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Original article

Assessment of Microbial Contamination of Circulating Currency and the Awareness and Hygiene Practices of Currency Users in Nalut, Libya

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Abstract
Circulating currency serves as a potential vehicle for transmitting pathogenic microorganisms, posing a significant public health risk. This study aimed to assess the microbial contamination levels of currency circulating in Nalut City, Libya, and to evaluate public awareness and behaviors regarding money handling. A cross-sectional, descriptive-analytical study was conducted from November 2025 to April 2026. A total of 121 circulating currency samples were collected from various commercial categories and analyzed using biochemical tests for microbial identification. Simultaneously, 194 questionnaires were randomly distributed to vendors and customers across diverse environments to assess awareness and behavioral practices. Microbial contamination was highly prevalent across tested samples. Staphylococcus epidermidis was the most frequent isolate (16.53%), followed by Staphylococcus aureus (15.70%), alongside various Gram-negative bacteria, most notably Burkholderia cepacia, Klebsiella spp., and Escherichia coli. Paper currency accounted for 75.6% of the total microbial isolates and exhibited a numerically higher contamination rate than coins (79.07% vs. 62.86%), although this difference did not reach statistical significance ($\chi^2 = 3.43$, $p = 0.064$). Geographically, food retail stores and vegetable shops recorded the highest true contamination rates (100.00% and 92.31%, respectively), while pharmacies and bakeries — despite contributing the largest sample shares — showed comparatively lower rates (59.09% and 57.69%), a variation confirmed as statistically significant ($\chi^2 = 11.948$, $p = 0.036$). Regarding human behavior, negative money-handling practices were more prevalent than positive hygiene behaviors among participants. While participants demonstrated a moderate level of health awareness regarding contaminated currency risks (61.86%), a significant gap persisted between knowledge and actual behavioral application. Age was significantly associated with both awareness and behavioral patterns ($p < 0.05$), whereas gender and educational level were significantly associated with awareness only, showing no measurable association with actual money-handling behavior. Conclusion of the study: circulating currency represents a potential environmental vector for microbial transmission in Nalut. The pronounced gap between public awareness and practice highlights the urgent need for targeted public health interventions and community awareness campaigns to promote safer currency-handling hygiene.
Keywords. Microbial, Circulating Currency, Awareness, Behaviors, Nalut.

Introduction

Microbial infections remain among the most critical global public health challenges, driving the transmission of numerous infectious diseases through both direct and indirect human contact. Amidst various environmental vectors, circulating currency notes and coins serve as significant fomites capable of harboring and transferring pathogenic bacteria, fungi, and viruses during daily socioeconomic transactions [1,2]. Pathogens are typically transmitted either directly, via respiratory droplets and skin-to-skin contact, or indirectly through contaminated inanimate surfaces known as fomites. High-touch objects and surfaces, in particular, serve as primary transmission vectors for a wide range of bacterial, fungal, and viral pathogens. Among these, circulating banknotes and coins provide substantial surface areas that undergo constant public exchange, facilitating cross-contamination during daily transactions [3,4,5]. Furthermore, the physical and chemical properties of the materials used in manufacturing paper notes and metallic coins heavily influence the survival rates, persistence, and proliferation of these loaded microorganisms.

Compared to polymer-based currencies, traditional paper banknotes exhibit a significantly higher propensity for bacterial retention and adherence, thereby reinforcing their critical role in pathogen transmission under substandard hygiene practices and adverse environmental conditions. The persistence and viability of these pathogenic microorganisms are predominantly dictated by specific environmental catalysts, most notably ambient temperature, relative humidity, and the accumulation of organic debris [6,7]. Paper currency has been demonstrated to harbor the highest microbial load, followed sequentially by vendors' hands and the food products sold [8]. Unhygienic handling practices—most notably the habit of moistening fingers with saliva while counting banknotes—significantly exacerbate the risk of hazardous microbial contamination. Consequently, banknotes circulate continuously and at a high frequency [9]. Lower-denomination notes exhibit significantly higher levels of contamination. Among various public venues, cafes and food-service establishments have been identified as primary hubs for the circulation of heavily contaminated funds [10,11].

Comprehensive microbiological assessments have documented the isolation of up to 12 distinct bacterial genera and five fungal species from circulating banknotes. Despite this high microbial prevalence, public behavior remains suboptimal; for instance, survey data indicated that while approximately 76% of consumers acknowledged that banknotes are contaminated vectors for infection, a substantial gap persists between this health awareness and safe handling practices [12]. Prior studies indicate that while the majority of individuals harbor positive attitudes toward hand hygiene, a profound disparity remains between health knowledge and actual behavioral compliance. To bridge this knowledge-attitude-behavior

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gap, current literature advocates for integrated educational frameworks that couple cognitive theories with practical behavioral strategies, including continuous supervision and regular hygiene reminders [13]. The biological evaluation quantifies the viral or bacterial load of these persistent vectors, whereas mapping user behaviors uncovers the human variables that dictate cross-contamination. Ultimately, factual awareness alone does not guarantee a reduction in microbial transmission without a corresponding shift in daily handling practices [14].

While numerous studies have documented the microbial contamination of circulating cash, there remains a critical literature gap regarding the direct correlation between public health awareness and actual money-handling practices. The significance of the present study lies in its comprehensive, dual-approach framework, which uniquely integrates empirical laboratory microbiological analyses with behavioral and awareness assessments, thereby providing robust scientific evidence for a deeper understanding of this public health issue. Furthermore, these findings are instrumental in designing targeted community health education programs and guiding individuals toward adopting safer hygiene habits to mitigate cross-contamination risks.

Materials and Methods

This investigation integrated a dual-methodological framework: a community-based behavioral questionnaire alongside empirical, laboratory-based microbiological evaluations of circulating currency. A structured questionnaire was randomly distributed to male and female community members across various public venues in Nalut. Out of 200 distributed copies, 194 completed questionnaires were successfully retrieved (a 97.0% response rate) and included in the final analysis. The survey instrument was divided into three core sections: Sociodemographic Characteristics: Documenting participants' age, gender, and educational attainment to evaluate their correlations with hygienic practices. Money-Handling Behaviors: Comprising 11 items that monitored daily hand-to-currency habits and public cross-contamination risks. Health Risk Awareness: Containing 12 items assessing public knowledge regarding the health hazards associated with contaminated cash vectors.

Currency Sampling and Collection

A total of 135 circulating currency samples were initially collected from diverse commercial establishments. These settings included food stores, vegetable shops, butcher shops, restaurants, bakeries, cafes, and pharmacies. During the sorting and transport phase, fourteen samples were excluded from the study due to external contamination risks or compromised sterile containment. Consequently, 121 valid currency samples spanning various metallic and paper denominations—specifically 0.25, 0.50, 1, 5, 10, and 20 Libyan Dinars (LYD)—were successfully retained for analysis. Each currency unit was handled using sterile forceps, placed immediately into individual, labeled sterile polyethylene bags, and transported under controlled conditions to the microbiology laboratory for immediate processing.

Microbiological Isolation and Techniques

Under strict aseptic laboratory conditions, both surfaces of each collected currency sample were thoroughly swabbed using sterile cotton swabs moistened with sterile saline. Each sample was carefully cross-referenced with its recorded metadata, including the serial number, specific commercial source, and currency denomination type. To enrich the microbial load, the swabs were immediately transferred into sterile tubes containing approximately 5 mL of Thioglycolate broth (fluid thioglycolate medium) and agitated vigorously to ensure the complete release and transfer of the collected microorganisms into the liquid medium. Following enrichment, the bacterial suspensions were subcultured onto a battery of selective, differential, and enriched solid media to isolate diverse clinically relevant pathogens. Utilizing a sterile inoculation loop, aliquots from the enriched broth were systematically streaked using the quadrant streak-plate technique onto Blood Agar (to evaluate hemolytic patterns), MacConkey Agar (for the selective isolation of Gram-negative enteric bacilli), and Mannitol Salt Agar (MSA, for the selective isolation and differentiation of halotolerant Staphylococci). All inoculated culture plates were uniquely labeled and subsequently incubated under aerobic conditions at 37°C for 24 to 48 hours. Following the incubation period, plates were macroscopically examined for visible microbial growth, colony morphology, and distinctive biochemical characteristics, such as mannitol fermentation.

Microbial Identification and Phenotypic Characterization

Following the incubation period, all culture plates were visually inspected to macroscopically determine the presence or absence of microbial growth. Samples exhibiting no detectable colonies after 48 hours were designated as negative for culturable microbial growth. Conversely, plates demonstrating visible growth were subjected to a systematic identification protocol to characterize the isolated bacterial and fungal strains. Preliminary phenotypic identification was based on distinct colony macro-morphology, including hemolytic patterns (alpha, beta, or gamma hemolysis) on Blood Agar and lactose fermentation profiles (lactose fermenters vs. non-lactose fermenters) on MacConkey Agar. To determine cellular morphology, arrangement, and cell wall characteristics, Gram staining was performed on isolated colonies, followed by bright-field light microscopy examination. Additionally, bacterial motility was assessed to further differentiate and classify the isolated Gram-positive and Gram-negative genera. Definitive species-level confirmation was achieved using standard biochemical screening cascades appropriate for each morphotype. Definitive confirmation of the isolated bacterial strains was achieved through a series of standard phenotypic biochemical tests. These core screening assays included the

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catalase test (to differentiate between *Staphylococci and Streptococci*), the oxidase test (to screen for non-fastidious Gram-negative bacilli), the indole test (as part of the IMViC cascade for enteric differentiation, particularly for *Escherichia coli*), and the coagulase test (to definitively distinguish between Staphylococcus aureus and coagulase-negative *Staphylococci*, such as *Staphylococcus* epidermidis).

Statistical methods used

The collected quantitative and qualitative data were systematically managed and analyzed using dual software platforms based on the data source. For the laboratory-based microbiological assays, descriptive statistics including frequencies and percentages were computed utilizing Microsoft Excel. For the community-based behavioral survey, data processing was executed using the Statistical Package for the Social Sciences (SPSS, version 26.0). The internal consistency and reliability of the questionnaire items were verified utilizing Cronbach's alpha coefficient, which yielded an acceptable value of 0.77, confirming the stability and validity of the survey tool. Descriptive statistical measures, including frequencies, percentages, arithmetic means, and standard deviations, were calculated to summarize the baseline characteristics. Inferential statistics were deployed to analyze relationships between study variables: the independent-samples t-test was utilized to compare composite behavioral and awareness scores between the two gender groups, while the One-Way Analysis of Variance (One-Way ANOVA), followed by Least Significant Difference (LSD) post-hoc pairwise comparisons where the overall F-test was significant, was applied to compare mean scores across age category (four groups) and educational level (five groups). The chi-square test of independence was additionally applied to compare contamination rates between paper and metallic currency (Table 2), and across currency-sampling venues (Table 3).

Ethical Considerations and Biosafety Measures

Formal ethical approval was officially reviewed and granted by the Scientific Research Ethics Committee at Nalut University, Libya. Informed verbal consent was obtained from all respondents before questionnaire distribution. Participants were fully briefed on the study's scope, and absolute anonymity and data confidentiality were maintained throughout the data handling process. Regarding the microbiological phase, circulating currency samples were collected from various retail and commercial establishments in full compliance with standard laboratory biosafety and occupational health guidelines. Aseptic techniques and personal protective equipment (PPE) were strictly employed during sample gathering, handling, and transport to eliminate secondary environmental contamination and to guarantee the absolute biosafety of both the field investigators and the community participants.

Results

First part: Results of microbial laboratory analysis of circulating currency

Of the 121 currency samples collected, 90 samples (74.4%) yielded culturable microbial growth and were subsequently identified to species/genus level, while the remaining 31 samples (25.6%) showed no detectable growth after 48 hours of incubation (Table 1). In cases of mixed colonial growth, only the predominant morphotype was identified, yielding a single isolate per positive sample; hence, the total of 90 isolates in Table 2 (68 from paper currency + 22 from coins) corresponds exactly to the 90 positive samples.

Table 1. Frequency and relative distribution of bacterial and fungal isolates and their Gram Stain Characteristics

Type of bacteria isolated	Number of impressions	Percentage	Gram positive	Gram negative
Staphylococcus aureus	19	15.7%	Gram+	
Staphylococcus epidermidis	20	16.5%	Gram+	
Klebsiella spp	10	8.3%		Gram-
Proteus spp	2	1.7%		Gram-
Streptococcus spp	2	1.7%	Gram+	
No growth	31	25.6%	-	-
Escherichia coli	8	6.6%		Gram-
Micrococcus spp	1	0.8%	Gram+	
Pseudomonas spp	4	3.3%		Gram-
Burkholderia cepacia	11	9.1%		Gram-
Enterobacter spp	4	3.3%		Gram-
Streptococcus alpha-hemolytic	1	0.8%	Gram+	
Bacillus spp	1	0.8%	Gram+	
Fungi (species)	Number of impressions	Percentage	-	-
Fungal grow	6	5.0%		
Candida spp	1	0.8%		
Total	121	100%		

Note. Percentages calculated relative to total samples (N = 121). Of these, 90 samples yielded positive microbial growth (see Table 2 for distribution by currency type).

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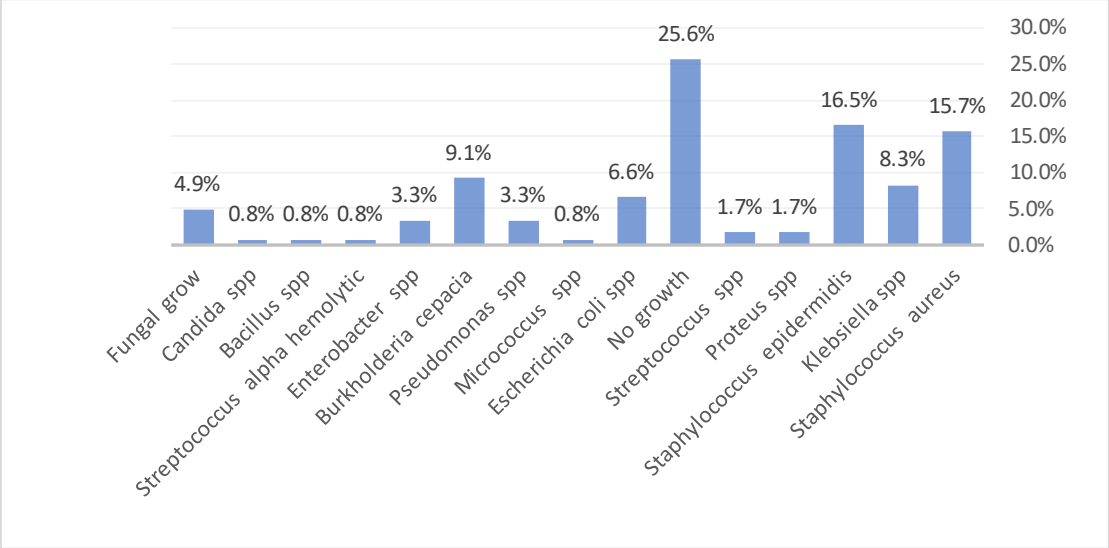

Figure 1. Graphical representation of the distribution of bacterial and fungal isolates

As documented in (Table 1 and Figure 1), a comprehensive array of microbial strains was successfully isolated and characterized from the circulating currency samples. Among all recovered microflora, the Gram-positive bacterium Staphylococcus epidermidis exhibited the highest isolation rate, accounting for 16.53% (n = 20) of the total profile, followed sequentially by *Staphylococcus aureus* at 15.70% (n = 19). Conversely, the lowest baseline recovery rate (0.83%, n = 1 each) was concurrently recorded for *Bacillus spp.*, *Micrococcus spp*., and *Candida spp.* In contrast, 31 currency samples (25.62%) showed no detectable microbial proliferation and were classified as "no growth" after the designated incubation period. To structure the findings, the identified isolates were systematically categorized based on their Gram-staining behavior, cellular morphology, and taxonomic properties as follows:

Gram-positive bacteria

Staphylococcus epidermidis led (16.5%) this group, followed by *Staphylococcus aureus* (15.7%); other species also appeared in low proportions, such as *Streptococcus spp.,* which were recorded twice (1.7%). *Micrococcus spp., Streptococcus alpha-hemolytic,* and *Bacillus spp.* appeared only once (0.8%).

Gram-negative bacteria

Burkholderia cepacia was identified as the predominant Gram-negative isolate at 9.2% (n=11), followed by *Klebsiella spp*. (8.3%, n=10) and *Escherichia coli* (6.6%, n=8). *Pseudomonas spp.* and *Enterobacter spp.* showed identical isolation frequencies (3.3%, n=4), with Proteus spp. comprising 1.7% (n=2) of the group.

Fungal and non-developing samples

The mycological evaluation of the circulating currency samples documented a low prevalence of fungal contamination. Specifically, *Candida spp.* was definitively identified in a single instance, accounting for 0.8% of the total distribution. Additionally, other unclassified fungal and mold proliferations were recorded in six separate cases, representing 4.9% of the isolated microflora. Conversely, the laboratory screening revealed that 31 currency samples exhibited a complete absence of culturable microbial growth, resulting in a "no growth" rate of 25.6% after the designated incubation period.

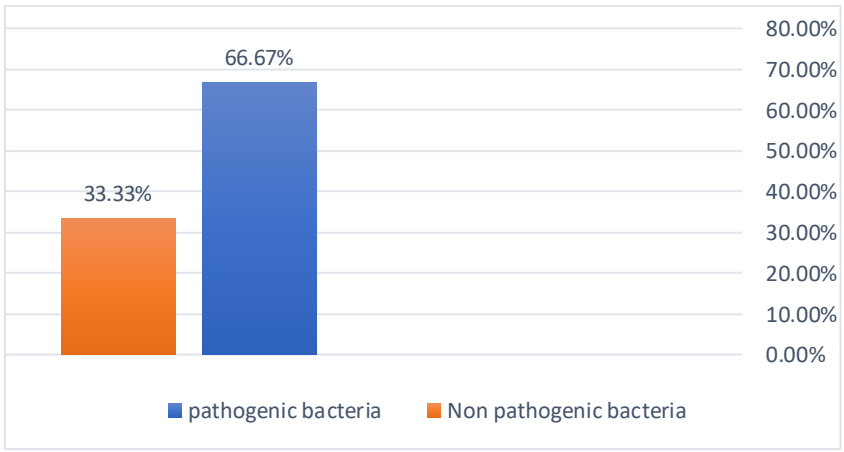

Figure 2. Graphical representation of the distribution of pathogenic bacteria and non-pathogenic bacteria

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Pathogenic and Non-Pathogenic Bacterial Categorization. As illustrated in (Figure 2), the isolated bacterial strains were systematically categorized based on their clinical relevance and pathogenic potential into pathogenic (including opportunistic pathogens) and non-pathogenic (commensal) cohorts. Out of the 12 distinct bacterial genera identified, pathogenic and opportunistic microorganisms accounted for the clear majority, representing 66.67% (n = 8) of the total bacterial diversity. Conversely, non-pathogenic or commensal strains constituted the remaining 33.33% (n = 4) of the classified microbial profile. This high proportion of clinically relevant bacteria underscores the potential of circulating currency to function as an active environmental vector for community-acquired infections.

Table 2. Frequency and percentage distribution of the number of microbes isolated from paper and metal currencies

Type of isolates	Number of impressions in paper currency	Percentage	Number of impressions in coins	Percentage
Bacterial isolates				
Staphylococcus aureus	12	17.6%	7	31.8%
Staphylococcus epidermidis	14	20.6%	6	27.3%
Klebsiella spp	7	10.3%	3	13.6%
Proteus spp	2	2.9%	0	/
Streptococcus spp	2	2.9%	0	/
Escherichia coli	6	8.8%	2	9.1%
Micrococcus spp	1	1.5%	0	/
Pseudomonas spp	4	5.9%	0	/
Burkholderia cepacia	8	11.8%	3	13.6%
Enterobacter spp	4	5.9%	0	/
Streptococcus alpha-hemolytic	1	1.5%	0	/
Bacillus spp	1	1.5%	0	/
Fungi (species)				
Fungal grow	5	7.4%	1	4.5%
Candida spp	1	1.5%	0	/
Total	68	-	22	-
No growth	18		13	
Total samples (N)	86	-	35	-
Contamination rate (%)	79.07%		62.86%	

***Note**. Percentages in the isolate distribution rows are calculated separately for each currency type relative to its own total isolate count: paper currency isolates (N = 68) and coin isolates (N = 22). The contamination rate (%) is calculated differently, as the proportion of samples yielding positive microbial growth relative to the total number of samples collected for each currency type: paper (N = 86) and coins (N = 35).*

As presented in (Table 2), paper banknotes yielded a higher number of microbial isolates than metallic coins, with 68 isolates recovered from paper currency compared to 22 from coins, corresponding to 75.6% and 24.4% of the total isolate pool, respectively. However, this raw isolate count reflects differences in sample size as well as contamination, since a greater number of paper samples (n = 86) than coin samples (n = 35) were collected overall. When contamination burden was instead assessed as the proportion of samples yielding culturable microbial growth relative to each currency type's own sample size, paper banknotes exhibited a contamination rate of 79.07% (68/86) compared to 62.86% (22/35) for coins — corresponding to a more modest 1.26-fold difference rather than the roughly three-fold difference suggested by raw isolate counts alone. A chi-square test of independence indicated that this difference did not reach statistical significance (χ^2 = 3.43, df = 1, p = 0.064), a finding that may be attributable to the limited sample size, particularly for coins (n = 35).
Furthermore, a profound divergence was noted regarding microbial diversity and richness between the two substrates. Paper banknotes exhibited maximum susceptibility, yielding 100% of the identified microbial taxa. In stark contrast, several microbial species were absent from metallic coins, with approximately 57% of the identified taxa failing to be recorded on coin surfaces. This variation strongly underscores that the structural and chemical composition of paper currency provides a significantly more hospitable microenvironment for microflora persistence and proliferation. Regarding mycological distribution, fungal species were documented at a higher prevalence in paper banknotes (7.4%, n = 5) compared to metallic coins (4.5%, n = 1), demonstrating that fungal persistence was approximately 1.6 times higher on paper-based currency.

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Table 3. Frequency and percentage distribution of bacterial and fungal isolates according to sample sources

Type of bacteria	butchers	Vegetable shops	Pharmacy	Bakeries	Restaurants	Food store	Café	N (%)
Staphylococcus aureus	1	2	4	6	2	4	-	19 (15.7%)
Staphylococcus epidermidis	3	3	3	6	3	1	1	20 (16.5%)
Klebsiella spp	3	2	2	1	2	-	-	10 (8.3%)
Proteus spp	-	1	1	-	-	-	-	2 (1.7%)
Streptococcus spp	-	1	1	-	-	-	-	2 (1.7%)
No growth	3	2	9	11	4	-	2	31 (25.62%)
Escherichia coli	-	4	-	1	2	-	1	8 (6.6%)
Micrococcus spp	1	-	-	-	-	-	-	1 (0.8%)
Pseudomonas spp	1	1	-	-	1	1	-	4 (3.3%)
Burkholderia cepacia	4	4	-	-	3	-	-	11 (9.1%)
Enterobacter spp	-	3	1	-	-	-	-	4 (3.3%)
Streptococcus alpha hemolytic	-	-	-	1	-	-	-	1 (0.8%)
Bacillus spp	-	1	-	-	-	-	-	1 (0.8%)
Fungal growth	1	2	1	-	2	-	-	6 (4.9%)
Candida spp.	-	-	-	-	1	-	-	1 (0.8%)
paper currencies	17	22	11	18	10	5	3	86 (71.07%)
metal currencies	0	4	11	8	10	1	1	35 (28.93%)
Total Number of samples (%)	17 (14.05%)	26 (21.48%)	22 (18.18%)	26 (21.48%)	20 (16.53%)	6 (4.96%)	4 (3.32%)	(100%)
Contamination rate (%)	82.35%	92.31%	59.09%	57.69%	80.00%	100.00 %	50.00%	74.38%

Note. *Note. The "N (%)" values in the Total row denote each venue's percentage share of the total 121 currency samples collected, reflecting sampling intensity rather than contamination severity. In contrast, "Contamination rate (%)" denotes the proportion of samples collected at each venue that yielded culturable microbial growth (Positive samples / N × 100), calculated after excluding "no growth" samples documented for that venue. Venues with the smallest sample sizes (Cafe, n = 4; Food store, n = 6) should be interpreted with caution given the correspondingly wide confidence intervals*.

As cross-tabulated in (Table 3), the physical distribution of the 121 analysed samples across the seven sampling venues varied considerably, with vegetable shops and bakeries each contributing the largest share of the overall sample pool at 21.48% (n = 26), followed by pharmacies at 18.18% (n = 22), restaurants at 16.53% (n = 20), butcher shops at 14.05% (n = 17), food retail stores at 4.96% (n = 6), and cafés at 3.32% (n = 4). However, when contamination burden was assessed as the proportion of samples yielding culturable microbial growth relative to each venue's own sample size, a markedly different pattern emerged. Food retail stores exhibited the highest contamination rate at 100.00% (6/6), followed by vegetable shops at 92.31% (24/26), butcher shops at 82.35% (14/17), and restaurants at 80.00% (16/20). Pharmacies and bakeries, despite contributing the largest absolute sample shares, demonstrated comparatively lower contamination rates of 59.09% (13/22) and 57.69% (15/26), respectively, while cafés recorded the lowest contamination rate at 50.00% (2/4). A chi-square test of independence, performed after combining the two smallest venue categories (cafés and food retail stores) to satisfy the minimum expected-cell-frequency assumption, confirmed that the contamination rate differed significantly across sampling venues ($\chi^2 = 11.948$, df = 5, p = 0.036). In terms of currency type distribution across the analysed 121 samples, traditional paper banknotes represented the vast majority of the processed matrices at 71.07% (n = 86), whereas metallic coins accounted for 28.93% (n = 35).

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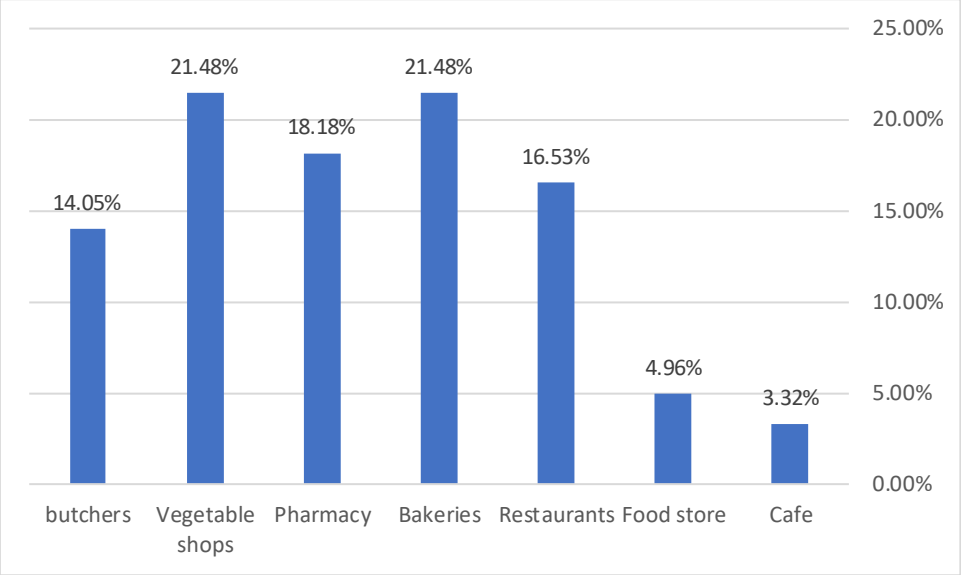

Figure 3. Graphical distribution of bacterial and fungal isolates according to sampling sources

As illustrated by the graphical representation in (Figure 3), the prevalence and density of microbial contamination exhibited a distinct spatial variation across the evaluated commercial and retail establishments in Nalut City.

Second part: describe the demographic characteristics of the participants

Table 4. Frequency and percentage distribution of the participants' demographic characteristics (N = 194)

Variables	Frequency	Percentage
Gender		
Male	86	44.3%
Female	108	55.7%
total	194	100%
Age		
18 > 25	48	24.7%
25 > 35	49	25.3%
35 > 50	67	34.5%
50 <	30	15.5%
	194	100%
Educational level		
Illiteracy level	19	9.8%
Secondary education	59	30.4%
undergraduate	102	52.6%
postgraduate studies	14	7.2%
	194	100%

Note. *For descriptive purposes, respondents with no formal education (n = 4) and primary-level education (n = 15) were combined into a single "illiterate" category (n = 19) to avoid excessively small cell sizes in the demographic summary. The inferential analyses reported in Table 8 (One-Way ANOVA) treat these two groups as separate categories, yielding five distinct educational levels; see Table 8 and its accompanying note for the disaggregated classification.*

The baseline sociodemographic characteristics of the 194 survey respondents recruited from the Nalut community are systematically outlined in (Table 4). Females constituted the majority of the analyzed cohort, accounting for 55.7% (n = 108) of the total sample, while males represented the remaining 44.3% (n = 86). Stratification by age demonstrated that the most active participating age group was individuals aged 35 to 49 years, which comprised 34.5% (n = 67) of the respondents. This was followed sequentially by the 25 to 34 age brackets at 25.3% (n = 49) and the young adult cohort aged 18 to 24 years at 24.7% (n = 48). Conversely, older adults aged 50 years and above constituted the lowest relative proportion, representing 15.5% (n = 30) of the total surveyed population. In terms of educational attainment, the vast majority of the participants held an undergraduate higher-education degree, accounting for 52.6% (n = 102). Respondents with secondary education qualifications represented the second-largest academic strata at 30.4% (n = 59), followed by individuals categorized within the illiterate group at 9.8% (n = 19). Finally, postgraduate degree holders comprised the smallest educational subgroup, accounting for only 7.2% (n = 14) of the overall participating community sample.

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Table 5. Frequency distribution, percentage, arithmetic mean, and standard deviation of sample members' answers about behaviors associated with handling money

variables	Yes	Some Times	No	standard deviation	arithmetic mean	Degree of approval
Do you handle money every day?	105 54.1%	76 39.2%	13 6.7%	0.62	2.47	High
Do you lick your fingers to moisten the money when counting?	67 34.5%	44 22.7%	83 42.8%	0.87	1.92	Low
Do you clean your hands (sterilize or wash) after handling cash?	21 10.8%	42 21.6%	131 67.5%	0.68	1.43	Low
Do you touch your face or phone immediately after handling cash?	100 51.5%	61 31.4%	33 17%	0.75	2.35	High
Do you clean or sterilize your wallet or the place where you put money?	12 6.2%	20 10.3%	162 83.5%	0.55	1.23	Low
Do you place cash on a surface such as a table or counter when dealing with a seller?	129 66.5%	39 20.1%	26 13.4%	0.72	2.53	High
Do you keep money in your body??	54 27.8%	36 18.6%	104 53.6%	0.87	1.74	Low
Do you share money with other people (children, friends) in an unclean way?	132 68%	31 16%	31 16%	0.76	2.52	High
Do you keep part of the money that you do not use daily in a drawer or closet for a long time?	141 72.7%	22 11.3%	31 16%	0.75	2.57	High
Have you ever seen children put money in their mouths?	159 82%	12 6.2%	23 11.9%	0.67	2.70	High
Do you store money in a designated, clean place?	73 37.6%	37 19.1%	84 43.3%	0.90	1.94	Low

From (Table 5), the high prevalence of self-reported negative money-handling behaviors (73.6%) explicitly highlights the human variable as a primary driver of environmental contamination in Nalut. Particularly concerning from an epidemiological perspective is that 34.5% of respondents actively practice saliva-assisted bill counting. This hazardous habit not only introduces upper respiratory and oral microflora—such as Staphylococcal species—directly onto the absorbent surface of paper banknotes but also creates a bidirectional transmission pathway where currency-borne opportunistic pathogens can be ingested via the fecal-oral or mucosal routes. Furthermore, the finding that 51.5% of participants touch their faces and mobile phones while handling currency illustrates how circulating cash acts as an epicenter for continuous cross-contamination. Since mobile devices are high-touch surfaces that are rarely disinfected, they serve as personal secondary reservoirs for pathogens like Escherichia coli and Burkholderia cepacia transferred from contaminated cash. Additionally, the widespread neglect of financial storage hygiene (83.5%) and the practice of sharing uncleaned money with vulnerable cohorts like children (68%) suggest that the community operates under a baseline of substandard sanitary practices.

Table 6. Frequency, percentage, and arithmetic mean distribution of sample members' answers about awareness of the risks of handling money

Variables	Yes	Some Times	No	standard deviation	arithmetic mean	Degree of approval
Do you think money can contain harmful microbes or bacteria, such as Staphylococcus or E. coli?	121 62.4%	20 10.3%	53 27.3%	0.88	2.35	High
Do you think money might be a way to transmit bacteria?	133 68.6%	17 8.8%	44 22.7%	0.84	2.46	High
Do you think bacteria stay on the surface of money for hours or days?	103 53.1%	27 13.9%	64 33%	0.91	2.20	High
Do you think that the transfer of money between people can cause the spread of infectious diseases?	105 54.1%	31 16%	58 29.9%	0.89	2.24	High

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Do you think washing hands after touching cash is important to reduce transmission?	141 72.7%	22 11.3%	31 16%	0.75	2.57	High
Do you think that coins in denominations of (one dinar - five dinars) are more polluted than other coins?	89 45.9%	34 17.5%	71 36.6%	0.91	2.09	High
Do you think that (new) money | is less polluting than (old) paper money?	105 54.1%	35 18%	54 27.8%	0.87	2.26	High
Do you think that the difference in places where money is traded (such as markets, restaurants, pharmacies) affects the level of bacterial contamination?	123 63.4%	25 12.9%	46 23.7%	0.85	2.40	High
Do you think that handling cash near food or meat on unclean surfaces contributes to the transport of bacteria?	143 73.7%	26 13.4%	25 12.9%	0.71	2.61	High
Do you think coins are less polluting than paper money?	78 40.2%	28 14.4%	88 45.4%	0.93	1.95	Low
Do you think dirty or damaged money is more contaminated with bacteria than clean money?	142 73.2%	23 11.9%	29 14.9%	0.74	2.58	High
Do you think that handling money (such as touching the mouth or not washing hands) increases the risk of disease?	153 78.9%	23 11.9%	18 9.3%	0.63	2.70	High
General arithmetic average	**2.37**					**High**

Cumulatively, 61.86% (n = 120) of the respondents were classified as possessing an acceptable level of overall health awareness, whereas 38.14% (n = 74) demonstrated a low awareness profile. The overall composite arithmetic mean for the awareness index was 2.37 (out of a 3-point Likert scale), indicating a moderate to high level of cognitive risk perception. Specifically, when assessing the cross-contamination link between currency handling and food safety, 73.7% (n = 143) of the participants correctly acknowledged that handling cash in proximity to food items or raw meat heavily contributes to bacterial transmission and foodborne outbreaks. Furthermore, a substantial majority of the surveyed cohort, 72.7% (n = 141), exhibited high situational awareness regarding personal hygiene, explicitly verifying that the handling of banknotes without subsequent hand hygiene—followed by touching the mouth or mucosal surfaces—significantly escalates the risk of contracting infectious diseases. This specific item registered a pronounced high arithmetic mean of 2.57, further validating that while the theoretical understanding of transmission dynamics is firmly established among the community members in Nalut, an operational disconnect persists when translating this cognitive awareness into daily tactile practices.

Table7. Independent-samples t-test results for behavioral and awareness composite scores by gender

Axis	Gender	n	Mean	SD	t	df	p
Behavioral score (11 items)	Male	86	23.65	3.40	0.978	192	0.329
	Female	108	23.20	2.97			
Awareness score (12 items)	Male	86	26.83	6.20	3.388	192	0.001
	Female	108	29.67	5.47			

Note. *Behavioral and awareness scores represent the summed responses to the 11-item money-handling behavior scale (range 11–33) and the 12-item health-risk awareness scale (range 12–36), respectively, with each item scored on a 3-point scale (No = 1, Sometimes = 2, Yes = 3).*

An independent-samples t-test (Table 7) revealed no statistically significant difference between male and female participants on the behavioral composite score (t(192) = 0.978, p = 0.329), indicating that money-handling practices were broadly homogeneous across gender. In contrast, a statistically significant difference emerged on the awareness composite score (t(192) = 3.388, p = 0.001), with female participants (M = 29.67) reporting higher health-risk awareness than male participants (M = 26.83).

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Table 8. One-way ANOVA results for behavioral and awareness composite scores by age category and educational level

Axis / Variable	Source	Sum of Squares	df	Mean Square	F	p
Behavioral × Age category	Between groups	172.140	3	57.380	6.193	0.000
	Within groups	1760.499	190	9.266		
	Total	1932.639	193			
Behavioral × Educational level	Between groups	27.772	4	6.943	0.689	0.600
	Within groups	1904.867	189	10.079		
	Total	1932.639	193			
Awareness × Age category	Between groups	286.847	3	95.616	2.769	0.043
	Within groups	6561.983	190	34.537		
	Total	6848.830	193			
Awareness × Educational level	Between groups	419.982	4	104.996	3.087	0.017
	Within groups	6428.848	189	34.015		
	Total	6848.830	193			

Note. *Educational level comprised five categories: illiterate (n = 19)†, primary, secondary, undergraduate, and postgraduate. †Note that Table 4 reports 19 illiterate respondents by combining the "no formal education" (n = 4) and "primary" (n = 15) categories used here in Table 8; both classification schemes are retained because they serve different descriptive and analytic purposes — see the clarification note added to Table 4.*

Table 9. Post-hoc LSD pairwise comparisons for significant ANOVA results

Axis	Comparison	Significant difference
Behavioral × Age	18–24 years vs. each of: 25–34, 35–49, 50+	Yes (18–24 group lower on all three)
Awareness × Age	18–24 years vs. 25–34 years; 18–24 years vs. 35–49 years	Yes (18–24 group lower on both)
Awareness × Educational level	Illiterate vs. Undergraduate; Illiterate vs. Postgraduate; Primary vs. Undergraduate; Primary vs. Postgraduate	Yes (lower-education groups lower on all four)

One-way ANOVA results (Table 8) further indicated that age category was significantly associated with both the behavioral score ($F(3,190) = 6.193$, $p < 0.001$) and the awareness score ($F(3,190) = 2.769$, $p = 0.043$). Post-hoc LSD comparisons (Table 9) revealed that the youngest age group (18–24 years) scored significantly lower than each of the three older age groups on the behavioral scale, and significantly lower than the 25–34 and 35–49 groups on the awareness scale. With respect to educational level, no significant difference was observed for the behavioral score ($F(4,189) = 0.689$, $p = 0.600$); however, a significant difference was found for the awareness score ($F(4,189) = 3.087$, $p = 0.017$), with post-hoc comparisons indicating that illiterate and primary-educated participants scored significantly lower than undergraduate and postgraduate participants. Collectively, these findings indicate that age is associated with both money-handling behavior and health-risk awareness, whereas educational attainment is associated with awareness specifically but shows no measurable association with actual money-handling behavior.

Discussion

The results of the study demonstrated widespread microbial contamination in circulating currency, with 90 microbial isolates from 121 circulating currency samples, confirming that money serves as a potential vehicle for the transmission of microorganisms between individuals; a similar finding was reported by [15,16]. The prevalence of Gram-positive bacteria was evident in the study results, with *Staphylococcus epidermidis* and *Staphylococcus aureus* being the most prevalent, along with the presence of Gram-negative bacteria such as *Escherichia coli, Klebsiella spp., Proteus spp.,* and *Burkholderia cepacia*. This indicates that human skin is a major source of contamination. While the presence of Gram-negative bacteria indicates fecal contamination associated with poor personal hygiene practices, these findings are consistent with studies [17,18,19]. paper banknotes were more susceptible to microbial contamination compared to coins, as the results showed. This is due to their porous nature, made of cotton fibers that trap moisture and organic matter, providing a suitable environment for the growth of microorganisms, while coins are characterized by smooth surfaces and contain metals such as copper, which has an inhibitory effect on microbial growth (Oligodynamic effect). A percentage of samples were also

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recorded as not showing microbial growth, which may be explained by differences in the duration of currency circulation or by exposure to environmental conditions unsuitable for the growth of microorganisms. In addition, fungal contamination was low, with little isolation of *Candida spp*. This indicates that fungi are less prevalent than bacteria, but their presence reflects the influence of environmental factors such as humidity and storage methods, and these results are consistent with those reported in [14]. From a health perspective, the results indicate that a large number of microorganisms were isolated on the circulating currency, including pathogenic and non-pathogenic (opportunistic or environmental) species. The presence of pathogenic species reflects the possibility that the currency may contribute to the transmission of some diseases, such as skin infections and diseases of the digestive and respiratory systems, especially with poor adherence to personal hygiene practices. In contrast, the presence of non-pathogenic species indicates that coins may constitute a suitable environment for the accumulation of environmental microflora, which is not directly harmful but may acquire an opportunistic character under appropriate conditions [12,20].

There is a clear variation in the level of microbial contamination of circulating currency according to the trading venue, with food retail stores, vegetable shops, butcher shops, and restaurants recording the highest true contamination rates (ranging from 80.00% to 100.00%), while pharmacies and bakeries recorded comparatively lower rates (57.69%–59.09%) despite contributing the largest shares of the overall sample pool. This increase is explained by the presence of moisture and organic matter residues, which provide a suitable environment for the survival and growth of microbes for longer periods [21,22]. 194 questionnaires were analyzed for participants, including 86 males (44.3%) and 108 females (55.7%). The most common age group was 35 and under 50 years old, with 67 (34.5%), followed by 25 and under 35, with 49 (25.3%). We find that the group from 18 to under 25 years old was 48 (24.7%). followed by the group 50 years and over, who participated the least in the study, with 30 (15.5%). We note that there is diversity in the education levels of the study participants. The results of the current study have proven that the demographic characteristics of the participants play a pivotal role in influencing the levels of health awareness and behavioral patterns followed when handling money. Negative behaviors were found to be more prevalent than positive behaviors regarding handling paper money, indicating a clear imbalance between healthy and unhealthy practices among members of the study population.

The prevalence of unhealthy behaviors associated with handling banknotes is largely due to the pressures of daily life and the nature of buying and selling practices, especially during peak times that impose a fast pace that prompts individuals to neglect preventive measures in favor of faster completion of transactions. High-risk trading environments, such as meat and food stores, also contribute to these practices, as cash is exchanged in conditions that lack immediate hygiene or sterilization, increasing the likelihood of contaminant transmission [23]. In addition to this, there is the influence of habit psychology, as the constant repetition of handling money generates a false sense of security that reduces awareness of microbial risks, thus entrenching wrong behaviors within the daily routine. It is noted that there was a significant level of cognitive awareness among participants regarding the microbial risks associated with banknote circulation, but this awareness was not clearly reflected in their actual behaviors in daily life [24,25]. This discrepancy indicates an applied gap between knowledge and practice. Individuals have sufficient awareness of the sources and risks of pollution, but they do not translate this awareness into regular preventive behavior. This reflects a pattern of ineffective perception, as awareness, within a theoretical framework, still does not have a sufficient impact on modifying daily behaviors, especially in light of life's pressures and the accelerating pace of interactions [26,27]. It was also found that age was significantly associated with both behavioral practices and awareness levels ($p < 0.05$ for both), and that educational level was significantly associated with awareness ($p = 0.017$) but not with actual behavior ($p = 0.600$), highlighting that the previously discussed knowledge–practice gap is not fully explained by educational attainment alone.

Limitation

Despite the significant insights generated by this dual-framework study, certain institutional and operational limitations must be acknowledged. The high cost of some culture media and laboratory consumables, supplies, and laboratory equipment has been an obstacle to providing some of the tools necessary to conduct examinations in the best possible way. This resulted in a reduced sample size.

Conclusion

Currency acts as a potential vehicle for transmitting microorganisms between individuals due to the significant prevalence of microbial contamination. It has also been shown that there is a clear gap between the level of awareness of the health risks associated with money circulation and actual behavior, as this awareness is not adequately reflected in daily practices. Demographic characteristics play a role in influencing the level of awareness and behavior. Conducting future research based on large samples covering a geographical area and larger societal groups is one of the recommendations of this study. We also propose integrating modern payment technologies such as plastic credit/debit cards, point-of-sale (POS) terminals, and mobile device touchscreens, alongside traditional circulating cash. Cards with circulating currencies will be used to achieve a deeper understanding of the extent of the spread of microbial pollutants across all circulating financial media, which contributes to developing comprehensive health.

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Conflicts of Interest

The authors declare no conflicts of interest. The authors have no personal or financial circumstances or interests that could be perceived as having inappropriately influenced the representation or interpretation of the reported research results.

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