door handles through standard phenotypic tests and 16S rRNA gene sequencing, complemented by antibiotic susceptibility testing using the Kirby-Bauer disc diffusion method. In hospital toilet facilities, the most common bacteria included Enterococcus faecalis (22%) and Acinetobacter baumannii (22%), with Escherichia coli (20%) being notable as well. Klebsiella aerogenes and Klebsiella pneumoniae appeared least frequently at 6%. In hospital laboratory, E. faecalis (35.3%) and Staphylococcus aureus (32.35%) dominated. Patient wards showed E. faecalis and S. aureus at 23.33%, while administrative offices had Bacillus cereus (38.89%). University hostel toilets had E. faecalis (32.75%) and S. aureus (22.41%), whereas external door handles mostly showed S. aureus at 50%. The Mann-Whitney U test indicated no significant difference in median bacterial prevalence between hospital and community door handles ($p > 0.05$). Contamination was highest in hospital toilets (83.33%), administrative offices (60%), and laboratory (56.67%), as well as university hostel toilets (96.67%). The Student's t-test indicated community door handles had significantly higher contamination than hospital handles ($p < 0.05$). Resistance to beta-lactams was widespread, with some bacteria exhibiting complete resistance (100%), while fluoroquinolone and aminoglycoside sensitivity were recorded in most isolates. The highest rates of multidrug-resistant bacteria were found on toilet door handles (30.00%), particularly in E. coli and K. aerogenes. This study recommends the implementation of antimicrobial coatings and better hygiene practices to mitigate public health risks.*

**KEYWORDS:** Bacterial contamination, High touch inanimate surface, *Enterococcus faecalis*, *Acinetobacter baumannii*, Multidrug resistance.



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## INTRODUCTION

The potential for infectious diseases to spread via microbial contaminants on high-touch surfaces, such as door handles, represents a major challenge to public health, especially considering the many outbreaks linked to fomites worldwide [1, 2]. Historically, the term 'fomite,' originally derived from the word 'fomes,' denoted objects capable of transmitting disease, capable of expressing pathogens from infected individuals, and assisting the indirect spread of infections over long distances [3]. This concept has existed since the 1500s. At present, a fomite is understood as any non-living object that can harbor infectious agents and contribute to their transfer to a new host once contaminated [3]. As the majority of individuals are indoors 90% of the time, the constructed environment and items that people frequently touch, like doorknobs, are often the primary sources of contamination and spread [4]. In hospital and community settings, door handles are especially prone to microbial contamination due to frequent use and the different microorganisms brought by users [5]. This situation presents a considerable obstacle in infection control, especially in hospitals where healthcare-associated infections threaten both patients and staff, comprising about 7% of total infections in developed countries and roughly 10% in developing nations [2]. Infections acquired in hospitals may result from bacteria, viruses, or fungi; however, bacteria account for approximately 90% of cases. Among the most prevalent bacterial pathogens are Gram-negative bacilli and Gram-positive cocci. The emergence of multidrug-resistant bacteria complicates treatment efforts further, making containment more challenging [6, 7]. Multidrug-resistant bacteria are defined as organisms resistant to multiple antibiotic classes, with the capacity to withstand at least one drug from three or more different antimicrobial categories [8]. The speed at which fomites get contaminated depends on a variety of factors, including humidity levels, the frequency of contact, the pathogen's ability to produce biofilms, and the overall hygiene of the environment [1, 9]. This understanding is especially critical in hospital settings, where standard cleaning protocols may not be enough, and pathogens such as *Clostridium difficile*, *Acinetobacter baumannii*, and vancomycin-resistant enterococci (VREs) present serious health threats to susceptible populations. In hospital settings, door handles—particularly in restrooms and shared spaces—are widely recognized as primary sources for microbial transmission, assisting the spread of organisms like *Staphylococcus aureus* and *Escherichia coli* [10]. These surfaces function as reservoirs for pathogens that could be transferred by people carrying microbial flora from different places or through contact with other contaminated surfaces. The contamination of door handles plays an important role in the ongoing transmission of hospital-acquired infections, which remains a global health challenge. Besides, fomites are acknowledged as a route for community-acquired infections [10, 11]. Public areas like schools, workplaces, eateries, and transit stations encounter high levels of foot traffic, raising the chances of microbial contamination on door handles and other commonly touched surfaces [12]. Research has indicated that bacteria can survive on surfaces for different durations, heightening the risk of spread [13]. Even with a better understanding of how fomites contribute to disease spread, the microbial communities present on door handles are not yet fully understood across different settings. This study aims to investigate the occurrence of multidrug-resistant bacterial contamination on door handles in both hospital and community settings at Okada, Edo State, Nigeria.


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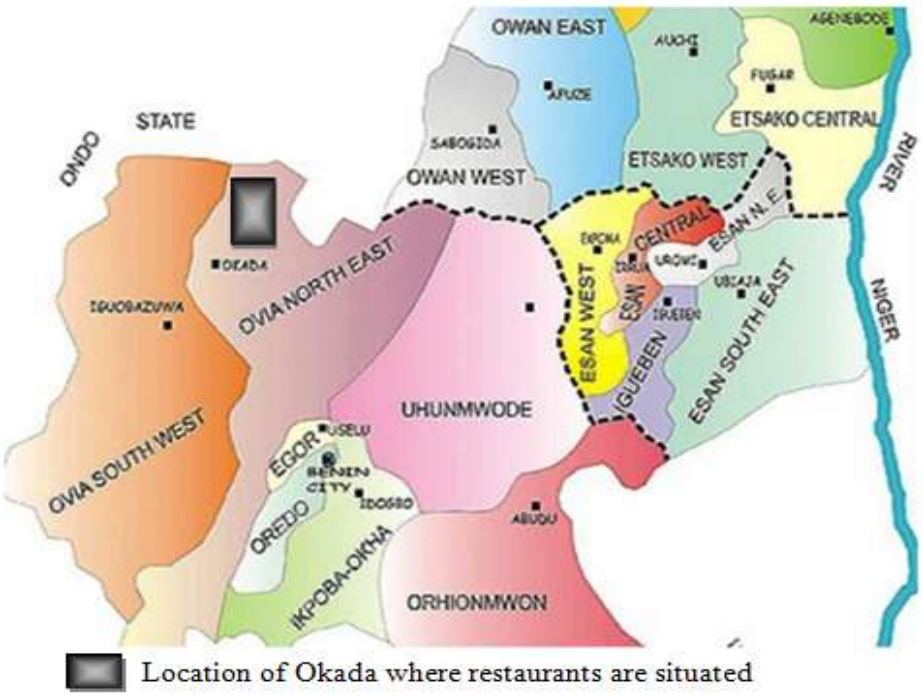
## MATERIALS AND METHODS

### Study area

Okada is the study area. It is the capital of Ovia North East Local Government in Edo State, Nigeria. It borders Okhai and Iguobazua to the southwest of Usen. It borders Iguomo to the north. It borders Ofunwegbe and Ekiadolor to the east (Figure 1). Okada is located between latitudes 4.5°N and 5°N. It is located between longitudes 5.5°E and 6°E. Okada gets about 2,300 millimeters of rain each year. It also has a lot of sunshine. The land is good for farming. The soil is very fertile. Okada is an important place. It has Nigeria's first private university, Igbinedion University, Okada. The area can grow into a city if conditions improve.

**Figure 1: Map of Edo State showing Okada, the study area**




### Study design and sample collection

The study was a descriptive cross-sectional study design. It was a period prevalence survey of door handles at the Igbinedion University Teaching Hospital, Okada, and in the Okada community environs from May to July 2025. At the hospital, samples were collected from door handles in the toilet facilities, laboratories, patient wards, and administrative offices. In the Okada community, samples were collected from door handles in toilet facilities at the Igbinedion University campus, and in toilet facilities at homes in Okada Town and Igbinedion University Hostels. Samples were also collected from door handles of laboratories and administrative offices of the Igbinedion University campus. Samples were collected from door handles in the external entrance/exit of homes at the Igbinedion University Hostels and Okada town. After six visitations of each of the sampling locations, a total of 330 samples, consisting of 120 samples from the hospital settings and 210 samples from the community settings, were collected aseptically using a sterile swab stick moistened in 2 ml 0.1% peptone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water. Each sample was collected by carefully swabbing the entire surface of the door handles. After sample collection, the swab sticks were transported to the laboratory, using a cold chain to circumvent the overgrowth of organisms, for analysis within six hours of sample collection.

**Bacterial enrichment of swabbed samples**

The contents of each swab stick were transferred into 3 ml of tryptic soy broth. The broth was then incubated at 37 °C for 16 to 18 hours.

**Bacterial isolation**

The bacteria in the enriched broth were isolated using the streak plate method [14]. A loop was used to inoculate samples on Tryptic Soy agar and MacConkey agar plates. The plates were cultured at 37°C for about 24 hours. The isolated bacteria were transferred to new agar plates to obtain pure cultures, which were stored in Nutrient agar slants at 4°C for later use.

**Phenotypic tests**

The bacterial isolates were identified using standard morphological and biochemical tests at the genus level. These tests included Gram staining, coagulase test, catalase test, oxidase test, indole test, citrate test, methyl red test, Voges–Proskauer test, and triple sugar iron agar test [15].

**Molecular characterization**

Standard molecular methods were used to identify the bacterial isolates at the species level [16, 17]. Pure DNA was extracted from the bacterial isolates using a Zymo-Spin column. The DNA was used as a template for a PCR test. The PCR used universal bacterial primers to spot the 16S rRNA gene, specifically 27F and 1492R primers. A fifty (50) µl reaction mixture was set up. It included 2 µL of DNA and all necessary reagents. The PCR was run on a GeneAmp machine with optimized settings. The PCR products were run on a 2% agarose gel. They were visualized and photographed. A DNA marker was included to estimate fragment size. After PCR, the products were purified for sequencing using the Sanger method [18]. Before sequencing, the amplicons were purified with Big Dye Terminator v3.1 (Applied Biosystems) and were analyzed on an ABI 3730×I DNA analyzer. The sequences were checked for accuracy with Sequencher software (Gene Codes v4.10.1). To identify the bacterial species, the detected sequences originating from these species were compared to a database. The BLASTN program was used to match the detected sequences with known 16S rRNA sequences in the National Center for Biotechnology (NCBI) GenBank database. Final confirmation was based on sequence similarity with reference data. The identified sequences were submitted to NCBI GenBank with accession numbers provided for future reference.

**Antibiotic sensitivity testing of the bacterial isolates**

The bacterial colonies were tested using the Kirby-Bauer disc diffusion method. This method follows the guidelines of the Clinical and Laboratory Standards Institute [19, 20]. The sensitivity of the bacterial isolates to common antibacterial drugs was tested. The drugs tested included ampicillin (10 µg), ampiclox (30 µg), cefuroxime (30 µg), ceftriaxone (30 µg), cefoxitin (30 µg), pefloxacin (5 µg), ciprofloxacin (5 µg), levofloxacin (5 µg), gentamicin (10


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µg), azithromycin (15 µg), and erythromycin (15 µg). Bacterial suspensions were prepared from each isolate and matched to 0.5 McFarland standards, which represent about $10^8$ colony-forming units. These suspensions were inoculated onto Mueller–Hinton agar plates. Discs with antibiotics were placed on the agar surface. The plates were incubated at 35°C for 16 to 18 hours. After incubation, the diameter of the zone of inhibition was measured around each disc. The zones were classified as sensitive, intermediate, or resistant. Classification was based on standard values provided by the CLSI. An isolate was considered multidrug-resistant if it was resistant to antibiotics from at least three different antibiotic classes.

**Estimation of multiple antibiotic resistance indices (MAR)**

The MAR method was used as described before [21]. It was used to estimate the risk of finding multidrug-resistant bacteria on door handles. MAR was calculated using the formula below (1). A MAR value higher than 0.20 showed a high risk of finding multidrug-resistant bacteria on the door handles.

$$\text{MAR} = \frac{\sum(\text{AS})}{\text{A} \times \text{n}} (1)$$

MAR stands for mean multiple antibiotic resistance index. AS is the resistance score of each bacterial isolate, which represents the number of antibiotic classes to which each bacterial isolate shows resistance. *A* is the total number of antibiotic classes tested. n is the total number of bacterial colonies examined.

**Statistical analysis**

The data was analyzed using Number Cruncher Statistical Software (NCSS) version 12. Frequencies for descriptive summary statistics were calculated. The Levene test of homogeneity, the Shapiro–Wilk test, the Student's t-test, and theMann-Whitney U parametric test were used to compare the groups. The results were considered statistically significant if the p-values were less than 0.05.

## RESULTS

**Bacterial occurrence on door handles**

Table 1 shows how often bacteria are found on door handles in the hospital and community in Okada. The door handles of toilets in the hospital showed that *E. faecalis* and *A. baumannii* bacteria were the most common. Each type accounted for 22% of bacteria found. *E. coli* was present in 20% of samples. The least common bacteria, each at 6%, were *K. aerogenes* and *K. pneumoniae*. *S. aureus*, *S. epidermidis*, and *B. cereus* each made up 8%. In the hospital laboratory, *E. faecalis* was the most frequent bacteria, making up 35.3%. *S. aureus* and *E. faecalis* both occurred at 32.35%. On the ward door handles, *E. faecalis* and *S. aureus* were most common, each at 23.33%. In administrative offices, *B. cereus* was the predominant bacteria at 38.89%. *S. aureus* was next at 25%. *P. aeruginosa* and *S. epidermidis* were the least common, both at 11.11%. *E. faecalis* was present at 13.89% in the offices.

In the university hostels, toilet door handles had *E. faecalis* as the most common, at 32.75%. *S. aureus* followed at 22.41%. *A. baumannii* and *S. epidermidis* were the least common, at


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10.35%. *E. coli* and *B. cereus* each accounted for 12.07%. The external entrance/exit door handles had *S. aureus* at 50%. Other bacteria there, including *S. epidermidis*, *M. luteus*, *E. faecalis*, and *B. cereus*, each made up 12.5%.

At the university campus, toilet door handles had *E. faecalis* and *A. baumannii* at 18.34%. *S. aureus* was at 11.67%. Laboratory door handles had *S. aureus* as the most frequent at 39.29%. *A. baumannii* occurred at 21.43%. The lowest bacteria on the laboratory door handles were *E. faecalis* and *S. epidermidis*, each at 19.64%. In the administrative offices, the most common bacteria found on the door handles were *S. aureus*, which made up 46.55% of all bacteria. The second most common was *E. faecalis*, which accounted for 18.97%. The bacteria found least often were *S. epidermidis*, *M. luteus*, *B. cereus*, and *K. pneumoniae*. Each of these was found at 8.62%.

In homes at Okada town, toilet door handles mostly had *S. aureus* at 29.63%. *B. cereus* was second at 16.67%. *S. epidermidis*, and *K. pneumoniae* each occurred at 11.11% with *A. baumannii* the least at 7.41%. External door handles in Okada town showed *S. aureus* at 39.58%. *B. cereus* followed at 16.67%. The lowest bacteria, each at 4.17%, were *S. epidermidis*, *M. luteus*, and *B. subtilis*. *P. aeruginosa* and *P. mirabilis* each were present at 10.41%.

Shapiro-Wilk's test showed that the bacterial data from hospital door handles were normally distributed ($p > 0.05$). The data from community door handles were not normally distributed ($p < 0.05$). Levene's test indicated that the data had equal variance ($p > 0.05$). The Mann-Whitney U test showed no significant difference ($p > 0.05$) between the median prevalence of bacteria on hospital door handles and community door handles.

Representative bacterial strains isolated from all door handles in the hospital and community have been deposited at the National Center for Biotechnology Information (NCBI) GenBank database, with accession numbers provided, as presented in Table 2.

**Table 1: Prevalence of bacterial species on the door handles**

| Bacteria isolated from door handles | Source of door handle | | | |
|---|---|---|---|---|
| | Hospital | | | |
| | Toilet, n =50<br>N (%) | Lab., n = 34<br>N (%) | Ward, n = 30<br>N (%) | Office, n = 36<br>N (%) |
| *Staphylococcus aureus* | 4 (8.00) | 11 (32.35) | 8 (26.67) | 9 (25.00) |
| *Staphylococcus epidermidis* | 4 (8.00) | 0 (0.00) | 0 (0.00) | 4 (11.11) |
| *Micrococcus luteus* | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| *Enterococcus faecalis* | 11 (22.00) | 12 (35.30) | 8 (26.67) | 5 (13.89) |
| *Bacillus cereus* | 4 (8.00) | 11 (32.35) | 7 (23.33) | 14 (38.89) |
| *Bacillus subtilis* | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| *Acinetobacter baumannii* | 11 (22.00) | 0 (0.00) | 7 (23.33) | 0 (0.00) |
| *Escherichia coli* | 10 (20.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| *Klebsiella aerogenes* | 3 (6.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| *Klebsiella pneumoniae* | 3 (6.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| *Pseudomonas aeruginosa* | 0 (0.00) | 0 (0.00) | 0 (0.00) | 4 (11.11) |
| *Proteus mirabilis* | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |


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| Bacteria isolated from door handles | Source of door handle | |
|---|---|---|
| | Community | |
| | University Hostel | |
| | Toilet, n = 58 | Entrance/exit, n = 56 |
| *Staphylococcus aureus* | 13 (22.41) | 28 (50.00) |
| *Staphylococcus epidermidis* | 6 (10.35) | 7 (12.50) |
| *Micrococcus luteus* | 0 (0.00) | 7 (12.50) |
| *Enterococcus faecalis* | 19 (32.75) | 7 (12.50) |
| *Bacillus cereus* | 7 (12.07) | 7 (12.50) |
| *Bacillus subtilis* | 0 (0.00) | 0 (0.00) |
| *Acinetobacter baumannii* | 6 (10.35) | 0 (0.00) |
| *Escherichia coli* | 7 (12.07) | 0 (0.00) |
| *Klebsiella aerogenes* | 0 (0.00) | 0 (0.00) |
| *Klebsiella pneumoniae* | 0 (0.00) | 0 (0.00) |
| *Pseudomonas aeruginosa* | 0 (0.00) | 0 (0.00) |
| *Proteus mirabilis* | 0 (0.00) | 0 (0.00) |

| Bacteria isolated from door handles | Source of door handle | | |
|---|---|---|---|
| | Community | | |
| | University Campus | | |
| | Toilet, n = 60 | Lab., n = 56 | Office, n = 58 |
| *Staphylococcus aureus* | 7 (11.67) | 22 (39.29) | 27 (46.55) |
| *Staphylococcus epidermidis* | 5 (8.33) | 11 (19.64) | 5 (8.62) |
| *Micrococcus luteus* | 0 (0.00) | 0 (0.00) | 5 (8.62) |
| *Enterococcus faecalis* | 11 (18.34) | 11 (19.64) | 11 (18.97) |
| *Bacillus cereus* | 5 (8.33) | 0 (0.00) | 5 (8.62) |
| *Bacillus subtilis* | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| *Acinetobacter baumannii* | 11 (18.34) | 12 (21.43) | 0 (0.00) |
| *Escherichia coli* | 6 (10.00) | 0 (0.00) | 0 (0.00) |
| *Klebsiella aerogenes* | 5 (8.33) | 0 (0.00) | 0 (0.00) |
| *Klebsiella pneumoniae* | 5 (8.33) | 0 (0.00) | 5 (8.62) |
| *Pseudomonas aeruginosa* | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| *Proteus mirabilis* | 5 (8.33) | 0 (0.00) | 0 (0.00) |

| Bacteria isolated from door handles | Source of door handle | |
|---|---|---|
| | Community | |
| | Okada Town | |
| | Toilet, n = 54 | Entrance/exit, n = 48 |
| *Staphylococcus aureus* | 16 (29.63) | 19 (39.58) |
| *Staphylococcus epidermidis* | 6 (11.11) | 2 (4.17) |
| *Micrococcus luteus* | 11 (20.37) | 2 (4.17) |
| *Enterococcus faecalis* | 0 (0.00) | 5 (10.42) |


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| | | |
|---|---|---|
| *Bacillus cereus* | 11 (20.37) | 8 (16.67) |
| *Bacillus subtilis* | 0 (0.00) | 2 (4.17) |
| *Acinetobacter baumannii* | 4 (7.41) | 0 (0.00) |
| *Escherichia coli* | 0 (0.00) | 0 (0.00) |
| *Klebsiella aerogenes* | 0 (0.00) | 0 (0.00) |
| *Klebsiella pneumoniae* | 6 (11.11) | 0 (0.00) |
| *Pseudomonas aeruginosa* | 0 (0.00) | 5 (10.41) |
| *Proteus mirabilis* | 0 (0.00) | 5 (10.41) |

n: number of bacterial isolates examined; N: number of bacterial species identified; %: percentage of identified species; Lab.: laboratory

**Table 2: NCBI accession numbers for bacterial organisms isolated from the door handles**

| Source of bacteria | Bacterial species | Strain | 16S rRNA gene accession number |
|---|---|---|---|
| Community | *Staphylococcus aureus* | IMID 101 | PX394066 |
| | *Staphylococcus epidermidis* | IMID 102 | PX394067 |
| | *Micrococcus luteus* | IMID 103 | PX394068 |
| | *Enterococcus faecalis* | IMID 104 | PX394069 |
| | *Bacillus cereus* | IMID 105 | PX394070 |
| | *Bacillus subtilis* | IMID 106 | PX394071 |
| | *Acinetobacter baumannii* | IMID 107 | PX394072 |
| | *Escherichia coli* | IMID 108 | PX394073 |
| | *Klebsiella aerogenes* | IMID 109 | PX394074 |
| | *Klebsiella pneumoniae* | IMID 110 | PX394075 |
| | *Pseudomonas aeruginosa* | IMID 111 | PX394076 |
| | *Proteus mirabilis* | IMID 112 | PX394077 |
| Hospital | *Staphylococcus aureus* | IMID 113 | PX394125 |
| | *Staphylococcus epidermidis* | IMID 114 | PX394126 |
| | *Enterococcus faecalis* | IMID 115 | PX394127 |
| | *Bacillus cereus* | IMID 116 | PX394128 |
| | *Acinetobacter baumannii* | IMD 117 | PX394129 |
| | *Escherichia coli* | IMID 118 | PX394130 |
| | *Klebsiella aerogenes* | IMID 119 | PX394131 |
| | *Klebsiella pneumoniae* | IMID 120 | PX394132 |
| | *Pseudomonas aeruginosa* | IMID 121 | PX394133 |


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**Contamination rate on door handles**

The data in Table 3 shows the bacterial contamination rate on door handles. In the hospital, the highest contamination was in the toilet with 83.33%. The next highest was in administrative offices with 60.00%. The lowest was in the laboratory at 56.67%. On the hospital ward, the contamination rate was 50.00%. At the university hostel, the toilet door handles had the highest rate at 96.67%. The external entrance/exit door handles had the lowest rate at 93.33%. At the university campus, the toilet door handles had a contamination rate of 100.00%. Laboratory door handles had a rate of 93.33%. Administrative office door handles had a rate of 96.67%. In homes in Okada town, the toilet had a contamination rate of 90.00%. The external entrance/exit door handles had the lowest rate at 80.00%. Shapiro-Wilk's test showed that the bacterial species contamination rates on door handles from the hospital and community datasets followed a normal distribution ($p > 0.05$). Levene's test showed that the variances between these datasets were equal. The student's t-test indicated that the mean contamination rate on community door handles was significantly higher ($p < 0.05$) than that on hospital door handles.

**Antibiotic resistance profile of bacteria isolated from door handles in the hospital**

Table 4 presents the resistance profile of bacteria from hospital door handles. The bacteria isolated from door handles of toilets in the hospital included *E. coli*, *K. aerogenes*, and *K. pneumoniae*. These bacteria were 100% resistant to the beta-lactam antibiotics tested, such as amoxicillin, ampiclox, cefuroxime, ceftriaxone, and cefoxitin. Other bacteria isolated from the toilets, including *S. aureus*, *S. epidermidis*, *E. faecalis*, *B. cereus*, and *A. baumannii*, showed different levels of resistance to beta-lactam antibiotics, ranging from 18.18% to 90.91%. Most of these bacteria were completely sensitive to fluoroquinolones like pefloxacin, ciprofloxacin, and levofloxacin (0%), except for *E. faecalis*, *K. aerogenes*, and *K. pneumoniae*, which had resistance levels from 9.09% to 100%.

**Table 3: Bacterial contamination rate on door handles**

| Door handle | | Prevalence of |
|---|---|---|
| Source | Location | ContaminationN (%) |
| Hospital | Toilet, n = 30 | 25 (83.33) |
| | Laboratory, n = 30 | 17 (56.67) |
| | Patient's ward, n = 30 | 15 (50.00) |
| | Admin. Office, n = 30 | 18 (60.00) |
| Community: | | |
| University Hostel | Toilet, n = 30 | 29 (96.67) |
| | Entrance/exit, n = 30 | 28 (93.33) |
| University Campus | Toilet, n = 30 | 30 (100.00) |
| | Laboratory, n = 30 | 28 (93.33) |
| | Admin. Office, n = 30 | 29 (96.67) |
| Okada Town | Toilet, n = 30 | 27 (90.00) |
| | Entrance/exit, n = 30 | 24 (80.00) |

n: number of door handles examined; N: number of door handles contaminated with bacteria
%: percentage prevalence


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**Table 4: Antibiotic resistance profile of bacteria isolated from door handles at the hospital**

| Location of door handle | Identified bacterial isolates | n | Resistance prevalence of tested antibiotics | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMP 10 µg N (%) | APX 30 µg N (%) | CXM 30 µg N (%) | CRO 30 µg N (%) | FOX 30 µg N (%) | PEF 5 µg N (%) | CIP 5 µg N (%) | LEV 5 µg N (%) | CN 10 µg N (%) | AZM 15 µg N (%) | E 15 µg N (%) |
| Toilet | *Staphylococcus aureus* | 4 | 4 (100.00) | 2 (50.00) | 3 (75.00) | 3 (75.00) | 4 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (25.00) | 1 (25.00) |
| | *Staphylococcus epidermidis* | 4 | 3 (75.00) | 3 (75.00) | 3 (75.00) | 3 (75.00) | 4 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (25.00) | 3 (75.00) |
| | *Enterococcus faecalis* | 11 | 11 (100.00) | 10 (90.91) | 11 (100.00) | 4 (36.36) | 11 (100.00) | 1 (9.09) | 1 (9.09) | 0 (0.00) | 1 (9.09) | 2 (18.18) | 9 (81.82) |
| | *Bacillus cereus* | 4 | 4 (100.00) | 1 (25.00) | 4 (100.00) | 3 (75.00) | 4 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (25.00) | 3 (75.00) |
| | *Acinetobacter baumannii* | 11 | 11 (100.00) | 2 (18.18) | 3 (27.27) | 10 (90.91) | 11 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (9.09) |
| | *Escherichia coli* | 10 | 10 (100.00) | 10 (100.00) | 10 (100.00) | 10 (100.00) | 10 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 9 (90.00) | 2 (20.00) | 10 (100.00) |
| | *Klebsiella aerogenes* | 3 | 3 (100.00) | 3 (100.00) | 3 (100.00) | 3 (100.00) | 3 (100.00) | 3 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (33.33) | 3 (100.00) |
| | *Klebsiella pneumoniae* | 3 | 3 (100.00) | 3 (100.00) | 3 (100.00) | 3 (100.00) | 3 (100.00) | 2 (66.67) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (33.33) | 3 (100.00) |
| Laboratory | *Staphylococcus aureus* | 11 | 11 (100.00) | 10 (90.91) | 11 (100.00) | 10 (90.91) | 11 (100.00) | 1 (9.09) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (9.09) | 10 (90.91) |
| | *Enterococcus faecalis* | 12 | 6 (50.00) | 2 (16.67) | 3 (25.00) | 3 (25.00) | 12 (100.00) | 2 (16.67) | 0 (0.00) | 0 (0.00) | 1 (8.33) | 1 (8.33) | 10 (83.33) |



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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Bacillus cereus* | 11 | 11 (100.00) | 2 (18.18) | 9 (81.82) | 9 (81.82) | 11 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (9.09) | 1 (9.09) | 8 (72.73) |
| Patient's ward | *Staphylococcus aureus* | 8 | 7 (87.50) | 3 (37.50) | 7 (87.50) | 2 (25.00) | 7 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (12.50) | 2 (25.00) | 2 (25.00) |
| | *Enterococcus faecalis* | 8 | 8 (100.00) | 7 (87.50) | 8 (100.00) | 7 (87.50) | 8 (100.00) | 1 (12.50) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 7 (87.50) |
| | *Bacillus cereus* | 7 | 7 (100.00) | 5 (71.43) | 6 (85.71) | 6 (85.71) | 7 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (14.23) | 1 (14.23) | 5 (71.43) |
| | *Acinetobacter baumannii* | 7 | 7 (100.00) | 1 (14.23) | 1 (14.23) | 6 (85.71) | 7 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (14.23) |
| Admin. Office | *Staphylococcus aureus* | 9 | 9 (100.00) | 8 (88.89) | 9 (100.00) | 8 (88.89) | 9 (100.00) | 1 (11.11) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 2 (22.22) | 7 (77.78) |
| | *Staphylococcus epidermidis* | 4 | 3 (75.00) | 1 (25.00) | 4 (100.00) | 3 (75.00) | 4 (100.00) | 1 (25.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 3 (75.00) |
| | *Enterococcus faecalis* | 5 | 5 (100.00) | 4 (80.00) | 5 (100.00) | 4 (80.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 3 (60.00) |
| | *Bacillus cereus* | 14 | 14 (100.00) | 4 (28.57) | 12 (85.71) | 12 (85.71) | 14 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (7.14) | 2 (14.29) | 10 (71.43) |
| | *Pseudomonas aeruginosa* | 4 | 4 (100.00) | 4 (100.00) | 4 (100.00) | 4 (100.00) | 4 (100.00) | 4 (100.00) | 1 (25.00) | 1 (25.00) | 0 (0.00) | 2 (50.00) | 4 (100.00) |

n: number of bacterial isolates that were tested; N: number of bacterial isolates that were resistant to the tested antibiotics; %: percentage resistance; AMP: ampicillin; APX: ampiclox; CXM: cefuroxime; CRO: ceftriaxone;

FOX: cefoxitin; PEF: pefloxacin; CIP: ciprofloxacin; LEV: levofloxacin; CN: gentamicin; AZM: azithromycin; E: erythromycin


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All bacteria except *E. faecalis*, *K. aerogenes*, and *K. pneumoniae* were fully sensitive to gentamicin (0%). The resistance to macrolides such as azithromycin and erythromycin varied between 9.09% and 100% among these bacteria.

Bacteria from laboratory door handles in the hospital included *S. aureus*, *B. cereus*, and *E. faecalis*. *S. aureus* was entirely resistant to ampicillin, cefuroxime, and cefoxitin (100%). *B cereus* was entirely resistant to ampicillin and cefoxitin (100%). *E. faecalis* was entirely resistant to cefoxitin (100%). The other bacteria showed resistance levels from 16.67% to 90.91% to beta-lactam antibiotics. Most bacteria from the laboratory door handles were entirely sensitive to fluoroquinolones (0%), except for some resistance seen in *S. aureus* and *E. faecalis* to pefloxacin, ranging from 9.09% to 16.67%. All bacteria were fully sensitive to gentamicin (0%) except for some resistance in *E. faecalis* and *B. cereus*, which was from 8.33% to 9.09%. Resistance to macrolides among these bacteria varied from 8.33% to 90.91%.

In the patient's ward, bacteria on door handles showed resistance to all tested beta-lactam antibiotics ranging from 14.23% to 100%. Resistance to fluoroquinolones was mostly absent, with *E. faecalis* exhibiting resistance to pefloxacin at 12.50%. *S. aureus* and *B. cereus* had resistance levels of 12.50% and 14.23%, respectively, to gentamicin. Resistance to macrolides varied from 14.29% to 100%.

Bacteria from administrative office door handles included *S. aureus* and *E. faecalis*, both fully resistant to ampicillin, cefuroxime, and cefoxitin at 100%. *S. epidermidis* was entirely resistant to cefuroxime and cefoxitin (100%). *P. aeruginosa* was fully resistant to all beta-lactams (100%). Other resistance to beta-lactam antibiotics in these bacteria ranged from 25% to 90.91%. Most bacteria were fully sensitive to pefloxacin, ciprofloxacin, and levofloxacin (0%), except for some resistance in *P. aeruginosa*, which ranged from 11.11% to 100%. All bacteria were fully sensitive to gentamicin (0%), except for some resistance in *P. aeruginosa* at 7.14%. Resistance to azithromycin and erythromycin varied from 14.29% to 100% among these bacteria.

**Antibiotic resistance profile of bacteria isolated from door handles at the university hostels**

Table 5 presents data on the resistance profile of bacteria found on door handles at the university hostels. All bacteria from toilet door handles were fully resistant to cefoxitin (100%). *E. faecalis*, *A. baumannii*, and *E. coli* were fully resistant to ampicillin (100%). *S. epidermidis* and *E. faecalis* were fully resistant to cefuroxime (100%). *E. faecalis* was also completely resistant to ceftriaxone (100%). Only *E. coli* was completely sensitive to ampiclox and cefuroxime (0%); the other bacteria showed resistance levels of 14.29% to 92.30%. All bacteria from toilet handles were fully sensitive to fluoroquinolones (0%). *S. aureus* and *E. coli* showed resistance to gentamicin at rates of 7.69% and 85.71%, respectively. The other bacteria were fully sensitive to gentamicin (0%). Bacteria such as *S. epidermidis*, *E. faecalis*, *B. cereus*, and *A. baumannii* were completely sensitive to azithromycin (0%). Resistance to azithromycin and erythromycin ranged from 14.29% to 89.47%.


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Bacteria from the external entrance/exit door handles were completely resistant to ampicillin and cefoxitin (100%). *S. epidermidis*, *M. luteus*, and *E. faecalis* were fully resistant to cefuroxime (100%). Resistance to ampicillin, ampiclox, cefuroxime, and ceftriaxone ranged from 85.71% to 100%. *S. aureus* showed resistance to pefloxacin at 10.71%. All other bacteria were completely sensitive to ciprofloxacin, levofloxacin, and pefloxacin (0%). *S. aureus* and *B. cereus* showed resistance to gentamicin at rates of 10.71% and 14.29%. Bacteria such as *S. epidermidis*, *E. faecalis*, and *B.cereus* were completely sensitive to azithromycin (0%). Resistance to azithromycin and erythromycin ranged from 10.71% to 82.14%.

**Table 5: Antibiotic resistance pattern of bacteria isolated from door handles at the university hostels**

| Location of door handle | Identified bacterial isolates | n | Resistance prevalence of tested antibiotics | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMP 10 µg N (%) | APX 30 µg N (%) | CXM 30 µg N (%) | CRO 30 µg N (%) | FOX 30 µg N (%) | PEF 5 µg N (%) | CIP 5 µg N (%) | LEV 5 µg N (%) | CN 10 µg N (%) | AZM 15 µg N (%) | E 15 µg N (%) |
| Toilet | *Staphylococcus aureus* | 13 | 12 (92.30) | 4 (30.77) | 11 (84.62) | 3 (23.08) | 13 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (7.69) | 2 (15.39) | 2 (15.39) |
| | *Staphylococcus epidermidis* | 6 | 5 (83.33) | 2 (33.33) | 6 (100.00) | 5 (83.33) | 6 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 5 (83.33) |
| | *Enterococcus faecalis* | 19 | 19 (100.00) | 17 (89.47) | 19 (100.00) | 19 (100.00) | 19 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 17 (89.47) |
| | *Bacillus cereus* | 7 | 2 (28.57) | 2 (28.57) | 1 (14.29) | 1 (14.29) | 7 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (14.29) |
| | *Acinetobacter baumannii* | 6 | 6 (100.00) | 2 (33.33) | 2 (33.33) | 5 (83.33) | 6 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (16.67) |
| | *Escherichia coli* | 7 | 7 (100.00) | 0 (0.00) | 0 (0.00) | 7 (100.00) | 7 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 6 (85.71) | 1 (14.29) | 5 (71.43) |
| Main Exit | *Staphylococcus aureus* | 28 | 28 (100.00) | 26 (92.86) | 26 (92.86) | 26 (92.86) | 28 (100.00) | 3 (10.71) | 0 (0.00) | 0 (0.00) | 2 (7.14) | 3 (10.71) | 23 (82.14) |



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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Staphylococcus epidermidis* | 7 | 6 (85.71) | 6 (85.71) | 7 (100.00) | 6 (85.71) | 7 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 5 (71.43) |
| *Micrococcus luteus* | 7 | 7 (100.00) | 6 (85.71) | 7 (100.00) | 6 (85.71) | 7 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (14.29) | 5 (71.43) |
| *Enterococcus faecalis* | 7 | 7 (100.00) | 6 (85.71) | 7 (100.00) | 6 (85.71) | 7 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 5 (71.43) |
| *Bacillus cereus* | 7 | 7 (100.00) | 6 (85.71) | 6 (85.71) | 6 (85.71) | 7 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (14.29) | 0 (0.00) | 5 (71.43) |

n: number of bacterial isolates that were tested; N: number of bacterial isolates that were resistant to the tested antibiotics; %: percentage resistance; AMP: ampicillin; APX: ampiclox; CXM: cefuroxime; CRO: ceftriaxone;

FOX: cefoxitin; PEF: pefloxacin; CIP: ciprofloxacin; LEV: levofloxacin; CN: gentamicin; AZM: azithromycin; E: erythromycin

**Antibiotic resistance profile of bacteria isolated from door handles at the university campus**

Table 6 presents the resistance of bacteria found on door handles at the university campus. The bacteria included *E. coli*, *K. aerogenes*, *K. pneumoniae*, and *P. mirabilis*. All these bacteria from toilet door handles were fully resistant to beta-lactam antibiotics such as amoxicillin, ampiclox, cefuroxime, ceftriaxone, and cefoxitin (100%). *E. faecalis*, *B. cereus*, and *A. baumannii* were also fully resistant to ampicillin (100%). *E. faecalis* showed full resistance to cefuroxime and ceftriaxone (100%). *S. aureus* and *S. epidermidis* were fully resistant to cefoxitin (100%). These bacteria also showed varied resistance to beta-lactam antibiotics, with rates between 14.29% and 85.71%. Most bacteria were fully sensitive to ciprofloxacin, levofloxacin, and pefloxacin (0%). *K. aerogenes*, *K. pneumoniae*, and *P. mirabilis* were fully resistant to pefloxacin (100%). *S. aureus*, *B. cereus*, *E. coli*, *K. aerogenes*, and *K. pneumoniae* were resistant to gentamicin at rates of 14.29%, 20.00%, 83.33%, and 100%. The other bacteria were fully sensitive (0%). Many bacteria, including *S. aureus*, *S. epidermidis*, *E. faecalis*, *B. cereus*, *A. baumannii*, and *E. coli*, were fully sensitive to azithromycin (0%). *S. aureus* and *A. baumannii* also showed full sensitivity to erythromycin (0%). Other resistance to azithromycin and erythromycin varied from 20.00% to 83.33%.


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All bacteria from laboratory door handles were fully resistant to cefoxitin (100%). *S. aureus*, *E. faecalis*, and *A. baumannii* were fully resistant to ampicillin (100%). *E. faecalis* was fully resistant to ceftriaxone (100%). Bacteria from laboratory handles showed variable resistance to ampicillin, ampiclox, cefuroxime, and ceftriaxone, with rates from 8.33% to 95.46%. Unlike the other bacteria, *S. aureus* resisted pefloxacin entirely (100%), but all were sensitive to ciprofloxacin and levofloxacin (0%). All bacteria from laboratory door handles were fully sensitive to gentamicin and azithromycin (0%). *A. baumannii* was fully sensitive to erythromycin (0%), while resistance rates to erythromycin reached 81.82% for other bacteria.

**Table 6: Antibiotic resistance profile of bacteria isolated from door handles at the university campus**

| Location of door handle | Identified bacterial isolates | n | Resistance prevalence of tested antibiotics | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMP 10 µg N (%) | APX 30 µg N (%) | CXM 30 µg N (%) | CRO 30 µg N (%) | FOX 30 µg N (%) | PEF 5 µg N (%) | CIP 5 µg N (%) | LEV 5 µg N (%) | CN 10 µg N (%) | AZM 15 µg N (%) | E 15 µg N (%) |
| Toilet | *Staphylococcus aureus* | 7 | 6 (85.71) | 1 (14.29) | 6 (85.71) | 6 (85.71) | 7 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (14.29) | 0 (0.00) | 0 (0.00) |
| | *Staphylococcus epidermidis* | 5 | 4 (80.00) | 1 (20.00) | 0 (0.00) | 4 (80.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 4 (80.00) |
| | *Enterococcus faecalis* | 11 | 11 (100.00) | 9 (81.82) | 11 (100.00) | 11 (100.00) | 7 (63.64) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 7 (63.64) |
| | *Bacillus cereus* | 5 | 5 (100.00) | 2 (40.00) | 4 (80.00) | 4 (80.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (20.00) | 0 (0.00) | 4 (80.00) |



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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Acinetobacter baumannii* | 11 | 11 (100.00) | 2 (18.18) | 2 (18.18) | 11 (100.00) | 11 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| | *Escherichia coli* | 6 | 6 (100.00) | 6 (100.00) | 6 (100.00) | 6 (100.00) | 6 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 5 (83.33) | 0 (0.00) | 5 (83.33) |
| | *Klebsiella aerogenes* | 5 | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 5 (100.00) | 1 (20.00) | 5 (100.00) |
| | *Klebsiella pneumonia* | 5 | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 5 (100.00) | 2 (40.00) | 5 (100.00) |
| | *Proteus mirabilis* | 5 | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (20.00) | 5 (100.00) |
| Laboratory | *Staphylococcus aureus* | 22 | 22 (100.00) | 21 (95.46) | 0 (0.00) | 20 (90.91) | 22 (100.00) | 2 (9.09) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 18 (81.82) |
| | *Staphylococcus epidermidis* | 11 | 10 (90.91) | 9 (81.82) | 11 (100.00) | 10 (90.91) | 11 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 9 (81.82) |
| | *Enterococcus faecalis* | 11 | 11 (100.00) | 10 (90.91) | 11 (100.00) | 11 (100.00) | 11 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 9 (81.82) |
| | *Acinetobacter baumannii* | 12 | 12 (100.00) | 2 (16.67) | 1 (8.33) | 10 (83.33) | 12 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| Admin. Office | *Staphylococcus aureus* | 27 | 27 (100.00) | 25 (92.59) | 27 (100.00) | 25 | 27 | 0 (0.00) | 0 | 0 | 0 (0.00) | 1 | 24 |


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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (92.59) | (100.00) | | (0.00) | (0.00) | | (3.70) | (88.89) |
| *Staphylococcus epidermidis* | 5 | 4 (80.00) | 2 (40.00) | 5 (100.00) | 4 (80.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 4 (80.00) |
| *Micrococcus luteus* | 5 | 5 (100.00) | 4 (80.00) | 5 (100.00) | 4 (80.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 3 (60.00) |
| *Enterococcus faecalis* | 11 | 11 (100.00) | 9 (81.82) | 11 (100.00) | 10 (90.91) | 11 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 10 (90.91) |
| *Bacillus cereus* | 5 | 5 (100.00) | 2 (40.00) | 4 (80.00) | 5 (100.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (20.00) | 2 (40.00) |
| *Klebsiella pneumoniae* | 5 | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 4 (80.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (20.00) | 5 (100.00) |

n: number of bacterial isolates that were tested; N: number of bacterial isolates that were resistant to the tested antibiotics; %: percentage resistance; AMP: ampicillin; APX: ampiclox; CXM: cefuroxime; CRO: ceftriaxone;

FOX: cefoxitin; PEF: pefloxacin; CIP: ciprofloxacin; LEV: levofloxacin; CN: gentamicin; AZM: azithromycin; E: erythromycin

All bacteria on the administrative office door handles resisted cefoxitin completely (100%). *K. pneumoniae* was completely resistant to all beta-lactam antibiotics (100%). Except for *S. epidermidis* and *B. cereus*which had 80% resistance to ampicillin and cefuroxime, the other bacterial isolates were completely resistant (100%). Other resistance to beta-lactam antibiotics ranged from 40% to 92.59%. *K. pneumoniae* resisted pefloxacin at 80%. All bacteria were fully sensitive to ciprofloxacin, levofloxacin, and pefloxacin (0%). All bacteria from these handles were fully sensitive to gentamicin (0%). Bacteria such as *S. epidermidis*, *M. luteus*, and *E. faecalis* were fully sensitive to azithromycin. Resistance to azithromycin and erythromycin varied from 3.70% to 100.00%.


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**Antibiotic resistance profile of bacteria isolated from door handles at homes in Okada town**

Table 7 presents data on bacteria found on door handles at homes in Okada town. Bacteria from toilet door handles in Okada town were completely resistant to cefoxitin (100%). Bacteria such as *M. luteus*, *B. cereus*, *A. baumannii*, and *K. pneumoniae* were fully resistant to ampicillin (100%). *S. epidermidis* and *M. luteus* showed complete resistance to cefuroxime (100%). *A. baumannii* was fully resistant to ceftriaxone (100%). *K. pneumoniae* was resistant to all beta-lactam antibiotics tested (100%). Most bacteria, except *K. pneumoniae,* which showed 83.33% resistance to pefloxacin, were sensitive to fluoroquinolones (100%). *S. aureus* and *B. cereus* showed resistance to gentamicin at 18.75% and 6.25%, respectively. Other bacteria were fully sensitive to gentamicin (0%). *S. epidermidis* and *A. baumannii* were fully sensitive to azithromycin (0%). *A. baumannii* was also fully sensitive to erythromycin (0%). Resistance to azithromycin and erythromycin varied from 6.25% to 83.33%.

Bacteria such as *B. subtilis*, *P. aeruginosa*, *M. luteus*, and *P. mirabilis* from external entrance/exit door handles were resistant to all tested beta-lactam antibiotics (100%).

**Table 7: Antibiotic resistance pattern of bacteria isolated from door handles at the Okada town**

| Location of door handle | Identified bacterial isolates | n | Resistance prevalence of tested antibiotics | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AMP 10 µg N (%) | APX 30 µg N (%) | CXM 30 µg N (%) | CRO 30 µg N (%) | FOX 30 µg N (%) | PEF 5 µg N (%) | CIP 5 µg N (%) | LEV 5 µg N (%) | CN 10 µg N (%) | AZM 15 µg N (%) | E 15 µg N (%) |
| Toilet | *Staphylococcus aureus* | 16 | 15 (93.75) | 3 (18.75) | 15 (93.75) | 3 (18.75) | 16 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 3 (18.75) | 1 (6.25) | 3 (18.75) |
| | *Staphylococcus epidermidis* | 6 | 5 (83.33) | 1 (16.67) | 6 (100.00) | 5 (83.33) | 6 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 5 (83.33) |
| | *Micrococcus luteus* | 11 | 11 (100.00) | 9 (81.82) | 11 (100.00) | 10 (90.91) | 11 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 2 (18.18) | 9 (81.82) |
| | *Bacillus cereus* | 11 | 11 (100.00) | 2 (18.18) | 10 (90.91) | 10 (90.91) | 11 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (6.25) | 2 (18.18) | 9 (81.82) |


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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Acinetobacter baumannii* | 4 | 4 (100.00) | 1 (25.00) | 1 (25.00) | 4 (100.00) | 4 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| | *Klebsiella pneumoniae* | 6 | 6 (100.00) | 6 (100.00) | 6 (100.00) | 6 (100.00) | 6 (100.00) | 5 (83.33) | 0 (0.00) | 0 (0.00) | 1 (16.67) | 4 (66.67) |
| Entrance/exit | *Staphylococcus aureus* | 19 | 19 (100.00) | 18 (94.74) | 19 (100.00) | 18 (94.74) | 19 (100.00) | 2 (10.53) | 0 (0.00) | 0 (0.00) | 2 (10.53) | 16 (84.21) |
| | *Staphylococcus epidermidis* | 2 | 2 (100.00) | 1 (50.00) | 2 (100.00) | 2 (100.00) | 2 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 2 (100.00) |
| | *Micrococcus luteus* | 2 | 2 (100.00) | 2 (100.00) | 2 (100.00) | 2 (100.00) | 2 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (50.00) |
| | *Enterococcus faecalis* | 5 | 5 (100.00) | 4 (80.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 4 (80.00) |
| | *Bacillus cereus* | 8 | 7 (87.50) | 1 (12.50) | 1 (12.50) | 1 (12.50) | 8 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (12.50) | 0 (0.00) |
| | *Bacillus subtilis* | 2 | 2 (100.00) | 0 (0.00) | 2 (100.00) | 2 (100.00) | 2 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 1 (50.00) |
| | *Pseudomonas aeruginosa* | 5 | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 4 (80.00) | 0 (0.00) | 4 (80.00) |
| | *Proteus mirabilis* | 5 | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 5 (100.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 3 (60.00) | 0 (0.00) | 4 (80.00) |

n: number of bacterial isolates that were tested; N: number of bacterial isolates that were resistant to the tested antibiotics; %: percentage resistance; AMP: ampicillin; APX: ampiclox; CXM: cefuroxime; CRO: ceftriaxone;

FOX: cefoxitin; PEF: pefloxacin; CIP: ciprofloxacin; LEV: levofloxacin; CN: gentamicin; AZM: azithromycin; E: erythromycin


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*S. aureus*, *S. epidermidis*, and *E. faecalis* were fully resistant to ampicillin (100%). *S. epidermidis* and *E. faecalis* were completely resistant to cefuroxime and ceftriaxone (100%). *S. aureus* was fully resistant to cefuroxime (100%). *S. aureus*, *S. epidermidis*, *M. luteus*, *E. faecalis*, and *B. cereus* were fully resistant to cefoxitin (100%). With the exception of *S. aureus*, which had 10.53% resistance to pefloxacin, most bacteria were fully sensitive to ciprofloxacin, levofloxacin, and pefloxacin (0%). *B. cereus*, *P. aeruginosa*, and *P. mirabilis* showed resistance to gentamicin at 12.50%, 80.00%, and 60.00% respectively. Other bacteria were completely sensitive to gentamicin (0%). *S. aureus* from the external exit door handles showed 10.53% resistance to azithromycin. *B. cereus* was fully sensitive to erythromycin (0%). Resistance to erythromycin ranged from 50.00% to 100% among other bacteria.

**Occurrence of multidrug resistance in bacteria isolated from hospital door handles**

Table 8 showed the occurrence of bacteria resistant to multiple drugs on hospital door handles. All *K. aerogenes* found on toilet door handles in the hospital were resistant to multiple drugs (100%). Multidrug-resistant *E. faecalis*, *E. coli*, and *K. pneumoniae* were also found on toilet door handles at rates of 9.09%, 90.00%, and 66.67% respectively. No multidrug-resistant strains of *S. aureus*, *S. epidermidis*, *B. cereus*, or *A. baumannii* were found on toilet door handles (0%).

On laboratory door handles in the hospital, *E. faecalis* had the highest rate of resistance at 16.67%. *S. aureus* and *B. cereus* each had rates of 9.09%.

At patient ward door handles, multidrug-resistant *S. aureus* and *E. faecalis* were each found at 12.50%. *B. cereus* was found at 1.15%. No multidrug-resistant *A. baumannii* (0%) was found on patient ward door handles.

The bacterium most often found on door handles in the hospital offices was *P. aeruginosa*, with all isolates occurring as multidrug-resistant (100%). *S. epidermidis* was found in 25% of isolates.

**Table 8: Prevalence of multidrug resistance in bacteria isolated from the hospital settings**

| Location of door handle | Identified bacterial species | n | Prevalence of multidrug-resistant bacteria N (%) |
|---|---|---|---|
| Toilet | *Staphylococcus aureus* | 4 | 0 (0.00) |
| | *Staphylococcus epidermidis* | 4 | 0 (0.00) |
| | *Enterococcus faecalis* | 11 | 1 (9.09) |
| | *Bacillus cereus* | 4 | 0 (0.00) |
| | *Acinetobacter baumannii* | 11 | 0 (0.00) |
| | *Escherichia coli* | 10 | 9 (90.00) |
| | *Klebsiella aerogenes* | 3 | 3 (100.00) |
| | *Klebsiella pneumoniae* | 3 | 2 (66.67) |
| | **All bacterial species** | **50** | **15 (30.00)** |


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| | | | |
|---|---|---|---|
| Laboratory | *Staphylococcus aureus* | 11 | 1 (9.09) |
| | *Enterococcus faecalis* | 12 | 2 (16.67) |
| | *Bacillus cereus* | 11 | 1 (9.09) |
| | **All bacterial species** | **34** | **4 (11.77)** |
| Patient's ward | *Staphylococcus aureus* | 8 | 1 (12.50) |
| | *Enterococcus faecalis* | 8 | 1 (12.50) |
| | *Bacillus cereus* | 7 | 1 (1.15) |
| | *Acinetobacter baumannii* | 7 | 0 (0.00) |
| | **All bacterial species** | **30** | **3 (10.00)** |
| Admin. Office | *Staphylococcus aureus* | 9 | 1 (11.11) |
| | *Staphylococcus epidermidis* | 4 | 1 (25.00) |
| | *Enterococcus faecalis* | 5 | 0 (0.00) |
| | *Bacillus cereus* | 14 | 0 (0.00) |
| | *Pseudomonas aeruginosa* | 4 | 4 (100.00) |
| | **All bacterial species** | **36** | **6 (16.67)** |

n: number of bacterial isolates that were tested; N: number of isolates that were multidrug-resistant bacteria; %: percentage prevalence

*S. aureus* was found in 11.11% of isolates. No multidrug-resistant strains of *E. faecalis* or *B. cereus* were found (0%).

Overall, multidrug-resistant bacteria were recovered most frequently from toilet door handles (30.00%) and least frequently from door handles in patient wards (10.00%).

**Occurrence of multidrug resistance in bacteria from door handles at the university hostels**

Table 9 showed the occurrence of bacteria that resisted multiple drugs on door handles at the university hostels. In the university hostels, toilet door handles had the most multidrug-resistant bacteria. Specifically, 71.43% of these bacteria were *E. coli* followed by *S. aureus*, which had a rate of 7.69%. No multidrug-resistant strains of *S. epidermidis*, *E. faecalis*, *B. cereus*, or *A. baumannii* (0%) were found on toilet door handles.

On the external entrance/exit door handles in the university hostels, multidrug-resistant strains of *S. aureus* and *B. cereus* were found at rates of 10.71% and 14.29%, respectively. No multidrug-resistant strains of *S. epidermidis*, *M. luteus*, or *E. faecalis* (0%) were found on the external entrance/exit door handles.

Overall, multidrug-resistant bacteria were most often found on toilet door handles (10.35%) and least often on external exit door handles (7.14%) in the university hostels.


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**Occurrence of multidrug resistance in bacteria from door handles at the university campus**

Table 10 shows the occurrence of bacteria that resisted multiple drugs on door handles at the university campus. All *K. aerogenes*, *K. pneumoniae*, and *P. mirabilis* found on toilet door handles were resistant to multiple drugs (100%). Twenty percent (20%) of *B. cereus* from toilet door handles were resistant to multiple drugs. No strains of *S. aureus*, *S. epidermidis*, *E. faecalis*, or *A. baumannii* were multidrug-resistant (0%).

**Table 9: Pattern of multidrug resistance in bacteria isolated from door handles at the university hostels**

| Location of door handle | Identified bacterial species | n | Prevalence of multidrug-resistant bacteria N (%) |
|---|---|---|---|
| Toilet | *Staphylococcus aureus* | 13 | 1 (7.69) |
| | *Staphylococcus epidermidis* | 6 | 0 (0.00) |
| | *Enterococcus faecalis* | 19 | 0 (0.00) |
| | *Bacillus cereus* | 7 | 0 (0.00) |
| | *Acinetobacter baumannii* | 6 | 0 (0.00) |
| | *Escherichia coli* | 7 | 5 (71.43) |
| | **All bacterial species** | **58** | **6 (10.35)** |
| Entrance/exit | *Staphylococcus aureus* | 28 | 3 (10.71) |
| | *Staphylococcus epidermidis* | 7 | 0 (0.00) |
| | *Micrococcus luteus* | 7 | 0 (0.00) |
| | *Enterococcus faecalis* | 7 | 0 (0.00) |
| | *Bacillus cereus* | 7 | 1 (14.29) |
| | **All bacterial species** | **56** | **4 (7.14)** |

n: number of bacterial isolates that were tested; N: number of isolates that were multidrug-resistant bacteria; %: percentage prevalence.

**Table 10: Pattern of multidrug resistance in bacteria isolated from door handles at the university campus**

| Location of door handle | Identified bacterial species | n | Prevalence of multidrug-resistant bacteria N (%) |
|---|---|---|---|
| Toilet | *Staphylococcus aureus* | 7 | 0 (0.00) |
| | *Staphylococcus epidermidis* | 5 | 0 (0.00) |
| | *Enterococcus faecalis* | 11 | 0 (0.00) |
| | *Bacillus cereus* | 5 | 1 (20.00) |
| | *Acinetobacter baumannii* | 11 | 0 (0.00) |
| | *Escherichia coli* | 6 | 5 (83.33) |
| | *Klebsiella aerogenes* | 5 | 5 (100.00) |
| | *Klebsiella pneumonia* | 5 | 5 (100.00) |


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| | | | |
|---|---|---|---|
| | *Proteus mirabilis* | 5 | 5 (100.00) |
| | **All bacterial species** | **60** | **21 (35.00)** |
| Laboratory | *Staphylococcus aureus* | 22 | 2 (9.09) |
| | *Staphylococcus epidermidis* | 11 | 0 (000) |
| | *Enterococcus faecalis* | 11 | 0 (0.00) |
| | *Acinetobacter baumannii* | 12 | 0 (0.00) |
| | **All bacterial species** | **56** | **2 (3.57)** |
| Admin. Office | *Staphylococcus aureus* | 27 | 0 (0.00) |
| | *Staphylococcus epidermidis* | 5 | 0 (0.00) |
| | *Micrococcus luteus* | 5 | 0 (0.00) |
| | *Enterococcus faecalis* | 11 | 0 (0.00) |
| | *Bacillus cereus* | 5 | 0 (0.00) |
| | *Klebsiella pneumoniae* | 5 | 4 (80.00) |
| | **All bacterial species** | **58** | **4 (6.90)** |

n: number of bacterial isolates that were tested; N: number of isolates that were multidrug-resistant bacteria; %: percentage prevalence

No multidrug-resistant strains were found on bacteria from laboratory door handles (0%), except *S. aureus*, which had a multidrug resistance rate of 9.09%.

No multidrug-resistant strains were found on bacteria from administrative office door handles (0%), except *K. pneumoniae*, with a prevalence rate of 80%.

Overall, multidrug-resistant bacteria were most common on toilet door handles, with a prevalence rate of 35%, while they were less common on door handles in administrative offices, with a rate of 6.9%. The least multidrug resistance was found on laboratory door handles, with a rate of 3.57%.

**Occurrence of multidrug resistance in bacteria from door handles in homes in Okada town**

Table 11 shows the multidrug-resistant bacteria found on door handles in homes in Okada town. Multidrug-resistant bacteria were recovered from toilet door handles. The most common bacterium on toilet door handles was *K. pneumoniae*, found in 66.67% of isolates. *S. aureus* was found in 18.75% while *B. cereus* was found in 9.09% of isolates. No multidrug-resistant strains of *S. epidermidis*, *M. luteus*, or *A. baumannii* (0%) were found on toilet door handles.

From external entrance/exit door handles, multidrug-resistant bacteria were also recovered. Strains of multidrug-resistant *S. aureus*, *P. aeruginosa*, and *P. mirabilis* were found. The prevalence rates were 10.53%, 80.00%, and 60.00%, respectively. No multidrug-resistant strains of *S. epidermidis*, *M. luteus*, *E. faecalis*, *B. cereus*, or *B. subtilis* were found on these handles.


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Overall, multidrug-resistant bacteria were found most often on external entrance/exit door handles at a prevalence rate of 18.75%. They were found least often on toilet door handles, with a 14.82% prevalence rate.

**Table 11: Pattern of multidrug resistance in bacteria isolated from door handles at Okada town**

| Location of door handle | Identified bacterial species | n | Prevalence of multidrug-resistant bacteria N (%) |
|---|---|---|---|
| Toilet | *Staphylococcus aureus* | 16 | 3 (18.75) |
| | *Staphylococcus epidermidis* | 6 | 0 (0.00) |
| | *Micrococcus luteus* | 11 | 0 (0.00) |
| | *Bacillus cereus* | 11 | 1 (9.09) |
| | *Acinetobacter baumannii* | 4 | 0 (0.00) |
| | *Klebsiella pneumoniae* | 6 | 4 (66.67) |
| | **All bacterial species** | **54** | **8 (14.82)** |
| Entrance/exit | *Staphylococcus aureus* | 19 | 2 (10.53) |
| | *Staphylococcus epidermidis* | 2 | 0 (0.00) |
| | *Micrococcus luteus* | 2 | 0 (0.00) |
| | *Enterococcus faecalis* | 5 | 0 (0.00) |
| | *Bacillus cereus* | 8 | 0 (0.00) |
| | *Bacillus subtilis* | 2 | 0 (0.00) |
| | *Pseudomonas aeruginosa* | 5 | 4 (80.00) |
| | *Proteus mirabilis* | 5 | 3 (60.00) |
| | **All bacterial species** | **48** | **9 (18.75)** |

n: number of bacterial isolates that were tested; N: number of isolates that were multidrug-resistant bacteria; %: percentage prevalence

**Multiple antibiotic resistance (MAR) indices of bacterial isolates on hospital door handles**

Table 12 shows the mean MAR indices for bacteria found on hospital door handles. *K. aerogenes* had the highest mean MAR index of 0.75. *A. baumannii* had the lowest index of 0.27. On laboratory door handles, the mean MAR index ranged from 0.46 for *B. cereus* to 0.50 for *S. aureus* and *B. cereus*. In patient wards, bacteria from door handles had mean MAR indices between 0.29 and 0.50. In administrative office door handles, the mean MAR indices ranged from 0.40 to 0.75.

**MAR indices of bacterial isolates on door handles at the university hostels**

Table 13 shows the mean MAR indices for bacteria found on door handles at the university hostels. The highest mean MAR index was for *E. coli*, which was 0.64 on toilet door handles at the university hostel. The lowest mean MAR index was 0.29, observed in *B. cereus* and *A. baumannii*. On the external entrance/exit door handles, the mean MAR index ranged from 0.43 for *S. epidermidis*, *M. luteus*, and *E. faecalis*, to 0.50 for *S. aureus*.


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**MAR indices of bacterial isolates on door handles at the university campus**

Table 14 shows the mean MAR indices for bacteria found on door handles at the university campus. The highest mean MAR index on toilet door handles was found in *K. aerogenes*, *K. pneumoniae*, and *P. mirabilis*, with a value of 1.00. The lowest MAR index on toilet door handles was in *A. baumannii*, with a value of 0.25. On laboratory door handles, the MAR indices ranged from 0.25 in *A. baumannii* to 0.48 in *S. aureus*. In the administrative offices, bacteria from door handles had MAR indices between 0.35 and 0.70.

**MAR indices of bacterial isolates on door handles at homes in Okada**

Table 15 shows the mean MAR indices for bacteria found on door handles at homes in Okada town. The highest MAR indices on toilet door handles were found in *A. baumannii* and *K. pneumoniae*. Both had a mean MAR index of 0.63. The lowest mean MAR index of 0.33 was found in *S. aureus*. For external exit door handles, the MAR indices ranged from 0.25 in *S. aureus* to 0.65 in *P. aeruginosa*.

**Table 12: Multiple antibiotics resistance index of bacterial isolates from door handles in the hospital settings**

| Location of door handle | Identified bacterial species | n | ∑AS | A | Mean MAR index |
|---|---|---|---|---|---|
| Toilet | *Staphylococcus aureus* | 4 | 5 | 4 | 0.31 |
| | *Staphylococcus epidermidis* | 4 | 7 | 4 | 0.43 |
| | *Enterococcus faecalis* | 11 | 21 | 4 | 0.47 |
| | *Bacillus cereus* | 4 | 7 | 4 | 0.43 |
| | *Acinetobacter baumannii* | 11 | 12 | 4 | 0.27 |
| | *Escherichia coli* | 10 | 29 | 4 | 0.73 |
| | *Klebsiella aerogenes* | 3 | 9 | 4 | 0.75 |
| | *Klebsiella pneumoniae* | 3 | 8 | 4 | 0.67 |
| | **All bacterial species** | **50** | **98** | **4** | **0.49** |
| Laboratory | *Staphylococcus aureus* | 11 | 22 | 4 | 0.50 |
| | *Enterococcus faecalis* | 12 | 24 | 4 | 050 |
| | *Bacillus cereus* | 11 | 20 | 4 | 0.46 |
| | **All bacterial species** | **34** | **66** | **4** | **0.49** |
| Patient's ward | *Staphylococcus aureus* | 8 | 10 | 4 | 0.31 |
| | *Enterococcus faecalis* | 8 | 16 | 4 | 0.50 |
| | *Bacillus cereus* | 7 | 13 | 4 | 0.46 |
| | *Acinetobacter baumannii* | 7 | 8 | 4 | 0.29 |
| | **All bacterial species** | **30** | **47** | **4** | **0.39** |
| Admin. Office | *Staphylococcus aureus* | 9 | 17 | 4 | 0.47 |
| | *Staphylococcus epidermidis* | 4 | 8 | 4 | 0.50 |
| | *Enterococcus faecalis* | 5 | 8 | 4 | 0.40 |


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|---|---|---|---|---|---|
| | *Bacillus cereus* | 14 | 24 | 4 | 0.43 |
| | *Pseudomonas aeruginosa* | 4 | 12 | 4 | 0.75 |
| | **All bacterial species** | **36** | **69** | **4** | **0.48** |

MAR: multiple antibiotic resistance index; AS: resistance score of each bacterial isolate, which represents the number of antibiotic classes to which each bacterial isolate shows resistance. A: total number of antibiotic classes tested; n: number of bacterial isolates examined.

**Table 13: Multiple antibiotics resistance index of bacterial isolates from door handles at the university hostels**

| Location of door handle | Identified bacterial species | n | ∑AS | A | Mean MAR index |
|---|---|---|---|---|---|
| Toilet | *Staphylococcus aureus* | 13 | 16 | 4 | 0.31 |
| | *Staphylococcus epidermidis* | 6 | 11 | 4 | 0.46 |
| | *Enterococcus faecalis* | 19 | 36 | 4 | 0.47 |
| | *Bacillus cereus* | 7 | 8 | 4 | 0.29 |
| | *Acinetobacter baumannii* | 6 | 7 | 4 | 0.29 |
| | *Escherichia coli* | 7 | 18 | 4 | 0.64 |
| | **All bacterial species** | **58** | **96** | **4** | **0.41** |
| Entrance/exit | *Staphylococcus aureus* | 28 | 56 | 4 | 0.50 |
| | *Staphylococcus epidermidis* | 7 | 12 | 4 | 0.43 |
| | *Micrococcus luteus* | 7 | 12 | 4 | 0.43 |
| | *Enterococcus faecalis* | 7 | 12 | 4 | 0.43 |
| | *Bacillus cereus* | 7 | 13 | 4 | 0.46 |
| | **All bacterial species** | **56** | **105** | **4** | **0.47** |

MAR: multiple antibiotic resistance index; AS: resistance score of each bacterial isolate, which represents the number of antibiotic classes to which each bacterial isolate shows resistance. A: total number of antibiotic classes tested; n: number of bacterial isolates examined.

**Table 14: Multiple antibiotics resistance index of bacterial isolates from door handles at the university campus**

| Location of door handle | Identified bacterial species | n | ∑AS | A | Mean MAR index |
|---|---|---|---|---|---|
| Toilet | *Staphylococcus aureus* | 7 | 8 | 4 | 0.29 |
| | *Staphylococcus epidermidis* | 5 | 11 | 4 | 0.55 |
| | *Enterococcus faecalis* | 11 | 18 | 4 | 0.41 |
| | *Bacillus cereus* | 5 | 15 | 4 | 0.75 |
| | *Acinetobacter baumannii* | 11 | 11 | 4 | 0.25 |
| | *Escherichia coli* | 6 | 16 | 4 | 0.67 |
| | *Klebsiella aerogenes* | 5 | 20 | 4 | 1.00 |


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| | | | | | |
|---|---|---|---|---|---|
| | *Klebsiella pneumonia* | 5 | 20 | 4 | 1.00 |
| | *Proteus mirabilis* | 5 | 20 | 4 | 1.00 |
| | **All bacterial species** | **60** | **139** | **4** | **0.58** |
| Laboratory | *Staphylococcus aureus* | 22 | 42 | 4 | 0.48 |
| | *Staphylococcus epidermidis* | 11 | 20 | 4 | 0.46 |
| | *Enterococcus faecalis* | 11 | 20 | 4 | 0.46 |
| | *Acinetobacter baumannii* | 12 | 12 | 4 | 0.25 |
| | **All bacterial species** | **56** | **94** | **4** | **0.42** |
| Admin. Office | *Staphylococcus aureus* | 27 | 51 | 4 | 0.47 |
| | *Staphylococcus epidermidis* | 5 | 9 | 4 | 0.45 |
| | *Micrococcus luteus* | 5 | 8 | 4 | 0.40 |
| | *Enterococcus faecalis* | 11 | 21 | 4 | 0.48 |
| | *Bacillus cereus* | 5 | 7 | 4 | 0.35 |
| | *Klebsiella pneumoniae* | 5 | 14 | 4 | 0.70 |
| | **All bacterial species** | **58** | **110** | **4** | **0.47** |

MAR: multiple antibiotic resistance index; AS: resistance score of each bacterial isolate, which represents the number of antibiotic classes to which each bacterial isolate shows resistance. A: total number of antibiotic classes tested; n: number of bacterial isolates examined.

**Table 15: Multiple antibiotic resistance index of bacterial isolates from door handles at the Okada town**

| Location of door handle | Identified bacterial species | n | ∑AS | A | Mean MAR index |
|---|---|---|---|---|---|
| Toilet | *Staphylococcus aureus* | 16 | 21 | 4 | 0.33 |
| | *Staphylococcus epidermidis* | 6 | 11 | 4 | 0.46 |
| | *Micrococcus luteus* | 11 | 20 | 4 | 0.46 |
| | *Bacillus cereus* | 11 | 20 | 4 | 0.46 |
| | *Acinetobacter baumannii* | 4 | 10 | 4 | 0.63 |
| | *Klebsiella pneumoniae* | 6 | 15 | 4 | 0.63 |
| | **All bacterial species** | **54** | **97** | **4** | **0.45** |
| Entrance/exit | *Staphylococcus aureus* | 19 | 37 | 4 | 0.49 |
| | *Staphylococcus epidermidis* | 2 | 4 | 4 | 0.50 |
| | *Micrococcus luteus* | 2 | 3 | 4 | 0.38 |
| | *Enterococcus faecalis* | 5 | 9 | 4 | 0.45 |
| | *Bacillus cereus* | 8 | 8 | 4 | 0.25 |
| | *Bacillus subtilis* | 2 | 3 | 4 | 0.38 |
| | *Pseudomonas aeruginosa* | 5 | 13 | 4 | 0.65 |
| | *Proteus mirabilis* | 5 | 12 | 4 | 0.60 |
| | **All bacterial species** | **48** | **89** | **4** | **0.46** |


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MAR: multiple antibiotic resistance index; AS: resistance score of each bacterial isolate, which represents the number of antibiotic classes to which each bacterial isolate shows resistance. A: total number of antibiotic classes tested; n: number of bacterial isolates examined.

## DISCUSSION

The rate of infections related to hospitals and communities is often linked to contamination caused by poor hygiene and failure to follow infection control rules. Contamination occurs when people do not wash their hands after using toilets or do not use disinfectants [22]. This study identified common bacteria on door handles in hospitals and communities at Okada. Bacteria that were Gram-positive in this study included *S. aureus*, *S. epidermidis*, *M. luteus*, *E. faecalis*, *B. cereus*, and *B. luteus* (Table 1). Bacteria that were Gram-negative include *A. baumannii*, *E. coli*, *K. aerogenes*, *K. pneumoniae*, *P. aeruginosa*, and *P. mirabilis* (Table 1). Other studies in Nigeria [22, 23] and outside Nigeria [24] reported similar bacteria on door handles. In hospital and community settings, *S. aureus*, *E. faecalis*, *B. cereus*, and *A. baumannii* were more common on door handles than other bacteria (Table 1). The prevalence of *E. faecalis* was as high as 38.89% in hospitals (Table 1). The prevalence of *S. aureus* reached 50% in community settings (Table 1). These high rates matched those reported in previous studies in Nigeria by Odigie et al. [25] and Ndu [26], as well as those outside Nigeria by Chaoui *et al*. [27] and Fakhoury and Nawas [28]. The lower prevalence of Gram-negative bacteria on door handles suggested that they were associated with fecal contamination [2]. This could mean hand hygiene was better in these settings, but their presence still showed sanitation lapses. The bacteria found on door handles could spread disease, as shown in earlier research [29].

In this study, high levels of bacteria were found on hospital and community door handles (Table 3). The study found more contamination in the community than in the hospital. Up to 100% of community door handles were contaminated (Table 3). Up to 83.33% of hospital door handles were contaminated (Table 3). The highest contamination was on toilet door handles. This matched findings from other Nigerian studies [30, 31] and studies outside Nigeria [32, 33]. Toilet door handles had more bacteria because of the high likelihood that people do not wash their hands well after using the toilet. Poor hand hygiene and infrequent cleaning increase the risk of spreading germs. Better awareness and cleaning policies are needed, especially in high-contact areas. The higher contamination in the community compared to the hospital in this study might be because hospitals are cleaned more often. Yet, bacteria can survive on surfaces for long times [2], which makes these organisms still contribute to the burden of contamination despite routine cleaning. The high bacterial contamination rates seen on door handles in this study is a serious concern for public health since these contaminated door handles can spread infections in hospitals and communities [1, 34].

The resistance of bacteria to antibiotics was also studied (Tables 4 to 7). Gram-negative bacteria like *E. coli*, *K. aerogenes*, *K. pneumoniae*, and *P. aeruginosa* on door handles showed high resistance to antibiotics. They were 100% resistant to drugs such as ampicillin, cefuroxime, ceftriaxone, and cefoxitin. However, these bacteria were fully sensitive to gentamicin and fluoroquinolones like ciprofloxacin and levofloxacin. Most Gram-positive


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bacteria showed resistance to the beta-lactam antibiotics, but they were fully sensitive to ciprofloxacin, levofloxacin, and gentamicin. They also showed varied resistance to other antibiotics such as azithromycin and erythromycin.

The results of this study indicated that many multidrug-resistant bacteria were present on door handles (Tables 8 to 11), making it harder to treat infections caused by them. Shapiro-Wilk's test showed that the prevalence data of multidrug-resistant bacteria from hospital and community door handles were normally distributed ($p > 0.05$). Levene's test indicated that the data had equal variance ($p > 0.05$). The student's t-test showed no significant difference ($p > 0.05$) between the mean prevalence of multidrug-resistant bacteria on hospital door handles and community door handles. Some studies in Nigeria found that Gram-negative bacteria were resistant to many antibiotics. These studies included those by Tsaku*et al*. [35] and Odigie *et al*. [25]. The current study showed similar results. Many isolates of *E. coli*, *K. aerogenes*, *K. pneumoniae*, and *P. aeruginosa* in this study were resistant to multiple drugs. Previous studies also showed these bacteria were common in hospitals and the community and were resistant to many drugs [36, 37]. This study found many Gram-negative bacteria resistant to different antibiotics, but a different study in Nigeria by Edi *et al*. [23] showed lower levels of multidrug resistance. This study also found that bacteria like *S. aureus*, *S. epidermidis*, *E. faecalis*, *B. cereus*, and *B. subtilis* were less multidrug-resistant. This supported earlier research that indicated that most multidrug-resistant bacteria in hospitals and communities were Gram-negative [36, 37]. The increase in multidrug-resistant bacteria could be linked to the misuse and overuse of antibiotics. This misuse could enable bacteria to get resistant genes [36]. Infections with multidrug-resistant bacteria could cause worse health problems, treatment failures, higher costs, and death [25].

All bacterial isolates from door handles in this study had MAR indices above 0.20 (Tables 12 to 15). This showed that these door handles could spread multidrug-resistant bacteria. The MAR index for bacteria like *K. aerogenes*, *K. pneumoniae*, and *P. mirabilis* was 1.00. This meant these bacteria contributed a lot to multidrug resistance in bacteria on door handles in hospitals and communities at Okada. The high MAR indices recorded in this study were similar to what was found by Tsaku*et al*. [35] in Nigeria.

This study found bacteria, especially multidrug-resistant bacteria, on door handles in hospitals and communities at Okada. This situation calls for quick action. Using antimicrobial coatings, such as copper-silver alloys, on surfaces like door handles could reducethe spread [38, 39]. These materials could kill bacteria and reduce contamination, especially in areas where many people touch surfaces. Using automatic doors or foot-operated handles could also help prevent the spread of bacteria. Cleaning high-touch surfaces often with approved disinfectants that kill many bacteria could also be important [22, 40]. The effectiveness of disinfectants could be linked to how many bacteria are present, how strong the disinfectant is, and how often surfaces are cleaned. Using UV light could also kill multidrug-resistant bacteria. It is also important to teach people how to wash their hands properly. Hand stations should be easy to reach at all entrances and exits.


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## CONCLUSION

This study revealed that similar types of bacteria were found contaminating door handles in hospital and community settings, and that bacterial prevalence between hospital and community door handles was not significant. The study also indicated that community door handles had significantly higher contamination rates than hospital handles. It was observed that resistance to beta-lactams was widespread, while fluoroquinolone and aminoglycoside sensitivity were recorded in most isolates. Toilet door handles had the highest rates of multidrug-resistant bacteria, notably in *E. coli* and *K. aerogenes*. This study recommends the implementation of antimicrobial coatings on door handles and better hygiene practices to mitigate public health risks.

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