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Research Article

Assessment of Hospital Sink Usage and Bacterial Contamination of Handwashing Sinks and Invasive Devices Within the Selected Hospitals in Kano Metropolis, Nigeria

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ABSTRACT
Hospital sinks and invasive medical devices can serve as reservoirs and transmission points for potentially pathogenic bacteria. This study investigated the occurrence and distribution of bacteria associated with hospital sinks and invasive medical devices in selected hospitals in Kano State, Nigeria. A cross-sectional study was conducted at Murtala Muhammad Specialist Hospital (MMSH) and Aminu Kano Teaching Hospital (AKTH), Kano. A total of 168 samples were collected from ward hand-washing sinks and invasive medical devices, including urinary catheters, cannulas, ventilators, nasogastric tubes, surgical drains, central venous catheters, and surgical implants. Samples were collected aseptically using sterile swabs and processed using standard microbiological techniques. Bacterial isolates were identified by Gram staining and conventional biochemical tests. Information on sink availability, water supply, cleaning frequency, and visible biofilm was obtained using a structured questionnaire. Data were analyzed using descriptive statistics, Student's *t*-test and chi-square test, with significance set at $p < 0.05$. Marked differences in sink availability and hygiene practices were observed between the hospitals. MMSH had a high bed-to-sink ratio (30:1–34:1), irregular water supply, variable cleaning frequency, and visible biofilm in two wards. AKTH had a lower bed-to-sink ratio (3:1–6:1), although water supply was scarce in most wards; sinks were cleaned daily and no visible biofilm was observed. Diverse bacterial isolates were recovered from sinks and invasive devices. At MMSH, invasive devices, particularly urinary catheters and cannulas, yielded substantial isolates, with *Proteus* spp. (10), *Enterobacter* spp. (11), *Klebsiella* spp. (20), *Bacillus* spp. (11), and *Escherichia coli* (7) predominating. At AKTH, sinks were important bacterial reservoirs, with *Klebsiella* spp. (33), *Enterobacter* spp. (23), and *Proteus* spp. (20) most frequently isolated, while urinary catheters were the most frequently contaminated invasive devices. Hospital sinks and invasive medical devices therefore harboured diverse bacterial populations, with different contamination patterns between MMSH and AKTH. The predominance of potentially pathogenic Gram-negative bacteria, particularly *Klebsiella*, *Enterobacter*, and *Proteus* spp., highlights their potential role in healthcare-associated infections. Improved sink hygiene, adequate water supply, environmental decontamination, and continuous surveillance are recommended to reduce bacterial transmission within healthcare facilities.

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INTRODUCTION

Healthcare-associated infections (HAIs) remain a major public health concern and may result from contaminated hands, medical devices and healthcare environments. Effective water, sanitation and hygiene (WASH) services, together with proper environmental cleaning, are essential components of infection prevention and control in healthcare facilities (WHO and UNICEF, 2023).

Hospital hand-washing sinks are essential for maintaining hand hygiene. Still, they may also become contaminated with microorganisms when they are poorly maintained, inadequately cleaned, or subject to an irregular water supply. Studies have reported the recovery of potentially pathogenic bacteria from hospital sinks and surrounding areas, including Gram-negative organisms such as *Klebsiella*, *Enterobacter*, *Proteus* and *Pseudomonas* species (Pirzadian *et al*., 2022; Hayward *et al*., 2024). Contaminated sinks may contribute to the spread of microorganisms through splashing, contaminated hands, and contact with surrounding surfaces.

Invasive devices, including urinary catheters, cannulas, central venous catheters, nasogastric tubes and surgical drains, provide potential routes through which microorganisms can enter vulnerable patients. Bacterial contamination of these devices is therefore an important infection prevention concern, particularly in healthcare facilities with inadequate hygiene infrastructure, irregular water supply and overcrowding.

In Nigeria, bacterial contamination of hospital environments and healthcare equipment has been documented. In Kano, Iliyasu *et al*. (2012) reported the isolation of several potentially pathogenic bacteria from operating-theatre fomites, including sinks, demonstrating the presence of bacterial contamination within hospital environments. Despite the importance of adequate sink facilities and proper environmental hygiene, limited information is available on hospital sink usage, water availability, cleaning practices, and bacterial contamination of hand-washing sinks and invasive devices in selected hospitals in Kano Metropolis. Therefore, this study assessed hospital sink usage and cleaning practices and determined the bacterial organisms recovered from hand-washing sinks and invasive devices in selected hospitals in Kano Metropolis, Nigeria.

MATERIALS AND METHODS

Study area

The study was conducted in Kano State; it is located in the Northwestern region of Nigeria. It lies approximately between latitude 10°33′N and 12°37′N and longitude 7°43′E and 9°35′E. It shares boundaries with Katsina State (northwest), Jigawa State (northeast), Bauchi State (southeast), and Kaduna State (southwest). According to the population projection by the National Population Commission of Nigeria (2023), Kano State has a population of 15,462,200 (≈15.46 million). The study was carried out in two major hospitals: Murtala Muhammad Specialist Hospital (MMSH) and Aminu Kano Teaching Hospital (AKTH). These health facilities were selected based on their high patient turnover, accessibility to both urban and rural population and their role in managing diseases within the state (NPC, 2023).

Ethical approval

Ethical approval was obtained from Kano State Ministry of Health (NHREC/17/03/2018) and Aminu Kano Teaching Hospital (NHREC/28/01/2020/AKTH/EC/3909) Ethical Clearance Committee.

Study population

The study was a cross-sectional study that comprised hospital wards' hand-washing sinks and invasive devices such as urinary catheter, nasogastric tube, ventilator, surgical implants, etc., from individual patients admitted at Murtala Muhammad Specialist Hospital (MMSH) and Aminu Kano Teaching Hospital, Kano, within Kano State. The samples were collected from patients of both sexes and all ages across different wards in the hospitals.

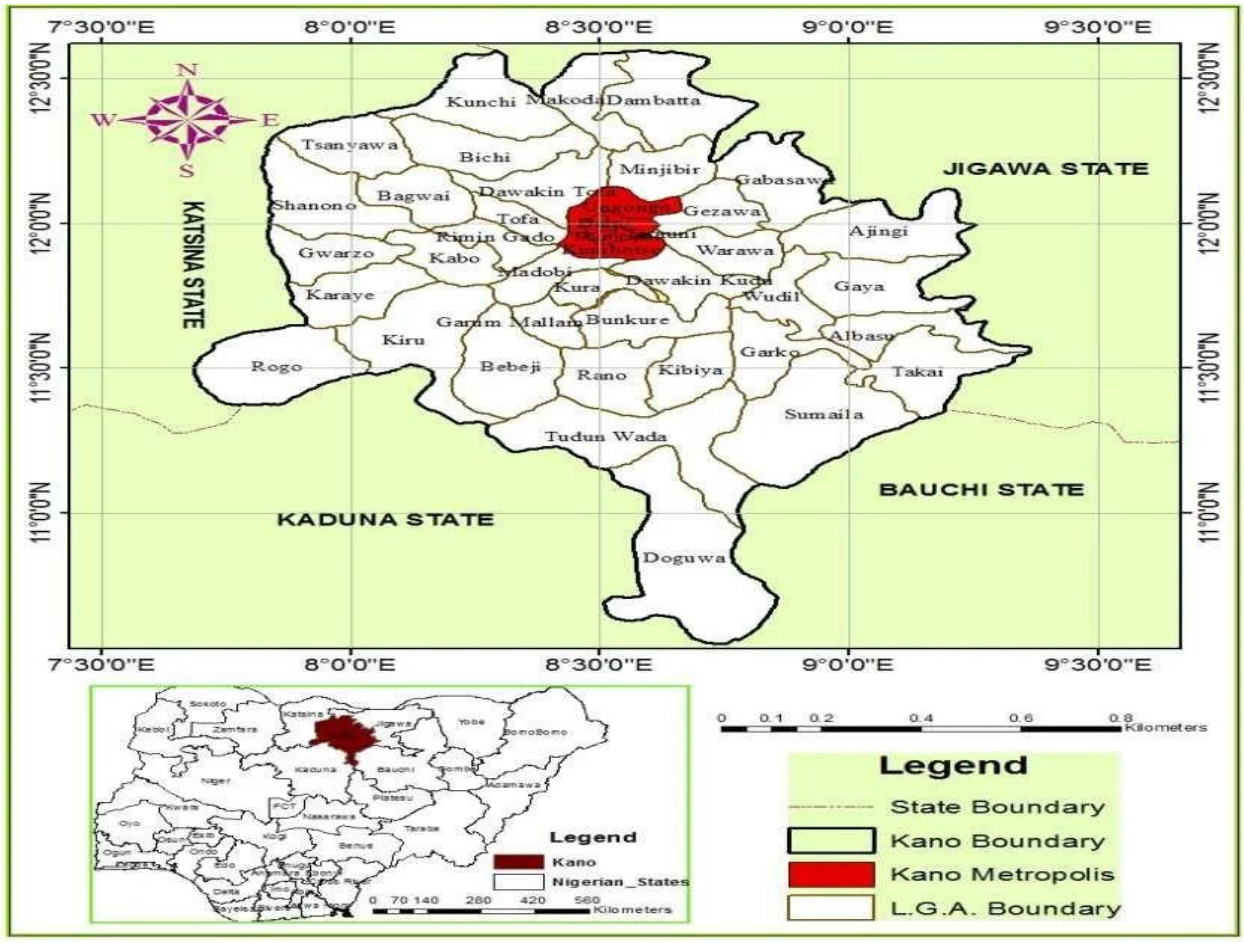


Figure 1: Map of Kano State, Nigeria

Inclusion criteria

The selection of wards, sinks, and patients to recruit into the study depend of the following inclusion criteria (1) present of a sink in any giving ward (2) patients admitted in the ward have an invasive device such as catheter, ventilators etc (3) the patients or relatives/guidance provide consent to collect the sample

Exclusion criteria

All hospital wards without sinks and hospitalized patients without invasive device were excluded from these studies.

Determination of sample size

The sample size was determined using the formula reported by Bartlett *et al*, (2001),

$$n=Z^2pq/d^2$$

Where n= minimum number of participants required in the survey, Z = is the standard normal deviate at 1.962, d = degree of occurrence at expected rate is 0.05, using the prevalence of 10% reported (Hayward *et al*., 2024; Proctor *et al*., 2024), the calculated minimum sample size was ≈ 138. After adding a 10% contingency to account for potential sample loss or contamination, the final sample size was 168 samples**.**

Assessment of Sink Hospital Usage Using Questionnaire

A structured questionnaire was administered to gather information on hand-washing sink usage, water supply, and hygiene practices across hospital wards, and to assess their association with the occurrence of visible biofilm.

Sample collection

Sample collection was carried out according to the method described by (Agbo *et al*., 2020). A total of 180 swab samples were collected for the study. Thirty-five (35) samples were collected in MMSH, while one hundred and forty-three (133) samples were collected from AKTH. The samples were collected from the ward's hand-

washing sinks using sterile swab sticks moistened with normal saline. Samples of the invasive devices (catheters, ventilators, nasogastric tubes, etc.) after removal were collected using sterile swab sticks moistened with normal saline, too. Proper labeling and documentation were ensured for traceability. Samples were transported to the laboratory under cold chain conditions and processed within 2–4 hours to maintain microbial viability (Cheesbrough, 2022).

Isolation of Bacteria

Isolation was carried out using standard culture techniques, the Samples were inoculated onto MacConkey agar (MCA) and Mannitol Salt Agar (MSA) using the streak-plate method. MacConkey agar was used for the isolation and differentiation of Gram-negative bacteria, while MSA was used for the selective isolation and differentiation of salt-tolerant bacteria, particularly staphylococci (Cheesbrough, 2022). The plates were incubated aerobically at 35–37 °C for 18–24 h and examined for characteristic colony morphology. Distinct colonies were subcultured to obtain pure cultures, which were subsequently identified using Gram staining and biochemical tests.

Identification of Bacterial Isolates

The bacteria isolated were identified phenotypically using Gram's staining, and certain biochemical test such as catalase, oxidase, urease, methyl red, Voges-Proskaeur, citrate, and triple sugar iron agar test as described by Cheesbrough, (2022).

Statistical analysis

The data collected were subjected to descriptive statistics, Student's t–test, and Chi-square test of independence analysis using Excel and SPSS IBM version 20.0. The results were considered statistically significant when the probability value was less than 0.05 ($P < 0.05$)

RESULTS

Hospital Sink Usage and Cleaning Practices in Selected Wards

The Hospital sink usage across the two hospitals is presented in Table 1. In MMSH, a high bed-to-sink ratio (30:1–34:1) was observed across all wards. Water supply was consistently irregular in all the 4 wards, and cleaning practices varied between daily and weekly frequencies. Visible biofilm was detected in 2 wards (MMW and maternity unit). In AKTH, lower bed-to-sink ratios (3:1 – 6:1) were observed, water supply was scarce in 6 wards, irregular in 3 wards, and regular in only 1 ward. Cleaning was conducted on a daily basis in all the wards, often using both detergent and disinfectant. No visible biofilm was observed in any of the wards.

Frequency of Occurrence of Bacteria Isolated from Sink and Invasive Devices

Table 2 shows the distribution and Frequency of Occurrence of bacteria isolated from sinks and invasive medical devices across different wards in MMSH and AKTH. Bacterial isolates were recovered from both hospital sinks and invasive medical devices, with variation in distribution across wards. At MMSH, the highest proportion of sink isolates was recorded in the Male and Female Medical Wards (33.33% each), while invasive-device isolates were highest in the Male Medical Ward (40.0%). At AKTH, the Female Medical Ward had the highest proportion of sink isolates (22.22%), whereas invasive-device isolates were most frequent in the Male Surgical Ward (30.23%). Overall, the distribution of bacterial isolates varied considerably between wards and sampling sources, indicating differences in bacterial contamination of hospital sinks and invasive medical devices.

Table 1: Hospital Sink Usage and Cleaning Practices in Selected Wards

Hospital	Ward	No of beds	No of sinks	Bed to sink ratio	Water supply	Cleaning agent	Sink cleaning frequency	Visible biofilm	p value
MMSH	MMW	30	1	30:1	Irregular	Detergent and disinfectant	Weekly	Yes	0.004
	EPU	30	1	30:1	Irregular	Detergent and water	Daily	No	
	Maternity unit	30	1	30:1	Irregular	Detergent and water	Weekly	Yes	
	FMW	34	1	34:1	Irregular	Detergent and water	Daily	No	
AKTH	MMW	34	11	3:1	Scarce	Detergent and water	Daily	No	
	FMW	32	13	3:1	Scarce	Detergent and disinfectant	Twice Daily	No	
	MSW	18	5	4:1	Irregular	Detergent and disinfectant	Daily	No	
	FSW	24	5	5:1	Scarce	Detergent and disinfectant	Daily	No	
	FOW	16	4	4:1	Scarce	Detergent and disinfectant	Daily	No	
	MOW	18	5	3:1	Scarce	Detergent and disinfectant	Daily	No	
	PSW	31	6	5:1	Irregular	Detergent and disinfectant	Daily	No	
	ICU	10	4	3:1	Regular	Detergent and water	Daily	No	
	Pediatric Ward	37	6	6:1	Scarce	Detergent and disinfectant	Daily	No	
	Gynecological ward	33	6	5:1	Irregular	Detergent and disinfectant	Daily	No	

Key: MMW: Male Medical ward, FMW: Female Medical Ward, EPU: Emergency Pediatric Ward, MSW: Male Surgical Ward, FSW: Female Surgical Ward, PSW: Pediatric Surgical Ward, MOW: Male Orthopedic Ward, FOW: Female Orthopedic Ward, ICU: Intensive Care Unit, Regular = continuous water supply; Irregular = intermittent supply; Scarce = very limited supply.

Table 2: Frequency of Occurrence of Bacteria Isolated from Sinks and Invasive Devices

Hospital	Ward	No of sink samples collected	No of bacteria isolated n (%)	No of invasive device samples collected	No of bacteria isolated [n (%)
MMSH	MMW	1	2(33.33)	13	24(40.0)
	EPU	1	1(16.67)	7	14(23.33)
	Maternity unit	1	1(16.67)	6	12(20.0)
	FMW	1	2(33.33)	5	10(16.67)
	Total	4	6(100)	31	60(100)
AKTH	MMW	11	20(18.52)	2	3(6.98)
	FMW	13	24(22.22)	11	7(16.27)
	MSW	5	10(9.26)	30	13(30.23)
	FSW	5	11(10.19)	4	5(11.63)
	FOW	4	9(8.33)	0	0(0.0)
	MOW	5	6(5.55)	5	5(11.63)
	PSW	6	10(9.26)	8	7(16.27)
	ICU	4	7(6.48)	2	1(2.33)
	Pediatric Ward	6	6(5.55)	4	1(2.33)
	Gynecological ward	6	5(4.64)	2	1(2.33)
	Total	65	108(100)	68	43(100)

Key: MMW: Male Medical ward, FMW: Female Medical Ward, EPU: Emergency Pediatric Ward, MSW: Male Surgical Ward, FSW: Female Surgical Ward, PSW: Pediatric Surgical Ward, MOW: Male Orthopedic Ward, FOW: Female Orthopedic Ward, ICU: Intensive Care Unit

(χ^2): 69.31, and p = < 0.0001 (extremely significant)

The Frequency of Bacteria Isolated from Different Sources in MMSH

Table 3 presents the results for biofilm-producing bacteria isolated from different sources. Urinary catheters and cannula recorded the highest number of isolates. In urinary catheters, *Proteus spp.* (6), *Bacillus spp.* (4), *Klebsiella spp.* (4), and *Escherichia coli* (3) were the most commonly isolated organisms. Cannula samples showed a high number of isolates, with *Enterobacter spp.* (7) and *Klebsiella spp.* (6) being the most predominant. Other organisms, such as *Bacillus spp.* (3) and *Proteus spp.* (1) were also present. Ventilator samples had fewer isolates, including *Klebsiella spp.* (3), *Enterobacter spp.* (2), *Bacillus spp.* (2), *Klebsiella pneumoniae* (2), *Proteus spp.* (1), and *Escherichia coli* (1). Nasogastric tube samples also yielded moderate isolates, particularly *Klebsiella spp.* (3) and *Escherichia coli* (3), along with *Bacillus spp.* (2) and *Staphylococcus spp.* (1). sink samples showed relatively fewer isolates compared to clinical devices, with only *Klebsiella spp.* (4) and *Proteus spp.* (2) identified.

The frequency of Bacteria Isolated from Different Sources In AKTH

From the table, sinks recorded the highest number of isolates, with *Klebsiella* spp. (33), *Enterobacter* spp. (23), and *Proteus* spp. (20) being the most predominant. Other organisms, such as *Bacillus* spp. (13) and *Escherichia coli* (7) were also frequently recovered from sinks. Invasive device samples showed lower isolates. Urinary catheters had the highest number of isolates among invasive device sources, with *Enterobacter* spp. (8), *Staphylococcus* spp. (7), and *Escherichia coli* (4) are commonly identified. Surgical drains and central venous catheters yielded relatively few isolates. *Enterobacter* spp. (4) and *Klebsiella* spp. (2) were identified in surgical drains, while only a single isolate of *Enterobacter* spp. was recovered from central venous catheters. *Staphylococcus* spp. (2) was detected in lung aspirate samples. Surgical implants had the least, with only one isolate of *Klebsiella* spp. recorded. less frequently isolated organisms, such as *Streptococcus* spp., *Streptococcus anginosus*, *Staphylococcus*

simulans, *Staphylococcus cohnii*, and *Enterococcus faecalis*, each occurring in very low numbers
.

Table 3: The Frequency of Bacteria Isolated from Different Sources in MMSH

Isolates	Source of isolates				
	Ventilator (n=3)	**Urinary Catheter (n=14)**	**Cannula (n=8)**	**Nasogastric tube (n=6)**	**Sink (n=4)**
Enterobacter spp.	2	2	7	0	0
Proteus spp.	1	6	1	0	2
Bacillus spp.	2	4	3	2	0
Streptococcus spp.	0	1	0	0	0
Staphylococcus spp.	0	2	0	1	0
Escherichia coli	1	3	0	3	0
Klebsiella spp.	3	4	6	3	4
Klebsiella pneumoniae	2	0	0	0	0
Enterococcus spp.	0	1	0	0	0

Key: MMSH: Murtala Muhammad Specialist Hospital
($\varkappa^2$): 44.82, p-value: 0.0656

Table 4: The Frequency of Bacteria Isolated from Different Sources In AKTH

Isolates	Source of Isolates					
	Urinary Catheter (n=41)	**Surgical Drain (n=20)**	**Central Venous Catheter (n=3)**	**Lungs Aspirate (n=3)**	**Surgical Implant (n=1)**	**Sink (n=65)**
Enterobacter spp.	8	4	1	0	0	23
Proteus spp.	2	1	0	0	0	20
Bacillus spp.	1	0	0	0	0	13
Streptococcus spp.	0	0	0	0	0	2
Staphylococcus spp.	7	2	0	2	0	4
Klebsiella spp.	3	2	0	0	1	33
Escherichia coli	4	0	0	0	0	7
Klebsiella pneumoniae	1	0	0	0	0	5
Klebsiella oxytoca	0	0	0	0	0	1
Streptococcus anginosus	0	0	0	0	0	1
Staphylococcus simulans	0	0	0	0	0	1
Staphylococcus cohnii	0	0	0	0	0	1
Enterococcus faecalis	1	0	0	0	0	0

Key: AKTH: Aminu Kano Teaching Hospital
($\varkappa^2$): 78.45, p-value: < 0.0001 (Highly Significant)

Table 5: Isolation and Identification of Bacteria from Hospital Sinks and Invasive Devices

Sample ID	Catalase	Coagulase	Oxidase	Indole	MR	VP	Citrate	Urease	TSI	Suspected Organism
Sink37	+	-	-	-	-	+	+	-	A/A	*Bacillus* spp.
Canula20	+	-	-	-	-	+	+	-	A/A	*Enterobacter* spp.
UC42	+	-	-	-	-	-	-	-	A/A	*Enterococcus* spp.
UC37	+	-	-	+	+	-	-	-	A/A+gas	*Escherichia coli*
Sink39	+	-	-	-	-	+	+	+	A/A+gas	*Klebsiella* spp.
Sink62	+	-	-	+	+	-	+	+	K/A	*Proteus* spp.
UC18	+	+/-	-	-	-	-	-	-	A/A	*Staphylococcus* spp.
UC17	-	-	-	-	-	-	-	-	A/A	*Streptococcus* spp.

DISCUSSION

The findings of the Assessment of Sink Hospital Usage Using Questionnaire reveal a stark contrast in sanitation infrastructure between the two facilities. MMSH maintains a uniform but minimal standard of one sink per ward, regardless of the number of beds (which range from 30 to 34). This suggests a potential deficiency in hand-hygiene accessibility, as a single sink for over 30 beds may not meet modern infection control standards. AKTH shows much higher sink counts, though the distribution is more varied. Wards like the MMW (11 sinks) and FMW (13 sinks) provide far better coverage per patient than any ward at MMSH. The statistically significantly higher mean at AKTH (6.50 vs 1.00) suggests that AKTH likely follows a more robust infrastructure plan for sanitation. The low sink-to-bed ratio at MMSH could be a critical point for hospital management to address to reduce the risk of hospital-acquired infections. While AKTH has fewer beds on average in some wards, it prioritizes a higher density of sinks. MMSH appears to have standardized on a "one per ward" model that is significantly lower than its counterpart. The independent t-test confirms a statistically significant difference at $p = 0.004$ using 5% level of significance, in sink provision between the two hospitals, with AKTH providing significantly more sinks per ward than MMSH. The findings of this study are consistent with international infection prevention guidelines, which emphasize the importance of adequate sink availability for effective hand hygiene compliance. In contrast, AKTH demonstrated significantly higher sink provision, suggesting stronger adherence to infection prevention infrastructure standards. The statistically significant difference observed between the two hospitals, therefore, reflects substantial disparities in sanitation infrastructure that may influence infection control outcomes. This agrees with evidence by Dancer (2022), who reported that inadequate environmental cleaning and poor water management significantly increase microbial persistence in hospital sink biofilms. Similarly, studies have shown that intermittent water flow and poor sink design enhance bacterial colonization and EPS production in hospital plumbing systems (Hayward *et al*., 2024).

The findings of the Percentage Prevalence of Bacteria Isolated from Sink and Invasive Devices indicate an extremely strong statistical association between the hospital and the source where bacteria are most frequently isolated. At MMSH, the vast majority of bacteria (60 out of 66 total isolates, or 91**%**) were found on invasive devices. Even though only 4 sink samples were taken, the ratio suggests that at MMSH, devices are the primary site of bacterial colonization compared to sinks. In contrast, at AKTH, the pattern flips. 71.5% (108 out of 151) of the total bacteria were isolated from sinks. Despite having a similar number of invasive device samples as sink samples (68 vs 65), the sinks at AKTH are significantly more "productive" for bacterial growth than the devices. The extremely low p-value (< 0.0001) means this difference is not random. It suggests that the environmental reservoirs of bacteria differ drastically between the two hospitals. At AKTH, the sinks are major reservoirs, likely due to the higher number of sinks and potential biofilm formation. At MMSH,

the risk is heavily concentrated on the invasive devices themselves, which poses a more direct threat to patient bloodstream infections. However, infection control teams at AKTH should focus on sink decontamination and drainage biofilms, while the team at MMSH should prioritize sterile technique and device maintenance protocols. Conclusively, there is a highly significant difference in where bacteria are found between the two hospitals. AKTH's contamination is primarily environmental (sinks), while MMSH's contamination is primarily clinical (devices). This finding is consistent with Cangui-Panchi *et al*. (2022), who reported that invasive medical devices significantly increase the risk of biofilm-associated infections, with up to 100% of catheter-related isolates exhibiting biofilm-forming capacity. Similarly, environmental sinks have been identified as reservoirs of multidrug-resistant organisms capable of transmission to patients (Laço *et al.*, 2025). The high number of sinks at AKTH (which we found in the first test) correlates with a high bacterial load. These sinks are acting as major environmental reservoirs. AKTH needs to implement aggressive biofilm control and stricter sink disinfection protocols to prevent these bacteria from jumping from the drain to the patient. Although MMSH has fewer bacteria in its sinks, the isolation rate on invasive devices is alarmingly high (40% in some wards). Since devices (catheters, IVs, etc.) have a direct path into the patient's body, the risk of Sepsis or Healthcare-Associated Infections (HAIs) is more immediate here. Having more sinks (as seen in AKTH) is better for hand hygiene compliance, but without maintenance, they become the number 1 source of ward contamination. Having fewer sinks (as seen in MMSH) might lead to poor hand hygiene, which likely explains why their invasive devices are so highly contaminated. AKTH needs to clean its sinks, while MMSH needs to provide more sinks to improve hand hygiene and protect its devices.

The findings of Bacteria Isolated from Different Sources in MMSH indicate that while there are visible patterns in the data, the association between the bacterial species and their source is not statistically significant at the standard $\alpha = 0.05$ level ($p > 0.05$). A p-value of 0.0656 is considered statistically not significant. This suggests a strong trend where certain bacteria prefer specific environments, but the sample size (total n = 66 isolates) might be too small to reach full statistical certainty. *Klebsiella* spp. is the most widespread biofilm producer, appearing in all five sources. Its presence in Sinks (n = 4) and Canulas (n = 6) suggests it is a highly adaptable pathogen that can survive both environmental and clinical conditions. *Enterobacter* spp. shows a high affinity for Canulas (n = 7), potentially indicating a specific risk during intravenous procedures. *Proteus* spp. is most frequent in Urinary Catheters (n = 6), which is consistent with its known role in catheter-associated urinary tract infections (CAUTIs) due to urease production and biofilm formation. Even though the test didn't meet the 0.05 threshold, the raw counts show that Urinary Catheters (n = 24 total isolates) and Canulas (n = 17) are the primary reservoirs for biofilm-producing bacteria at MMSH. These areas require the strictest adherence to aseptic protocols. The distribution of biofilm-producing bacteria is nearly significant ($p = 0.066$), indicating that while most pathogens are widespread, certain species like *Proteus* and *Enterobacter* show strong preferences for specific devices (catheters and canulas, respectively)**.** This observation agrees with studies describing *Klebsiella* species as highly adaptable biofilm-forming pathogens capable of colonizing both environmental reservoirs and invasive medical devices (Vuotto *et al*., 2017). *Proteus spp.* was predominantly isolated from urinary catheters, which is consistent with its established role in catheter-associated urinary tract infections due to urease production and crystalline biofilm formation. Likewise, *Enterobacter spp.* demonstrated a high frequency on canulas, supporting previous reports that intravenous devices provide favorable surfaces for biofilm development by opportunistic Gram-negative bacteria. Although the association was not statistically significant, urinary catheters and canulas accounted for the highest number of biofilm-producing bacterial isolates, indicating that these devices remain critical reservoirs for healthcare-associated infections and should therefore receive priority attention in infection prevention and aseptic management protocols.

The statistical analysis for Bacteria Isolated from Different Sources in AKTH shows a clear and dangerous pattern and the Sinks are the undisputed "hotspots" for biofilm-producing bacteria. With 111 total isolates coming from sinks compared to only 40 from all other medical devices combined, the hospital environment is as much a threat as the equipment itself. *Klebsiella* spp. and *Enterobacter* spp. are heavily concentrated in the sinks. These are typically water-associated or enteric bacteria that form stubborn biofilms in drains. *Staphylococcus* spp. remains a major player in Urinary Catheters and Surgical Drains, suggesting that while the sinks are contaminated, the bacteria on the devices may be coming from the patient's own skin flora during insertion. Species like *S. anginosus*, *S. simulans*, and *S. cohnii* were only found in the sinks. This suggests the sinks are hosting unique bacterial communities that have not yet "jumped" to the patients, providing a window for preventive disinfection. At AKTH, there is a highly significant ($p < 0.0001$) association between the source and the type of bacteria. The sinks are serving as a massive reservoir for Gram-negative biofilm producers (*Klebsiella* and *Enterobacter*), representing a major environmental risk for cross-contamination. The predominance of *Klebsiella spp.* and *Enterobacter spp.* in sink isolates is consistent with previous studies describing hospital drainage systems as important ecological niches for Gram-negative biofilm-forming organisms (Kotay *et al*., 2019; Hopman *et al*., 2022). These findings highlight the urgent need for aggressive sink decontamination, drainage biofilm control, and strengthened environmental infection prevention strategies within the hospital setting.

CONCLUSION

The study demonstrated substantial differences in hospital sink availability, water supply and cleaning practices between MMSH and AKTH. MMSH had a bed-to-sink ratio of 30:1–34:1, compared with 3:1–6:1 at AKTH, indicating considerably poorer sink availability at MMSH. Water supply was irregular in all four assessed MMSH wards, while at AKTH it was scarce in six wards, irregular in three and regular only in the ICU.

A total of 69 sink samples and 99 invasive-device samples were examined. The study recovered 114 bacterial isolates from sinks and 103 from invasive devices. AKTH sinks yielded the highest number of isolates, with 108 isolates from 65 samples, while MMSH sinks yielded 6 isolates from 4 samples. In contrast, invasive-device samples yielded 60 isolates from 31 samples at MMSH and 43 isolates from 68 samples at AKTH.

The distribution of isolates according to hospital and sampling source was statistically significant ($\chi^2 = 69.31$, $p < 0.0001$). At AKTH, Klebsiella spp. (33), Enterobacter spp. (23) and Proteus spp. (20) were the predominant bacterial isolates from sinks, collectively accounting for 70.4% of the 108 sink isolates.

The findings indicate that both hospital sinks and invasive devices can harbour potentially important bacterial organisms and should therefore receive greater attention in infection prevention and control programmes. Improving sink availability, ensuring reliable water supply, strengthening cleaning practices, maintaining environmental hygiene and implementing appropriate invasive-device management are recommended to reduce bacterial contamination and the potential risk of healthcare-associated infections.

However, because the study did not establish genetic relationships between environmental and clinical isolates, the findings should be interpreted as evidence of bacterial contamination and potential environmental reservoirs rather than definitive evidence of transmission from sinks to patients.

Recommendations

1. Ensure continuous and reliable water supply in all hospital wards, particularly areas caring for vulnerable patients.
2. Strengthen sink cleaning and environmental decontamination procedures, with particular attention to sink drains, overflow areas and plumbing components.
3. Strengthen infection prevention practices for invasive devices, including aseptic insertion, appropriate maintenance and prompt removal when devices are no longer required.
4. Conduct molecular studies of selected sink and clinical isolates in future investigations to determine genetic

relatedness and establish whether environmental organisms are epidemiologically linked to patient infections.

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