
REVIEWS

A Systematic Review on the Microbial and Parasitic Contamination of Naira Notes

Oluwatosin Q Orababa¹, Jeffrey D Soriwei², Olabisi O Anibaba¹, Margaret T Arowolo¹ & Munirat O Olayiwola¹

¹ University of Lagos, Nigeria

² University of Bedfordshire, United Kingdom

Abstract

Currency notes are essential components of our day-to-day activities as they play great roles in our transactions. However, they have continued to serve as media of exchange of pathogenic microorganisms and parasites. The naira note has been greatly mishandled by Nigerians over the years, and this has led to the circulation of dirty, contaminated, and mutilated notes. This systematic review was carried-out to provide an up-to-date summary of the public health risks associated with contaminated naira notes. This systematic review was conducted and reported in conformation with the Preferred Reporting Items for Systematic Reviews and Meta-analyses Protocols 2015 (PRISMA-P) statements and checklists. Databases (PubMed, AJOL, and Google Scholar) were searched for published articles on the microbial and parasitic contamination of naira notes. A total of 26 studies were analyzed for this review. The studies majorly reported high microbial contamination in lower denomination naira notes (N10 and N100). The pathogens from naira notes reported in the studies include *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Salmonella typhi*, *Vibrio cholera*, *Aspergillus niger*, and *Blastomyces dermatitidis*. Eggs and cysts of *Ascaris lumbricoides* eggs, hookworm, lice of the genus *Pediculus humanus corporis*, *Enterobius vermicularis*, flagellates, and *Entamoeba histolytica* were reported in the studies. A high degree of resistance of bacterial pathogens from naira notes to commonly used antibiotics was also observed in this study. Currency notes serve as fomites for the transfer of pathogenic microorganisms and parasites. Most of the organisms reported in this study have been implicated in human infections including food-borne infections, urinary tract infections, and respiratory infections. Good hygiene and proper education of Nigerians on the public health risks posed by mishandling naira notes should be done to reduce the spread of pathogens and parasites through naira notes.

Keywords: Bacteria, Fungi, Parasites, Naira notes, Public health, Antibiotic resistance.

Introduction

The Nigerian paper currency (naira note) whose denomination includes N5, N10, N20, N50, N100, N200, N500, and N1000 is used as legal tender for various purposes, depending on the handler of the note(s). It could be used for settling debts, paying bills, exchange of goods and services, and sometimes given as a gift. Money is transferred from person to person (either young or old), although paper currency contains a disinfectant that inhibits the growth of microorganisms during its production. Studies have shown that money serves as a fomite for transferring various types of pathogenic microorganisms such as *Escherichia coli*, *Salmonella typhi*, *Staphylococcus aureus*, *Klebsiella*, *Pseudomonas*, *Aerobacter*, and *Streptococcus faecalis* amongst all other pathogenic microorganisms [1, 2, 3]. Some of these pathogens are known to be important reservoirs for multidrug resistance gene, hence transferring them to other pathogens.

Due to the ubiquitous nature of microorganisms, the Nigerian naira note becomes contaminated through several routes. The mishandling and abuse of the naira note has been implicated as one of the routes in which paper currency is contaminated. Attitudes such as coughing and sneezing during handling, usage of saliva or unclean water in the counting or handling of the paper currency with soiled hands from the toilet, and spraying of money during ceremonies which finds its way to the ground and is eventually stepped upon with unclean foot-wear are some of the routes in which naira notes are contaminated with microorganisms and parasites [4]. Other routes of contamination include the atmosphere, during storage [5, 6], wounds, and counting machines [7].

The continuous contamination of the paper currency is a public health concern as pathogenic microorganisms are being transferred from person to person without the knowledge of the handler, which leads to illness and has resulted in high mortality and morbidity [8]. Traders in

Nigeria, especially the uneducated ones, keep naira notes in awkward areas such as private parts, armpits, socks, and shoes. Some of these places contain opportunistic pathogens that can be transferred from one person to another during transactions. Eggs, cysts, and trophozoites of parasites, can also be transferred through these activities as a result of poor hand hygiene. Pathogens and parasites are known to persist on inanimate surfaces for long periods, hence making them stand a good chance to cause infections such as food poisoning, and urinary tract infections especially in immunocompromised individuals, through transmission [9].

Many epidemiological studies have been conducted in different parts of Nigeria, reporting the bacterial, fungal, and/or parasitic contamination of naira. However, to the best of our knowledge, there is currently no systematic review that comprehensively and holistically analyzes the public health risks associated with microbial and parasitic contamination of naira notes in Nigeria. This study aims to review the extent of naira contamination in different parts of Nigeria. Data from studies such as this are essential in the development of public health policies that will help reduce the spread of pathogens and parasites through naira notes.

Methodology

This systematic review was conducted and reported in conformation with the Preferred Reporting Items for Systematic Reviews and Meta-analyses Protocols 2015 (PRISMA-P) statements and checklists [10].

Search method

Databases such as MEDLINE (via PubMed), Google scholar, and African Journals Online (AJOL) were searched for eligible articles for this study. A combination of words such as “Naira notes”, “naira notes”, “microbial contamination”, “Parasitic contamination”, “Public health risks”, “Nigerian paper currency” was used during the search. A supplementary literature search was also carried out using the reference list of the eligible articles. The literature search was carried out independently by two authors (O. Q. O and J. D. S). The last search date was 28/07/2020.

Eligibility criteria (inclusion and exclusion criteria)

Nigerian studies that reported the prevalence of at least one of bacteria, fungi, and parasites on naira paper currency were considered for inclusion. Studies that also reported antibiotic susceptibility profiles of bacteria from naira notes were included. Studies that considered just one organism were excluded. Studies with reports of microbial contamination of currencies other than naira were also excluded from this study. Studies that analyzed less than four different naira denominations were excluded. Lastly, samples with no definite number of sample sizes were excluded from this review.

Data extraction

A data extraction form was created for this study. Two reviewers (M.O.O. and O.O.A) independently extracted data from the eligible studies for review. They resolved all disagreements through discussion. A third reviewer (M.T.A) also confirmed the extracted data in an attempt to minimize bias. The following data were extracted from the eligible studies; first author and year of publication, country zone, the infectious agent of interest, sample size, denomination, and antimicrobial susceptibility testing.

Scope of study

The scope of this systematic review is to determine the trend and public health risk associated with the microbial and parasitic contamination of naira notes. This study also analyzed the antimicrobial resistance patterns of bacterial isolates from naira notes.

Results

Study characteristics

The database search identified a total of 612 articles, amongst which 18 articles were selected for this study. An additional 8 articles were added to the study through the reference list search. A total of 24 articles were analyzed for this systematic review. The screening procedure for the included studies is shown in figure 1. Only cross-sectional studies were selected for this review. Seven of the studies were conducted in the South-West [3, 11, 12, 13, 14, 15, 16], five in North-Central [4, 17, 18, 19, 20], four in South-South [1, 21, 22, 23], three in North-West [2, 8, 24], two from North-East [25, 26] and two from South-East [6, 27]. One of the studies combined isolates collected from North-Central and North-East parts of Nigeria [5].

Ten of the studies reported only bacterial isolates [3, 8, 16, 17, 19, 20, 22, 24, 25, 26], one of the studies reported only fungal isolates [5] and four of the studies reported only parasites [6, 14, 15, 18]. Six of the studies reported combined bacterial and fungal isolates [2, 12, 13, 21, 23, 27], and two of the studies reported combined bacteria isolates and parasites [4, 11]. One of the studies reported combined bacteria, fungi, and parasites [1]. Antimicrobial susceptibility testing of bacterial isolates was reported in 8 of the studies included [8, 11, 12, 16, 17, 19, 21, 22]. The characteristics of the included studies are shown in table 1.

Studies that reported bacteria isolates from naira

There were nine (9) studies that reported bacteria isolates from naira notes. The first was a study conducted in the South-west. Samples were randomly collected from different occupational groups of people, namely: market people, artisans, office workers, bankers, students, commuters, farmers, and butchers. This study isolated *Escherichia coli* O157: H7 (56%), *Salmonella typhi* (60%), *Pseudomonas aeruginosa* (178%), and *Staphylococcus aureus* (198%) in ascending order [3]. The second study was a study conducted in the North-West. Samples were collected from three hospitals and a

school environment between January 2016 to January 2018. The study's findings revealed a contamination rate of 84.7% in naira notes with potentially pathogenic bacteria. The rate of bacterial contamination of naira notes circulating in hospitals (87.5%) was slightly higher than that of non-hospital environments (82%). *S. aureus*, *S. epidermidis*, *E. coli*, *Bacillus species*, *Streptococcus species*, *Proteus species*, *Klebsiella spp*, *Salmonella spp*, and *P. aeruginosa* were the most frequent isolated bacteria. A comparison of bacteria type

and frequency of occurrence of isolates from the hospital and nonhospital currency notes showed a significant difference ($p < 0.005$) with *S. epidermidis* (38% Vs 32.5%), *P. aeruginosa* (30% Vs 16%), *Bacillus spp.* (26.5% Vs 12.5%), *E. coli* (25% Vs 15%), *Salmonella spp.* (14% Vs 24%) and *Acinetobacter spp.* (5% Vs 0%) respectively [8].

Figure 1. Flow chart of the study selection procedure

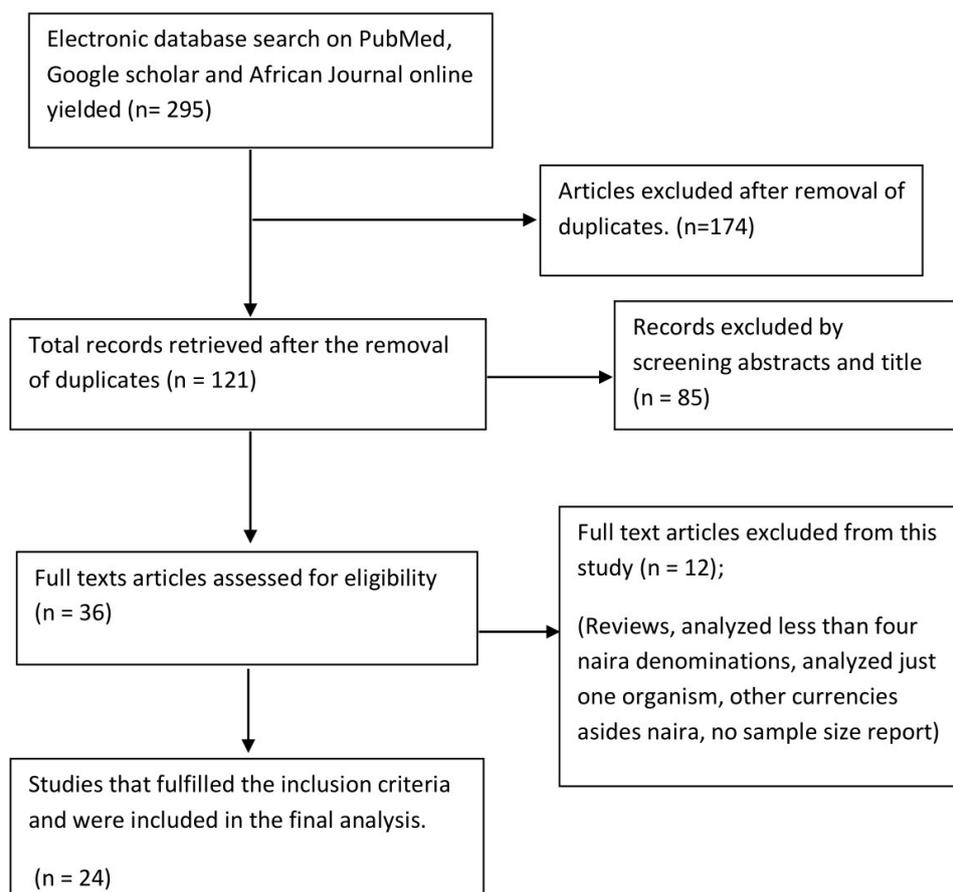


Table 1. Characteristics of studies

First author and year	Study design	Region	Microbe of interest	Denomination analyzed	Sample size	Antimicrobial susceptibility testing
Adegoke (2019)	Cross-sectional study	Southwest	Parasites Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	160	Yes
Ademokoya (2018)	Cross-sectional study	Southwest	Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	40	None
Ajobiewe (2012)	Cross-sectional study	Northcentral and Northeast	Fungi	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	200	None
Aminu (2018)	Cross-sectional study	Northwest	Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	400	Yes
Ayandele (2011)	Cross-sectional study	Southwest	Bacteria, fungi	₦5, ₦10, ₦20, ₦50.	16	Yes
Kawo (2009)	Cross-sectional study	Northwest	Bacteria, fungi	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500.	140	None
Enerijiofi (2016)	Cross-sectional study	South-South	Bacteria Fungi	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	224	Yes
Matur (2010)	Cross-sectional study	North central	Parasites Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	200	None
Malaifa (2011)	Cross-sectional study	North central	Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	160	Yes
Mbata (2016)	Cross-sectional study	South-South	Bacteria Fungi Parasites	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	48	None
Musa (2019)	Cross-sectional study	Northwest	Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	80	None
Oduleye (2016)	Cross-sectional study	Southwest	Bacteria, Fungi	₦5, ₦10, ₦20, ₦50, ₦100, ₦200	60	None
Okoh (2016)	Cross-sectional study	Southwest	Parasite	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	192	None

Okwa (2016)	Cross-sectional study	Southwest	Parasite	₦5, ₦10, ₦20, ₦50, ₦100	100	None
Oluduro (2014)	Cross-sectional study	Southwest	Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	205	Yes
Ombugadu (2019)	Cross-sectional study	Northcentral	Parasites	₦5, ₦10, ₦20, ₦50	200	None
Uko (2017)	Cross-sectional study	Southsouth	Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	Not stated	Yes
Yakubu (2014)	Cross-sectional study	Southsouth	Bacteria, Fungi	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	40	None
Adamu (2012)	Cross-sectional study	Northeast	Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	160	None
Awe (2010)	Cross-sectional study	Northcentral	Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	8	Yes
Mbajuika (2014)	Cross-sectional study	Southeast	Bacteria Fungi	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500	21	None
Orji (2012)	Cross-sectional study	Southeast	Parasite	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	640	None
Umeh (2007)	Cross-sectional study	Northcentral	Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	59	None
Imarenezor (2018)	Cross-sectional study	Northeast	Bacteria	₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500, ₦1000	40	Yes

The third study was conducted in North-Central between January to June 2011. Samples were randomly collected from different occupational groups: fish sellers, meat sellers, vegetable sellers, food vendors, okada riders, taxi drivers, office workers, students, and beggars. The results of the study revealed the highest prevalence for *Bacillus* species (27.1%), *Streptococcus* species (18.8%), *Staphylococcus* species (5.1%), *Clostridium* species (1.9%), and *E. coli* (1.4%) [17]. The fourth study was conducted in the North- West. Samples were collected from traders in selected markets. Four species of bacteria, *S. aureus*, *Proteus*, *Salmonella*, and *E. coli* were isolated. Of the 67 (83.8%) isolates, the most frequently encountered were *S. aureus* (52.2 %), followed by *E. coli* (31.3 %), *Salmonella* species (11.9 %), and *Proteus* species (4.5 %) [24].

The fifth study was conducted in South-West. Samples were collected randomly from bus passengers, bus conductors, food vendors, markets, students, and staff of Obafemi Awolowo University, Ile-Ife, Nigeria. Thirteen bacterial genera namely *Bacillus*, *Corynebacterium*, *Staphylococcus*, *Lactobacillus*, *Micrococcus*, *Aeromonas*, *Citrobacter*, *Edwardsiella*, *Klebsiella*, *Moraxiella*, *Pseudomonas*, *Enterobacter*, and *Proteus* were isolated with *Bacillus* (64.59%) appearing the most frequent [16]. The sixth study in North-East between July and August 2010. Samples were randomly collected from traders, water vendors, bus conductors, food sellers, students, and civil servants. Of the samples collected, 52.5% had bacterial contamination. The genera of bacteria isolated included *Staphylococcus* sp. (22.5%), *Escherichia coli* (12.5%), *Pseudomonas* sp. (6.25%), *Klebsiella* sp. (5%), *Streptococcus* sp. (3.75%) and *Proteus* sp. (2.5%) [25].

The seventh study was carried out in the North-Central. Samples were collected by exchanging notes from various people with new notes. Volunteers included teachers, mechanics, drivers, bankers, meat sellers, and traders. Eight species of bacteria including *S. aureus*, *E. coli*, *P. mirabilis*, *Klebsiella* sp., *P. aeruginosa*, *Salmonella* sp. *Streptococcus faecalis*, and *B. Subtilis* were isolated. The least prevalent of the bacterial isolates was *Salmonella* (2%), while *S. aureus* was the most prevalent (28%) [19]. The eighth study was conducted in North-Central between March and April 2006. Samples were obtained from students and staff of the University of Agriculture, Makurdi. Of the samples, 89.8% had bacterial contamination. The microorganisms isolated were *E. coli* (80%), *Aerobacter* (59%), *Salmonella* (40.9%), yeast cells (36.4%), *S. faecalis* (31.8%), *S. aureus* (27.3%), and coagulase-negative staphylococci (18.2%) [20].

The ninth study was carried out in South-South. Samples were collected from traders in a market. Nine species of bacteria were isolated in high numbers from the notes most of which were coliforms as well as human pathogens. In composition were *E. coli*, *P. aeruginosa*, *Salmonella* sp. *Shigella* sp. *Vibrio* sp., *S. aureus*, *Klebsiella* sp., *Proteus* sp., and *Bacillus* sp [22]. The tenth study was done in the north-eastern part of

Nigeria. The study analyzed clean, dirty, and mutilated naira notes. Some of the bacterial pathogens isolated included *E. coli*, *S. aureus*, *P. aeruginosa*, *Bacillus* sp., *Salmonella* sp., *Klebsiella* sp., and *Streptococcus* sp. in descending order of prevalence [26].

Studies that reported fungal isolates from naira

Only one of the studies reported fungal isolates alone. This study analyzed currency notes from both the North Central and North-eastern parts of Nigeria. The samples were collected from students, food sellers, market traders, and banks around Maiduguri Metropolis and Federal Capital Territory Abuja. The fungi flora of the various denominations of Nigerian currency notes included *Aspergillus* species and *Blastomyces dermatitidis* [5].

Studies that reported parasites

Four studies reported parasites from naira notes. The first study was conducted in the South-West between November 2014 and January 2015. Samples were randomly collected from consenting individuals divided into students, food vendors, butchers, and petrol station attendants in the Ibadan metropolis. A total of 192 naira notes were obtained, among which 27 (14.0%) were found to be contaminated with parasites. All the clean and polymer notes from this study were found not to be contaminated with parasites. The recovered parasites from the contaminated paper notes included *Enterobius vermicularis* (3.6%), hookworm (3.1%), *A. lumbricoides* (1.6%), and *Stroglyoides stercoralis* (1.0%) [14].

The second study was carried out in the South-West. The samples were obtained from food vendors, beggars, butchers, bus conductors, hawkers, traders, and students in a University environment. The notes were grouped into dirty and dirty/mutilated. Eggs and cysts of parasites contaminated 59% of the naira notes. The dirty notes (64.2%) and the mutilated notes (54.9%) were contaminated. Eggs of *A. lumbricoides* 38.9%, Hookworm 25.4%, *E. vermicularis* 3.38%, *Trichurus trichiura* 10.1%, and cysts of *E. histolytica* 8.4% were recovered [15].

The third study was carried out in the North-central in 2015. Naira notes were obtained from traders, transporters, food vendors, and students of Nasarawa State University, and some commercial banks in Keffi. Among the naira notes analyzed, 40 (20%) were contaminated by cysts and eggs of parasites such as *E. histolytica* 4 (2%), *Giardia lamblia* 4(2%), *A. lumbricoides* 12 (6%), and hook worm ova 20 (10%) [18].

The fourth study was carried out in the South-east between July and December 2010. Samples were collected from food vendors, churches, students, beggars, and banks in Ihiala local government, Anambra state. Out of 640 examined, 400 were paper notes with 110 (27.5%) parasites contaminated on their surface, 240 were polymer notes with 14(5.8%) found contaminated with parasites. Eggs and cysts of the following parasites were recovered; *E. histolytica* (9%), *S* (2%), flagellates

(3.5%), and lice (1.5%). Paper (55.6%) and polymer (12.2%) of the mutilated and very dirty notes were the most contaminated [6].

Studies that reported combined bacteria and fungi isolates.

Six of the studies reported combined bacteria and fungi isolates. The first study was conducted in the South-West. Samples were obtained from many locations and occupational groups in Ogbomoso North Local Government Area in Oyo State, Nigeria. The microorganisms isolated included; *S. aureus*, *S. epidermidis*, *B. subtilis*, *B. megaterium*, *E. aerogenes*, *E. coli*, *P. putida*, and *Aeromonas hydrophila*, *A. niger*, *Fusarium solani* and *Colletotrichum truncatum*, *C. gloeosporoides*, and *Trichoderma reesei* [12].

The second study was conducted in the North-West. Samples were collected from taxi drivers, bus conductors, business operators, traders, beggars, food sellers, and other individuals in Sabon-gari market (Kano metropolis) and Bayero University old campus. The bacteria isolated include the genera of *Bacillus* (27.1%), *Brucella* (1.4%), *Clostridium* (1.9%), *Corynebacterium* (5.5%), *Listeria* (3.9%), *Micrococcus* (2.4%) and *Staphylococcus* (18.8%) while fungi include the genera of *Aspergillus* (16.5%), *Fusarium* (5.1%), *Mucor* (10.6%), *Penicillium* (1.9%) and *Rhizopus* (0.4%) [2].

The third study was conducted for two seasons. The peak of the dry season (December 2013 to August 2014) in the South-South. Samples were collected from various traders and customers in selected markets in Edo State. *E. coli* was the most isolated bacteria with 29.12% and 24.64%, *S. aureus* 16.86% and 21.80%, *Bacillus* sp. 15.33% and 16.13%, *S. epidermidis* 16.09% and 18.95%, *Klebsiella* sp. 12.26% and 9.95% while *Salmonella* sp. was the least with 10.34% and 8.53% for dry and rainy seasons respectively. The fungi isolated were *A. niger* 24.18% and 21.88%, *A. flavus* 19.78% and 19.64%, *Candida albicans* 13.19% and 13.84% *Penicillium* spp 9.89% and 12.05%, *Rhizopus* spp 19.23% and 18.75%, *Fusarium* spp 13.74% and 13.84% for dry and rainy seasons respectively [21].

The fourth study was carried out in the South-West, Samples were collected from students, drivers, meat sellers, and beggars. The bacteria isolated included the genera of *Bacillus*, *Brucella*, *Pseudomonas*, *Escherichia*, *Klebsiella*, *Micrococcus*, and *Staphylococcus* while fungi included the genera of *Aspergillus*, *Fusarium*, *Mucor*, *Penicillium*, and *Rhizopus* [13]. The fifth study was conducted in the South-South. Collection of samples were made from volunteers who included traders, beggars, motor conductors in parks in Benin-City metropolis, students of the University of Benin, and food vendors. *E. coli* had the highest bacterial percentage occurrence of 28.5% followed by *S. aureus* (25.8%), *S. sp.* (16.2%), *Pseudomonas* sp. (18.3%), and *Bacillus* sp. (11.5%). *A. niger* had the highest fungal percentage occurrence of

30.2% followed by *Penicillium* sp (29.5%), *Rhizopus* sp. (26.5%), and *Trichoderma* sp. (13.8%) [23].

The sixth study was carried out in the South-East. The naira notes analyzed were obtained from fish sellers in three markets. Bacterial flora showed seven isolates with percentage occurrences of *S. aureus* 69.91%, *E. coli* (52.39%), *Pseudomonas* spp (33.33%), *Bacillus* spp (66.67%), *Klebsiella* spp (42.86%), *Streptococcus* spp (38.10%), *Salmonella* (52.39%). The occurrence of the fungi isolates were yeasts (76.19%), *Aspergillus* spp (52.38%), *Penicillium* spp (28.57%), and *Rhizopus* (19.05%) [27].

Studies that reported combined bacteria isolates and parasites

Two of the studies reported combined bacteria isolates and parasites. The first study was carried out in the South-West. Naira notes were randomly collected aseptically from various sources in Akure. Parasites eggs/cysts isolated include eggs/cysts of *E. vermicularis* (8.9%), hookworm (4.9%), *E. histolytica* (34.5%), flagellates (5.4%), *Ascaris* sp. (29%), *Strongyloides stercoralis* (2.2%), *Isospora* sp. (3.1%) and *T. trichiura* (12.9%). The bacterial species isolated from the samples examined are *S. aureus* (23.1%), *E. coli* (17.2%), *Pseudomonas* sp (15.8%), *S. epidermidis* (9.9%), *Klebsiella* sp. (9.4%), *Proteus* sp (8.1%), *Salmonella* sp. (8.6%), and *Bacillus* sp. (7.9%) [11].

The second study was carried out between April and May 2008 in the North-Central. The parasites encountered include *A. lumbricoides* eggs (4.5%), hookworm ova (8.5%), lice of the genus *Pediculus humanus corporis* (5.0%), *E. vermicularis* eggs (0.5%), flagellates cysts (1.5%), and *E. histolytica* cysts (12.5%). Bacteria isolated after culture were *Staphylococcus* spp (30.5%), *E. coli* (9.0%), *Klebsiella* spp (6.5%), *Pseudomonas* spp (6.5%) and *Proteus* spp (5.5%) [4].

Studies that reported combined bacteria, fungi, and parasites.

One of the studies reported combined bacteria, fungi, and parasites. The study was carried out in the South-South. Samples were obtained from beggars, bus conductors, market women, students, food vendors, and workers. One-hundred and eighty-eight (188) organisms were isolated and they included *E. coli*, *Klebsiella* sp., *S. aureus* and *Proteus* sp. accounting for 90 (50%), *T. trichiuria*, *A. lumbricoides*, and hookworm accounting for 55 (29.25%) and *Aspergillus* sp., *C. albican* and *Penicillium* sp accounting for 39 (20.74%) [1].

Antibiotic resistance of bacteria isolates from the studies

Aminu and Yahaya [8] reported a high rate of resistance of bacterial isolates from naira notes to ampicillin (83% and 82%), cotrimoxazole (75% and 65%), and amoxicillin clavulanate (59% and 54%) for hospital and non-hospital currency notes respectively. Mailafia *et al.* [17] reported multidrug resistance (MDR) of *Staphylococcus* and *Streptococcus* isolates to all

tested antimicrobial agents, while *Bacillus* species and *E. coli* isolated displayed resistance to ampicillin, streptomycin, gentamicin, and erythromycin. The *Clostridium* species were resistant to all the antibiotics used except erythromycin. Oluduro *et al.* [16] reported that all their isolates were resistant to more than one of the antibiotics. Resistance ranged from 18.18% to 100% in Gram-negative bacteria and 26.6% to 100% in Gram-positive isolates. *Enterobacter* sp. and *Edwardsiella* sp. recovered were resistant to all the antibiotics tested except septrin. According to Awe *et al.* [19], *S. aureus* and *P. mirabilis* showed resistance to all the antibiotics tested while the other bacterial isolates showed resistance to at least three of the antibiotics tested.

Uko *et al.* [22] also reported MDR bacteria from naira notes with *Shigella* sp. and *S. aureus* exhibiting resistance against eight of the antibiotics tested. *Klebsiella* showed resistance to seven antibiotics, whereas *Proteus* sp., *Pseudomonas* sp., *E. coli*, and *Bacillus* sp. were resistant to six of the tested antibiotics, *Salmonella* sp. were resistant against 5 antibiotics. All the bacteria isolated by Ayandele and Adeniyi [12] showed 100% resistance to augmentin, nitrofurantoin, and amoxicillin, 87.5% resistance to tetracycline, chloramphenicol, and streptomycin, and 50% resistance to ceftriazone, cotrimoxazole, and gentamycin. Enerijiofi and Olatunji [21] reported a resistance range of 40% to 86.70%. *S. epidermidis* isolates showed a high resistance pattern to ampicillin, levofloxacin, ciprofloxacin, and chloramphenicol. *E. coli* isolates were resistant against ampicillin, ofloxacin, streptomycin, and septrin. Lastly, Adegoke *et al.* [11] reported multidrug resistance of *S. aureus* to six out of eight antibiotics while *Bacillus* sp showed resistance to four of the antibiotics used. Lastly, Imarenezor *et al.* [26] reported multidrug resistance in *P. aeruginosa* isolates from naira denominations to five out of six antibiotics used, which included augmentin, gentamycin, streptomycin, chloramphenicol, and ampiclox. Their *E. coli*, *Klebsiella* sp., and *Salmonella* sp. isolates showed resistance to three antibiotics.

Discussion

This study has comprehensively analyzed the public health hazards associated with naira notes. Naira notes with lower denominations (₦10 and ₦100 notes) were reported to have the highest percentage contamination rate while higher denominations (₦500 and ₦1000 notes) had the least percentage contamination rate. High contamination of lower denomination currency notes has also been reported in Bangladesh [28].

The most predominant bacteria found on naira denominations include *S. aureus*, *E. coli*, and *B. subtilis* according to the studies in this review. Other common bacteria reported in naira notes include *P. aeruginosa*, *Klebsiella* spp., *Bacillus* spp., *Acinetobacter* sp., *Lactobacillus* sp., *Enterobacter* sp., and *Vibrio cholerae*. Some of these organisms have been reported in currencies from other countries [29, 30]. Environmental and climatic conditions of tropical regions favor the proliferation of many of these bacterial pathogens on

surfaces [31, 32]. The presence of *Staphylococci* is usually indicative of contamination from the skin, mouth, or nose or due to rubbing off from humans, as the organism is a normal flora of the human body. Strains of *Staphylococcus* species including coagulase-negative can cause several diseases [33, 34]. The clinical significance of *S. aureus* in skin infection, urinary tract infection, toxic shock syndrome, and respiratory tract infection have been documented [35]. The isolation of *Bacillus* species from naira notes is in line with the findings of Hadwen *et al.* [36] which reported the presence of *Bacillus* spp. from currency notes. These organisms can produce spores and hence persist in the environments over a long period.

The presence of enteric bacteria such as *E. coli* has been widely accepted as an indicator of fecal contamination which may be attributed to the possibility that many people disregard hand washing after using toilets indicating that paper currencies can act as potential sources of enteric diseases [37]. *E. coli* and *Klebsiella* are typical coliforms whose presence as well as that of *Salmonella*, *Vibrio*, *Shigella*, and *P. aeruginosa* indicates fecal contamination of the naira notes. *P. aeruginosa* is one of the three *Pseudomonas* species involved in human diseases. It has been implicated in eye and skin infections as well as external otitis [38]. *Klebsiella*, *Salmonella*, and *E. coli* are clinically important members of *Enterobacteriaceae*. *Klebsiella* is associated with infections of the urinary tract and wounds [39]. Many species of *Salmonella* are pathogens of man and animals. Naira notes are transferred from person to person without adequate sanitization or disinfection. Hence, they can act as fomites for the transmission of infectious agents.

Other microorganisms with high incidences identified in this review (*Proteus mirabilis*, *Citrobacter freundii*, *Proteus vulgaris*, *Enterobacter aerogenes*, *Aeromonas sobria*, and *Corynebacterium kutscheri*, *Listeria* spp, *Brucella* spp., *Mycobacterium tuberculosis*, *Vibrio cholera*, *Micrococcus* spp, *Corynebacteria* spp) may be implicated in nosocomial infections with possible cross transfer from the hospital environment to the community, and vice versa and are frequently associated with different types of diseases especially in immunocompromised and immunosuppressed patients [40]. The high level of microbial contamination of naira notes is a potential hazard to Nigerians because money is continuously in circulation, hence the possibility of pathogenic bacteria being transmitted as demonstrated by Hardy *et al.* [41]. In Nigeria, cash transactions are used more frequently than credit cards, traveler's cheques, and money orders. Nigerians are known to keep money in places like brassieres, pockets, table covers, and local pots, and these places are inhabited by microorganisms which may have contributed to the high microbial loads observed in the studies.

This review study also shows that Nigerian currency notes are indiscriminately contaminated with a variety of fungi species some of which are pathogens. This review identified the following medically important fungi: *B.*

dermatitidis, *A. niger*, *A. fumigatus*, *Fusarium spp*, *Mucor spp*, *Penicillium spp*, *C. albicans*, *Rhizopus spp*, *Trichoderma reesei*, *Colletotrichum gloeosporoides*, and *Colletotrichum truncatum*. *A. niger* was the most prevalent fungi identified in this review. Some authors [42, 43] had similarly reported such findings.

A. niger is ubiquitous in nature. The organism is a common secondary invader following bacterial otitis [44]. It may also cause pulmonary disease in immunocompromised patients and the production of oxalate crystals in clinical specimens. *A. niger* is less likely to cause human disease than some other *Aspergillus* species, where if a large amount of spore were inhaled, a serious lung disease Aspergillosis can occur. *A. fumigatus* is an ubiquitous fungus with airborne conidia, it is also saprophytic and plays important roles in the geochemical cycling of carbon and nitrogen [45]. Its natural ecological niche is the soil, wherein it survives and grows on organic debris. *F. solani* may also cause a range of invasive mycoses and a range of opportunistic infections in immunocompromised patients [46], the fungal isolates could also produce mycotoxins in food, which is dangerous to human and other animals.

B. dermatitidis is a thermally dimorphic fungus and a probable saprobe of the soil. It specifically inhibits decaying wood materials and is rarely isolated as a natural habitat. The isolation of *B. dermatitidis* from paper currencies can be linked to contact of these currency notes with soil that is rich in organic contents such as plant materials, animal feces, and insect remains. Cutaneous and systemic (disseminated) blastomycosis are the two clinical forms of the disease [47]. Blastomycosis in general is acquired by inhalation and initially presents with a pulmonary infection, which may later disseminate to other organs and systems [5]. Primary cutaneous infection due to direct inoculation of the fungus into the skin is also likely [48].

The presence of parasitic contaminants from the currency notes in the studies confirmed that currencies act as vectors playing important roles in the transmission of parasites [49]. This can be associated with the methods of handling the currency notes among Nigerians. It also reflects the current poor level of hygiene and knowledge about risks posed by the mishandling of naira notes. Parasite cysts and eggs isolated from naira notes are of high risks to humans. Most of the parasites isolated can be transmitted through the oral route. This becomes more worrisome when it is considered in Nigeria, where many people tongue – wet their fingers when counting money. Also, poor handling practices including spraying during ceremonies, handling currency notes with dirty hands contaminated with human and animal faeces. Also stepping on naira notes while dancing at parties may contaminate them with cysts and eggs of parasites from contaminated footwear [50].

The parasites reported in this study include *A. lumbricoides* eggs, hookworm ova, lice of the genus *Pediculus humanus corporis*, *E. vermicularis* eggs,

flagellates cysts, and *E. histolytica* cysts [4]. *A. lumbricoides* is the most frequent parasites from naira notes based on the reports from the studies analyzed for this review. *A. lumbricoides* causes ascariasis, a disease that is spread through oral contact with materials contaminated with the ova of *Ascaris*. *A. lumbricoides* eggs are quite resilient and can survive extreme environmental conditions. The eggs are coated with mucopolysaccharide which makes them adhesive to surfaces including paper currencies [15]. Infection with a large number of *Ascaris* worms may cause abdominal pains or intestinal obstruction. *E. histolytica* causes the disease amoebiasis which is spread orally through the ingestion of the cyst. The pathology of the invasive form of amoebiasis is manifested with amoebic dysentery, liver abscess, or possible death [51].

The multi-drug resistance observed among the bacteria in the studies further emphasizes the public health significance of naira notes. Bacterial agents like *Staphylococcus*, and *E. coli* have been known to develop resistance to commonly used antibiotics [52]. Many studies have reported the isolation of drug resistant bacteria from currency notes [42, 53, 54, 55]. Difficulty in the treatment of bacterial infections have been associated with the acquisition of resistant genes and this has been a global health problem [56]. The World Health Organization (WHO) has reported that thousands of deaths that are caused by *Salmonella sp.*, *E. coli*, and *S. aureus* are due to failure in therapy caused by resistance to the chemotherapeutic agents [52].

The lack of standard health facilities, crowded living conditions, and climatic conditions are some of the factors that encourage the survival of pathogenic microbes in developing countries like Nigeria [57]. Also, the difficulty to access clean water for handwashing and environmental sanitation are contributing factors to the spread of pathogens and parasites in the environment. The presence of antibiotic-resistant human pathogens on naira notes poses a great threat to public health as many of these pathogens can transfer their resistance genes to other pathogens [58, 59]. Multidrug resistance in some of the bacteria could be attributed to the presence of mobile genetic elements such as plasmid [60, 61].

Conclusion

Pathogenic microorganisms have been indicated to contaminate money spent in almost every part of the world. This delineation did not leave out the Nigerian currency. Studies on the prevalence of microbial contamination on the naira notes and the antimicrobial resistance of these microorganisms have been carried out in different parts of the country, with results showing the presence of pathogenic bacteria, fungi, and parasites, in addition to a high rate of resistance of pathogenic bacteria to several antibiotics used in the studies. This review deduced that contaminated Nigerian currency notes could pose a high risk, hence, public enlightenment on proper handling of the naira notes, proper education on public health risks associated with contaminated notes, and cashless policies are highly recommended.

Competing interests

The authors declare that they have no competing interests.

Supplementary file 1

[PRISMA-P \(Preferred Reporting Items for Systematic review and Meta-Analysis Protocols\) 2015 checklist.](#)

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