

Characterization of pathogenic microorganisms from Indian coins and currencies collected from various sources

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Abstract— Coins and currency notes are ubiquitous in daily transactions, rendering them potential carriers of diverse microorganisms, including pathogenic bacteria, fungi, and viruses. The presence of these microbes on money poses significant public health risks, contributing to the spread of infectious diseases. This review comprehensively discusses microbial contamination on banknotes and coins, exploring their sources, methods for detection, and the potential health implications for individuals. Furthermore, it highlights crucial preventive measures, such as improved hygiene practices and the adoption of digital transaction alternatives, to effectively mitigate the microbial risks associated with currency handling.

IndexTerms— Microbial contamination, Currency hygiene, Pathogenic microorganisms, Banknote microbiota, Fomite transmission, Hand hygiene, Antimicrobial coatings, Digital transactions, UV-C sterilisation, Public health risks.

I. INTRODUCTION

Money, whether in the form of banknotes or coins, plays a crucial role in economic transactions, circulating widely amongst individuals, businesses, and institutions (Smith et al., 2023). Its frequent handling and prolonged exposure to diverse environments, however, render it a significant vector for microbial contamination (Angelakis & Raoult, 2014; Chandy & Mathai, 2012; Purohit & Shah, 2021). Unlike other commonly touched objects like mobile phones or door handles, currency is rarely subjected to cleaning or disinfection processes, allowing microbial communities to persist and spread through human interactions. The material composition of currency, along with environmental factors like humidity, temperature, and the presence of organic residues, influences how effectively microorganisms can survive and proliferate on its surface (Chen & Martin, 2021; Cozorici et al., 2022; Vriesekoop et al., 2010).

Extensive global research has consistently confirmed that banknotes and coins can harbour various pathogenic and opportunistic microorganisms, including bacteria, fungi, and viruses. Studies from diverse regions, including Bangladesh (Ahmed & Parveen, 2021; Ahmed et al., 2010), Pakistan (Badvi et al., 2013; Baloch et al., 2012; Shami et al., 2015; Ullah et al., 2025), Nigeria (Adeyeye et al., 2012; Amira et al., 2011; Awe et al., 2010; Eja et al., 2013; Enabulele & Amadi, 2012; Fasanmi et al., 2012; Feglo & Nkansah, 2010; George et al., 2012; Giwa et al., 2012; Igwe & Ogbonna, 2015; Isara & Adigun, 2013; Iwu & Iwu, 2018; Kawo et al., 2009; Mbajiuka & Orji, 2013; Musa & Sani, 2012; Okiki et al., 2012; Oyero & Emikpe, 2007; Shinkafi & Baba, 2013; Umeh et al., 2007), Iraq (Hassan, 2012; Hussein, 2012; Mohammed & Abdullah, 2013; Zarea & Al-Hussainy, 2019), and Saudi Arabia (Al-Ghamdi & Al-Zahrani, 2014; Alshami & Alnajjar, 2017; Hassan et al., 2016), reveal common bacterial contaminants like *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* (Basak & Deb, 2022; Bej & Bhunia, 2020; Gohil & Bhavsar, 2014; Niyomdechcha et al., 2025). Furthermore, research indicates that polymer-based banknotes tend to retain fewer bacteria compared to cotton-based paper notes, suggesting that currency material plays a critical role in microbial adherence (Cozorici et al., 2022; Wang & Huang, 2016).

The critical role of hand hygiene in microbial transmission via currency has been extensively investigated (Kim et al., 2022; Pal et al., 2020). Studies highlight that poor hand hygiene practices significantly contribute to bacterial dissemination through money, particularly in high-contact areas like hospitals, markets, and public transport systems (Lamichhane et al., 2009; Tekerekoğlu et al., 2013). Research examining bacterial survival on currency used in food-related settings emphasises the risk of foodborne pathogen transmission (Clark & Roberts, 2020; Vriesekoop et al., 2010). Additionally, Gram-negative bacteria, often associated with gastrointestinal infections, are prevalent on frequently handled items, including banknotes and coins (Edwards & Murphy, 2015).

Beyond bacteria, fungal contamination of currency is a growing concern. Studies report that fungal species such as *Candida* species, *Aspergillus* species, and *Penicillium* species can persist on paper money for extended periods, posing risks to immunocompromised individuals (Ali & Rashed, 2011; Amudhan et al., 2014; Mohammed & Abdullah, 2013; Neel et al., 2005; Phillips & Green, 2014; Vasanth & Parameswari, 2018). Viral particles have also been detected, with research demonstrating that respiratory and gastrointestinal viruses can remain viable on banknotes for several hours to days, raising concerns about money's potential role in disease outbreaks (Turner & Brown, 2012; Walker et al., 2013).

The persistence of microbial contaminants on currency has prompted exploration of various enumeration and identification techniques. Studies evaluating sampling methodologies concluded that swabbing and imprinting provide accurate microbial quantification (Singh & White, 2019; Taylor & Hall, 2018). Traditional culture-based techniques remain widely utilised for microbial isolation, whilst molecular approaches, including Polymerase Chain Reaction (PCR) and 16S rRNA sequencing, enhance the precision of microbial identification, especially for non-culturable organisms (Adams et al., 2017; Niyomdechcha et al., 2025).

Banknotes are generally categorised into two primary material types: traditional paper notes (typically cotton fibres, sometimes blended with linen) and polymer (plastic) notes. For instance, Euro banknotes are manufactured entirely from purified cotton paper, known for its distinct texture and wear resistance. Cotton cellulose's high degree of polymerisation makes it stronger than wood-derived cellulose (Purohit & Shah, 2021). In contrast, U.S. dollar bills are produced from a custom 75% cotton and 25% linen blend, a durable cellulosic fibre derived from flax plants, further enhanced by dyes and sizing agents for strength and functionality (Purohit & Shah, 2021). This material difference is significant in determining microbial adherence.

Given the public health implications, researchers have proposed several mitigation strategies. Investigations show that antimicrobial coatings on polymer-based notes significantly lower bacterial adherence (Cozorici et al., 2022). Additionally, UV sterilisation has been highlighted for reducing microbial loads on frequently handled items, including currency (Purohit & Shah, 2021). In recent years, digital payment methods have gained prominence as a crucial alternative to physical cash transactions, significantly reducing microbial transmission risks (Pal et al., 2020; Vriesekoop et al., 2010).

This review aims to synthesise existing literature on microbial contamination of currency, providing an in-depth analysis of the microorganisms commonly found on money, enumeration and identification methodologies, and associated health risks. Furthermore, it discusses practical strategies to mitigate microbial contamination, highlighting the importance of hygiene practices, technological advancements, and alternative transaction methods to ensure safer currency handling.

II. SOURCES OF MICROBIAL CONTAMINATION

Currency, as a frequently exchanged medium, is continuously exposed to diverse environmental conditions and human interactions, rendering it a significant reservoir for microbial contamination. The microbial load on currency primarily arises from direct human contact, environmental exposure, and contamination from food and waste. Direct handling transfers pathogens from human skin, respiratory droplets, and bodily secretions onto banknotes and coins. This leads to the presence of bacteria such as *Staphylococcus aureus*, *Escherichia coli*, fungi including *Candida* species, and even viral particles on currency surfaces, indicating its role in indirect disease transmission (Angelakis & Raoult, 2014; Chen & Martin, 2021; Purohit & Shah, 2021). The risk is significantly heightened in public spaces like hospitals, markets, restaurants, and public transport systems, where diverse microbial populations are frequently encountered (Kim et al., 2022; Lamichhane et al., 2009; Tekerekoğlu et al., 2013).

Currencies and coins act as reservoirs for a wide range of microorganisms due to their extensive circulation and exposure to unhygienic conditions. The primary source is direct human handling, where bacteria and viruses are transferred from skin, respiratory droplets, and bodily fluids to the currency surface (Abo-Amer & Abo-Amer, 2010; Adeyeye et al., 2012; Ahmed & Parveen, 2021; Ahmed et al., 2010; Ali & Ali, 2013; Amira et al., 2011; Awe et al., 2010; Baloch et al., 2012; Barua & Ghosh, 2010; Basak & Deb, 2022; Basavarajappa et al., 2013; Bej & Bhunia, 2020; Bhattacharya & Shit, 2014; Chaudhary & Singh, 2016; Chitnis et al., 2000; Dadzie & Akosah, 2008; Dibah et al., 2010; Eja et al., 2013; El-Dars & Hassan, 2005; Elumalai et al., 2012; Enabulele & Amadi, 2012; Fasanmi et al., 2012; Feglo & Nkansah, 2010; George et al., 2012; Ghazipour et al., 2012; Giwa et al., 2012; Gohil & Bhavsar, 2014; Goud et al., 2008; Guruprasad et al., 2012; Hassan, 2012; Hassan et al., 2016; Hussein, 2012; Igwe & Ogbonna, 2015; Isara & Adigun, 2013; Iwu & Iwu, 2018; Jilani & Dhanasekaran, 2015; Kawo et al., 2009; Kibret & Abera, 2011; Mbajiuka & Orji, 2013; Mehta & Shah, 2015; Musa & Sani, 2012; Neel et al., 2005; Okiki et al., 2012; Oyero & Emikpe, 2007; Pradeep et al., 2012; Shinkafi & Baba, 2013; Singh & Tapliyal, 2009; Uddin et al., 2015; Umeh et al., 2007; Vasanth & Parameswari, 2018; Wang & Huang, 2016; Yong & Thung, 2014; Zarea & Al-Hussainy, 2019). Poor personal hygiene, particularly the failure to wash hands after coughing, sneezing, or using the restroom, significantly increases the microbial load on money (Kim et al., 2022). Pathogens like *E. coli*, *S. aureus*, *Pseudomonas* species, and various enteric bacteria are consistently identified on banknotes and coins (AlShaibani, 2024; Uddin et al., 2015; Ullah et al., 2025). High-traffic environments where money is commonly exchanged, such as public markets, hospitals, and food service areas, further amplify the risk of contamination due to high human traffic and unsanitary conditions (Lamichhane et al., 2009; Tekerekoğlu et al., 2013).

Specific behavioural practices, like saliva-wetting fingers when counting money, directly introduce oral bacteria onto currency surfaces (Mohammed & Abdullah, 2013). Although metal coins are less porous than paper banknotes, they are still susceptible to microbial adhesion, with certain metal ions potentially favouring the survival of specific bacterial species (Ghosh et al., 2020). Storage conditions, including humid wallets, soiled cash registers, or prolonged exposure to dust and moisture, also create favourable environments for microbial survival and multiplication (Purohit & Shah, 2021). Research indicates that lower denomination notes often harbour higher microbial counts due to their more frequent exchange amongst a wider population base (Pradeep et al., 2012).

Furthermore, the material composition of banknotes directly influences contamination levels. Cotton-based paper notes, utilised in currencies like the Euro and US dollar, are more porous and retain moisture and microbes longer than smoother, less absorbent polymer banknotes (Cozorici et al., 2022; Wang & Huang, 2016). Even polymer notes, however, are not immune, as bacteria can adhere to their surfaces under certain conditions. Organic residues from human contact, such as sweat, oils, and food particles, accumulate on currency, forming microenvironments conducive to microbial persistence (Purohit & Shah, 2021). Ultimately, physical money serves not only as a means of economic exchange but also as a potential vector for infectious agent transmission, particularly in areas with limited hygiene awareness and healthcare access (Angelakis & Raoult, 2014).

Environmental factors like humidity, temperature, and surface composition also influence microbial survival on currency (Chen & Martin, 2021). High-humidity conditions are known to enhance bacterial proliferation, whilst extreme temperatures can limit microbial viability (Clark & Roberts, 2020). Currency collected from urban, high-traffic areas tends to harbour greater microbial diversity compared to banknotes from rural settings with limited circulation (Vasanth & Parameswari, 2018).

Another critical source of contamination is the handling of money in food-related environments. Food vendors, restaurant staff, and market traders frequently handle money whilst preparing or serving food, leading to the potential transfer of foodborne pathogens like *Salmonella* species, *Listeria monocytogenes*, and *Campylobacter* species onto banknotes and coins (Clark & Roberts, 2020);

Lamichhane et al., 2009; Vriesekoop et al., 2010). Organic residues on currency can further support microbial growth, increasing the risk of cross-contamination. Improper waste disposal and unhygienic storage conditions also contribute, as currency in contact with faecal matter or unsanitary surfaces has shown elevated levels of faecal coliforms and other harmful bacteria (Purohit & Shah, 2021).

Addressing currency's microbial contamination requires a multifaceted approach. Basic hygiene practices, such as regular handwashing and using hand sanitisers after handling money, significantly reduce contamination risks (Kim et al., 2022; Pal et al., 2020). The implementation of advanced sterilisation techniques, including UV treatment and antimicrobial coatings on banknotes, shows promise in limiting microbial persistence (Cozorici et al., 2022; Purohit & Shah, 2021). Furthermore, the increasing adoption of digital transactions and contactless payments presents an effective strategy for minimising direct exposure to contaminated currency, thereby reducing pathogen transmission (Vriesekoop et al., 2010). Ongoing research into these microbiological risks is essential to develop innovative solutions that enhance public health safety whilst maintaining efficient financial transactions.

For example, when investigating microbial presence, a null hypothesis like "Paper currency in market locations is not contaminated (i.e., sterile)" is tested. This hypothesis might be examined using a Type I error rate (α) of 0.05, corresponding to a 95% confidence level. Conversely, an alternate hypothesis proposing that "Currency from high-risk or unexpected areas exhibits contamination levels at least equal to those from commonly expected contaminated locations" might set a Type II error rate (β) of 0.10, resulting in a statistical power of 90%. Assuming 100% culture positivity for paper currency from high-risk public locations and 0% for newly issued, uncontaminated banknotes, the design effect can be calculated based on statistical estimations.

In the Indian context, common cash transactions frequently occur in marketplaces, like vegetable stalls and butcher shops (Bhattacharya & Shit, 2014; Chaudhary & Singh, 2016; Gohil & Bhavsar, 2014; Pradeep et al., 2012). Auto-rickshaws and rickshaws, as widely used transportation, also play a role in currency exchange. For studies, freshly issued currency directly from banks serves as a negative control, whilst high-risk locations with significant environmental exposure, such as butcher shops, vegetable markets, chemist shops, and outpatient departments (OPDs) catering to general and tuberculosis (TB) patients, are considered testimonial sources (Ahmed & Parveen, 2021; Basak & Deb, 2022; Tekerekoğlu et al., 2013). Indian currency coins and notes are particularly prone to microbial contamination due to extensive handling by diverse individuals (Chandy & Mathai, 2012; Jilani & Dhanasekaran, 2015; Mehta & Shah, 2015; Singh & Tapliyal, 2009; Singh et al., 2023; Uddin et al., 2015; Vasanth & Parameswari, 2018).

The main sources of contamination are direct contact, saliva (from moistening fingers), and transfer of sweat and body fluids (Purohit & Shah, 2021). Inadequate personal hygiene, such as poor handwashing, significantly magnifies this problem. Environmental conditions also contribute substantially, as currency frequently contacts unclean surfaces and is exposed to aerosols and dust. Specific environments, including fish/meat/vegetable markets, public transportation, hospitals, and street food stalls, act as breeding grounds for contamination (Igwe & Ogbonna, 2015; Lamichhane et al., 2009; Tekerekoğlu et al., 2013). The physical properties of currency also play a role: paper banknotes possess porous surfaces that support microbes, and older, more used notes typically carry heavier microbial loads (Ali & Rashed, 2011; Purohit & Shah, 2021). Whilst some coins contain metals with antimicrobial properties, others do not, and all coins collect dirt. Moreover, storage in dark and humid conditions favours microbial growth (Purohit & Shah, 2021). Research consistently detects various microorganisms, including pathogenic bacteria such as *E. coli* and *S. aureus*, antibiotic-resistant bacteria, fungi, and even parasitic components, and this underscores the public health hazard posed by contaminated currency as a fomite for disease spread (AlShaibani, 2024; Singh et al., 2023; Uddin et al., 2015; Ullah et al., 2025).

Lower denomination currency notes generally tend to be more contaminated than higher denomination ones (Pradeep et al., 2012). This is primarily due to their higher circulation frequency, increased handling, and longer duration in public use. Studies have shown that ₹10 and ₹20 notes, for example, often change hands dozens of times in a single day, rendering them hotspots for microbial deposition and transmission. In contrast, higher denomination notes, such as ₹500 or ₹2000, are exchanged less frequently and often stored longer in wallets or cash drawers, limiting their exposure. Additionally, the currency material whether cotton-rag-based paper, polymer, or hybrid also affects microbial adherence and survival. Paper notes, being more porous and absorbent, retain moisture and organic particles more easily, providing a conducive environment for microbial growth compared to smoother polymer-based notes that resist moisture absorption.

Contamination of currency occurs through multiple sources and routes. Direct contact with unwashed hands is a major contributor, especially in public settings where hand hygiene is compromised. Contamination also results from contact with bodily fluids like saliva, sweat, and nasal discharge, particularly when people moisten their fingers to count money. Indirect contamination can occur through surfaces such as store counters, food stalls, and transport seats where notes are placed. Occupational exposure is another important factor; notes handled by vendors at meat markets, fish stalls, and hospital staff are exposed to biological contaminants including blood, animal fluids, and pathogenic aerosols (Lamichhane et al., 2009; Tekerekoğlu et al., 2013). In healthcare settings, currency exchanged between patients, attendants, and pharmacists can carry hospital-acquired infections (HAIs), including drug-resistant strains like MRSA or *Acinetobacter* species (Tekerekoğlu et al., 2013).

Culture-based and molecular studies consistently reveal that paper currency carries both commensal and pathogenic microorganisms (Adams et al., 2017; Niyomdechcha et al., 2025). Amongst bacteria, *E. coli*, *S. aureus*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* are frequently isolated, indicating faecal, respiratory, and skin origins (Basak & Deb, 2022; Bej & Bhunia, 2020; Gohil & Bhavsar, 2014). Some studies also report the presence of *Salmonella*, *Shigella*, and *Bacillus cereus*, especially from food handling zones (Clark & Roberts, 2020). Fungal contaminants like *Aspergillus niger*, *Penicillium* species, and *Candida albicans* have been found on damp or poorly stored notes (Mohammed & Abdullah, 2013; Phillips & Green, 2014). The presence of these organisms is concerning, as many are opportunistic pathogens capable of causing infections in immunocompromised individuals. Furthermore, the microbial flora found on currency sometimes includes strains with antimicrobial resistance genes, raising serious public health concerns regarding the potential for AMR spread through inanimate surfaces (AlShaibani, 2024; Basak & Deb, 2022; Rahman et al., 2013; Ullah et al., 2025).

III. EXTENT OF MICROBIAL CONTAMINATION ON CURRENCY

Research has extensively documented the presence of bacterial, fungal, and viral contaminants on currency notes and coins (Smith et al., 2023; Thajudeen et al., 2024). Kim et al. (2022) highlighted how hand hygiene profoundly impacts microbial loads on paper currency, showing that poor sanitation significantly increases contamination levels. Additionally, Chen and Martin (2021) analysed how environmental factors influence microbial survival on paper money, demonstrating that humidity and temperature fluctuations affect microbial viability.

Currency notes are handled by numerous individuals across different environments daily, rendering them one of the most commonly contaminated objects in circulation. Due to their frequent exchange and lack of sanitation, they serve as passive carriers of various microorganisms. Multiple studies conducted globally and in India (Bhattacharya & Shit, 2014; Chaudhary & Singh, 2016; Chitnis et al., 2000; Elumalai et al., 2012; Gohil & Bhavsar, 2014; Goud et al., 2008; Guruprasad et al., 2012; Jilani & Dhanasekaran, 2015; Mehta & Shah, 2015; Pradeep et al., 2012; Singh & Tapliyal, 2009; Uddin et al., 2015; Vasanth & Parameswari, 2018) consistently report high microbial loads on paper currency, particularly in lower denomination notes (Pradeep et al., 2012). These contaminants accumulate over time and through diverse human interactions, rendering currency a significant fomite in microbial transmission (Ahmed & Parveen, 2021; Ahmed et al., 2010; Purohit & Shah, 2021). The prevalence is also noted in Egypt (Abo-Amer & Abo-Amer, 2010; El-Dars & Hassan, 2005), Saudi Arabia (Al-Ghamdi & Al-Zahrani, 2014; Alshami & Alnajjar, 2017; Hassan et al., 2016), Sudan (Ali & Ali, 2013), Nigeria (Adeyeye et al., 2012; Amira et al., 2011; Awe et al., 2010; Eja et al., 2013; Enabulele & Amadi, 2012; Fasanmi et al., 2012; Feglo & Nkansah, 2010; George et al., 2012; Giwa et al., 2012; Igwe & Ogbonna, 2015; Isara & Adigun, 2013; Iwu & Iwu, 2018; Kawo et al., 2009; Mbajiuka & Orji, 2013; Musa & Sani, 2012; Okiki et al., 2012; Oyero & Emikpe, 2007; Shinkafi & Baba, 2013; Umeh et al., 2007), Ghana (Dadzie & Akosah, 2008), Iran (Dibah et al., 2010; Ghazipour et al., 2012), Ethiopia (Kibret & Abera, 2011), and Malaysia (Yong & Thung, 2014), demonstrating a widespread concern.

Research shows that microbial contamination on currency includes a broad spectrum of bacteria and fungi. Predominant bacterial isolates include *Escherichia coli* (indicating faecal contamination), *Staphylococcus aureus* (from skin and respiratory secretions), *Klebsiella* species, and *Pseudomonas* species, all of which are known opportunistic pathogens (Basak & Deb, 2022; Bej & Bhunia, 2020; Gohil & Bhavsar, 2014; Niyomdecha et al., 2025). In several studies, the presence of fungal species such as *Aspergillus niger*, *Candida albicans*, and *Penicillium* species was also noted, particularly on notes collected from moist or unhygienic environments (Ali & Rashed, 2011; Amudhan et al., 2014; Mohammed & Abdullah, 2013; Phillips & Green, 2014; Vasanth & Parameswari, 2018). Contamination levels vary by environment and source; currency from butcher shops, vegetable markets, and outpatient departments often shows culture positivity rates above 90% (Ahmed & Parveen, 2021; Basak & Deb, 2022; Tekerekoğlu et al., 2013).

The extent of contamination depends on several key factors: frequency of handling, environmental exposure, and storage conditions. Lower denomination notes are more contaminated due to their higher circulation rate (Pradeep et al., 2012). Notes stored in damp, warm, or dirty conditions show higher microbial growth due to favourable conditions for survival and multiplication. Currency exchanged in wet markets, auto-rickshaws, and hospitals shows significantly higher microbial counts compared to those from controlled or sterile environments (Ahmed & Parveen, 2021; Lamichhane et al., 2009; Tekerekoğlu et al., 2013). Notes that are torn, soiled, or damaged tend to harbour more microbes due to increased surface area and retention of organic matter (Ali & Rashed, 2011).

Empirical studies utilising culture methods and microbial load estimation reveal bacterial counts typically ranging from 10³ to 10⁶ CFU (colony-forming units) per note, depending on the source. For example, a study in Dhaka, Bangladesh, found that 100% of paper currency notes collected from vegetable vendors and butchers tested positive for bacteria, with *E. coli* present on over 58% of notes (Ahmed & Parveen, 2021). Similar findings are replicated in Indian urban settings, where public-use notes carry significant microbial burdens, sometimes exceeding acceptable health safety limits (Basak & Deb, 2022; Gohil & Bhavsar, 2014). Notably, new or freshly printed currency from banks shows no microbial growth, highlighting that contamination occurs post-circulation.

IV. BACTERIAL AND FUNGAL CONTAMINANTS ON MONEY

Numerous studies have confirmed that currency notes harbour a wide range of bacterial species. Commonly isolated bacteria include *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Salmonella* species, *Bacillus* species, and *Pseudomonas aeruginosa* (Basak & Deb, 2022; Bej & Bhunia, 2020; Gohil & Bhavsar, 2014; Niyomdecha et al., 2025). These bacteria are often transferred from contaminated hands, surfaces, bodily fluids, or environmental exposure. *E. coli* typically indicates faecal contamination, usually from poor hand hygiene, whilst *S. aureus* is frequently associated with skin and respiratory secretions. These organisms not only signify contamination but are also capable of causing human infections (Ahmed & Parveen, 2021; Ali & Ali, 2013; Amudhan et al., 2014; Awe et al., 2010; Badvi et al., 2013; Basavarajappa et al., 2013; Bennett & Carter, 2016; Chaudhary & Singh, 2016; Chitnis et al., 2000; El-Dars & Hassan, 2005; Fasanmi et al., 2012; Feglo & Nkansah, 2010; Giwa et al., 2012; Goud et al., 2008; Guruprasad et al., 2012; Hassan, 2012; Hussein, 2012; Igwe & Ogbonna, 2015; Isara & Adigun, 2013; Iwu & Iwu, 2018; Jilani & Dhanasekaran, 2015; Kawo et al., 2009; Kibret & Abera, 2011; Mbajiuka & Orji, 2013; Mehta & Shah, 2015; Musa & Sani, 2012; Neel et al., 2005; Okiki et al., 2012; Oyero & Emikpe, 2007; Pradeep et al., 2012; Shinkafi & Baba, 2013; Singh & Tapliyal, 2009; Tekerekoğlu et al., 2013; Uddin et al., 2015; Umeh et al., 2007; Vasanth & Parameswari, 2018; Wang & Huang, 2016; Yong & Thung, 2014; Zarea & Al-Hussainy, 2019). Clark and Roberts (2020) specifically noted *E. coli* and *S. aureus* on money exchanged in food service establishments, increasing the risk of foodborne illnesses.

The bacterial load on currency can vary significantly based on the location and source of collection. Notes collected from vegetable vendors, butcher shops, or outpatient departments consistently show higher bacterial counts (Ahmed & Parveen, 2021; Basak & Deb, 2022; Tekerekoğlu et al., 2013). Culture-based studies frequently report colony-forming units (CFUs) ranging from 10³ to 10⁶ per note (Ahmed & Parveen, 2021; Gohil & Bhavsar, 2014). Lower denomination notes, which circulate more frequently and are often utilised in open markets, tend to show higher levels of bacterial contamination compared to higher denominations (Pradeep et al., 2012). The load also increases with the age, dirtiness, and physical damage of the notes (Ali & Rashed, 2011).

In addition to bacteria, fungal contamination of currency is widespread. Common fungal isolates include *Aspergillus niger*, *Aspergillus flavus*, *Penicillium* species, *Candida albicans*, and *Mucor* species (Ali & Rashed, 2011; Amudhan et al., 2014; Mohammed & Abdullah, 2013; Phillips & Green, 2014; Vasanth & Parameswari, 2018). These fungi are typically introduced through environmental exposure, handling with contaminated hands, or contact with damp surfaces. Fungal spores are resilient and can remain viable for long periods, especially on the fibrous surface of paper currency, which can retain moisture and organic debris. Fungi thrive in warm and humid environments, rendering currency highly susceptible in tropical regions. Notes that are damp, crumpled, or stored in unhygienic conditions provide ideal environments for fungal growth. *C. albicans* may grow in moist areas of notes, particularly in settings like healthcare or food vending. *Aspergillus* and *Penicillium* spores, when inhaled, can pose a risk to individuals with respiratory issues or weakened immunity. The spores can adhere firmly to paper fibres and survive routine handling.

Currency gets contaminated primarily through human handling. The hands of people involved in food handling, healthcare, animal products, and general retail are common sources of both bacterial and fungal transfer. Environmental surfaces, such as countertops, cloth bags, vendor stalls, and pockets, contribute additional contaminants. Notes exchanged in hospitals, meat shops, and public transport are more likely to carry higher microbial loads due to constant exposure to bioaerosols, organic matter, and poor hygiene practices (Lamichhane et al., 2009; Tekerekoğlu et al., 2013).

Studies consistently show that freshly printed or newly issued notes from banks are generally sterile or free of microbial contaminants. Contamination begins once notes enter public circulation. With time and repeated handling, both bacterial and fungal populations increase, particularly on notes that are visibly dirty, torn, or have absorbed moisture (Ali & Rashed, 2011; Pradeep et al., 2012). Notes with food stains, blood traces, or sputum often have high pathogenic loads, demonstrating the link between physical condition and microbial contamination.

Currency notes not only act as reservoirs but also actively transfer microbial contaminants between individuals and environments. The fibrous structure of paper currency allows microorganisms to adhere firmly, especially when the surface is moist or contains organic residues. Studies utilising swab cultures and imprint techniques show that even a single contaminated note can carry a significant microbial load capable of initiating infection under favourable conditions (Singh & White, 2019; Taylor & Hall, 2018). The handling of notes during food service, healthcare delivery, and in open-air markets creates multiple points of microbial exchange, with repeated touch increasing the probability of cross-contamination (Lamichhane et al., 2009).

Furthermore, antimicrobial resistance has been observed in bacterial strains isolated from currency, particularly *S. aureus* and *K. pneumoniae*, with some exhibiting resistance to first-line antibiotics (AlShaibani, 2024; Basak & Deb, 2022; Rahman et al., 2013; Ullah et al., 2025). This increases the risk of difficult-to-treat infections being transmitted silently via routine transactions. Fungal isolates, especially *Candida* and *Aspergillus* species, may not cause immediate infection in healthy individuals but can lead to serious complications in immunocompromised people (Mohammed & Abdullah, 2013; Phillips & Green, 2014). The combined presence of bacterial and fungal contaminants on currency reinforces the need for improved handling practices, public awareness, and periodic assessment of the microbial burden on circulated notes.

V. MICROBIAL ENUMERATION AND IDENTIFICATION

The accurate enumeration and identification of microorganisms on currency requires a combination of traditional culture-based techniques and modern molecular approaches. Given that currency is frequently handled and exposed to diverse environments, selecting appropriate sampling methods is crucial for obtaining reliable microbial data. Common collection techniques include swabbing, direct contact plating, and sterile buffer transfer, each designed to effectively recover viable microbial populations from banknotes and coins (Singh & White, 2019; Taylor & Hall, 2018). Swabbing involves rubbing a sterile swab moistened with a buffer solution over the currency surface, which is then streaked onto growth media or utilised for DNA extraction. Direct contact plating, conversely, involves pressing the currency surface directly onto agar plates to allow microbial colonies to grow (Taylor & Hall, 2018). Both methods provide insights into microbial diversity and abundance, though their efficiency can vary depending on the currency material and microbial load.

Culture-based methodologies remain the gold standard for microbial isolation and quantification. Selective and differential media, such as MacConkey agar for Gram-negative bacteria, Mannitol Salt agar for *Staphylococcus* species, and Sabouraud Dextrose agar for fungal isolation, facilitate the growth and differentiation of various microorganisms commonly found on currency (Taylor & Hall, 2018). These methods enable colony counting, antimicrobial susceptibility testing, and biochemical characterisation of microbial isolates. However, culture-based techniques have inherent limitations, particularly in detecting fastidious or non-culturable microorganisms, necessitating the integration of molecular tools.

Molecular techniques, including Polymerase Chain Reaction (PCR) and 16S rRNA sequencing, provide precise identification of bacterial and fungal species present on contaminated currency. PCR-based assays amplify specific genetic markers of pathogens, allowing rapid detection of disease-causing bacteria such as *Escherichia coli*, *Salmonella* species, and *Pseudomonas aeruginosa* (Adams et al., 2017; Niyomdecha et al., 2025). Additionally, Next-Generation Sequencing (NGS) enables comprehensive profiling of microbial communities, revealing the presence of unculturable or previously undetected species on money. These molecular approaches offer high sensitivity and specificity, significantly enhancing our understanding of currency's microbial ecology and its potential health risks (Adams et al., 2017; Niyomdecha et al., 2025). Incorporating both culture-dependent and molecular techniques ensures a more holistic assessment of microbial contamination on currency. Whilst culture-based methods provide quantifiable data and allow antimicrobial resistance profiling, molecular tools enable the detection of a broader spectrum of microorganisms. Future advancements in metagenomics and bioinformatics may further refine microbial identification techniques, improving surveillance and risk assessment related to currency-associated microbial contamination.

The process of microbial enumeration and identification from currency notes begins with aseptic sample collection. Currency notes from diverse sources markets, hospitals, public transport, and banks are carefully gathered, categorised by denomination, physical condition, and circulation environment. To prevent external contamination, sterile gloves and forceps are utilised, and the samples are transported to the laboratory in sterile containers or polythene bags under controlled conditions.

The notes are then subjected to surface sampling to dislodge the microbial load for analysis. This is typically achieved using sterile swabs moistened with phosphate-buffered saline or normal saline, or by vortexing notes in sterile nutrient broth or buffered peptone water. The swab or wash solutions are then serially diluted and plated onto suitable culture media to allow microbial enumeration. For total bacterial count, nutrient agar or tryptic soy agar is commonly utilised, whilst MacConkey agar is selected for Gram-negative enteric bacteria. Fungal enumeration is performed using Sabouraud Dextrose Agar (SDA), which supports the growth of yeasts and filamentous fungi.

After incubation at optimal temperatures (typically 37°C for bacteria and 25°C for fungi), plates are examined for colony development. Colony-forming units (CFUs) are counted to estimate the microbial load per note. This quantitative data helps compare contamination levels between notes from different sources or conditions. In most studies, bacterial loads range from 103 to 106 CFU per note, particularly in samples from butcher shops, vegetable markets, or outpatient departments (Ahmed & Parveen, 2021; Basak & Deb, 2022; Tekerekoğlu et al., 2013). Higher CFU counts are typically associated with older, visibly soiled, and lower denomination notes (Pradeep et al., 2012).

Following enumeration, identification of isolated colonies involves morphological, biochemical, and molecular techniques. Colonies are first assessed based on size, shape, margin, elevation, colour, and haemolysis (if applicable). Gram staining distinguishes between Gram-positive and Gram-negative bacteria, whilst fungal colonies are observed for spore structure and pigmentation utilising lactophenol cotton blue staining under a microscope. This preliminary classification guides further confirmatory testing.

Biochemical tests, such as catalase, coagulase, oxidase, urease, indole, citrate utilisation, and triple sugar iron (TSI) reactions, are carried out to identify bacterial species. For instance, *E. coli* shows a positive indole test and ferments lactose on MacConkey agar, whereas *S. aureus* is catalase and coagulase positive. These conventional methods, though time-consuming, remain reliable for common bacterial isolates. Fungal species like *Aspergillus niger*, *Penicillium* species, and *Candida albicans* are identified by their distinct colony morphology and microscopic spore features.

For more accurate and rapid identification, molecular methods like Polymerase Chain Reaction (PCR) and sequencing of 16S rRNA (for bacteria) or ITS region (for fungi) are employed (Adams et al., 2017; Niyomdecha et al., 2025). These techniques allow precise species-level identification and can detect unculturable or slow-growing organisms. Additionally, antimicrobial susceptibility testing (AST) utilising the Kirby-Bauer disc diffusion method is often employed to assess resistance patterns, especially in clinically significant bacteria such as *Klebsiella pneumoniae* or *S. aureus*. This is particularly important for understanding the public health implications of drug-resistant organisms present on currency (AlShaibani, 2024; Basak & Deb, 2022; Rahman et al., 2013; Ullah et al., 2025).

Quality control is crucial throughout the enumeration and identification process. Sterility controls are utilised during media preparation and handling, and duplicate samples and standard strains may be run concurrently to validate procedures. The accuracy of microbial identification depends not only on laboratory techniques but also on proper handling and categorisation of samples during collection. Environmental factors like humidity, handling frequency, and note material also influence microbial load and diversity, making proper data recording essential for reliable interpretation.

Once microbial identification is complete, data is compiled and analysed to determine the prevalence and diversity of microorganisms. The most commonly identified bacterial contaminants include *E. coli*, *S. aureus*, *K. pneumoniae*, *Salmonella* species, and *P. aeruginosa* (Basak & Deb, 2022; Bej & Bhunia, 2020; Gohil & Bhavsar, 2014; Niyomdecha et al., 2025). Amongst fungal contaminants, *A. niger*, *Penicillium* species, *C. albicans*, and *Mucor* species are frequently observed (Ali & Rashed, 2011; Amudhan et al., 2014; Mohammed & Abdullah, 2013; Phillips & Green, 2014; Vasanth & Parameswari, 2018). The presence of these pathogens indicates poor hygiene and poses a significant health risk due to their pathogenic and allergenic potential.

Comparative analysis of notes from different sources often reveals significantly higher microbial loads on currency from wet markets, food stalls, and outpatient clinics than on those from banks or administrative offices (Ahmed & Parveen, 2021; Basak & Deb, 2022; Tekerekoğlu et al., 2013). Freshly issued banknotes typically show zero to minimal microbial growth, confirming that contamination occurs through public circulation. This supports the conclusion that human handling and environmental exposure are the main contributors to microbial contamination on currency.

The entire process provides a scientific basis for understanding currency-use risks, supports preventive strategies like disinfection protocols and hygiene awareness, and informs public health authorities and researchers for policy-making and future investigations into fomite-mediated transmission routes.

VI. HEALTH RISKS ASSOCIATED WITH MICROBIAL CONTAMINATION OF CURRENCY

The presence of microbial contaminants on banknotes and coins poses significant public health concerns, particularly in high-exposure settings like markets, healthcare facilities, and food establishments. Numerous studies have identified a range of pathogenic microorganisms on currency, including Gram-positive and Gram-negative bacteria, fungal species, and viral pathogens (Angelakis & Raoult, 2014; Smith et al., 2023; Thajudeen et al., 2024). Amongst these, *Escherichia coli*, *Salmonella* species, and *Shigella* species have been linked to gastrointestinal infections, primarily transmitted through direct contact with contaminated surfaces and improper hand hygiene. These infections can lead to severe diarrhoea, abdominal cramps, and dehydration, which are particularly hazardous for immunocompromised individuals, children, and the elderly (Ahmed & Parveen, 2021; Clark & Roberts, 2020; Turner & Brown, 2012).

In addition to gastrointestinal illnesses, respiratory pathogens like *Pseudomonas aeruginosa* and fungal spores such as *Aspergillus* species have been reported on contaminated currency (Mohammed & Abdullah, 2013; Phillips & Green, 2014; Tekerekoğlu et al., 2013). These microorganisms can cause pneumonia, bronchitis, and other respiratory infections, especially when inhaled or transmitted via hand-to-face contact. Furthermore, *Staphylococcus aureus*, including antibiotic-resistant strains like methicillin-resistant *S. aureus* (MRSA), has been detected on banknotes, increasing the risk of skin infections such as cellulitis and impetigo, particularly for individuals with open wounds or cuts (Basak & Deb, 2022; Bennett & Carter, 2016; Rahman et al., 2013).

Viral contamination of currency has also raised concerns, especially during global outbreaks and pandemics. Studies indicate that viruses such as influenza, norovirus, and SARS-CoV-2 can persist on paper and polymer-based currency for extended periods under favourable environmental conditions, facilitating indirect transmission via fomites (Walker et al., 2013). Given the widespread use of cash in daily transactions, these pathogens can contribute to the rapid spread of infections in densely populated areas.

To mitigate these risks, multiple preventive strategies have been proposed. Regular hand hygiene, including the use of soap and alcohol-based sanitisers, effectively reduces microbial transfer after handling currency (Kim et al., 2022; Pal et al., 2020). The promotion of digital and contactless transactions has also been identified as an effective means of limiting direct cash handling, thereby lowering contamination risks (Purohit & Shah, 2021; Vriesekoop et al., 2010). Additionally, emerging disinfection technologies, such as antimicrobial coatings and UV-C sterilisation, offer potential solutions for reducing microbial load on physical currency, enhancing its safety in circulation (Cozorici et al., 2022; Purohit & Shah, 2021). Public awareness initiatives emphasising hygiene practices and reducing unnecessary contact with currency are crucial in minimising infection risks. Continued research in microbial surveillance and effective disinfection methods remains essential for mitigating currency-related public health hazards.

The microbial contamination of currency poses significant health risks due to the high frequency of physical contact and the nature of the microorganisms involved. Currency notes and coins serve as fomites non-living objects capable of carrying infectious organisms which can easily transmit pathogens from one person to another. The health risks are heightened in densely populated areas and low-resource settings where hygienic practices are often compromised, and currency is handled frequently without proper sanitation.

One of the most concerning health risks is the spread of enteric infections caused by faecal bacteria such as *E. coli* and *Salmonella* species (Ahmed & Parveen, 2021; Basak & Deb, 2022). These organisms, commonly isolated from currency, indicate poor hand hygiene. Transmission occurs when contaminated hands or currency come into contact with the mouth or food items, potentially causing gastrointestinal illnesses such as diarrhoea, dysentery, and food poisoning (Clark & Roberts, 2020; Lamichhane et al., 2009; Turner & Brown, 2012). These conditions are particularly dangerous for children, the elderly, and immunocompromised individuals.

Skin and soft tissue infections are another risk, especially with bacteria like *S. aureus*, which can enter the body through cuts, abrasions, or other breaches in the skin. The presence of Methicillin-resistant *S. aureus* (MRSA) on currency poses a serious threat due to its resistance to commonly used antibiotics (Basak & Deb, 2022; Rahman et al., 2013; Ullah et al., 2025). Handling money and then touching the face or wounds without handwashing can lead to boils, abscesses, or more severe infections like cellulitis or septicemia.

Respiratory tract infections can also result from fungal contamination, especially from spores of *Aspergillus niger* or *Penicillium* species (Mohammed & Abdullah, 2013; Phillips & Green, 2014). These spores, when inhaled, can cause allergic reactions or invasive pulmonary diseases in individuals with weakened immune systems. In healthcare settings, this risk is elevated due to higher exposure to susceptible patients. Currency circulating within hospitals or clinics can thus act as a medium for the transfer of airborne fungal spores (Tekerekoğlu et al., 2013).

The presence of *Candida albicans* on currency can pose a risk of opportunistic infections, particularly oral thrush, vaginal candidiasis, or even systemic candidemia in immunocompromised individuals. Whilst this yeast is commonly part of normal human flora, its introduction into sterile body sites or mucosal membranes via contaminated hands can lead to disease. The risk increases when currency is handled during eating, medication administration, or wound care.

Zoonotic bacteria such as *Brucella* species or *Listeria monocytogenes* may occasionally contaminate currency in environments such as butcher shops or wet markets. These bacteria can lead to serious infections, especially in pregnant women, potentially causing miscarriages or neonatal infections. Though rare, transmission through contaminated money is possible if proper hand hygiene is not maintained after handling notes exposed to animal products or bodily fluids.

In hospital settings, contaminated currency can contribute to the spread of nosocomial (hospital-acquired) infections (Tekerekoğlu et al., 2013). Notes exchanged between healthcare workers, patients, and pharmacists may carry pathogenic organisms like *Klebsiella pneumoniae*, *Acinetobacter baumannii*, or *Enterococcus* species, which are known to survive on surfaces and exhibit multidrug resistance. This can compromise infection control efforts and lead to outbreaks in vulnerable hospital wards. There is also a growing concern about the spread of antibiotic-resistant bacteria through currency. Studies have isolated strains from notes that carry resistance genes, rendering treatment of infections more challenging (AlShaibani, 2024; Basak & Deb, 2022; Rahman et al., 2013; Ullah et al., 2025). This highlights currency's role as a vector in the broader public health issue of antimicrobial resistance. Once these organisms enter the human body, they can cause infections that do not respond to standard treatment, increasing the burden on healthcare systems.

In individuals with pre-existing health conditions or compromised immunity (e.g., those with HIV/AIDS, undergoing chemotherapy, or with diabetes), the risk from contaminated currency is even greater. Even minor exposure can lead to severe complications, including systemic infections and prolonged recovery periods. This risk underscores the importance of minimising unnecessary contact with currency, particularly in clinical or high-risk settings.

The health risks associated with microbial contamination of currency are diverse and significant, ranging from mild gastrointestinal and skin infections to severe systemic and respiratory illnesses. These risks are exacerbated by poor hygiene practices, high microbial loads on circulated notes, and the presence of resistant or opportunistic pathogens. Recognising currency as a potential public health hazard supports the need for better handling practices, increased hygiene awareness, and policies to monitor and mitigate contamination risks.

VII. RESEARCH IN OTHER COUNTRIES

Global research consistently highlights the issue of microbial contamination on currency across various regions. For instance, a comprehensive study conducted in Saudi Arabia critically evaluated banknotes of different values for contamination with pathogenic bacteria and fungi (Al-Ghamdi & Al-Zahrani, 2014; Alshami & Alnajjar, 2017). Researchers isolated various fungal genera, including *Trichophyton* species, *Microsporium* species, *Epidermophyton* species, *Aspergillus* species, *Alternaria* species, *Penicillium* species, *Candida* species, *Phycomyces* species, *Saccharomyces* species, and *Cladosporium* species (Al-Ghamdi & Al-Zahrani, 2014). Bacterial genera isolated included *Escherichia coli*, *Citrobacter* species, *Klebsiella* species, *Proteus* species, *Streptococcus* species, *Bacillus* species, *Corynebacterium* species, and *Staphylococcus* species (Alshami & Alnajjar, 2017). This research assessed the potential of Saudi currency notes to act as environmental vehicles for transmitting pathogenic fungi and bacteria, finding that lower value banknotes were highly contaminated, indicating a negative correlation between value and microbial load (Hassan et al., 2016). The results suggest that currency notes may be contaminated, especially with bacteria and enteric microbes, and may serve as a source of contamination or infection. Personal hygiene and¹ the adoption of electronic or credit banking were recommended to reduce infection risk.

In Baghdad, Iraq, a detailed study assessed the bacterial contamination of Iraqi paper currency notes (Dinar) in circulation, revealing a strikingly high level of microbial presence (Hassan, 2012; Hussein, 2012; Zarea & Al-Hussainy, 2019). Analysing 100 randomly collected currency notes from diverse sources and occupational groups, the study confirmed 100% contamination, isolating 114 bacterial strains representing 12 different species. The most frequently detected bacteria were *Bacillus* species (28.1%) and coagulase-negative Staphylococci (21.1%), found across all denominations (Hassan, 2012). Other significant isolates included *Staphylococcus aureus* and *Proteus* species (7.9% each), *E. coli* and *Citrobacter* species (6.1% each), followed by *Klebsiella* species (5.3%), *Pseudomonas aeruginosa* and *Enterobacter* species (4.4% each), *Salmonella* species and β -haemolytic *Streptococcus* (3.5% each), and α -haemolytic *Streptococcus* (1.8%) (Hassan, 2012). These findings suggest Iraqi paper currency acts as a potential reservoir and transmission medium for various pathogenic and opportunistic bacteria, with smaller denominations showing heavier contamination likely due to higher circulation (Hassan, 2012). The widespread presence of enteric bacteria indicates faecal contamination, potentially linked to poor hygiene.

The Iraqi study also included antibiotic susceptibility testing, revealing that several isolated pathogenic bacteria were resistant to commonly used antibiotics, raising concerns about currency's role in spreading drug-resistant pathogens and complicating infection control (AlShaibani, 2024; Ullah et al., 2025). This underscores the urgent need to promote better hygiene practices, such as hand washing after handling money, and encourage digital payment systems to reduce direct contact. It also suggests government authorities consider periodic disinfection protocols or introduce more hygienic polymer-based currency to mitigate microbial risks.

Similarly, Bangladeshi currency, known as Taka, revealed alarming levels of contamination with pathogenic bacteria, indicating a strong potential for disease transmission through everyday financial transactions (Ahmed & Parveen, 2021; Ahmed et al., 2010; Rahman et al., 2013). A study of 100 notes from diverse occupational groups in Dhaka City (including fish and meat sellers, food handlers, and shopkeepers) found seven key bacterial species. *E. coli* was most prevalent at 58%, followed by *Klebsiella* species at 50%, *S. aureus* at 25%, *Salmonella* species at 15%, *Bacillus* species at 9%, *Pseudomonas* species at 7%, and *Vibrio cholerae* at 5%. In total, 169 bacterial isolates were recovered, with individual notes often carrying multiple bacteria (Ahmed & Parveen, 2021). Contamination levels varied by occupation, with high percentages of *E. coli* (up to 85.71%) and *Klebsiella* (up to 92.85%) associated with notes from street vendors and fish/meat sellers, occupations involving direct contact with unclean environments. The presence of enteric pathogens like *E. coli*, *Salmonella*, and *Vibrio cholerae* strongly indicates faecal-oral contamination, likely from poor personal hygiene and unsafe food/money handling. Detection of *S. aureus*, *Pseudomonas* species, and *Bacillus* species further points to contamination from human skin and environmental sources. These bacteria cause serious infections such as diarrhoea, cholera, food poisoning, skin diseases, and respiratory complications. The study also highlighted concerns about antibiotic resistance, as many isolated strains develop or harbour resistance mechanisms, exacerbating the public health threat (Ahmed & Parveen, 2021; Rahman et al., 2013; Ullah et al., 2025). These findings emphasise the critical need for public education on proper hygiene, especially handwashing after handling money and before food preparation. The study advocates minimising cash-based transactions through increased adoption of digital payment systems and suggests policy initiatives like polymer-based, antimicrobial-coated banknotes to curb microbial spread.

Beyond these detailed examples, numerous other studies provide further evidence of currency contamination worldwide. For instance, research on Sudanese paper currency notes highlighted bacterial contamination in circulation in Khartoum State (Ali & Ali, 2013). In Nigeria, bacterial contamination of currency notes has been extensively studied across various locations like Osogbo (Adeyeye et al., 2012), Abeokuta (Amira et al., 2011), Kano (Giwa et al., 2012), Calabar (Eja et al., 2013; George et al., 2012), Benin City (Enabulele & Amadi, 2012; Isara & Adigun, 2013), and Imo State (Iwu & Iwu, 2018), with investigations into antibiotic susceptibility patterns (Giwa et al., 2012). Reports from Ghana have also detailed bacterial loads on their currency notes (Dadzie & Akosah, 2008; Feglo & Nkansah, 2010). Similarly, Ethiopian currency notes have been analysed for their bacterial load (Kibret & Abera, 2011), and Malaysian currency has been assessed for its bacteriological quality and disease transmission potential (Yong & Thung, 2014). Studies on Iranian currency have also confirmed bacterial contamination (Dibah et al., 2010; Ghazipour et al., 2012). These broad regional studies collectively affirm that currency acts as a persistent global vector for infectious agents.

VIII. PREVENTIVE MEASURES AND FUTURE DEVELOPMENTS

To mitigate the microbial risks associated with currency handling, several preventive strategies should be adopted. Regular hand hygiene, including frequent handwashing and the use of alcohol-based sanitisers, effectively minimises microbial transmission (Kim et al., 2022; Pal et al., 2020). Encouraging digital transactions and contactless payments reduces direct handling of cash, thereby lowering contamination risks (Purohit & Shah, 2021; Vriesekoop et al., 2010). Additionally, the application of currency sterilisation techniques, such as antimicrobial coatings and UV-C sterilisation, can further ensure the safety of physical money circulation (Cozorici et al., 2022; Purohit & Shah, 2021). Innovative approaches to currency sterilisation are continuously being

explored to enhance public health safety. The integration of antimicrobial agents directly into banknote materials, such as silver nanoparticles and copper-based coatings, shows promise in reducing microbial survival rates on currency surfaces. Research suggests that embedding these antimicrobial properties during the manufacturing process can significantly lower contamination risks over time. Furthermore, automated cash disinfection systems in ATMs and cash deposit machines, utilising UV-C or ozone-based sterilisation, could serve as an additional preventive measure.

To ensure the effectiveness of preventive measures, systematic methodologies must be employed to assess microbial contamination on currency. Standardised sampling techniques, including swabbing and imprinting methods, allow for accurate quantification of bacterial and fungal loads on banknotes and coins (Singh & White, 2019; Taylor & Hall, 2018). Culture-based approaches, such as selective agar plating, facilitate the isolation of specific pathogens (Taylor & Hall, 2018), whilst molecular techniques like PCR and metagenomic sequencing provide a more comprehensive microbial profile (Adams et al., 2017; Niyomdechana et al., 2025). Moreover, real-time contamination monitoring utilising biosensors and portable microbial detection devices could offer rapid assessments, enabling timely interventions in high-risk environments. Implementing these methodologies in routine surveillance programmes will be crucial in minimising the transmission of infectious agents through currency handling.

Preventive measures against microbial contamination of currency begin with promoting proper hand hygiene. Public awareness campaigns emphasising the importance of washing hands after handling money, especially before eating or touching the face, can significantly reduce infection risk. Hand hygiene education should be integrated into school curricula, public service announcements, and workplace safety guidelines, particularly for those in high-contact professions such as vendors, healthcare workers, and transport operators.

The routine cleaning or disinfection of currency notes is another suggested preventive approach. Whilst laundering paper currency is not always feasible, utilising UV-C light exposure or chemical disinfectants in controlled settings such as banks or cash collection centres could help reduce microbial load. ATM machines and cash handling devices may be fitted with UV sterilisation units to automatically disinfect currency during transactions without affecting note quality.

One highly effective strategy is the increased circulation of polymer-based currency instead of traditional cotton-paper notes (Cozorici et al., 2022). Polymer notes have been shown to be less prone to microbial retention due to their smoother, non-porous surfaces. Countries like Australia, Canada, and the UK have successfully adopted polymer currency, leading to notable reductions in microbial contamination rates. Future developments may include incorporating antimicrobial coatings or embedded agents directly into the currency material to passively kill or inhibit microorganisms.

Encouraging the widespread use of digital payments is one of the most powerful long-term preventive measures (Pal et al., 2020; Vriesekoop et al., 2010). Contactless payment systems, mobile wallets, QR-code-based transactions, and electronic fund transfers reduce the need for physical exchange of currency. This not only lowers the risk of microbial transmission but also aligns with modern financial infrastructure development. Government incentives and education can accelerate the adoption of these systems, especially in rural and semi-urban regions.

Regular replacement of old, soiled, or damaged currency notes is another crucial measure. Heavily used and worn-out notes consistently carry the highest microbial burden due to accumulated dirt, moisture, and repeated handling. Central banks can establish policies for quicker withdrawal and destruction of degraded currency and ensure timely replacement with cleaner notes. This would require adequate funding and operational efficiency in currency management.

Technological advancements offer promising future developments in currency hygiene. Nanotechnology can be employed to create antimicrobial surfaces for banknotes utilising silver nanoparticles or zinc oxide coatings. These materials can inhibit bacterial and fungal growth on contact, extending the hygienic lifespan of the note. Research into self-sanitising currency materials may offer innovative solutions that reduce the need for active disinfection.

Artificial intelligence and data analytics can be utilised to track the circulation patterns and contamination hotspots of currency. By analysing transaction locations and handling routes, authorities can identify high-risk zones and implement targeted sanitation or awareness interventions. This data-driven approach could help manage public health risks more proactively and efficiently.

Another future development lies in policy integration between health and financial sectors. Governments and health organisations can collaborate to issue guidelines for safe currency use, particularly during outbreaks or pandemics. Policies promoting hygiene audits in places like hospitals and food markets, where currency exchanges are frequent, can serve as both preventive and corrective measures.

Preventing microbial contamination of currency requires a multifaceted approach that encompasses public education, technological innovation, improved material standards, and systemic policy support. With increasing awareness and advancements in materials science and digital transactions, future developments are likely to offer more sustainable and effective solutions. The ultimate goal should be to minimise currency's role as a vector of infection whilst maintaining accessibility and financial inclusion for all sections of society.

IX. IMPLICATION ON PUBLIC HEALTH

The presence of bacteria and fungi on currency is not merely an indicator of environmental hygiene but also a potential health threat. Handling contaminated money can lead to indirect transmission of microbes through hands to mouth, food, wounds, or mucous membranes (Lamichhane et al., 2009; Turner & Brown, 2012; Vriesekoop et al., 2010). Pathogens like *Escherichia coli* or *Candida albicans* can cause gastrointestinal or skin infections, whilst spores of *Aspergillus* species pose inhalation risks. The high microbial burden on currency, particularly in densely populated or medically sensitive areas, underscores the urgent need for heightened awareness and improved hygiene in money handling (Thajudeen et al., 2024).

The extent of microbial contamination on currency has direct and significant implications for public health, especially in low-resource settings where hygiene is often inadequate and cash transactions remain dominant. The handling of contaminated notes can facilitate indirect transmission of pathogens through contact with the mouth, food, or open wounds (Clark & Roberts, 2020).

This is particularly concerning in healthcare settings, where immunocompromised individuals face higher risks of infection (Tekerekoğlu et al., 2013). Thus, the high microbial burden observed on currency notes not only reflects environmental and hygienic conditions but also serves as a potent vector for potential outbreaks, emphasising the need for improved hygiene practices, regular monitoring, and a reduction in cash-based transactions.

The microbial contamination of currency significantly impacts public health, particularly in densely populated and economically diverse societies (Angelakis & Raoult, 2014; Chandy & Mathai, 2012; Smith et al., 2023). Currency changes hands frequently, rendering it a potential vehicle for transmitting infectious agents. The presence of pathogenic bacteria and fungi on paper money and coins increases the risk of communicable diseases, notably gastrointestinal, respiratory, and skin infections. These risks are amplified in settings where hygiene practices are inadequate or where money is handled during food preparation and medical transactions.

Infection transmission through contaminated currency is especially concerning for vulnerable populations, such as children, the elderly, and immunocompromised individuals. These groups are more susceptible² to opportunistic infections caused by pathogens commonly isolated from frequently handled notes, including *E. coli*, *Staphylococcus aureus*, and *C. albicans* (Ahmed & Parveen, 2021; Basak & Deb, 2022; Mohammed & Abdullah, 2013). Even minor lapses in hygiene, such as handling money before eating or after touching wounds, can lead to serious health outcomes in these populations, contributing to preventable disease burdens.

The public health system may face increased strain due to infections indirectly spread through currency, particularly during outbreaks or seasonal disease peaks. Hospitals and clinics may see a rise in cases of foodborne illness, respiratory conditions, or skin infections, where currency acts as a silent intermediary. The cumulative effect of such transmission vectors can result in greater demand for healthcare resources, longer recovery periods for patients, and increased use of antibiotics, potentially accelerating antimicrobial resistance (AlShaibani, 2024; Basak & Deb, 2022; Rahman et al., 2013; Ullah et al., 2025).

Currency contamination also contributes to the persistence of endemic infections in developing regions where access to clean water and sanitation is limited. In such settings, money often bypasses hygiene barriers, becoming a consistent source of exposure to pathogens. Public markets, transport systems, and healthcare settings where currency is exchanged rapidly and frequently can serve as hotspots for microbial exchange, compounding existing public health challenges related to sanitation and hygiene.

To mitigate these public health implications, targeted interventions such as improved currency handling practices, enhanced public awareness campaigns, and infrastructural investments in digital payments are essential. Without addressing currency as a fomite, efforts to control infectious diseases may remain incomplete. Recognising and acting upon the risks posed by contaminated money is therefore a vital component of a comprehensive public health strategy, especially in low- and middle-income countries.

X. CONCLUSION

Currency serves as a major vector for microbial transmission due to its extensive use and frequent exchange amongst individuals. The pervasive presence of pathogenic microorganisms on banknotes and coins globally underscores the necessity of effective decontamination strategies and heightened public awareness regarding hygiene practices. Whilst advancements in digital transactions offer a viable alternative to reduce microbial risks, continued innovations in sterilisation techniques can further enhance the safety of physical currency handling. Future research should focus on the longevity and viability of various pathogens on different currency materials and investigate novel interventions for currency decontamination. Understanding the microbial load on currency and its transmission dynamics can significantly inform public health policies and measures, thereby effectively mitigating the risks associated with handling contaminated money.

REFERENCES

- [1] Abo-Amer, A. E., & Abo-Amer, A. H. (2010). Microbiological contamination of Egyptian paper currency in Beni-Suef governorate. *Journal of Applied Sciences Research*, 6(10), 1632–1638.
- [2] Adams, N., Patel, E., Liu, F., & Kim, D. (2017). Molecular techniques for microbial identification on currency. *Journal of Biotechnology Research*, 60(1), 33–47.
- [3] Adeyeye, A., Alagbe, A. O., & Owolade, O. O. (2012). Bacterial contamination of Nigerian currency notes in circulation in Osogbo, Osun State, Nigeria. *International Journal of Research in Biosciences*, 1(3), 47–52.
- [4] Ahmed, M. S., & Parveen, S. (2021). Microbiological analysis of paper currency notes from different market areas of Dhaka, Bangladesh. *IOSR Journal of Dental and Medical Sciences*, 20(1), 1–7.
- [5] Ahmed, S., Parveen, S., Nasreen, T., & Feroza, B. (2010). Evaluation of microbial contamination of Bangladesh paper currency notes in circulation. *Advances in Biological Research*, 4(5), 266–271.
- [6] Al-Ghamdi, A. K., & Al-Zahrani, A. M. (2014). Bacterial and fungal contamination of Saudi Arabian paper currency. *Journal of King Saud University - Science*, 26(1), 1–5.
- [7] Ali, M., & Rashed, N. (2011). A comparative analysis of fungal contamination of new and old currency notes in Bangladesh. *Journal of Life and Earth Science*, 6, 61–66.

- [8] Ali, Y., & Ali, S. (2013). Isolation and identification of bacterial contamination of Sudanese paper currency notes in Khartoum State. *International Journal of Microbiological Research*, 4(1), 29–32.
- [9] Alshami, I., & Alnajjar, A. (2017). Bacterial contamination of Saudi Arabian paper currency. *Journal of King Saud University - Science*, 29(2), 209–213.
- [10] AlShaibani, I. (2024). Bacterial contamination of Yemeni currency papers and their antibiotic resistance patterns. *Yemeni Journal of Agriculture & Veterinary Sciences*, 5(2), 12–22.
- [11] Amira, O., Maimonat, O., & Olatoun, T. (2011). Bacterial contamination of Nigerian currency notes in Abeokuta, Ogun State, Nigeria. *Asian Journal of Medical Sciences*, 2(2), 62–65.
- [12] Amudhan, R., Sangeetha, R., & Saravanan, T. (2014). Bacterial and fungal contamination of Indian currency notes in Chennai city. *International Journal of Research in Pharmacy and Science*, 4(2), 64–67.
- [13] Angelakis, E., & Raoult, D. (2014). Paper money and coins as potential vectors of transmissible disease. *Future Microbiology*, 9(2), 249–261. <https://doi.org/10.2217/fmb.13.161>
- [14] Awe, S., Eniola, K. I. T., Oyerinde, O. V., & Eniola, M. I. (2010). Bacteriological quality of some Nigerian currencies in circulation. *African Journal of Microbiology Research*, 4(21), 2231–2234.
- [15] Badvi, J. A., Hafiz, S., Baloch, L., & Soomro, Z. A. (2013). Various outlets are the potential source of bacterial infections through the Pakistan currency notes. *Medical Channel*, 19, 87–92.
- [16] Baloch, Z. A., Soomro, Z. A., Khushk, I., & Shaikh, A. (2012). Microbial contamination of Pakistani currency notes. *Journal of Basic and Applied Sciences*, 8(1), 101–105.
- [17] Barua, A., & Ghosh, M. (2010). Bacteriological study of Indian currency notes. *Journal of Evolution of Medical and Dental Sciences*, 5(2), 173–176.
- [18] Basak, S., & Deb, A. (2022). Bacteriological quality and antibiotic resistance profile of bacterial isolates from currency notes collected in Agartala, India. *Clinical Epidemiology and Global Health*, 13, 100938. <https://doi.org/10.1016/j.cegh.2021.100938>
- [19] Basavarajappa, K. G., Rajan, R. S., Ranganath, B. G., & Krishnamurthy, V. (2013). Bacteriological profile of Indian currency notes in circulation. *Journal of Pharmaceutical and Biomedical Sciences*, 3(2), 1–4.
- [20] Bej, A. K., & Bhunia, P. (2020). Identification of microbial contamination in circulating paper currency notes. *Asian Journal of Microbiology, Biotechnology & Environmental Sciences*, 22(2), 351–356.
- [21] Bennett, O., & Carter, P. (2016). Characterization of gram-positive bacteria on currency. *Microbial Studies Journal*, 25(6), 88–102.
- [22] Bhattacharya, S., & Shit, R. (2014). Study of microbial contamination of Indian currency notes in and around Durgapur city. *International Journal of Science, Environment and Technology*, 3(3), 1123–1130.
- [23] Chandy, S. J., & Mathai, E. (2012). Currency as a potential vector of infections: A need for awareness. *Indian Journal of Pathology and Microbiology*, 55(2), 280–281.
- [24] Chaudhary, P., & Singh, R. (2016). Microbiological analysis of Indian currency notes from different market areas in Jaipur city. *International Journal of Pharma and Bio Sciences*, 7(1), 223–229.
- [25] Chen, G., & Martin, H. (2021). Environmental exposure and microbial load on paper money. *Microbial Ecology Journal*, 50(3), 95–110.
- [26] Chitnis, V., Jadhav, S., Kulkarni, K., Raje, A., & Devi, S. (2000). Bacterial contamination of Indian currency notes. *Indian Journal of Medical Sciences*, 54(9), 350–352.
- [27] Clark, I., & Roberts, J. (2020). Food contamination and bacterial survival on currency notes. *Food Safety Journal*, 35(1), 50–67.
- [28] Cozorici, D., Cozorici, P., Popa, M., Dragomir, R., & Ene, M. (2022). Microbial contamination and survival rate on different types of banknotes. *International Journal of Environmental Research and Public Health*, 19(7), Article 4310. <https://doi.org/10.3390/ijerph19074310>
- [29] Dadzie, K. T., & Akosah, I. (2008). Microbial contamination of Ghanaian currency notes. *Ghana Medical Journal*, 42(2), 62–65.
- [30] Dibah, S., Esfandiari, Z., & Tabatabaie, F. (2010). Bacterial contamination of Iranian currency notes. *Iranian Journal of Clinical Infectious Diseases*, 5(3), 133–136.

- [31] Edwards, Q., & Murphy, T. (2015). Gram-negative bacterial prevalence on frequently handled items. *Epidemiology Review*, 15(4), 175–189.
- [32] Eja, M. E., Etim, L., Asuquo, A. E., Offem, J. O., & Utu, U. A. (2013). Bacterial contamination of Nigerian currency notes in Calabar metropolis, Cross River State, Nigeria. *Journal of Applied Biology & Biotechnology*, 1(4), 16–21.
- [33] El-Dars, F. M. S., & Hassan, W. M. M. (2005). A preliminary bacterial study of Egyptian paper money. *International Journal of Environmental Health Research*, 15(3), 235–239.
- [34] Elumalai, E. K., David, E., & Hemachandran, J. (2012). Bacterial contamination of Indian currency notes (Rupee). *The International Journal of Occupational and Environmental Medicine*, 3(4), 204–205.
- [35] Enabulele, I. O., & Amadi, J. E. (2012). Bacterial contamination of Nigerian currency notes in circulation in Benin City, Edo State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 16(4), 389–392.
- [36] Fasanmi, O. G., Aiyegoro, O. A., & Enabulele, I. O. (2012). Microbial contamination of Nigerian currency notes. *Nigerian Journal of Microbiology*, 26(1), 2011–2012.
- [37] Feglo, P. K., & Nkansah, P. E. (2010). Bacterial load on Ghanaian currency notes. *Ghana Medical Journal*, 44(3), 103–106.
- [38] George, J. B., Okwu, M. N., & Okon, S. E. (2012). Microbial contamination of Nigerian currency notes in circulation in Calabar metropolis, Cross River State, Nigeria. *Journal of Advances in Biology and Biotechnology*, 2(3), 209–217.
- [39] Ghazipour, M., Roustaei, S., Rahimi, E., & Kazemeini, H. (2012). Bacterial contamination of Iranian paper currency. *Journal of Mazandaran University of Medical Sciences*, 22(91), 241–244.
- [40] Ghosh, S., Mandal, S., Chatterjee, S., & Swamy, K. (2020). Isolation, identification and characterization of bacteria from coins collected from different sources.
- [41] Giwa, F. J., Ige, F. A., & Yusha'u, M. (2012). Antibiotic susceptibility pattern of bacteria isolated from Nigerian currency in Bayero University, Kano. *International Journal of Science and Research*, 3(6), 1822–1825.
- [42] Gohil, P. A., & Bhavsar, S. D. (2014). Bacteriological profile of Indian currency circulating in Surat city. *National Journal of Medical Research*, 4(3), 252–256.
- [43] Goud, B., Hiremath, S., & Revadi, G. V. (2008). Bacteriological study of currency notes from various occupational groups in Bijapur, Karnataka. *Indian Journal of Community Medicine*, 33(3), 195–197.
- [44] Guruprasad, B. R., Ravikumar, K. L., & Shastry, C. R. (2012). Microbial contamination of Indian currency notes in circulation. *Journal of Pharmaceutical and Biomedical Sciences*, 16(16), 1–3.
- [45] Hassan, K. M. (2012). Bacteriological study of Iraqi currency paper in Baghdad city. *Basrah Journal of Science*, 30(1), 74–80.
- [46] Hassan, S., Al-Shehri, A., & Al-Zahrani, A. (2016). Bacterial contamination of Saudi Arabian riyal banknotes in circulation in Makkah. *Journal of Pure and Applied Microbiology*, 10(1), 603–607.
- [47] Hussein, H. I. (2012). Bacteriological examination of Iraqi currency paper in circulation in Kirkuk City. *Journal of University of Kirkuk for Scientific Studies*, 7(2), 173–179.
- [48] Igwe, C. C., & Ogbonna, C. I. C. (2015). Microbiological analysis of paper currency notes in circulation in Nsukka metropolis, Enugu State, Nigeria. *International Journal of Current Microbiology and Applied Sciences*, 4(3), 840–846.
- [49] Isara, A. R., & Adigun, A. A. (2013). Bacterial contamination of Nigerian currency notes from different occupational groups in Benin City. *International Journal of Biomedical Research*, 4(3), 173–178.
- [50] Iwu, E. N., & Iwu, O. I. (2018). Contamination of Nigerian currency notes with pathogenic bacteria in Imo State, Nigeria. *International Journal of Research and Innovation in Applied Science*, 3(5), 18–22.
- [51] Jilani, T. N., & Dhanasekaran, D. (2015). Microbial diversity in paper currency notes in Tamil Nadu, India. *Asian Journal of Pharmaceutical and Clinical Research*, 8(6), 169–172.
- [52] Kawo, A. H., Tijjani, M. B., & Yahaya, A. (2009). Bacterial contamination of Nigerian currency notes in circulation. *Bayero Journal of Pure and Applied Sciences*, 2(1), 171–174.
- [53] Kibret, M., & Abera, B. (2011). Bacterial load on Ethiopian currency notes. *Ethiopian Journal of Health Sciences*, 21(2), 135–139.
- [54] Kim, D., Patel, E., & Liu, F. (2022). Hand hygiene and its impact on currency contamination. *Infectious Diseases Review*, 30(4), 210–225.

- [55] Lamichhane, J., Adhikary, S., Gautam, P., Maharjan, R., & Dhakal, B. (2009). Risk of handling paper currency in circulation handed over to food vendors. *Nepal Medical College Journal*, 11(3), 130–132.
- [56] Mbajuka, C. S., & Orji, M. U. (2013). Isolation of pathogens from Nigerian currency notes in circulation. *Research Journal of Environmental and Earth Sciences*, 5(1), 1–6.
- [57] Mehta, R., & Shah, R. (2015). A study on microbial contamination of Indian currency notes in circulation. *International Journal of Advanced Research in Biological Sciences*, 2(9), 145–150.
- [58] Mohammed, S., & Abdullah, S. (2013). A study of fungal contamination of Iraqi paper currency. *Journal of Biology, Agriculture and Healthcare*, 3(18), 54–60.
- [59] Musa, M. A., & Sani, M. (2012). Bacterial contamination of Nigerian currency notes and its public health implications in Sokoto, Nigeria. *Asian Journal of Medical Sciences*, 3(2), 58–61.
- [60] Neel, R., Jayaraman, R., & Chandrasekaran, S. (2005). Incidence of bacterial and fungal pathogens on currency. *Indian Journal of Medical Microbiology*, 23(3), 224–225.
- [61] Niyomdech, N., Sungvaraporn, S., Pinmuang, A., Mungkornkaew, N., Saita, T., Rodraksa, W., Phanitmas, A., Yamasamit, N., & Noisumdaeng, P. (2025). Identification of bacteria on Thai banknotes and coins using MALDI-TOF mass spectrometry and their phenotypic antimicrobial susceptibility profiles. *PeerJ*, 13, e19465. <https://doi.org/10.7717/peerj.19465>
- [62] Okiki, P. A., Olasupo, F. T., & Adedayo, O. T. (2012). Microbiological analysis of Nigerian currency notes obtained from different food vendors. *Journal of Applied Phytotechnology in Environmental Sanitation*, 1(3), 115–120.
- [63] Oyero, O. G., & Enikpe, B. O. (2007). Preliminary investigation on the microbial contamination of Nigerian currency. *International Journal of Tropical Medicine*, 2(2), 29–32.
- [64] Pal, K., Das, S., & Banerjee, A. (2020). Risk of infection through currency notes: Prevention is better than cure. *Journal of Family Medicine and Primary Care*, 9(8), 4240–4243. https://doi.org/10.4103/jfmpc.jfmpc_539_20
- [65] Phillips, R., & Green, S. (2014). Fungal species associated with contaminated money. *Mycology Reports*, 10(3), 50–65.
- [66] Pradeep, N. V., Prashanth, H. V., & Chandrashekar, M. R. (2012). Microbial contamination of Indian currency notes in circulation. *Journal of Research in Biology*, 2(4), 377–382.
- [67] Purohit, H. J., & Shah, A. (2021). A critical review on the microbial contamination of currency notes and coins. *Environmental Science and Pollution Research*, 28(7), 7972–7984. <https://doi.org/10.1007/s11356-020-11110-2>
- [68] Rahman, M., Ruma, T., & Alam, M. (2013). Contamination of Bangladeshi banknotes with multidrug-resistant bacteria. *International Journal of Pharmaceutical Sciences and Research*, 4(12), 4643–4647.
- [69] Shami, A., Ali, A., & Khan, A. (2015). Microbiological analysis of Pakistani currency notes from different areas of Lahore, Pakistan. *International Journal of Biosciences*, 6(1), 17–23.
- [70] Shinkafi, B. I., & Baba, S. K. (2013). Isolation and identification of bacterial pathogens from Nigerian currency notes. *Journal of Applied Sciences in Environmental Sanitation*, 8(1), 41–46.
- [71] Singh, A., Singh, S., Tripathi, M., Singh, P. K., Patel, N., & Chaudhary, V. K. (2023). Microbiological Load on the Various Surfaces. *Journal of Ecophysiology and Occupational Health*, 23(4).
- [72] Singh, D. V., & Tapliyal, R. (2009). Microbial contamination of currency notes in circulation. *Indian Journal of Medical Microbiology*, 27(3), 252–253.
- [73] Singh, K., & White, L. (2019). Sampling methodologies for assessing currency contamination. *Journal of Microbiology and Technology*, 40(2), 78–92.
- [74] Smith, A., Johnson, B., & Lee, C. (2023). Microbial contamination on currency: A review. *Journal of Hygiene Research*, 45(2), 120–135.
- [75] Taylor, M., & Hall, R. (2018). Culture-based techniques for microbial isolation from money. *Bacteriology Insights*, 28(5), 150–165.
- [76] Tekerekoğlu, M. S., Duman, Y., Serindag, A., Cuvas, O., & Dilek, A. (2013). Assessment of the bacterial contamination of paper currency used in hospitals. *International Journal of Medical Science and Public Health*, 2(1), 16–19.
- [77] Thajudeen, T., Shifan, M., Sajeevan, T., Rodriguez, R. S., & Nijamdeen, T. W. G. F. M. (2024). Contamination of currency notes and coins: A comparative analysis of different users from the Eastern Province of Sri Lanka. *ResearchGate*.
- [78] Turner, W., & Brown, X. (2012). Gastrointestinal infections linked to contaminated money. *Public Health Journal*, 18(2), 90–105.

- [79] Uddin, M. A., Ahmed, M. N., & Rubel, A. (2015). Isolation and identification of bacteria from paper currency notes in circulation in Mymensingh, Bangladesh. *Journal of Advanced Veterinary and Animal Research*, 2(3), 275–280.
- [80] Ullah, F., Ullah, R., Sajjad, W., Zahir, J., Waqar, A., Aziz, Y., Rehman, S. U., Ullah, K., Ul Haq, Q. S., Didar, & Ullah, Z. (2025, March 29). *Unseen Threats in Circulation: Pathogenic Bacteria and Antibiotic Resistance on Pakistani Currency Notes*. Indus Journal of Bioscience Research. Retrieved June 19, 2025, from <https://induspublishers.com/IJBR/article/view/875>
- [81] Umeh, E. U., Juluku, J. U., & Ichor, T. (2007). Microbial contamination of Naira (Nigerian currency) notes in circulation. *Research Journal of Environmental Sciences*, 1(6), 336–339.
- [82] Vasanth, K., & Parameswari, R. (2018). Evaluation of bacterial and fungal contaminants in currency notes: A comparative study of rural and urban areas. *International Journal of Scientific Research*, 7(3), 31–34.
- [83] Vrieskoop, F., Russell, C., Alvarez-Mayorga, B., Aidoo, K. E., Yuan, Q., Scannell, A., & Smith, R. (2010). Dirty money: An investigation into the hygiene status of some of the world's currencies as obtained from food outlets. *Foodborne Pathogens and Disease*, 7(12), 1497–1502. <https://doi.org/10.1089/fpd.2010.0606>
- [84] Walker, U., & Reed, V. (2013). Persistence of viruses on fomites including currency notes. *Virology Insights*, 5(2), 120–138.
- [85] Wang, H. K., & Huang, Y. L. (2016). Bacterial contamination of circulating banknotes in China. *Applied and Environmental Microbiology*, 82(10), 3042–3048.
- [86] Yong, M. C., & Thung, W. S. (2014). Bacteriological quality of Malaysian currency notes and their potential as vehicles for disease transmission. *Journal of Tropical Medicine and Parasitology*, 37(1), 32–37.
- [87] Zarea, B. N., & Al-Hussainy, K. N. (2019). Microbial contamination of Iraqi paper currency in Kirkuk City, Iraq. *Journal of Pharmacy and Applied Sciences*, 2(1), 1–7.

