Comprehensive Analysis of Multidrug-Resistant (MDR), Extensively Drug-Resistant (XDR), and Pandrug-Resistant (PDR) Microbial Contaminants on Nigerian Currency Notes: Implications for Antimicrobial Resistance and Public Health Strategies

Abstract

Aim: This study investigates the microbial contamination and antibiotic resistance patterns on Nigerian currency notes, emphasizing their public health implications. The study aims to assess contamination levels across regions, denominations, and note types while evaluating the resistance profiles of isolated microorganisms.

Methods: A total of 112 currency notes, spanning all eight denominations, were collected from rural (Oyan) and urban (Osogbo) regions in Osun State, Nigeria. Microbial isolation and identification were performed using standard culture techniques, while antibiotic susceptibility was assessed via the Kirby-Bauer disc diffusion method. Data were analyzed using SPSS.

Results: Microbial analysis revealed high contamination rates, with *Klebsiella*sp (35.7% rural, 23.2% urban) and *Staphylococcus aureus* (28.6% rural, 26.8% urban) being the most prevalent bacterial isolates. *Aspergillus*sp was the dominant fungal contaminant, particularly in rural areas. Polymer-based notes exhibited lower contamination compared to paper-based notes. Antibiotic susceptibility tests highlighted alarming multidrug resistance (MDR), with *Staphylococcus aureus* showing high resistance to Penicillins and Cephalosporins. *Pseudomonas aeruginosa* displayed extensive drug resistance (XDR) to multiple antibiotic classes, leaving limited treatment options.

Conclusion: Nigerian currency notes are significant reservoirs of microbial contamination and multidrug-resistant pathogens, posing severe public health risks. The study underscores the need for improved hygiene practices, public awareness campaigns, and a transition to polymer-based notes. Strengthened antibiotic stewardship programs and regulatory measures are essential to combat rising antimicrobial resistance and prevent pathogen dissemination through currency handling.

Keywords: Bacteria, Contamination, Currencies, Disease, Fungi.

Introduction

The widespread use of cash in everyday transactions renders currency notes one of the most frequently handled objects globally. Since the early 1900s, scientific observations have pointed to the potential for currency notes to act as vehicles for pathogen transmission (Yar, 2020). Early studies suggested this risk, and subsequent research has consistently confirmed that viable pathogenic organisms—including viruses, bacteria, and fungi—can be isolated from the surfaces of banknotes, sometimes persisting for extended periods in ambient conditions (Yar, 2020). This contamination poses a public health risk, particularly in regions where cash transactions remain predominant and awareness of currency hygiene is limited.

A study conducted in Ghana examined the microbial flora and antibiotic activities of bacteria found on paper currency notes in circulation (Yar, 2020). The researchers found a diverse array

of bacterial contaminants, including both pathogenic and non-pathogenic species, highlighting the potential for currency notes to harbor and disseminate harmful microorganisms. Similarly, an investigation into the bacterial contamination of toilet door handles on a university campus in Nigeria revealed the presence of various skin-associated and soil-associated bacteria, suggesting that commonly touched surfaces can act as fomites for the transmission of infectious diseases (Alonge et al., 2018).

Modern banknotes are manufactured from durable materials such as cotton, linen, and additional textile fibers to enhance longevity and resistance to wear. Recognizing the hygienic benefits of alternative materials, many countries have adopted polymer-based currency substrates that demonstrate improved tear resistance, water repellence, and lower contamination rates compared to traditional paper notes (Alemu, 2014; Angelakis et al., 2014). However, both types of banknotes are still prone to microbial contamination due to handling and storage practices, particularly in humid and densely populated regions, such as Nigeria, where cash usage is high and public health policies regarding currency hygiene are not robustly enforced.

In Nigeria, where the use of cash remains widespread due to economic and infrastructure factors, currency notes undergo extensive circulation and frequent handling in diverse conditions, often without adequate sanitation. Studies have shown that Naira notes circulating in Nigeria are heavily contaminated with various microbial species, including *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Salmonella typhi*, *Vibrio cholera*, *Asp ergillusniger*, and *Blastomyces dermatitidis* (Orababa et al., 2021). *Staphylococcus aureus* has been identified as the most predominant bacterial contaminant of Nigerian currency notes (Musa et al., 2020). Ofoedu et al. (2021) reported that over 80% of notes sampled in Owerri, Nigeria, were contaminated with bacteria, and high levels of fecal coliforms were associated with handling practices among meat and fish vendors. These findings highlight that poor sanitary habits, such as sneezing or coughing onto hands before handling money, inadequate handwashing, and storage of currency in unsanitary conditions, significantly contribute to contamination (Yar, 2020; Ofoedu et al., 2021). Also, notably, a high degree of resistance to commonly used antibiotics has been observed among the bacterial pathogens isolated from Naira notes, posing a significant public health challenge (Orababa et al., 2021).

Pathogens isolated from currency notes are often capable of causing infections, particularly in individuals with compromised immunity. Studies in nearby West African countries, as well as in various Nigerian states, corroborate these findings. For example, studies by Ngwai (2011) and Yar (2020) demonstrate that currency notes, particularly in street market environments, are frequently contaminated with bacteria associated with gastrointestinal and respiratory infections. Handling practices, such as the common habit of wetting fingers with saliva to count money, have been identified as additional routes of contamination in these studies. In particular, a study by Oyelami et al. (2020) found *Staphylococcus* and *Klebsiella sp* as common contaminants on Nigerian notes, with increased contamination on notes from rural areas where educational outreach on hygiene is often limited.

Despite advancements in currency materials, which may reduce microbial load, notes continue to act as fomites for pathogen transmission in both urban and rural Nigerian communities. This study, therefore, aims to address key knowledge gaps by assessing the prevalence and types of pathogens contaminating Nigerian currency notes, evaluating contamination levels across denominations and between paper and polymer notes, and assessing antibiotic resistance patterns in isolated strains. Such information is crucial for guiding public health recommendations on currency handling and advocating for policies that mitigate the risks associated with cash transactions.

Methodology

Study Design,Sites and Population(not needed)

This experimental study, conducted in Osun State, Nigeria, aimed to investigate the bacterial contamination of Nigerian currency notes collected fromdifferent banks~~branches~~. Samples were gathered from both ~~a~~ local settlement (Oyan-Odo Otin/Ila local government) and an urban area (Osogbo town), targeting the general public in each location. The study included all eight denominations of the Nigerian naira notes (N1000, N500, N200, N100, N50, N20, N10, and N5), with seven notes from each denomination collected from both locations, totaling 56 samples per location and 112 samples in total. The process involved preparing the samples for microbial determinations, inoculation, incubation, and identification of different bacterial isolates.

Sample Collection

Currency samples were collected from various cash handlers, who provided informed consent to ensure voluntary participation and compliance with ethical standards, and were then transported in sterile ziplock bags to the laboratory for analysis. Currency notes were collected at hourly interval from persons walking into a bank location for cash deposit. Seven (7) samples were collected daily, sample size was achieved in eight working days (Ofoedu*et al*., 2021).

Processing of Samples

The empty ziploc bags were cultured as a control. Each denomination was soaked in sterile peptone water for about 50 min with regular shaking to dislodge the microbial cells into suspension. The suspensions were subsequently analysed for total bacteria by serial diluting (10 fold) and plating 1 ml of each suspension on nutrient agar using pour plate method (Collins 1967). The plates were incubated at 37°C for 24 h for bacteria growth. Also, 1ml of the suspension were inoculated into Sabouroid Dextrose Agar (SDA) with antibiotics (with chloramphenicol, gentamicin, and tetracycline core) and incubated at room temperatures and at 37°C for 48 hours to isolate fungal agents.

Isolation and Identification of Bacterial and Fungal isolates

Discrete colonies were subcultured on chocolate agar, MacConkey and Mannitol salt agar to obtain pure cultures which were stored at 4^0C and used subsequently for microscopic characterization and biochemical analyses (Cheesebrough, 2006). Fungal isolates were characterized and identified according to the method of Fawole and Oso (2001).

Determination of Antibiotics Susceptibility TestBacterial isolates

Antibiotics susceptibility patterns of bacteria isolates was determined using modified Kirby-Bauer disc diffusion technique on Mueller Hinton agar plates according to the Clinical and Laboratory Standards Institute (CLSI) guidelines (2020). The antibiotics used on Gram-Positive isolates included: Ampiclox (25/?µg), Erythromycin (15 µg), Cotrimoxazole (25 µg), Ciprofloxacin (10 µg), Gentamicin (10 µg), Zinacef/Cefuroxime (30 µg), Rocephin/Ceftriaxone (30 µg), Augmentin (30 µg). While for Gram-Negative antibiotics disc used included: Chloramphenicol (30 µg), Streptomycin (10 µg), Cotrimoxazole (25 µg), Ciprofloxacin (5 µg), Gentamicin (10 µg), Zinacef/Cefuroxime (30 µg), Rocephin/Ceftriaxone (30 µg), Augmentin(30 µg). Weprepared a turbid suspension of the isolates in sterile saline, matching the 0.5 McFarland standard was prepared. Using a sterile swab, we dipped it into the suspension, removed excess liquid, and the suspension was streakedthe Mueller-Hinton agar evenly. After drying for a few minutes, we placed antibiotic discs on the agar using sterile forceps. This was done for all isolates, and the plates were incubated at 37°C for 18-24 hours. Results were interpreted as susceptible, intermediate, or resistant based on CLSI guidelines (2020).

Data Analysis

Statistical analysis was carried out using SPSS-Statistical package.

Results

All samples collected were studied independently ~~for~~ from both locations to be able to ascertain the degree of contamination when compared. Table 1 shows the comparison between rural (Oyan) and urban (Osogbo) areas shows that *Klebsiella sp* and *Staphylococcus aureus* were the most common bacterial isolates in both locations, with *Klebsiella sp* being more prevalent in the rural area (35.7% vs. 23.2%) and *Proteus mirabilis* showing a significant difference in prevalence between the locations (8.9% in rural vs. 3.6% in urban). There was a significant difference in bacterial prevalence between the locations ($p = 0.024$). In terms of fungal isolates, *Aspergillus sp* was more common in rural areas (37.5% vs. 16.1% in urban). There was a significant difference in fungal prevalence between the locations ($p = 0.014$) (Table 1).

Table 1: Bacterial and fungal isolates compared between both locations

Comment [D1]: Rephrase the heading

Comment [D2]: Remove brand names for the antibiotics.

Comment [D3]: Please remove the word 'we' and rephrase this sentence.

Comment [D4]: Rewrite this paragraph in simple sentences.

Comment [D5]: Rephrase the heading

Variable	Rural (Oyan) Organism n(%)	Urban (Osogbo) Organism n(%)	Df	X^2	p-value
Bacterial Isolate					
Escherichiacoli	2(3.6)	2(3.6)			
Klebisellaspp	20(35.7)	13(23.2)			
Proteus mirablis	5(8.9)	2(3.6)	5	14.508	0.024*
Pseudomonas aeruginosa	0	1(1.8)			
Staphylococus aureus	16(28.6)	15(26.8)			
NBG	13(23.2)	23(41.1)			
Fungal Isolates					
Aspergillus sp	21(37.5)	9(16.1)			
Candida spp.	8(14.3)	6(10.7)	2	12.444	0.014*
NFG	27(44.2)	41(73.2)			

Source: (Research result 2021)

Comment [D6]: Write full name NBG in the table or mention in the paragraph.

Comment [D7]: Write full name NFG in the table or mention in the paragraph.

Comment [D8]: Not required.

It is observed in figure 1 that the rural area (Oyan) maintained higher percentages in currency contamination than the urban site (Osogbo). The #100 note recorded 85.7% for both locations (Figure 1).

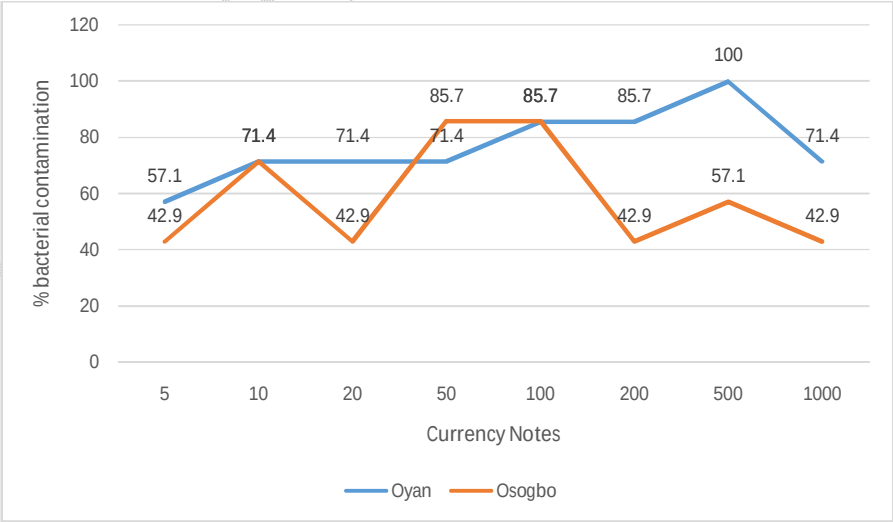

Figure 1: Microbial occurrence in both locations.

Comment [D9]: Rewrite the heading as 'Prevalence of currency contamination in Oyan and Osogbo.

The distribution of bacterial isolates across various Nigerian currency denominations shows that *Klebsiella sp* was the most frequent bacterium, particularly on N10, N200, and N500 notes (42.9% each), while *Escherichia coli* was found on N50, N500, and N1000 notes at lower frequencies (7.1%-14.3%), and *Staphylococcus aureus* was most prevalent on N100 notes (57.1%), with no-bacterial growth (NBG) more common on lower-value notes like N5 and N10 (Table 2).

Table 2: Occurrence of Bacterial Isolates on Nigerian Currency Notes

Comment [D10]: Mention 'on different currency dominations' in the heading and rephrase.

Bacterial Isolate	**Variable (Notes)**							
	5	**10**	**20**	**50**	**100**	**200**	**500**	**1000**
Escherichiacoli	0	0	0	1(7.1)	0	0	2(14.3)	1(7.1)
Klebisellasp	2(14.3)	6(42.9)	3(21.4)	5(35.7)	4(28.6)	5(35.7)	6(42.9)	2(14.3)
Proteus mirablis	2(14.3)	0	0	2(14.3)	0	1(7.1)	1(7.1)	1(7.1)
Pseudomonas aeruginosa	0	0	1(7.1)	0	0	0	0	0
Staphylococus aureus	3(21.4)	4(28.6)	4(28.6)	3(21.4)	8(57.1)	3(21.4)	2(14.3)	4(28.6)
NBG	7(50.0)	4(28.6)	6(42.9)	3(21.4)	2(14.3)	5(35.7)	3(21.4)	6(42.9)

Source: (Research result 2021)

Comment [D11]: Not required.

The fungal isolates on Nigerian currency notes show that *Aspergillus* sp was most common on N100 notes (50.0%) and N50 notes (42.9%), while *Candida spp.* was less frequent but more present on lower denominations such as N5 and N20, and no-fungal growth (NFG) was highest on N1000 notes (85.7%) and N10 notes (77.5%) (Table 3).

Comment [D12]: Last line about NFG is not needed. This result finding doesn't seem significant.

Table 3: Occurrence of Fungal Isolates on Nigerian Currency Notes

Comment [D13]: Headings need to be rephrased.

Fungal Isolates	**Variable (Notes)**							
	5	**10**	**20**	**50**	**100**	**200**	**500**	**1000**
Aspergilliussp	2(14.3)	3(21.4)	2(14.3)	6(42.9)	7(50.0)	4(28.6)	5(35.7)	1(7.1)
Candida sp	3(21.4)	0	2(14.3)	1(7.1)	3(21.4)	2(14.3)	2(14.3)	1(7.1)
NFG	9(64.3)	11(77.5)	10(71.4)	7(50.0)	4(28.6)	8(57.1)	7(50.0)	12(85.7)

Source: (Research result 2021)

Comment [D14]: Not required.

The antibiotic resistance patterns of *Staphylococcus aureus* show high resistance to Ampiclox (83.3%) and Zinacef/Cefuroxime (82.9%), with moderate resistance to Augmentin (78.9%) and Gentamicin (47.4%), and low resistance to Ciprofloxacin (3.9%) and Erythromycin (8.8%), indicating these may remain effective treatment options (Table 4). *Staphylococcus aureus* shows widespread MDR characteristics, with high resistance to Penicillins (Ampiclox, 83.3%; Augmentin, 78.9%) and Cephalosporins (Cefuroxime, 82.9%; Ceftriaxone, 38.5%). Moderate resistance to Sulfonamides (Cotrimoxazole, 38.2%) and Aminoglycosides (Gentamicin, 47.4%) further supports the classification of MDR. However, resistance to Macrolides (Erythromycin, 8.8%) and Fluoroquinolones (Ciprofloxacin, 3.9%) remains low, which means *Staphylococcus aureus* does not meet XDR criteria as these classes remain effective for treatment (Table 4).

Table 4: Percentage distribution of antibiotic resistance patterns in Gram-positive organism

Antibiotics	**Antibiotic Classes**	*Staphylococus aureus* (n=31)
Ampiclox	Penicillin	83.3
Erythromycin	Macrolide	8.8
Cotrimoxazole	Sulfonamide	38.2
Ciprofloxacin	Fluoroquinolone	3.9
Gentamicin	Aminoglycoside	47.4
Zinacef/Cefuroxime	Cephalosporin	82.9
Rocephin/Ceftriaxone	Cephalosporin	38.5
Augmentin	Penicillin	78.9

Source: (Research result 2021)

Comment [D15]: Remove patterns

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For Gram-negative organisms, *Pseudomonas aeruginosa* exhibited an alarming XDR profile, with 100% resistance to Amphenicols (Chloramphenicol), Cephalosporins (Cefuroxime, Ceftriaxone), Fluoroquinolones (Ciprofloxacin), and Aminoglycosides (Gentamicin). The only observed susceptibility is to Streptomycin and Penicillins (Augmentin), leaving very limited treatment options. Other Gram-negative organisms, including *Klebsiella*sp, *Proteus mirabilis*, and *Escherichia coli*, demonstrated clear MDR characteristics. *Klebsiella*sp showed high resistance to Amphenicols (89.2%) and Cephalosporins (Cefuroxime, 77.1%; Ceftriaxone, 82.9%), with moderate resistance to Aminoglycosides (Gentamicin, 73.3%) and Fluoroquinolones (Ciprofloxacin, 48.3%). *Proteus mirabilis* similarly exhibited MDR, with resistance to Amphenicols (93.1%), Fluoroquinolones (71.2%), and Aminoglycosides (59.3%). While *Escherichia coli* demonstrated MDR, with resistance to Cephalosporins (Cefuroxime, 78.4%; Ceftriaxone, 88.6%) and Amphenicols (73.7%), susceptibility to Penicillins and other classes indicates it does not meet XDR criteria.

Table 4: Percentage distribution of antibiotic resistance patterns in Gram-Negative organisms

Comment [D17]: Remove patterns

Antibiotics	Antibiotic Classes	*Escherichia coli* (n=4)	*Proteus mirablis* (n=7)	*Klebsiella sp* (n=33)	*Pseudomonas aeruginosa* (n=1)
Chloramphenicol	Amphenicol	73.7	93.1	89.2	100
Streptomycin	Aminoglycoside	33.2	25	40.4	0
Cotrimoxazole	Sulfonamide	45.5	63.2	22.7	0
Ciprofloxacin	Fluoroquinolone	53.3	71.2	48.3	100
Gentamicin	Aminoglycoside	81.2	59.3	73.3	100
Zinacef/Cefuroxime	Cephalosporin	78.4	65	77.1	100
Rocephin/Ceftriaxone	Cephalosporin	88.6	73.1	82.9	100
Augmentin	Penicillin	48.4	52.3	49.1	0

Source: (Research result 2021)

Comment [D18]: Remove this column, not required

Comment [D19]: Not required. Please remove.

Discussion

This study highlights significant differences in microbial contamination and antibiotic resistance between rural and urban environments, emphasizing the impact of environmental, socioeconomic, and hygiene factors. *Klebsiella sp* was the most prevalent organism in the study. Similarly, a study by Ofoedu et al. (2021) showed that about 81.7% of currency notes were contaminated with either *Escherichia coli*, *Klebsiella sp* or *Staphylococcus* sp in varying degrees. The higher prevalence of *Klebsiella*sp in rural areas (35.7% vs. 23.2% in urban areas) reflects poorer sanitation, limited access to clean water, and unhygienic handling of currency in rural settings. Cash-based transactions in open markets increase direct contact with contaminated surfaces, facilitating microbial transfer. Similarly, the dominance of *Aspergillus*sp in rural areas (37.5% vs. 16.1%) can be attributed to the agricultural nature of these settings, which expose currency to fungal spores present in dust and soil. These observations are consistent with findings from Ofoedu et al. (2021), who reported higher microbial loads in rural areas due to environmental conditions and socioeconomic disparities. These results/observations show the behavioral attitude to hygiene of rural residents (Edem et al., 2021).

The type and denomination of currency also influenced contamination levels. Higher-value notes (e.g., ₦100, ₦200, ₦500) showed greater bacterial and fungal contamination compared to lower denominations like N5 and N10. This is consistent with a study by Kiyevhobu et al (2023) ₦100 and ₦ 200 notes had the highest number of organisms present. Similarly, a study by Ofoedu et al. (2021) showed that ₦100 currency note appeared the most contaminated whereas ₦5 note appeared the least contaminated. This trend is likely due to the longer circulation cycles and frequent handling of higher-value notes, which increases their exposure to diverse microbial sources. *Klebsiella*sp was the most prevalent bacterium on higher denominations, likely due to its ability to persist on surfaces, while lower denominations were more likely to exhibit no bacterial growth (NBG). The frequent use of polymer notes (e.g., N5, N10) in smaller transactions may contribute to lower contamination, as polymer surfaces are less porous and

easier to clean than paper notes (Prasai et al., 2010). Similarly, *Aspergillus*sp was most common on paper notes (N100), aligning with a study by Abdullahi et al. (2023) that reported ₦100 as the note with the most contamination rate and *Aspergillus niger* as the most prevalent fungi in the study. The reason for this observation may be due to poor water quality and high humidity in rural areas, which facilitate the growth of fungi like *Aspergillus* sp. These fungi can contaminate Naira notes through contact with hands and surfaces that have been exposed to contaminated water, as water sources often serve as reservoirs for fungal spores, including *Aspergillus*sp(Mbong et al., 2023).

The sampled naira notes were found to be highly contaminated with resistant bacterial isolates, particularly those exhibiting multidrug resistance (MDR) and extensively drug resistance (XDR). This study underscores the alarming prevalence of antibiotic resistance on naira notes, posing a significant public health challenge. Resistance is categorized into three key types: MDR (resistance to at least one antibiotic in three or more classes), XDR (resistance to all but two or fewer antibiotic classes), and pandrug resistance (PDR, resistance to all antibiotics across all classes) (Akinjogunla et al., 2024; Almakrami et al., 2024). *Staphylococcus aureus* demonstrated high levels of MDR in this study, with pronounced resistance to commonly used antibiotics such as Penicillins (Ampiclox, 83.3%; Augmentin, 78.9%) and Cephalosporins (Cefuroxime, 82.9%; Ceftriaxone, 38.5%). These findings suggest the diminished efficacy of these first-line antibiotics in treating S. aureus infections. Despite this, low resistance rates were observed for Macrolides (Erythromycin, 8.8%) and Fluoroquinolones (Ciprofloxacin, 3.9%), suggesting their continued utility as alternative treatments. Similarly, a study carried out in Kaduna, the north-western region of Nigeria, by Obajuluwa et al. (2024) reported 60.8%, 17.7% and 1.3% of bacterial isolates to be MDR, XDR and PDR, respectively. The situation for Gram-negative bacteria is particularly concerning, with *Pseudomonas aeruginosa* exhibiting an XDR profile. The pathogen displayed 100% resistance to Cephalosporins, Amphenicols, Fluoroquinolones, and Aminoglycosides. These resistance levels reflect the organism's robust adaptive mechanisms, including efflux pumps, enzymatic breakdown of antibiotics, and biofilm formation, which collectively render many therapeutic options ineffective. The limited susceptibility observed to Streptomycin and Penicillins (Augmentin) highlights the critical need for alternative treatment strategies for infections caused by this bacterium. Other Gram-negative organisms, including *Klebsiella* sp, *Proteus mirabilis, and Escherichia coli*, demonstrated consistent MDR profiles, with significant resistance to Cephalosporins and Amphenicols. This widespread resistance likely stems from the indiscriminate use of antibiotics in healthcare and agricultural sectors, which creates selective pressure favoring resistant strains. These results align with patterns observed by Otaigbe and Elikwu (2023), which discussed how inappropriate antibiotic use driven by weak regulatory frameworks contributes significantly to antimicrobial resistance in low- and middle-income countries (LMICs). Furthermore, substandard and counterfeit antibiotics, common in resource-constrained settings, exacerbate resistance by delivering subtherapeutic doses that fail to eradicate pathogens (McManus and Naughton, 2020; Zabala et al., 2022). These results underscore the antibiotic resistance patterns observed in this study,

suggesting that currency notes may serve as vectors for transmitting resistant bacteria. This finding emphasizes the urgent need for stringent hygiene practices and regular disinfection of frequently handled objects to curb the spread of resistant pathogens. Additionally, comprehensive antibiotic stewardship programs are essential to regulate antimicrobial use across various sectors. Strengthened policies should aim to limit the misuse of critical antibiotics, promote the development of novel treatments, and raise public awareness about the risks of resistance. Without immediate action, the unchecked rise of antibiotic resistance could compromise the effectiveness of existing therapies, posing severe threats to global public health.

Conclusions and Public Health Implications

This study highlights Nigerian currency notes, particularly lower denominations and paper-based notes, as significant reservoirs of bacterial and fungal contamination, including multidrug-resistant pathogens. The findings reveal stark differences in contamination patterns between rural and urban areas, influenced by environmental, socioeconomic, and hygiene-related factors. The high prevalence of *Klebsiella*sp and *Staphylococcus aureus* with multidrug resistance on naira notes underscores the public health risks associated with their frequent handling, especially in areas with poor sanitation. To address these risks, the study emphasizes the need for improved hygiene practices, such as regular handwashing after handling currency, alongside the disinfection of frequently used items. Transitioning to durable, polymer-based notes could further reduce contamination risks due to their less porous and easier-to-clean surfaces. Additionally, robust antibiotic stewardship programs and stronger regulatory measures to curb the misuse of antibiotics and tackle counterfeit drugs are essential to combat the escalating threat of antimicrobial resistance. Immediate and coordinated efforts are critical to safeguarding public health and mitigating the spread of resistant pathogens.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

Not applicable

Reference

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