Original article

Investigating *Staphylococcus aureus* contamination on high-touch surfaces in schools and public spaces

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Abstract

Staphylococcus aureus is a common bacterial pathogen responsible for a wide range of infections and is capable of persisting on high-touch surfaces, thereby posing a risk for community transmission. Although numerous studies have focused on clinical settings, data on *S. aureus* contamination in public spaces, particularly in developing countries, remain limited. This study aimed to investigate the prevalence and distribution of *S. aureus* contamination on high-contact surfaces in schools, public transportation systems, and shopping malls in Bangkok, as well as to examine environmental factors influencing contamination levels. A cross-sectional observational study was conducted between May and June 2025. A total of 95 surface swab samples were collected from classrooms, restrooms, ticket machines, elevator buttons, and food courts. Detection of *S. aureus* was performed using a rapid latex agglutination test kit, with validation through positive and negative controls. Data were analyzed using descriptive statistics, Pearson correlation analysis, and principal component analysis (PCA) to assess associations between contamination levels, surface contact frequency, and site characteristics. The prevalence of *S. aureus* contamination varied substantially across sites. High contamination rates were observed in classrooms (80.00%), restrooms (44.44%), BTS ticketing areas (42.90%), and one shopping mall (100.00%). In contrast, cafeterias and ferry terminals, despite high contact frequency, exhibited low or no detectable contamination. PCA findings indicated that surface material and cleaning frequency were stronger predictors of contamination than contact frequency alone. This study demonstrates significant *S. aureus* contamination on high-touch public surfaces, particularly in areas with inadequate sanitation practices. The findings underscore the importance of implementing targeted cleaning protocols, enhancing public hygiene awareness, and strengthening microbial surveillance in urban public environments. Future research should incorporate molecular diagnostic techniques to identify antimicrobial-resistant strains and to evaluate seasonal variations in contamination patterns.

Keywords: *Staphylococcus aureus*, surface contamination, public health, high-touch surfaces, sanitation practices

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Introduction

Staphylococcus aureus (S. aureus) is a gram-positive bacterium that colonizes approximately 30% of healthy individuals and poses a significant threat in both healthcare and community environments. Although often a harmless commensal organism residing on the skin and nasal passages, *S. aureus* can become pathogenic when introduced to wounds or mucosal barriers, leading to conditions such as skin infections, sepsis, endocarditis, and toxic shock syndrome. The emergence of methicillin-resistant *S. aureus* (MRSA) has further complicated treatment and containment efforts, making *S. aureus* one of the most persistent and adaptable pathogens in public health today (Tong et al., 2015; Chambers & DeLeo, 2009).

Numerous studies have identified high-touch surfaces as critical points for microbial transmission, with *S. aureus* frequently detected on surfaces in hospitals, gyms, and public transportation (Otter et al., 2013; Guerrero et al., 2022). These environments facilitate fomite-based transmission, especially in areas with high human traffic and insufficient sanitation protocols. However, most research has been conducted in clinical or high-income country contexts. There remains limited data on *S. aureus* contamination in public spaces such as schools, shopping centers, and transportation systems in developing countries, particularly in Southeast Asia. In Thailand, where urban crowding and sanitation variability are common, understanding bacterial contamination patterns in everyday environments is vital for infection control.

Despite the known risk, the specific relationship between surface contamination, touch frequency, and environmental sanitation practices is still poorly understood. For example, it is unclear whether higher surface contact correlates with greater contamination or whether material type and cleaning frequency play more significant roles. Few studies to date have systematically compared these variables across multiple types of public settings.

This study aims to investigate the prevalence and distribution of *Staphylococcus aureus* contamination on high-touch surfaces in schools, public transportation systems, and shopping malls in Bangkok. Specifically, it seeks to:

1. Assess the contamination rate of *S. aureus* on different types of high-contact surfaces;
2. Compare contamination levels across different environments (schools, transport systems, malls);
3. Explore the influence of surface material, touch frequency, and sanitation practices on bacterial presence.

By addressing these objectives, this research intends to provide evidence-based recommendations for improving public hygiene strategies in urban settings.

Methodology

Research Design

This was a cross-sectional observational study conducted over a period of eight weeks between May and June 2024. The aim was to assess the prevalence of *Staphylococcus aureus* contamination on high-touch surfaces in public spaces such as schools, public transport systems, and department stores in Bangkok.

Population and Sampling

The target sampling sites included:

- Four secondary schools,
- Five public transportation nodes (e.g., BTS, MRT, ferry terminals, airport), and
- Five department stores.

A purposive sampling technique was used to select 95 high-touch surface points based on surface type (e.g., plastic, metal), estimated contact frequency, and accessibility. Each site provided 6–10 sampling points (e.g., classroom desks, restroom doorknobs, elevator buttons).

Instrument

The study utilized a rapid latex agglutination test kit (Hygiena Foodproof SL Staphylococcus aureus Detection Kit), validated for its specificity to *S. aureus* antigens.

Sterile cotton swabs and sealed colorimetric reagent tubes were used for sample collection and immediate processing.

Positive and negative controls were used to validate the reliability of each batch of test kits. Positive control used *S. aureus* strain ATCC 25923 (provided by the school biology lab).

Data Collection Procedures

Sample Collection Process

Samples were collected by trained student researchers and supervised by a biologist researcher. Sampling was done during off-peak hours to avoid interference. Each surface was swabbed following CDC environmental surface sampling protocols.

Swabbing Technique and Collection Medium

Each high-touch surface (approximately 10 cm^2 area) was swabbed using a sterile, pre-moistened cotton swab.

After swabbing, each swab was placed into a colorimetric reagent tube containing nutrient broth with phenol red pH indicator, which turns yellow in response to bacterial metabolism and acid production.

Transport of Specimens

After sealing, tubes were labeled and transported in an insulated container within 2 hours to the designated school laboratory, where they were immediately incubated. Samples not processed within 2 hours were refrigerated at 4°C for up to 12 hours.

Testing Procedure and Personnel

Tests were conducted using the latex agglutination method:

- All tubes were incubated at 28–30°C for 24–72 hours.
- Presence of *S. aureus* was indicated by color change and agglutination reaction under light microscopy.
- Testing was performed and cross-checked by two high-school science students under supervision of a faculty advisor trained in microbiology.

Laboratory Conditions

All processing was conducted in the school science laboratory, equipped with basic microbiological tools (incubator, alcohol burner, pipettes). Surfaces were disinfected with 70% ethanol before and after sample processing. While not a certified biosafety laboratory, all activities followed safety protocols including glove use, mask-wearing, and proper waste disposal.

Positive Control

Each testing session included:

- Positive control: a tube inoculated with known *S. aureus* strain (ATCC 25923), producing a predictable color change and agglutination pattern.
-Negative control: a sterile swab with no contact to surface placed in reagent tube, which remained unchanged.

Data Analysis

Statistical analysis was performed using R version 4.4.1 **(**RS team, 2024**).** Descriptive statistics, including mean, standard deviation, and standard error of the result, were calculated**.** Pearson correlation analysis was utilized to assess the relationship of the presence of *Staphylococcus aureus* and observed locations**.** Principal component analysis **(**PCA**)** was employed to explain multiple correlations among the presence of *Staphylococcus aureus* and observed locations**.**

Quality Assurance

Quality assurance measures were implemented to ensure data reliability and minimize contamination risks throughout the study. Sampling tools were sterilized using autoclaving procedures to maintain sterility. Strict aseptic techniques were followed during sample handling and incubation to prevent external contamination. Additionally, test results were cross-validated using duplicate swabs and controlled laboratory conditions to verify accuracy and consistency. These measures ensured the integrity of the data and enhanced the reliability of the study's findings.

Result

The results of this study demonstrate significant variability in *Staphylococcus aureus* contamination rates across high-touch surfaces in schools, public transportation systems, and shopping malls, with contamination influenced by surface materials, touch frequency, and sanitation practices.

Schools

In schools, classrooms exhibited the highest contamination rate (80.00%), followed by restrooms (44.44%), while libraries and cafeterias had contamination rates of 40.00% and 0.00%, respectively. Notably, the cafeteria, despite having the highest touch frequency (3,000 touches), showed no contamination, suggesting that effective cleaning protocols can significantly mitigate bacterial presence. Conversely, classrooms and restrooms, with lower touch frequencies, exhibited higher contamination rates, indicating that sanitation frequency and moisture on surfaces may be more critical factors than contact frequency. High-touch areas such as desks, sinks, and doorknobs were particularly prone to contamination, emphasizing the need for targeted cleaning efforts in these spaces.

The Figure (1) and Table (2) emphasize an inverse relationship between contamination rates and touch frequency in some areas, such as the cafeteria, where high touch frequency does not correspond to bacterial contamination. Conversely, the restroom and library showed relatively high contamination rates despite lower touch frequencies compared to the cafeteria.

Public Transportation

In public transportation systems, the BTS (Skytrain) had the highest contamination rate (42.90%), with bacterial presence detected on ticket vending machines, elevator buttons, and seats. The MRT (Subway) showed a moderate contamination rate (28.60%), with contamination identified on handrails and emergency exit doors. In contrast, the airport and ferry systems demonstrated lower contamination rates of 14.30% each, despite high touch frequencies (180,000 and 1,000 touches, respectively). These findings suggest that material properties and rigorous sanitation practices in airports and ferries may contribute to lower contamination levels. Public transportation touchpoints such as ticket machines, handrails, and elevator buttons emerged as key reservoirs for bacterial contamination, highlighting the importance of regular cleaning in these areas.

The accompanying Figure (2) and Table (3) illustrates the relationship between contamination rates and touch frequencies across the tested locations, revealing important patterns. Key observations include those locations with higher touch frequencies, such as the BTS and airport, exhibit an increased potential for contamination, even though the contamination rates vary. This suggests that the frequency of contact plays a significant role in the likelihood of contamination. On the other hand, locations with lower touch frequencies, such as the ferry system, correlate with reduced contamination risks. This emphasizes the importance of both the number of interactions with surfaces and the need for effective cleaning protocols in high-traffic areas to mitigate contamination risks.

Shopping Malls

Shopping malls displayed significant variability in contamination rates. Mall A exhibited the highest contamination rate (100.00%) despite a moderate touch frequency (3,914 touches), indicating that factors such as inconsistent cleaning protocols or surface materials likely contributed to bacterial persistence. Malls B and M had similar contamination rates (85.70%) but lower touch frequencies (4,500 and 3,900 touches, respectively). In contrast, Malls P and L, with the highest touch frequencies (7,800 touches), showed the lowest contamination rate (57.10%), suggesting that frequent contact might reduce bacterial buildup in some cases by disrupting accumulation. These results underscore the role of cleaning practices and surface characteristics in contamination control.

The Figure (3) and Table (4) comparing the contamination rates and touch frequency provides insights into the relationship between these two variables. Mall A had the highest contamination rate (100.00%) despite a moderate touch frequency of 3,914.28. This suggests that touch frequency alone does not fully explain the contamination levels in a location. Mall B and Mall M showed similar contamination rates (85.70%), with touch frequencies of 4,500 and 3,900, respectively. This indicates a consistent trend across these two locations where higher touch frequencies lead to higher contamination rates.

Comparative Analysis

Across all environments, contamination rates varied depending on a combination of factors:

-Touch Frequency: High touch frequency did not always correlate with higher contamination. For example, the cafeteria (0.00%) and Malls P and L (57.10%) demonstrated low contamination rates despite high touch frequencies, indicating effective cleaning practices.

-Surface Materials: Non-porous surfaces such as stainless steel or antimicrobial-treated materials likely contributed to lower contamination rates in certain environments, such as airports and ferries.

-Sanitation Practices: Consistent and targeted cleaning protocols played a crucial role in reducing contamination, as observed in the cafeteria and certain malls.

These this study results showed the complex interplay between environmental factors, sanitation efforts, and bacterial persistence, emphasizing the need for targeted hygiene strategies to mitigate contamination risks across public spaces.

Discussion

The primary objective of this study was to investigate the prevalence and distribution of *Staphylococcus aureus* contamination on high-touch surfaces across schools, public transportation systems, and shopping malls, focusing on the influence of contact frequency, environmental factors, and sanitation practices.

The findings revealed significant contamination variability across environments. In schools, classrooms exhibited the highest contamination rate (80.00%), followed by restrooms (44.44%), while cafeterias showed no detectable contamination despite high touch frequency. This suggests that cleaning frequency and surface material play a more critical role in bacterial persistence than touch frequency alone, with inadequate cleaning and moist surfaces contributing to higher contamination levels (Ikuta et al., 2022).

In public transportation, the BTS system demonstrated the highest contamination rate (42.90%), particularly on ticket vending machines and elevator buttons. Conversely, the airport and ferry systems showed lower contamination rates (14.30%) despite higher touch

frequencies, indicating the impact of surface material and sanitation practices, such as frequent cleaning or the use of antimicrobial coatings (Song et al., 2023).

Shopping malls exhibited substantial variability, with Mall A showing the highest contamination rate (100.00%) despite moderate touch frequency, whereas Malls P and L, with the highest touch frequencies, demonstrated lower contamination rates (57.10%). These findings suggest that frequent touching may disrupt bacterial accumulation in some cases, but the overall trend is influenced by cleaning protocols and surface characteristics (Multidrug-resistant Bacterial Infections Increasing in Thailand and Likely Elsewhere in Asia, 2016).

The results align with previous studies identifying public spaces as significant reservoirs for bacterial contamination. Similar studies have reported high bacterial loads on public transportation touchpoints and shopping cart handles, supporting the importance of effective sanitation practices (Tong et al., 2015). These findings underscore the need for targeted cleaning protocols, particularly in high-risk areas such as classrooms, restrooms, ticket machines, and shopping cart handles. Antimicrobial cleaning agents and materials, combined with regular disinfection, could significantly reduce contamination (Chambers & DeLeo, 2009). Additionally, public awareness campaigns promoting hand hygiene and the use of hand sanitizers in high-traffic areas could mitigate the spread of *S. aureus*. Routine microbial testing could further evaluate the effectiveness of these measures and identify areas requiring improvement (Lowy, 1998).

Limitation

While this study provides valuable insights, several limitations should be addressed in future research. Differentiating between resistant and non-resistant strains of *S. aureus* would offer a clearer understanding of public health risks (Pathogen Safety Data Sheets, 2012). Additionally, the impact of seasonal and environmental factors, such as temperature and humidity, on bacterial survival was not assessed and should be explored in future studies. Incorporating advanced molecular techniques, such as PCR, could enhance strain detection and characterization (Foster, 1996).

Conclusion

This study examined *Staphylococcus aureus* contamination on high-touch surfaces in schools, public transportation, and shopping malls, revealing variability influenced by cleaning protocols, surface materials, and environmental conditions. Classrooms and public transport touchpoints showed the highest contamination, while areas like cafeterias exhibited low contamination despite high touch frequency, highlighting the importance of sanitation practices over contact frequency.

Recommendations include targeted cleaning, antimicrobial surfaces, and public hand hygiene awareness. Limitations such as the lack of strain differentiation and environmental factors suggest future research should incorporate molecular techniques and broader environmental assessments. Overall, this study underscores the need for effective hygiene measures to mitigate *S. aureus* transmission and enhance public health safety.

Antibiotic-resistant strains and seasonal variations would provide additional insights into bacterial contamination control.

Recommendation

Expanding the study to include other public environments, such as hospitals and recreational facilities, would provide a broader perspective on bacterial contamination.

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Table 1 Comparing available detection test kits for *Staphylococcus aureus*, including the colorimetric detection method used in your study

Test Kit	Detection methods	Speed and Efficiency	Accuracy and Reliability	Versatility	Cost-Effectiveness	Quality Assurance
Rapid Latex Agglutination Test Kit	Latex agglutination, antigen-antibody reaction	Results in 24-72 hours, rapid compared to traditional methods	High accuracy and reliability across various sample types (food, clinical)	High versatility, works for food, clinical, and environmental samples	Relatively cost-effective, affordable balance between performance	Stringent quality assurance protocols such as sterilization and preservation (Esmail S et al., 2021)
Lateral Flow Immunoassays (LFAs)	Immunoassay with antibodies, lateral flow detection	Results in 15-30 minutes, very fast for rapid decisions	Moderate accuracy, potential sensitivity and specificity issues	Moderately versatile, but limitations with complex matrices	Low-cost, simple design, minimal equipment needed	Variable quality assurance depending on manufacturer protocols (Koczula KM et al., 2016)
Loop-mediated Isothermal Amplification (LAMP)	DNA amplification with isothermal heat	Results in less than 1 hour, fast and efficient	Highly accurate, reliable with high sensitivity	Limited versatility, requires specific sample types and conditions	Higher cost due to specialized equipment and reagents	High-quality assurance when controlled conditions are maintained (Long LJ et al., 2022)
Fluorescence-based Assays	Fluorescent labeling, DNA or antigen detection	Results in 1-2 hours, relatively fast with high sensitivity	High accuracy and sensitivity, but requires specialized equipment	Less versatile, specific conditions and equipment required	Moderate cost, requires expensive equipment and reagents	High quality assurance with controlled conditions (Nath P et al., 2023)
Enzyme-linked Immunosorbent Assay (ELISA)	Antigen-antibody binding and colorimetric change	Results in 2-4 hours, slower than other methods but highly quantitative	Highly reliable, considered the gold standard for quantitative tests	Least versatile, often requires specific sample conditions and types	Most expensive due to the need for sophisticated lab equipment	Rigorous quality control, equipment calibration essential (Sakamoto S et al., 2018)
Colorimetric Detection	Colorimetric change upon antigen binding	Varies based on specific method, typically moderate speed	Reliable for many applications, moderate to high accuracy	Versatile for various sample types depending on the assay used	Generally cost-effective, cheaper than more advanced methods	High quality assurance with controlled test conditions in study

Table 2 Contamination Rates and Touch Frequency by Location at school

Location	Negative	Positive	Total	Contamination rate (%)	Frequency of Touching
Library	6	4	10	40.00	25
Toilet	5	4	9	44.44	320
Cafeteria	10	0	10	0.00	3,000
Classroom	8	2	10	20.00	20

Table 3 Contamination Rates and Touch Frequency by Location at Public Transportation

Location	Negative	Positive	Total	Contamination rate (%)	Frequency of Touching
MRT	5	2	7	28.60	68,000
BTS	4	3	7	42.90	10,0000
Ferry	6	1	7	14.30	1,000
Airport	6	1	7	14.30	180,000

Table 4 Contamination Rates and Touch Frequency by Location at public locations

Location	Negative	Positive	Total	Contamination rate (%)	Frequency of Touching
Mall B	1	6	7	85.70	4,500
Mall M	1	6	7	85.70	3,900
Mall P & Mall L	3	4	7	57.10	7,800
Mall A	0	7	7	100.00	3,914.28

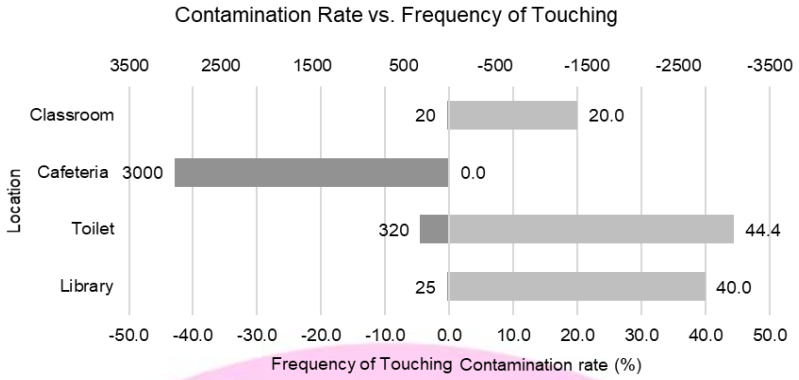


Figure 1 Analysis of Contamination Rate and Touching Frequency in School

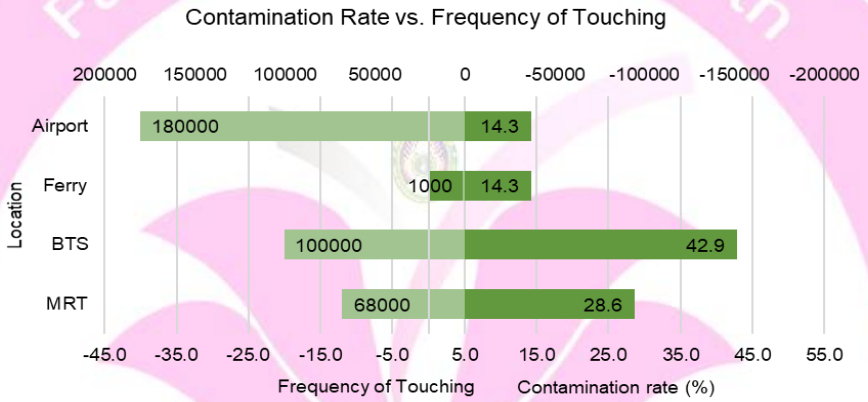


Figure 2 Analysis of Contamination Rate and Touching Frequency in Public Transportation

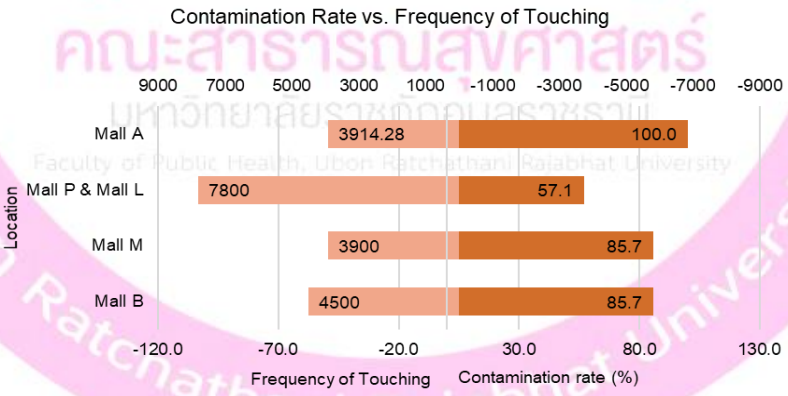


Figure 3 Analysis of Contamination Rate and Touching Frequency in Public Locations