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Research Article
Multi-Year Assessment of Bacterial Contamination on Hand Sanitizer Dispensers at a Community College in Queens, New York: Microbial Contamination of Hand Sanitizer Dispensers

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Abstract

Background and Objective: Hand sanitizer dispensers (HSDs) are widely used in institutional settings to reduce pathogen transmission; however, their external surfaces may serve as reservoirs for microorganisms due to repeated user contact. This study aimed to characterize microbial contamination on HSDs across a multi-year period at Queensborough Community College, New York and assess associations between dispenser use and contamination levels. **Materials and Methods:** The HSDs were sampled in ten campus buildings during Fall 2013 (n = 42) and Fall 2014 (n = 42), with targeted follow-up sampling in three buildings during Spring 2016 (n = 15) and two locations in Summer 2023 (n = 8). Sterile swabs were used to collect samples from dispenser surfaces, which were cultured on Tryptic Soy Agar and evaluated using a semi-quantitative growth scale (0-4). Representative isolates underwent Gram staining and morphological characterization, with 2023 isolates identified to species level using MALDI-TOF mass spectrometry. Growth scores were summarized as Mean±SD and Fisher's exact test assessed sanitizer status vs. contamination ($p<0.05$). **Results:** Microbial growth was detected on HSDs in 80% of buildings in 2013 and 90% in 2014, with mean contamination scores ranging from 0.3-2.0 and 0.5-2.7, respectively. The Administration and Art buildings exhibited the highest contamination levels. All characterized isolates were Gram-positive bacteria, including *Staphylococcus warneri* and *Priestia flexa*. No statistically significant association was observed between sanitizer fill status and contamination level (Fisher's exact test: 2013, $p = 0.14$; 2014, $p = 0.70$). **Conclusion:** The HSDs in college environments can harbor predominantly non-pathogenic Gram-positive microorganisms. While the identified organisms pose minimal risk to immunocompetent individuals, routine surface disinfection, enhanced maintenance protocols and evidence-based dispenser design modifications are recommended to ensure hygiene infrastructure integrity in educational settings.

Key words: Hand sanitizer dispensers, fomites, environmental microbiology, college hygiene, surface contamination

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

College and university campuses present unique challenges for maintaining environmental hygiene due to high population density, intensive use of shared facilities and continuous student turnover. These challenges are particularly pronounced in urban community colleges, where buildings may serve thousands of students daily, creating environments conducive to microbial cross-contamination through high-touch surfaces[1,2].

Hand sanitization has become a cornerstone of infection-prevention strategies in institutional settings, with alcohol-based hand sanitizer dispensers (HSDs) now ubiquitous in educational facilities. While the antimicrobial efficacy of alcohol-based sanitizers against transient hand flora is well established[3], accumulating evidence suggests that dispenser surfaces themselves may accumulate microorganisms through repeated user contact, potentially transforming protective devices into microbial reservoirs within the built environment[4].

Numerous studies have documented bacterial contamination on high-touch surfaces in healthcare, educational and public settings. Commonly isolated organisms include *Staphylococcus* spp., *Bacillus* spp. and other environmental bacteria[5,6]. Of greater concern is the detection of antibiotic-resistant organisms on frequently touched surfaces in community environments[7-9]. These findings underscore the potential for fomite-mediated transmission in high-traffic environments where surface contact rates may exceed cleaning frequency[10].

Community colleges represent an especially important context for environmental hygiene research due to their diverse student populations, including immunocompromised individuals, adult learners and international students with varied microbiota backgrounds[11]. Heightened awareness of environmental contamination following the COVID-19 pandemic has further emphasized the importance of monitoring and maintaining hygiene infrastructure in institutional settings[12].

Despite growing recognition of the role of high-touch surfaces in microbial transmission, relatively few studies have quantitatively assessed microbial contamination on hand sanitizer dispenser (HSD) surfaces in college or university settings and longitudinal data spanning multiple years are particularly scarce. This gap is even more pronounced in urban community colleges, where sustained high foot traffic, heterogeneous user populations and continuous facility use may promote persistent or fluctuating contamination patterns that are not captured by single-time-point surveys. Addressing this limitation, the present multi-year study aimed to: (1) Assess the prevalence and extent of microbial contamination on HSD surfaces across campus buildings, (2) Characterize Gram-staining and morphological properties of recovered isolates, (3) Identify bacterial species present on selected dispensers and (4) Evaluate temporal patterns of contamination across multiple sampling periods. We hypothesized that HSD surfaces would harbor diverse microbial communities and that contamination levels would vary according to building type and usage intensity.

MATERIALS AND METHODS

Study design and timeline: This longitudinal observational study was conducted at Queensborough Community College (QCC), Bayside, New York, across four sampling periods: Fall 2013 (Trial 1), Fall 2014 (Trial 2), Spring 2016 (follow-up study) and Summer 2023 (case study with molecular identification). A cross-sectional survey design with repeated sampling at selected high-traffic locations was employed.

Study sites

2013 and 2014 Comprehensive Surveys (Trials 1 and 2): Ten campus buildings were surveyed: Medical Arts, Humanities, Library, Science, Oakland, Engineering, Kennedy, Art, Student Union and Administration. All accessible HSDs in each selected building were sampled, yielding a total of 42 dispensers per trial year (range: 2-8 dispensers per building, depending on building size and layout).

2016 follow-up study: Three buildings (Administration, Art and Library) were resampled based on elevated mean contamination scores (>1.3) observed during Trials 1 and 2. A total of 15 dispensers were sampled from these locations.

2023 case study: Two additional locations (Bookstore and Grounds Department) were included to expand building representation and facilitate molecular identification using updated technology. All dispensers at these sites were sampled (n = 8 total).

Sample collection: Sampling was conducted between 6:00 PM and 8:00 PM on weekdays to minimize disruption to campus activities and maintain consistent environmental conditions across sampling periods. Two areas on each dispenser were sampled: (1) The dispensing area directly beneath the nozzle where sanitizer is expelled and (2) The front panel surface (Fig. 1). Sterile cotton swabs (Puritan®

Fig. 1: Example of a wall-mounted hand sanitizer dispenser included in the study (brand shown for illustrative purposes only)

Medical Products, Guilford, ME) pre-moistened with sterile distilled water were used to swab each designated area using a standardized zigzag pattern covering approximately 25 cm^2 of surface area. Each swab was immediately placed into a sterile 15 mL polypropylene transport tube and transported to the microbiology laboratory within 2 hrs of collection in an insulated container. All samples were processed upon arrival at the laboratory. For the statistical analyses examining sanitizer fill status, only dispensers for which both surface contamination data and fill status information were recorded were included (Trial 1: n = 29; Trial 2: n = 30). Dispensers were excluded from this specific analysis if fill status was not documented at the time of sampling or if samples were compromised during transport. All other analyses included the complete dataset of 42 dispensers per trial year.

Microbiological culture and enumeration: Upon arrival at the laboratory, each swab was vortexed at maximum speed (approximately 3000 rpm) for 10 sec to dislodge bacteria from the swab fibers and then inoculated onto Tryptic Soy Agar (TSA; BD Difc™, Franklin Lakes, NJ) using a standardized four-quadrant streaking technique to enable semi-quantitative assessment. Negative control swabs moistened with sterile distilled water but not used to sample any surface were processed in parallel with each batch of samples. Plates were incubated aerobically at 37°C for 48 hrs, with preliminary observations recorded at 24 hrs.

Following incubation, microbial growth was assessed using a semi-quantitative scoring system (0-4 scale):

- 0 = No visible growth
- 1 = Growth in the first quadrant only (scant)
- 2 = Growth in the first and second quadrants (light)
- 3 = Growth in the first, second and third quadrants (moderate)
- 4 = Growth across all four quadrants (heavy/confluent)

Colony counts, morphological characteristics (size, shape, color, texture, elevation) and growth patterns were recorded for each plate.

Microbiological characterization

Gram staining and morphology (2013-2016): Gram staining was performed on representative isolates from each morphologically distinct colony type using standard methods. Slides were examined under oil immersion microscopy (1000× magnification) to determine Gram reaction and cellular morphology (cocci, bacilli, or other forms).

Hemolysis testing (2016): Cocci isolates from the 2016 follow-up study were subcultured onto 5% sheep blood agar plates (Remel™, Lenexa, KS) and incubated at 37°C for 24 hrs. Plates were examined for hemolytic activity (α-hemolysis, β-hemolysis, or γ-hemolysis/no hemolysis).

Spore staining (2016): Rod-shaped isolates morphologically consistent with *Bacillus* spp. were subjected to Schaeffer-Fulton endospore staining to confirm the presence of heat-resistant endospores. Briefly, heat-fixed smears were flooded with malachite green and steamed for 5 min, rinsed with water and counterstained with safranin. Slides were examined at 1000× magnification; endospores appeared green against red/pink vegetative cells.

Species identification (2023): Pure cultures of representative isolates from the 2023 case study were submitted to Quantus, Inc. (Blue Bell, PA, USA) for species-level identification using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS; Bruker MALDI Biotyper®).

Data analysis: Descriptive statistics (Mean±Standard Deviation) were calculated for growth scores by building and sampling year. To evaluate whether sanitizer fill status (filled vs. empty) influenced the likelihood of detectable microbial contamination, contingency table analysis was performed using Fisher's exact test (two-sided) for each trial year independently. Statistical analyses were conducted using GraphPad Prism version 11 (GraphPad Software, San Diego, CA, USA). Statistical significance was defined as $p<0.05$.

Ethics statement: This study involved environmental surface sampling only and did not include human participants, personal data collection, or clinical specimens. Therefore, institutional review board approval and informed consent were not required under institutional research ethics guidelines.

RESULTS

Overall contamination prevalence: Microbial growth was detected on hand sanitizer dispensers in 8 of 10 buildings (80%) during Trial 1 (2013) and 9 of 10 buildings (90%) during Trial 2 (2014). The Oakland building showed no detectable contamination across both sampling periods, while the Medical Arts building showed no contamination in Trial 1 but did exhibit growth in Trial 2. All negative control swabs processed throughout the study remained sterile, confirming that contamination detected on test samples originated from the dispenser surfaces and not from sampling materials or laboratory procedures.

Spatial and temporal variation in contamination levels: Growth scores exhibited considerable spatial variation across buildings and temporal variation between sampling years (Fig. 2). Mean growth scores ranged from 0.3 to 2.0 in Trial 1 (2013) and from 0.5 to 2.7 in Trial 2 (2014).

Three buildings demonstrated consistently elevated microbial contamination: Administration, Art and Student Union. The Administration building exhibited the highest contamination in both trials, with mean growth scores of 1.8±0.4 (Trial 1) and 2.7±0.5 (Trial 2). The Art building showed the second-highest contamination in Trial 1 (2.0±0.6) but decreased to 1.5±0.4 in Trial 2, though contamination remained in the light-to-moderate range. The Student Union building demonstrated the most dramatic increase, rising from 0.7±0.3 (Trial 1) to 2.0±0.7 (Trial 2). The Science, Library and Kennedy buildings exhibited moderate growth levels, with scores ranging from 0.5 to 1.3 across both trials. An overall upward trend in microbial growth scores was observed from Trial 1 to Trial 2 across most sampling locations (Fig. 2).

Effect of sanitizer fill status on contamination: To assess whether the presence or absence of sanitizer in dispensers influenced surface contamination, we compared growth outcomes (growth detected vs. no growth detected) between filled and empty dispensers using Fisher's exact test for each trial independently (Fig. 3a-b). This analysis included only dispensers with complete documentation of both fill status and contamination outcomes ($n = 29$ Trial 1, $n = 30$ Trial 2), representing a subset of the total 42 dispensers sampled annually.

In Trial 1, microbial growth was detected more frequently on filled dispensers (17/19; 89.5%) than on empty dispensers (6/10; 60.0%); however, this association did not reach statistical significance ($p = 0.14$). In Trial 2, growth was observed in 4/10 (40.0%) filled dispensers and 11/20 (55.0%) empty dispensers, again showing no significant association ($p = 0.70$). Overall, across both trials, sanitizer fill status did not significantly influence the likelihood of detecting microbial contamination on dispenser surfaces.

Morphological and staining characteristics (2016 follow-up study): The 2016 follow-up study focused on three buildings (Administration, Art and Library) that had exhibited elevated contamination in previous years. All isolates characterized

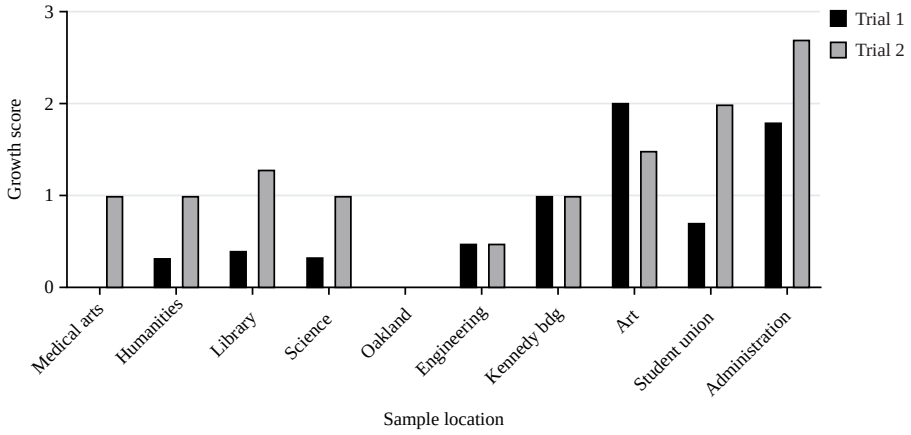

Fig. 2: Mean microbial growth scores (0-4 scale) for hand sanitizer dispensers sampled across ten campus buildings during Trial 1 (2013) and Trial 2 (2014)
Higher scores indicate greater surface contamination

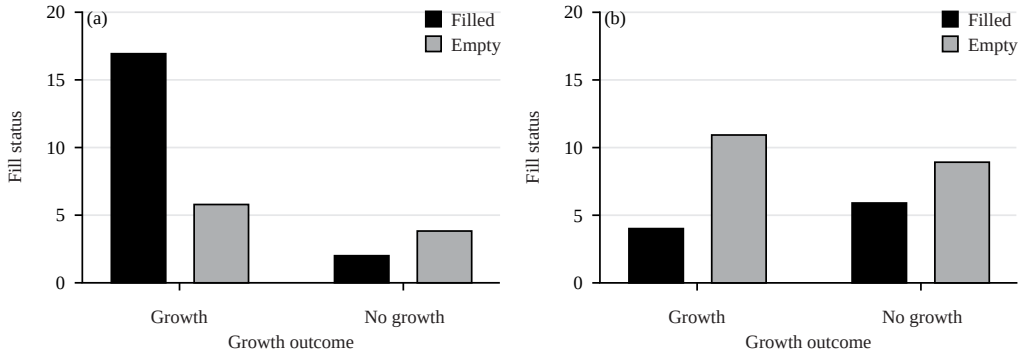

Fig. 3(a-b): Sanitizer fill status and microbial growth outcome for, (a) Effect of fill status (fill vs empty) on growth (Trial 1) and (b) Effect of fill status (fill vs empty) on growth (Trial 2)
Bars represent the number of dispensers classified as filled or empty by growth outcome (growth vs no growth). Differences were evaluated using Fisher's exact test and were not statistically significant (Trial 1: p = 0.1432; Trial 2: p = 0.6999), (a) Trial 1 (2013) and (b) Trial 2 (2014)

Table 1: Gram staining results and morphological characteristics from follow-up study (2016)

Location	Gram reaction	Number of morphotypes	Colony description	n
Administration	Positive	1	Bacillus (rod-shaped)	5
Art	Positive	1	Cocci (spherical)	5
Library	Positive	2	Bacillus and Cocci	5

N: Number of dispensers sampled per location

during this phase displayed Gram-positive cell wall characteristics upon Gram staining (Table 1), indicating the predominance of Gram-positive bacteria on sampled dispenser surfaces. The Library exhibited the greatest microbial diversity, yielding two distinct morphotypes (bacilli and cocci), while the Administration and Art buildings each yielded one predominant morphotype.

All cocci isolates demonstrated γ-hemolysis (no hemolysis) on blood agar plates, indicating the absence of hemolytic activity. Schaeffer–Fulton spore staining confirmed the presence of heat-resistant endospores in all bacillus isolates (Fig. 4c), consistent with their identification as spore-forming Gram-positive rods belonging to the *Bacillus* group.

Species identification (2023 case study): The MALDI-TOF mass spectrometry identified two bacterial species from the 2023 case study samples (Table 2). Both species identified were Gram-positive bacteria commonly associated with environmental sources and human skin microbiota.

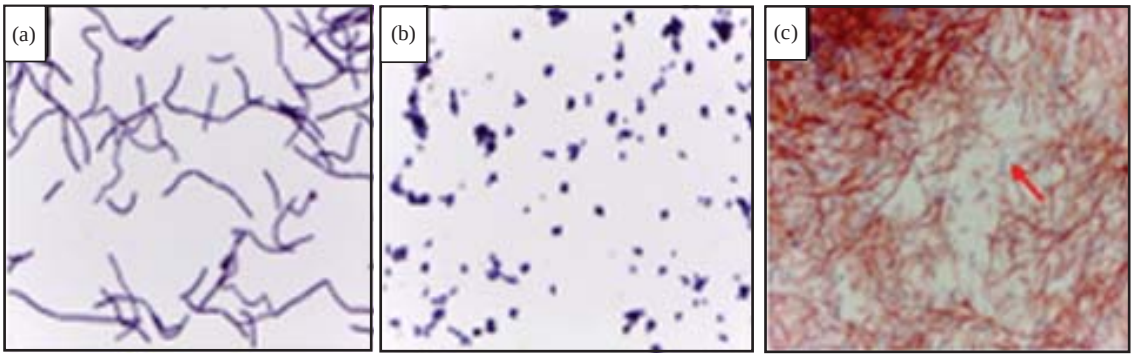

Fig. 4(a-c): Staining results showing Bacillus, Coccus and Spores from isolates, (a) Gram stain showing Gram-positive bacilli (rods). Rod-shaped bacteria appear purple/violet, consistent with Gram-positive cell wall structure, (b) Gram stain showing Gram-positive cocci (spherical cells). Spherical bacteria appear purple/violet and are arranged in clusters, typical of *Staphylococcus* species and (c) Schaeffer-Fulton spore stain of Bacillus isolate. Endospores appear green (indicated by arrow, while vegetative cells appear red/pink. The presence of heat-resistant endospores confirms identification as spore-forming Bacillus species

Representative staining results are shown in Fig. 4. Gram staining revealed both rod-shaped (Fig. 4a) and cocci (Fig. 4b) Gram-positive bacteria. Endospore staining confirmed spore formation in bacillus isolates, with green-stained endospores visible within red/pink vegetative cells (Fig. 4c), Magnification: 1000×

Table 2: Species identification from 2023 case study using MALDI-TOF mass spectrometry

Location	Species identified	Gram reaction	Morphology	Identification score
Bookstore	*Staphylococcus warneri*	Positive	Coccus	2.34
Bookstore	*Priestia flexa*	Positive	Bacillus	2.18
Grounds dept.	*Priestia flexa*	Positive	Bacillus	2.21

Staphylococcus warneri, a coagulase-negative staphylococcus, was recovered from one dispenser in the Bookstore location. *Priestia flexa* (formerly *Bacillus flexus*), a spore-forming environmental bacterium, was identified from both the Bookstore and all samples from the Grounds Department

DISCUSSION

This multi-year survey demonstrates that hand sanitizer dispensers in college environments harbor diverse microbial communities, with contamination patterns influenced by building use characteristics and user contact frequency. Similar findings have been reported in healthcare and public settings, where HSDs have been shown to act as unintended microbial reservoirs despite their intended role in infection prevention[4,13,14].

The exclusive recovery of Gram-positive bacteria from characterized isolates aligns with prior research demonstrating that desiccation-tolerant bacteria such as *Bacillus* and *Staphylococcus* species dominate dry indoor surfaces[15,16]. The detection of *Bacillus* species (identified as *Priestia flexa* in 2023 samples) is consistent with environmental deposition from airborne dust and soil particles[17], while the formation of heat-resistant endospores enhances survival under the adverse environmental conditions present on frequently touched surfaces[18,19]. The identification of *Priestia flexa* specifically supports an environmental rather than human origin for these organisms, as this species is commonly found in soil and outdoor environments[20].

The recovery of *Staphylococcus warneri*, a coagulase-negative staphylococcus commonly found on human skin, indicates that direct human contact contributes to dispenser contamination. While typically non-pathogenic in healthy individuals, coagulase-negative staphylococci can occasionally act as opportunistic pathogens, particularly in immunocompromised individuals or those with indwelling medical devices[21,22]. Although Methicillin-resistant *Staphylococcus aureus* (MRSA) was not detected in this study, the presence of staphylococci species on dispenser surfaces highlights the potential for microbial transfer from contaminated hands to shared surfaces and vice versa[23,24].

The absence of a statistically significant association between sanitizer fill status and surface contamination (Trial 1: $p = 0.14$; Trial 2: $p = 0.70$) suggests that microbial accumulation on dispenser surfaces results primarily from repeated human contact rather than from sanitizer depletion or lack of functional hand hygiene product availability[25]. This finding has important practical implications: Simply maintaining adequate sanitizer levels is insufficient to prevent dispenser surfaces from becoming contaminated. Rather, routine surface disinfection protocols targeting the external surfaces of dispensers are necessary to maintain the overall hygiene of these devices.

The lack of correlation between fill status and contamination also indicates that contamination is driven by external factors specifically, user contact with the dispenser activation mechanism and front panel rather than internal factors related to sanitizer presence or absence. This underscores the paradoxical nature of hand hygiene infrastructure: devices intended to reduce pathogen transmission may themselves become vectors for microbial transfer if not properly maintained.

The consistently elevated contamination observed in the Administration, Art and Student Union buildings likely reflects differences in user traffic volume, cleaning frequency and usage patterns. The Administration building, which houses student services offices and experiences high foot traffic throughout the day, exhibited the highest mean contamination scores in both sampling years. The Student Union, a social and dining hub, showed a dramatic increase in contamination from Trial 1 to Trial 2, possibly reflecting increased usage or changes in cleaning protocols between sampling periods. These findings suggest that high-traffic areas require more frequent cleaning and maintenance of hygiene infrastructure to prevent microbial accumulation.

Although the bacterial species identified in this study (*Staphylococcus warneri* and *Priestia flexa*) are generally considered non-pathogenic to healthy individuals, their presence on hand sanitizer dispensers raises several concerns. First, the presence of any bacteria on surfaces intended to promote hand hygiene represents a potential breakdown in environmental infection control. Second, while the specific organisms detected pose minimal risk to immunocompetent individuals, community colleges serve diverse populations, including immunocompromised students and older adult learners who may be more susceptible to opportunistic infections. Third, the presence of environmental and skin-associated bacteria on these surfaces confirms that hand-to-surface and surface-to-hand transmission pathways are active in this setting, which could facilitate the spread of more concerning pathogens under different circumstances.

The heightened awareness of surface contamination and fomite transmission following the COVID-19 pandemic underscores the importance of maintaining all aspects of hygiene infrastructure, not just ensuring that hand sanitizer is available[12]. This study demonstrates that the external surfaces of dispensers warrant the same attention as other high-touch surfaces such as door handles, elevator buttons and stair railings.

Based on these findings, we recommend several evidence-based interventions to minimize microbial contamination of hand sanitization infrastructure:

- **Routine surface disinfection protocols:** Implement daily disinfection of all HSD external surfaces using EPA-registered products effective against Gram-positive and Gram-negative bacteria. Maintain cleaning logs documenting date, time, location and responsible staff member
- **Dispenser design improvements:** Prioritize touchless or sensor-activated dispensers to minimize direct contact. Where manual dispensers are used, select models with smooth, non-porous surfaces that facilitate cleaning and disinfection
- **Periodic microbiological surveillance:** Conduct quarterly or bi-annual environmental sampling to monitor contamination trends, evaluate cleaning protocol effectiveness and identify high-risk locations requiring enhanced intervention
- **Educational campaigns:** Educate students, faculty and staff about proper hand hygiene techniques and the importance of minimizing contamination of shared hygiene devices through signage and awareness programs

Several limitations should be acknowledged. First, the semi-quantitative growth scoring system (0-4 scale) provides less precision than quantitative colony counting or molecular enumeration methods. Second, sampling at discrete time points may have missed temporal fluctuations in contamination. Third, molecular characterization using MALDI-TOF was limited to 2023 samples, leaving earlier isolates unidentified at the species level. Fourth, this study did not assess viral contamination or antibiotic resistance profiles, both of which have significant public health implications. Fifth, environmental factors such as temperature, humidity, air exchange rates and dispenser placement were not systematically recorded and may influence microbial persistence. Finally, cleaning frequency and protocols were not standardized or documented across buildings, potentially contributing to observed contamination differences. Future studies should employ quantitative enumeration methods, continuous sampling, comprehensive molecular identification (16S rRNA sequencing or metagenomics), viral detection assays, antimicrobial susceptibility testing, environmental monitoring and standardized cleaning protocols.

CONCLUSION

Hand sanitizer dispensers in a community college setting harbored microbial contamination dominated by Gram-positive bacteria, including environmental organisms (*Priestia flexa*) and human skin commensals (*Staphylococcus warneri*). Although these organisms pose minimal risk to immunocompetent individuals, their persistence on high-touch hygiene devices supports the need for routine surface disinfection and improved maintenance practices. Sanitizer fill status did not significantly affect contamination outcomes, indicating that surface contact rather than product availability drives microbial accumulation. Institutions should prioritize daily disinfection protocols, periodic microbiological surveillance and dispenser designs that minimize direct contact.

SIGNIFICANCE STATEMENT

This study demonstrates that hand sanitizer dispensers, though intended to reduce microbial transmission, can function as contaminated high-touch surfaces within a community college environment. The work highlights consistent and location-specific patterns of microbial growth, confirming that dispenser contamination is common and persistent over time. Importantly, the study shows that sanitizer fill status does not significantly influence contamination, indicating that contamination is driven mainly by frequent human contact rather than product availability. These findings provide practical evidence to support improved hygiene infrastructure through routine external surface disinfection, enhanced maintenance protocols and adoption of dispenser designs that minimize direct contact, thereby strengthening infection prevention strategies in educational and public settings.

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