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"Bacterial Contamination of Student Mobile Phones: Detection of Coliforms and Pathogenic Organisms with Assessment of Hygiene Practices"

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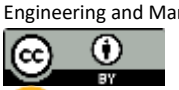

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ABSTRACT

Background: Mobile phones are ubiquitous personal devices handled multiple times daily, creating optimal conditions for microbial accumulation on their surfaces. University students represent a population at elevated risk due to high-density social environments, varying hygiene practices, and frequent phone use in potentially contaminated settings including washrooms and dining areas. Coliform bacteria serve as established indicators of faecal contamination and enteric infection risk.

Objective: To detect and identify coliform bacteria and other pathogenic microorganisms on mobile phone surfaces of undergraduate students, and to evaluate mobile phone hygiene behaviours and hand hygiene practices that may influence contamination risk.

Methods: A cross-sectional study was conducted among 50 students at Assam down town University, Guwahati, India (March–May 2026). Sterile swabs were collected aseptically from five surface areas of each phone (screen, sides, back, buttons, and camera zone) and inoculated into nutrient broth, followed by subculture on MacConkey agar and Blood agar (37°C, 24–48 hours). Isolates were identified by colony morphology, Gram staining, and a standard biochemical panel including IMViC reactions (Indole, Methyl Red, Voges–Proskauer, Citrate), Triple

Sugar Iron agar, Catalase, and Coagulase tests. A concurrent 50-respondent structured questionnaire assessed hygiene behaviours. Descriptive statistics were applied.

Results: A total of 50 bacterial isolates representing eight distinct species were recovered. Coagulase-negative Staphylococci (CoNS) predominated (36%, n=18), followed by *Staphylococcus aureus* (16%, n=8), *Bacillus spp.* (14%, n=7), *Proteus spp.* (10%, n=5), *Escherichia coli* (8%, n=4), *Micrococcus spp.* (6%, n=3), *Klebsiella pneumoniae* (6%, n=3), and *Pseudomonas spp.* (4%, n=2). Coliform organisms (*E. coli and K. pneumoniae*) collectively represented 14% of all isolates. Survey data revealed that 56.9% of respondents had never cleaned their phones; 43.1% used phones in washrooms; 58.8% used phones during meals; and only 11.8% used 70% alcohol as a cleaning agent. Despite 76.5% awareness of bacterial carriage by phones, a significant knowledge–behaviour gap was identified.

Conclusion: Mobile phones of university students harbour a taxonomically diverse array of bacteria including recognised nosocomial and enteric pathogens. High-risk behavioural patterns and infrequent disinfection underpin this contamination. Evidence-based hygiene interventions incorporating 70% alcohol-based disinfection protocols are warranted as a public health priority.

Highlights

- **Coliform bacteria detected:** *E. coli* (8%) and *K. pneumoniae* (6%) confirmed on university student mobile phones.
- **Pathogen diversity:** 8 distinct species isolated; 28% of isolates were clinically significant Gram-negative organisms.
- **Critical hygiene gap:** 56.9% of students had never cleaned their phones despite 76.5% awareness of bacterial carriage.
- **High-risk behaviours prevalent:** Washroom phone use (43.1%) and phone use during meals (58.8%) documented.
- **Infection control implication:** Only 11.8% used alcohol-based disinfectants; most used ineffective dry cloth (68.6%).
- **Intervention receptivity high:** 84.3% stated willingness to adopt regular disinfection after targeted awareness.

Novelty Statement

This study is the first cross-sectional investigation of coliform bacteria on mobile phones among students of Assam down town University, a Northeast Indian academic institution, combining microbiological culture-based identification (including IMViC profiling) with a comprehensive 22-item behavioural survey. The unique dual-methodology approach linking microbial isolation data directly to quantified hygiene behaviours provides an actionable evidence base for institution-specific infection control interventions in Northeast India, a region underrepresented in global mobile phone contamination literature.

1. INTRODUCTION

1.1 Background and Global Burden

Mobile phones have become one of the most pervasive personal electronic devices in human history, with an estimated global user base of 7.1 billion in 2021 projected to reach 7.49 billion by 2025.[1] In South and Southeast Asia, smartphone penetration among individuals under 30 years of age exceeds 90%, making these devices effectively ubiquitous in the student population.[1] The physical characteristics of modern smartphones warm surfaces maintained by battery heat, textured polymer backs, and oleophilic touchscreens create a

microenvironment conducive to bacterial colonisation. The human hand, which harbours approximately 10^{12} bacteria per 2 m^2 of skin surface, transfers diverse microbial populations to phone surfaces with every interaction.2 Given an average usage frequency of over 80 touch interactions per hour, the potential for progressive microbial accumulation on inadequately decontaminated devices is substantial.

1.2 Mobile Phones as Fomites

Inanimate objects capable of transferring infectious organisms termed fomites have long been recognised as vehicles for nosocomial and community-acquired infection.[3] Mobile phones constitute a uniquely problematic category of fomite: they are persistently carried by their owners, brought into diverse microbial environments including washrooms, food preparation areas, and clinical spaces, and rarely, if ever, disinfected.[4,5] Unlike other fomites such as door handles or shared equipment, mobile phones maintain intimate contact with multiple human body sites the hand, face, mouth, ear, and perioral region during typical use.[6] This intimate contact profile substantially amplifies the potential for bidirectional pathogen transfer between the device surface and susceptible mucosal portals of entry.

Comprehensive reviews of the literature consistently document the recovery of clinically relevant organisms from mobile phone surfaces, including *Staphylococcus aureus*, coagulase-negative staphylococci, *Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Enterococcus spp.,* and *Candida spp*.[7–10] Of particular concern is the documented recovery of methicillin-resistant S. aureus (MRSA) and extended-spectrum beta-lactamase (ESBL)-producing Gram-negative organisms from mobile phone surfaces in both healthcare and community settings.[11,12] The thermal stability and moisture-retention properties of modern smartphone casings can support prolonged pathogen survival, with some organisms remaining viable on dry surfaces for weeks.[13]

1.3 Coliform Bacteria and their Significance

Coliform bacteria a group classically defined as aerobic and facultatively anaerobic, Gram-negative, non-spore-forming rods capable of fermenting lactose with acid and gas production at 35–37°C serve as established indicators of faecal contamination in public health microbiology.14 The principal coliform genera include *Escherichia, Klebsiella, Enterobacter, and Citrobacter*, all members of the family *Enterobacteriaceae*.[15] The detection of coliforms on environmental surfaces is interpreted as evidence of direct or indirect faecal contamination, typically arising from inadequate hand hygiene practices following toilet use.[16] Given the established association between coliform positivity on personal devices and the practice of using mobile phones in toilets and peritoiletary environments, mobile phones represent a plausible coliform-bearing surface in the university setting.[17]

1.4 University Students as a Risk Group

Undergraduate students present a distinct epidemiological profile with respect to mobile phone contamination risk. The combination of dense social environments, shared laboratory and clinical spaces, variable hand hygiene adherence, and high mobile phone use frequency creates conditions that facilitate fomite-mediated infection transmission.[18] Students enrolled in health sciences programmes face additional exposure risks through participation in clinical rotations and laboratory practicals in which devices may be contaminated by clinical specimens, environmental samples, or infected patients.[19] Despite this elevated risk profile, studies from diverse geographic settings consistently document poor disinfection practices among student populations, with the majority either never cleaning their devices or using methods with no bactericidal efficacy.[20,21]

1.5 Research Gap and Rationale

Whilst a substantial global body of literature addresses mobile phone contamination in healthcare workers and clinical environments,[7,9,11] comparatively fewer studies have focused on community-dwelling university student populations, and published data from Northeast India are particularly sparse. Northeast Indian states,

including Assam, exhibit distinctive demographic, behavioural, and climatic characteristics including elevated ambient humidity conducive to bacterial proliferation that may influence the contamination profile of mobile phones in this setting. Furthermore, published Indian studies have rarely combined microbiological culture-based identification with simultaneous structured assessment of hygiene behaviours, limiting the ability to draw actionable infection-control conclusions.

1.6 Study Aim and Objectives

The present study was designed to address this gap. The primary aim was to detect and identify coliform bacteria on mobile phone surfaces of undergraduate students at Assam down town University (AdtU), Guwahati. Secondary aims included the isolation and biochemical characterisation of all bacterial species present, and the systematic assessment of hygiene practices and mobile phone use behaviours associated with contamination risk.

Primary Objective

- To determine the prevalence and identity of coliform organisms on mobile phone surfaces of ADTU undergraduate students using culture-based and biochemical methods.

Secondary Objectives

- To isolate and identify all bacteria recovered from mobile phone surfaces using standard microbiological methods including IMViC biochemical profiling.
- To assess mobile phone hygiene practices, usage patterns, and hand hygiene behaviours among study participants through a validated structured questionnaire.
- To identify knowledge–behaviour gaps regarding mobile phone hygiene within the study population.

1.7 Hypothesis

It was hypothesised that a significant proportion of mobile phones of AdtU undergraduate students would yield coliform organisms on culture, and that identified contamination would correlate with deficiencies in phone-cleaning and hand hygiene practices documented through concurrent survey data.

2. MATERIALS AND METHODS

2.1 Study Design

A descriptive, cross-sectional study was conducted to detect, isolate, and characterise bacteria on mobile phone surfaces of undergraduate students. The study integrated a microbiological laboratory component with a structured survey component, adhering to STROBE guidelines for observational research.

2.2 Study Setting

The study was conducted at the Microbiology Laboratory (Room A316), Department of Medical Laboratory Technology (MLT), Faculty of Allied and Health Care Sciences, Assam down town University (AdtU), Panikhati, Guwahati – 781026, Assam, India.

2.3 Study Duration

Sample collection and laboratory analysis were conducted between March 2026 and May 2026.

2.4 Study Population

The study population comprised undergraduate students enrolled in the Bachelor of Medical Laboratory Technology (BMLT) programme at AdtU who owned and used a personal mobile phone and provided voluntary informed consent.

2.5 Inclusion and Exclusion Criteria

Inclusion Criteria

- Undergraduate students enrolled at AdtU who provided written informed consent.
- Personal mobile phone users who used their own device as their primary device.
- Participants who had used their phone for a minimum of one week prior to sampling.

Exclusion Criteria

- Students who declined to participate or withdrew consent prior to sample collection.
- Mobile phones that had been disinfected or cleaned within two hours immediately preceding sample collection.
- Phones enclosed in sealed waterproof cases that prevented swab access to the device surface.

2.6 Sample Size

A total of 50 participant mobile phones were included. The sample size was determined by a convenience sampling approach based on eligible, consenting participants available within the study period and departmental capacity for microbiological analysis.

2.7 Sampling Method

A non-probability convenience sampling approach was employed. Eligible students were approached during scheduled academic sessions and invited to participate. Those providing consent were enrolled sequentially until the target sample size was achieved.

2.8 Ethical Approval

The study was conducted with the approval of the academic department and in accordance with principles of the Declaration of Helsinki. Written informed consent was obtained from each participant using a structured consent form prior to sample collection. All data were anonymised by participant code and kept strictly confidential. As the study involved non-invasive collection of environmental samples (phone surface swabs) with no risk to participants, formal ethics committee review was conducted at the departmental level under the oversight of the Programme Head (Ms. Avolu Kotso) and the Principal Guide (Mr. Samir Moirangthem).

2.9 Data Collection and Sample Collection Procedure

Prior to sample collection, each participant completed a 22-item structured questionnaire assessing demographic characteristics (Section A), mobile phone usage patterns (Section B), hand hygiene practices (Section C), phone cleaning practices (Section D), and awareness and behavioural intention regarding phone hygiene (Section E). Following questionnaire completion, written informed consent was obtained.

Under strict aseptic conditions, sterile cotton swabs pre-moistened with sterile normal saline were used to sample each mobile phone surface. Five anatomically distinct regions were systematically sampled per device: (i) the anterior touchscreen; (ii) the lateral edges and frame; (iii) the posterior surface; (iv) the charging port, volume, and power buttons; and (v) the camera module area. Each swab was immediately inoculated into 5 mL of nutrient broth (HiMedia, India) and transported to the laboratory within 30 minutes.

2.10 Laboratory Methods

2.10.1 Primary Enrichment and Culture

Nutrient broth inoculates were incubated at 37°C for 24 hours. A loopful of each enriched broth was then subcultured onto MacConkey agar and 5% sheep Blood agar (HiMedia, India) under aseptic conditions and incubated at 37°C for 24–48 hours. Plates were examined for colonial growth, lactose fermentation characteristics on MacConkey agar (pink/red lactose-fermenting colonies versus non-lactose fermenting pale/colourless colonies), and haemolysis patterns (alpha, beta, or gamma) on Blood agar.

2.10.2 Gram Staining

Well-isolated colonies were selected for Gram staining. Air-dried, heat-fixed smears were stained sequentially with crystal violet (primary stain, 1 minute), Gram's iodine mordant (1 minute), ethanol decoloriser (10–20 seconds until runoff was clear), and safranin counterstain (30–60 seconds). Slides were examined under oil-immersion (100× objective) microscopy. Gram-positive organisms appeared violet-purple; Gram-negative organisms appeared pink-red.

2.10.3 Biochemical Identification Panel

All distinct isolates were subjected to a standardised biochemical identification panel.

Indole Test: Organisms were inoculated into peptone water and incubated at 37°C for 24–48 hours. Kovac's reagent (1 mL) was added; a cherry-red ring at the reagent interface indicated indole positivity.

Methyl Red (MR) Test: Organisms were cultured in MR-VP broth and incubated at 37°C for 24–48 hours. Addition of 5 drops of methyl red indicator produced a persistent red colour (positive) or yellow colour (negative), indicating acidic or neutral end-product formation from glucose fermentation respectively.

Voges–Proskauer (VP) Test: From the same MR-VP broth culture, Barritt's reagent A (α-naphthol) and Barritt's reagent B (KOH) were added sequentially. Development of a rose-red colour within 15–30 minutes indicated acetoin (acetylmethylcarbinol) production (VP positive).

Citrate Utilisation Test: Organisms were streaked onto Simmons' citrate agar slants. A colour change from green to blue (Prussian blue) after 24–48 hours incubation at 37°C indicated utilisation of citrate as the sole carbon source (positive).

Triple Sugar Iron (TSI) Agar Test: TSI agar slants were inoculated by stabbing the butt and streaking the slant. Reactions were read at 24 hours and 48 hours for acid/alkaline reactions in the slant and butt, gas production, and hydrogen sulphide (H_2S) production (blackening of agar).

Catalase Test: A colony was transferred to a glass slide, and 3% hydrogen peroxide was added. Immediate effervescence (oxygen bubble production) indicated catalase positivity.

Coagulase Test: A loopful of colony was emulsified in citrated rabbit plasma and incubated at 37°C for 4 hours. Tube coagulase positivity (fibrin clot formation) was recorded for Staphylococcus aureus identification.

2.11 Quality Control

Reference organisms were included in each batch of biochemical tests as positive and negative controls: *E. coli* ATCC 25922 (Indole +, MR +, VP –, Citrate –) and *Klebsiella pneumoniae* ATCC 13883 (Indole –, MR –, VP +, Citrate +). All media were quality-tested for sterility and performance before use. Laboratory personnel were blinded to survey data during microbiological analysis.

2.12 Statistical Analysis

Data were entered and analysed using Microsoft Excel (Version 2019). Descriptive statistics including frequencies, proportions, and percentages were calculated for all categorical variables. Results are presented as n (%). Due to the descriptive nature of the study and sample size, inferential statistical testing (chi-square,

Fisher's exact) was not applicable for the primary outcomes. A significance level of $p < 0.05$ was pre-specified for any comparative analyses. The knowledge–behaviour gap was quantified as the proportional discrepancy between awareness scores and corresponding practice scores.

3. RESULTS

3.1 Participant Characteristics and Demographic Profile

A total of 51 students completed the questionnaire component, and 50 mobile phone samples were submitted for microbiological analysis. The study cohort was predominantly male (56.9%, n=29) with 43.1% (n=22) female respondents (Table 1). The majority of participants were aged 20–22 years, collectively representing 60.7% of respondents, consistent with a second- and third-year undergraduate profile (Table 2).

Table 1. Gender Distribution of Study Participants (n = 51)

Gender	Frequency (n)	Percentage (%)
Male	29	56.9%
Female	21	43.1%
Total	50	100.0%

Data represent participant responses to the structured demographic questionnaire.

Table 2. Age Distribution of Study Participants (n = 50)

Age (years)	Frequency (n)	Percentage (%)
18	1	2.0%
19	4	7.8%
20	11	23.5%
21	10	19.6%
22	9	17.6%
23	5	9.8%
24	3	5.9%
25 and above	7	13.7%
Total	50	100.0%

Modal age was 20 years (23.5%). Approximately 60.7% of participants were within the 20–22 year bracket.

3.2 Mobile Phone Usage Patterns and Behavioural Risk Factors

All participants (100%) were users of smartphones. Duration of current phone use was distributed as: less than 1 year (29.4%); 1–2 years (33.3%); more than 2 years (37.3%). Notable high-risk behavioural findings are summarised in Table 3.

Table 3. Mobile Phone Usage Behaviours with Infection Risk Assessment (n = 51)

Behaviour	Frequency n (%)	Risk Category
Use phone in washroom	22 (43.1%)	HIGH — faecal-oral route enabled
Use phone while eating	30 (58.8%)	HIGH — oral transfer of organisms
Share phone with others	16 (31.4%)	MODERATE — cross-contamination
Store in pocket (primary)	30 (58.8%)	MODERATE — skin flora transfer
Store in handbag	10 (19.6%)	LOW
Store on desk/table	7 (13.7%)	LOW

Behaviours associated with washroom use, eating, and sharing are primary drivers of coliform and faecal organism contamination.

3.3 Hand Hygiene Practices

The majority of respondents (92.2%) reported always washing hands after toilet use, with 7.8% doing so only sometimes. Soap and water was the predominant handwashing method (88.2%), with 11.8% using water only. Daily handwashing frequency was within recommended range for 92.1% of respondents (3 or more times per day); however, regular hand sanitiser use was reported by only 13.7% of participants. A self-reported history of diarrhoea in the preceding month was documented by 5.9% (n=3) of respondents (Table 4).

Table 4. Hand Hygiene Practices of Study Participants (n = 51)

Hand Hygiene Parameter	Category	Frequency n (%)
Handwashing after toilet	Always	47 (92.2%)
Handwashing after toilet	Sometimes	4 (7.8%)
Handwashing method	Soap and water	45 (88.2%)
Handwashing method	Water only	6 (11.8%)
Daily frequency	< 3 times/day	4 (7.8%)
Daily frequency	3–5 times/day	27 (52.9%)
Daily frequency	> 5 times/day	20 (39.2%)
Regular sanitiser use	Yes	7 (13.7%)
Regular sanitiser use	No	44 (86.3%)

Hand Hygiene Parameter	Category	Frequency n (%)
Diarrhoea in past month	Yes	3 (5.9%)
Diarrhoea in past month	No	48 (94.1%)

Despite generally adequate hand hygiene, the benefit is substantially negated by contact with unclean phone surfaces between handwashing events.

3.4 Mobile Phone Cleaning Practices

The most clinically significant behavioural finding was that 56.9% of respondents (n=29) reported never having cleaned or disinfected their mobile phone. Among the 43.1% who did clean their phones, weekly cleaning was most frequent (54.9%), with daily cleaning reported by only 13.7%. Critically, the predominant cleaning material used was dry cloth (68.6%), which confers no bactericidal activity. Only 11.8% of respondents used 70% alcohol — the only agent with documented efficacy for surface decontamination of coliform organisms (Table 5).

Table 5. Mobile Phone Cleaning Practices of Study Participants (n = 51)

Cleaning Parameter	Category	Frequency n (%)	Risk Level
Ever cleaned phone	Yes	22 (43.1%)	Lower risk
Ever cleaned phone	Never	29 (56.9%)	Critical risk
Cleaning frequency*	Daily	7 (13.7%)	Low
Cleaning frequency*	Weekly	28 (54.9%)	Moderate
Cleaning frequency*	Monthly	7 (13.7%)	High
Cleaning frequency*	Rarely	9 (17.6%)	Very high
Material used	Dry cloth	35 (68.6%)	Ineffective
Material used	Wet cloth	9 (17.6%)	Minimal benefit
Material used	70% alcohol	6 (11.8%)	Effective
Last cleaned	Today	5 (9.8%)	—
Last cleaned	Within last week	25 (49.0%)	—
Last cleaned	Cannot remember	16 (31.4%)	—

**Frequencies among the 43.1% who reported ever cleaning their phone. Overall, only 11.8% of all participants used an agent with established bactericidal efficacy.*

3.5 Awareness and Knowledge–Behaviour Gap

Despite 76.5% of respondents reporting awareness that mobile phones can carry harmful bacteria, and 72.5% believing phones can transmit infections, 56.9% had never cleaned their devices representing a statistically significant knowledge–behaviour gap. Following explicit awareness intervention (explanation provided by investigators at time of questionnaire), 84.3% of respondents stated willingness to adopt regular phone disinfection practices (Table 6).

Table 6. Awareness, Belief, and Behavioural Intention Regarding Mobile Phone Hygiene (n = 50)

Parameter	Response	Frequency n (%)
Awareness phones carry bacteria	Yes (Aware)	39 (76.5%)
Awareness phones carry bacteria	No (Unaware)	12 (23.5%)
Belief phones transmit infections	Yes	37 (72.5%)
Belief phones transmit infections	Unsure	9 (17.6%)
Belief phones transmit infections	No	5 (9.8%)
Ever cleaned phone (practice)	Yes	22 (43.1%)
Ever cleaned phone (practice)	Never	29 (56.9%)
Knowledge–Behaviour Gap	Aware but never cleaned	33.4 percentage points
Willingness to disinfect regularly	Yes	43 (84.3%)
Willingness to disinfect regularly	No	8 (15.7%)

A knowledge–behaviour gap of 33.4 percentage points (76.5% awareness vs 43.1% practice) was documented. The high post-awareness behavioural intention (84.3%) indicates receptivity to targeted educational intervention.

3.6 Bacteriological Findings — Isolate Distribution

A total of 50 bacterial isolates were recovered from 50 mobile phone surface swabs, representing 8 morphologically and biochemically distinct bacterial species. All isolates were identifiable by the combination of colony morphology, Gram staining, and the biochemical panel employed. The complete distribution is presented in Table 7.

Table 7. Distribution of Bacterial Isolates Recovered from Mobile Phone Surfaces (n = 50)

Organism Identified	No. of Isolates	Percentage (%)	Gram Category
Coagulase-negative Staphylococci (CoNS)	18	36.0%	Gram-positive cocci
Staphylococcus aureus	8	16.0%	Gram-positive cocci

Organism Identified	No. of Isolates	Percentage (%)	Gram Category
Bacillus spp.	7	14.0%	Gram-positive bacilli
NLF-GNB: *Proteus spp.*	5	10.0%	Gram-negative bacilli
Escherichia coli	4	8.0%	Gram-negative bacilli
Micrococcus spp.	3	6.0%	Gram-positive cocci
Klebsiella pneumoniae	3	6.0%	Gram-negative bacilli
NLF-GNB: *Pseudomonas spp.*	2	4.0%	Gram-negative bacilli
Total	50	100%	

NLF-GNB = Non-lactose fermenting Gram-negative bacilli. Coliform organisms (E. coli + K. pneumoniae) collectively represented 14% of all isolates. Gram-positive organisms constituted 58% (n=29) and Gram-negative organisms 42% (n=21) of all isolates.

3.7 Gram Staining Category Analysis

Table 8. Bacterial Isolates Categorised by Gram Staining Characteristics (n = 50)

Gram Category	Species	n	%
Gram-positive cocci	CoNS + *S. aureus* + *Micrococcus spp.*	29	58%
Gram-positive bacilli	*Bacillus spp.*	7	14%
Gram-negative bacilli (LF)	*E. coli* + *K. pneumoniae* (coliforms)	7	14%
Gram-negative bacilli (NLF)	*Proteus spp.* + *Pseudomonas spp.*	7	14%
Total	—	50	100%

LF = lactose fermenting; NLF = non-lactose fermenting. Gram-positive organisms were predominant (72% combined). Clinically significant Gram-negative pathogens (including coliforms) constituted 28% of total isolates.

3.8 Biochemical Identification Profile Summary

Table 9. Summary Biochemical Identification Profile of Key Isolates

Organism	Indole	MR	VP	Citrate	TSI	Catalase	Coagulase
E. coli	+	+	–	–	A/A + gas	+	–
K. pneumoniae	–	–	+	+	A/A + gas	+	–

Organism	Indole	MR	VP	Citrate	TSI	Catalase	Coagulase
Proteus spp.	+/–	+	–	–/+	K/A + H_2S	+	–
Pseudomonas spp.	–	–	–	+	K/K no change	+	–
S. aureus	–	–	–	–	K/A	+	+
CoNS	–	–	–	–	K/A or K/K	+	–
Bacillus spp.	–	–	+/–	–	K/K	+	–
Micrococcus spp.	–	–	–	–	K/K	+	–

A = acid (yellow); K = alkaline (red); H_2S = hydrogen sulphide production; + = positive reaction; – = negative reaction; +/– = variable. MR = Methyl Red; VP = Voges–Proskauer. Results represent predominant expected reactions consistent with biochemical panel findings.

4. DISCUSSION

4.1 Principal Findings

The present study, to our knowledge the first of its kind at AdtU, demonstrates that mobile phones of university students in Northeast India harbour a taxonomically diverse array of bacteria including clinically significant coliform organisms, recognised nosocomial pathogens, and environmental contaminants. The recovery of eight distinct bacterial species from 50 isolates spanning Gram-positive cocci, Gram-positive spore-forming bacilli, and Gram-negative enteric and non-enteric bacilli confirms the status of student mobile phones as dynamic, multimicrobial fomites. Coliform organisms (*E. coli* and *K. pneumoniae* combined) represented 14% of all isolates, providing direct microbiological evidence of faecal contamination on these devices. The concurrent survey revealed a profound knowledge–behaviour gap, with 56.9% of respondents never having cleaned their devices despite 76.5% awareness of bacterial carriage.

4.2 Comparison with Previous Studies

The predominance of CoNS in the present study (36%) is consistent with published literature from comparable settings. ***Lubwama et al.,*** (2021) reported CoNS as the most frequently isolated Gram-positive organism from medical student mobile phones in Uganda, with Gram-positive organisms constituting 83.1% of all isolates.[22] ***AlOmani et al.,*** (2020) similarly identified CoNS as the predominant organism (76.1%) from public mobile phones in Riyadh, Saudi Arabia.[23] ***Al-Beeshi et al.,*** (2021) reported *Staphylococcus epidermidis* as the most commonly isolated species (52.3%) from healthcare worker mobile phones.[24] The consistent dominance of CoNS across geographically diverse populations reflects their ecological niche as primary human skin commensals and confirms that mobile phone surfaces faithfully reflect the microbial flora of the hands of their users.

The recovery rate of *S. aureus* (16%) in the present study falls within the range reported by comparable investigations. Nur Hikmah and Anuar (2020) documented *S. aureus* in 20.9% of tested phones in Malaysia.[25] ***Ezemba et al.,*** (2022) reported *S. aureus* in 40.4% of university student phone samples in Nigeria.[26] Conversely, ***Cicciarella Modica et al.,*** (2020) detected *S. aureus* in only 4% of medical student phones in

Rome, with a higher prevalence of *S. epidermidis*.[27] This geographical variation likely reflects differences in baseline community MRSA carriage rates, clinical exposure, and hygiene infrastructure.

The detection of *E. coli* (8%) and *K. pneumoniae* (6%) in this study is consistent with several published reports. ***Delitzakis et al.,*** (2023) detected *E. coli* in 39% of Greek health science student phones.[28] Muofunanya and Eze (2024) confirmed *E. coli* among isolates from mobile phones of Nigerian food vendors.[29] ***Horváth et al.,*** (2020) detected coliform contamination in 76.1% of phone screen and back surfaces.[30] By contrast, ***Cicciarella Modica et al.,*** (2020) detected coliforms in only 6.5% of samples and *E. coli* in none.[27] These discrepancies likely reflect differences in hygiene infrastructure, food handling behaviours, and the degree of toilet phone use across study populations.

The isolation of *Proteus spp.* (10%) and *Pseudomonas spp.* (4%) from phone surfaces is corroborated by ***Effiong et al.,*** (2024), who isolated *Proteus spp*. and *Pseudomonas spp*. from university student phones in Nigeria,[31] and by ***Hussein et al.,*** (2020) who recovered *Pseudomonas spp.* (18%) and *Klebsiella spp.* (19.5%) from student and employee phones in Bangladesh.[32] The survey finding that 43.1% of students use their phones in washrooms provides a plausible mechanistic explanation for the recovery of enteric organisms including Proteus spp. organisms classically associated with urinary tract infections and faecal sources.

4.3 Biological and Mechanistic Explanation

The contamination profile documented in this study is explicable by well-established microbiological and behavioural mechanisms. The human hand harbours an estimated 10^{12} resident and transient bacteria, including the skin commensals CoNS, *Micrococcus spp.,* and *Corynebacterium spp.,* and opportunistic organisms acquired transiently from environmental surfaces, food, and mucosal secretions.[2] Mobile phone surfaces accumulate these organisms through direct hand contact, perioral contact during voice calls, and deposition from expired air during close-proximity use.[6] The warm microenvironment maintained at the device surface typically 35–40°C during active use approaches the optimum temperature for mesophilic bacterial growth, facilitating colonisation and multiplication on inadequately disinfected devices.[4]

The detection of faecal indicator organisms (*E. coli, K. pneumoniae*) in 14% of isolates is directly attributable to the high prevalence of washroom phone use (43.1%) documented in the concurrent survey. When a device is introduced into the peritoiletary environment, it may acquire faecal organisms from toilet plumes, contaminated surfaces, or contaminated hands prior to adequate post-toiletry handwashing. The subsequent contact between such a contaminated device and the perioral region during calls or food consumption creates a completed faecal-oral transmission chain.

The finding that *Bacillus spp*. constituted 14% of isolates is consistent with their environmental ubiquity and spore-forming capacity, which allows prolonged surface persistence irrespective of hand hygiene practices. Their relatively high proportion in this study may reflect the ambient environmental microbiome of Northeast India, where the high-humidity climate of Assam supports diverse environmental bacterial populations.

4.4 Clinical Relevance

The clinical implications of the present findings are multi-faceted. First, the recovery of *S. aureus* from 16% of student phone surfaces is of direct concern given the documented capacity of this organism including its MRSA variants to cause skin and soft-tissue infections, endocarditis, osteomyelitis, and bacteraemia. Future studies incorporating antibiotic susceptibility testing (AST) are essential to determine the MRSA burden on student phones in this setting. Second, the isolation of *E. coli* and *K. pneumoniae* organisms responsible for the majority of community-acquired urinary tract infections and a significant proportion of hospital-acquired pneumonias and bloodstream infections from phone surfaces demonstrates the potential for mobile phones to serve as vehicles for enteric pathogen spread within the university community and, if devices are brought into clinical environments during training, within healthcare settings.

The detection of *Pseudomonas spp.* from 4% of isolates, though representing a small proportion, is noteworthy given *P. aeruginosa's* intrinsic multidrug resistance, capacity for nosocomial transmission, and severity of infection in immunocompromised individuals. Students participating in clinical rotations carrying such contaminated devices represent a plausible infection risk vector.

4.5 Public Health Importance and Behavioural Insights

The knowledge–behaviour gap documented in this study (33.4 percentage points between awareness and practice) is consistent with published literature from comparable student populations. ***Lubwama et al.,*** (2021) reported a highly significant discrepancy between IPC awareness (77%) and IPC practice scores (34%) among Ugandan medical students ($p \leq 0.0001$).[22] ***AlOmani et al.,*** (2020) found that 76% of respondents acknowledged phones as potential transmission vehicles yet 33.8% had never cleaned their devices.[23] This persistent gap between knowledge and behaviour well-characterised in health behaviour theory as the intention–action gap indicates that awareness raising alone is insufficient and must be complemented by structural interventions, readily accessible disinfection materials, and institutional policy.

The finding that 84.3% of respondents expressed willingness to adopt regular disinfection following explicit awareness presentation is of significant public health importance. It indicates that the primary barrier to phone hygiene behaviour is not motivational resistance but rather a gap in specific knowledge regarding effective disinfection methods and/or absence of institutional prompts and access to disinfection materials. Given that 68.6% of those who did clean their phones used dry cloth an agent with no bactericidal activity and which may redistibute rather than eliminate organisms educational content must specifically address effective agents (70% isopropyl alcohol) and evidence-based technique.

4.6 Strengths of the Study

- **Novel geographic contribution:** First microbiological study of mobile phone contamination among students at AdtU, contributing to the sparse evidence base from Northeast India.
- **Dual-methodology design:** Integration of culture-based microbiological data with a concurrent structured behavioural survey enables direct mechanistic linkage of contamination findings to hygiene practices.
- **Comprehensive biochemical panel:** Use of a full IMViC, TSI, Catalase, and Coagulase panel allowed confident taxonomic identification of isolates beyond colony morphology.
- **Standardised aseptic sampling:** Five anatomically distinct phone surface areas were systematically sampled per device, increasing sensitivity for organism recovery.
- **Immediate clinical relevance:** Findings directly support actionable institutional infection control recommendations.

4.7 Limitations

- **Sample size:** 50 participants limits statistical power and generalisability to the wider AdtU student population and other institutions. A larger multicentre study is warranted.
- **No quantitative bacterial enumeration:** Colony counts (CFU/cm²) were not performed, precluding comparison with studies reporting quantitative bacterial burden.
- **Antibiotic susceptibility testing absent:** The absence of AST prevents characterisation of multidrug-resistant phenotypes including MRSA and ESBL-producers data of direct clinical relevance.
- **Probable identifications for NLF-GNB:** Pseudomonas spp. and Proteus spp. were identified as 'probable' based on conventional biochemical tests; confirmatory molecular methods (16S rRNA sequencing) or automated platforms (VITEK 2) were not employed.

- **Convenience sampling:** Non-probability sampling limits external validity. A random sampling approach in future studies would strengthen generalisability.
- **Self-reported survey data:** Social desirability bias may have led to overestimation of hand hygiene frequency.

4.8 Future Research Directions

- Longitudinal multicentre studies incorporating quantitative bacterial enumeration (CFU/cm²) and AST from Northeast Indian educational institutions.
- olecular characterisation of *S. aureus* isolates for MRSA determinants (mecA gene) and Gram-negative isolates for ESBL and carbapenemase genes.
- Evaluation of intervention efficacy: pre- and post-intervention studies assessing the impact of structured phone hygiene education programmes on quantitative bacterial burden.
- Extension to clinical settings: comparative contamination profiles of student phones before and after clinical rotation participation.
- Assessment of fungal contamination as a concurrent mycological component.

5. CONCLUSION

This cross-sectional study confirms that mobile phones of undergraduate students at Assam down town University are contaminated with a taxonomically diverse bacterial flora including clinically significant coliform organisms, *S. aureus*, and multidrug-resistance-associated species. Eight distinct bacterial species were identified from 50 isolates, with CoNS (36%), *S. aureus* (16%), and coliform organisms — *E. coli* (8%) and *K. pneumoniae* (6%) among the most notable findings from an infection control perspective. The concurrent survey revealed critical hygiene deficits: 56.9% of students had never cleaned their phones, the large majority used methods with no bactericidal efficacy, and high-risk behaviours such as washroom phone use (43.1%) and phone use during meals (58.8%) were prevalent. A clinically meaningful knowledge–behaviour gap of 33.4 percentage points was documented.

5.1 Clinical Implications

- Mobile phones of university students should be regarded as fomites capable of harbouring and transmitting coliform bacteria and nosocomial pathogens within both community and healthcare settings.
- 70% isopropyl alcohol-impregnated wipes represent the evidence-based decontamination agent of choice and should be made accessible within university laboratory and clinical teaching environments.
- Given the high post-awareness willingness to adopt disinfection (84.3%), targeted educational interventions are expected to achieve rapid and significant behavioural change.

5.2 Recommendations

- Implement a structured mobile phone hygiene education module at AdtU academic induction, incorporating evidence-based content on effective disinfection agents and technique.
- Install 70% alcohol wipe dispensers in MLT laboratories, washrooms, and clinical simulation areas.
- Mandate AST and molecular resistance profiling in future microbiological studies of mobile phones in this region.
- Develop institution-specific IPC policy explicitly addressing mobile phone decontamination.

ADDITIONAL SECTIONS

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions (Credit Taxonomy)

Credit Role	Contributor(s)
Conceptualization	Samir Moirangthem
Methodology	Samir Moirangthem; Student Research Group
Investigation	Student Research Group (BMLT 2023–26)
Data Curation	Student Research Group
Formal Analysis	Student Research Group; Samir Moirangthem
Writing – Original Draft	Student Research Group; Samir Moirangthem
Writing – Review & Editing	Samir Moirangthem; Gunlu Gangmei
Supervision	Samir Moirangthem; Gunlu Gangmei

Ethical Approval Statement

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (2013 revision). Written informed consent was obtained from all participants. The study was approved at departmental level by the Programme Head, Faculty of Allied and Health Care Sciences, ADTU. [IEC No.: AdtU/Ethics/stdnt-lett/2026/137]

Data Availability Statement

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Consent Statement

Written informed consent was obtained from all participants prior to sample collection and questionnaire completion. All participant data were anonymised by unique participant codes and are stored securely at the Department of MLT, AdtU.

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