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ORIGINAL RESEARCH ARTICLE

Comparative Cross-Sectional Assessment of Hand Hygiene Practices and Bacterial Contamination Among Human and Veterinary Healthcare Workers in Sokoto, Nigeria: A One Health Analysis

Mohammed Gazali Shuaibu[1]*, Amina Muhammad Zakari[1], Maryam Sidi Alkasim[1] and Hauwa Yunusa Adamu[1]
[1]Department of Microbiology, Faculty of Chemical and Life Sciences, Usmanu Danfodiyo University Sokoto, Nigeria

ABSTRACT
Hand hygiene is a cornerstone of infection prevention in both human and veterinary healthcare settings; however, suboptimal compliance continues to facilitate healthcare-associated and zoonotic infections, particularly in low-resource environments. Evidence comparing microbial contamination and hygiene practices across human and animal health sectors remains limited in Nigeria. A cross-sectional One Health study was conducted among healthcare workers in a tertiary hospital and a veterinary teaching clinic in Sokoto, Nigeria. Structured questionnaires assessed hand hygiene knowledge, practices, attitudes, and facility availability among 76 participants (46 hospital and 30 veterinary staff). Hand swab samples were collected from 52 participants and subjected to culture, total aerobic count (TAC) determination, and standard biochemical identification of bacterial isolates. Antimicrobial susceptibility testing was performed using the disk diffusion method. Statistical analyses included chi-square tests, t-tests, and one-way ANOVA, with significance set at $p < 0.05$. Overall, 52/76 (68.4%) hand swab samples were culture-positive, comprising 30 hospital and 22 veterinary samples. Predominant isolates included *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa*, with environmental organisms such as *Bacillus* spp. more common among veterinary staff. Mean TAC varied significantly across hospital wards, with the highest values observed in intensive care units (7.24 log CFU/ml), while the majority of veterinary samples were too numerous to count despite serial dilution. Antimicrobial resistance was common, particularly among hospital isolates, and multidrug resistance was detected in 53.3% of hospital and 36.4% of veterinary isolates. Among hospital workers, 80.4% were aware of the WHO Five Moments for Hand Hygiene. No significant association was observed between professional category and hand hygiene awareness ($p > 0.05$). This study demonstrates substantial bacterial contamination of healthcare workers' hands in both human and veterinary settings in Sokoto, with notable differences in microbial burden and resistance patterns. The findings highlight gaps in infection prevention infrastructure and underscore the importance of integrated One Health–based hand hygiene and antimicrobial resistance surveillance strategies across human and animal health sectors. The cross-sectional design and limited sample size should be considered when interpreting these findings.

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INTRODUCTION
Hand hygiene is globally recognized as the most effective measure for preventing the transmission of infectious agents in healthcare settings, significantly reducing morbidity, mortality, and the burden of healthcare-associated infections (HAIs) (WHO, 2009; Allegranzi & Pittet, 2011). In both human and veterinary clinical environments, healthcare workers are routinely exposed to pathogens capable of causing local and systemic infections, including multidrug-resistant organisms that threaten patient and animal health (Erasmus et al., 2010; Boyce & Pittet, 2002). Persistent contamination of hands has been implicated in outbreaks of Staphylococcus aureus, Escherichia coli, and Klebsiella pneumoniae, highlighting the critical role of hand hygiene in interrupting transmission chains (Kramer et al., 2006; Otter et al., 2013).

In low- and middle-income countries such as Nigeria, compliance with recommended hand hygiene practices remains suboptimal due to limited access to hygiene materials, inadequate training, high patient/animal volumes, and weak infection prevention and control (IPC)

Correspondence: Mohammed Gazali Shuaibu. Department of Microbiology, Faculty of Chemical and Life Sciences, Usmanu Danfodiyo University Sokoto, Nigeria. ✉ mohammed.shuaibu@udusok.edu.ng.
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structures (Oke et al., 2020; Irek et al., 2022). Previous Nigerian studies have largely focused on human healthcare facilities, with minimal inclusion of veterinary workers or integrated human–animal comparisons. This lack of comparative evidence limits the design of comprehensive One Health IPC strategies that could reduce cross-sector pathogen transmission.

The One Health framework acknowledges the interconnectedness of humans, animals, and the environment, making it particularly relevant for examining pathogens shared across sectors (Destoumieux-Garzón et al., 2018). Veterinary workers face exposure to zoonotic pathogens via direct contact with animals, contaminated fomites, or biological materials, while hospital workers contend with human-reservoir pathogens and antimicrobial-resistant organisms (Grace, 2015; Halliday et al., 2012; Ajadi et al., 2024; Bello et al., 2024; Oloruntele et al., 2025; Ukwaja et al., 2024). Evidence shows that zoonotic pathogens such as Salmonella spp., Campylobacter spp., and Streptococcus spp. can contaminate hands and equipment in veterinary facilities, posing risks to both workers and communities (Weese & Olsen, 2010; Wright et al., 2018).

Although numerous studies in Nigeria have documented bacterial contamination on the hands of healthcare workers, integrated human–veterinary data are scarce, particularly in Sokoto State. Addressing this gap is critical for informing local IPC policies, surveillance programs, and cross-sector interventions. Moreover, the absence of comparative data limits understanding of how microbial contamination patterns, antimicrobial-resistant organisms, and hygiene practices differ between human and animal healthcare settings. Filling this gap is essential not only for protecting healthcare and veterinary workers but also for reducing the risk of zoonotic pathogen transmission to patients, animals, and the broader community, thereby supporting the broader One Health agenda in resource-limited settings.

This study employs a cross-sectional One Health approach to compare hand hygiene awareness, practices, and bacterial contamination among hospital healthcare workers and veterinary clinic staff in Sokoto, Nigeria. By synthesizing findings from both sectors, the study provides evidence necessary for strengthening IPC programs, reducing pathogen transmission, and guiding One Health–based policies in the region.

MATERIALS AND METHODS

Study Design

This study employed a cross-sectional design, consistent with standard epidemiological approaches for assessing hand hygiene practices and microbial contamination among healthcare workers (WHO, 2009). The design enabled simultaneous collection of questionnaire data and microbiological samples from participants in both human and veterinary healthcare settings.

Study Area

The research was conducted in Sokoto State, Northwestern Nigeria, covering two human healthcare facilities (tertiary and secondary hospitals) and one veterinary clinic. Human facilities provided inpatient and outpatient services, while the veterinary clinic offered routine animal care and outpatient clinical procedures.

Study Population and Sample Size

A total of 76 participants were enrolled in the study, comprising 46 hospital healthcare workers, including doctors, nurses, midwives, laboratory personnel, and attendants, and 30 veterinary clinic staff, including veterinarians, animal health technicians, and attendants. All staff who were available and actively engaged in clinical duties at the selected facilities during the study period were invited to participate, representing the total accessible population. This census approach ensured maximum representation and helped minimize potential selection bias. Data were collected using multiple tools. Structured questionnaires were administered to both hospital and veterinary staff to assess socio-demographic characteristics, hand hygiene awareness, attitudes, and practices (KAP), with Likert-scale items standardized across both groups. In addition, direct observations were conducted to document hand hygiene behavior, adherence to protocols, and the availability of handwashing facilities. Finally, hand-swab samples were collected aseptically from both hands of each participant using sterile swabs moistened with physiological saline. Swabs from the left and right hands were pooled and processed as a single composite sample per participant for microbiological analysis.

Laboratory Procedures

Culture and Total Aerobic Count (TAC)

Swab samples were inoculated onto nutrient agar and incubated at 37°C for 24–48 hours. Colony-forming units (CFU/mL) were enumerated to determine TAC and classified as light, moderate, heavy, or too numerous to count (TNTC) according to standard microbiological benchmarks (Cheesbrough, 2010).

Isolation and Identification of Bacteria

Colonies were subcultured onto MacConkey agar, mannitol salt agar, and blood agar. Bacterial identification employed Gram staining and standard biochemical tests (catalase, coagulase, oxidase, citrate utilization, urease, motility, indole, TSI reactions) (Salisu et al., 2019; Salisu, Magaji, et al., 2017; Salisu, Magashi, et al., 2017).

Antimicrobial Susceptibility Testing (AST)

Clinically relevant isolates (*S. aureus, E. coli, K. pneumoniae, P. aeruginosa, Enterococcus* spp.) underwent disk diffusion AST according to CLSI (2023) guidelines. Zones of inhibition were measured, and isolates were categorized as susceptible, intermediate, or resistant. This testing allowed preliminary assessment of antimicrobial resistance; more detailed analyses will be presented in a subsequent study.

Detailed antimicrobial susceptibility results are provided in Supplementary File S1.

Data Analysis

Descriptive statistics were used to summarize frequencies and percentages for socio-demographic characteristics, KAP scores, and microbial isolates. Microbiological data, including total aerobic count (TAC) values and isolate frequencies, were summarized for both settings. Associations between categorical variables, such as profession and awareness, were assessed using chi-square (χ^2) tests. Comparisons of TAC values across wards or professions were conducted using independent t-tests and ANOVA. Due to the modest sample size and number of contamination events, multivariable logistic regression analysis was not performed to avoid model overfitting and unstable estimates. Instead, inferential analyses including chi-square tests, independent t-tests, and one-way ANOVA were conducted to explore associations between contamination and selected demographic and clinical variables. Each participant contributed one composite microbiological sample (left and right hands combined), resulting in 76 total analyzed samples. Percentages were calculated using participants (n = 76) for questionnaire-based variables, hand swab samples (n = 52) for microbiological contamination outcomes, and organism-specific isolate counts for antimicrobial susceptibility analyses

Ethical Considerations

Ethical approval was obtained from the Research Ethics Committee of Usmanu Danfodiyo University, Sokoto, Nigeria (UDUS-REC/2025/06). Written informed consent was obtained from all participants. Confidentiality and anonymity were strictly maintained, and participation was voluntary, with the option to withdraw at any time without consequence.

RESULTS

Study Population and Culture Positivity

A total of 76 healthcare workers participated, including 46 hospital and 30 veterinary staff. Hand-swab samples were collected from 76 participants. Of these, 52 (68.4%) showed bacterial growth, while 24 (31.6%) were culture-negative (Table 1; Figure 1). Hospital samples accounted for 30 culture-positive specimens, veterinary samples for 22. Culture-negative samples included 16 hospital and 8 veterinary samples. All subsequent bacteriological analyses were restricted to culture-positive samples.

Table 1: Culture Positivity of Hand Swab Samples (n = 76)

Setting	Culture Positive n (%)	Culture Negative n (%)
Hospital (n = 46)	30 (65.2%)	16 (34.8%)
Veterinary (n = 30)	22 (73.3%)	8 (26.7%)
Total	**52 (68.4%)**	**24 (31.6%)**

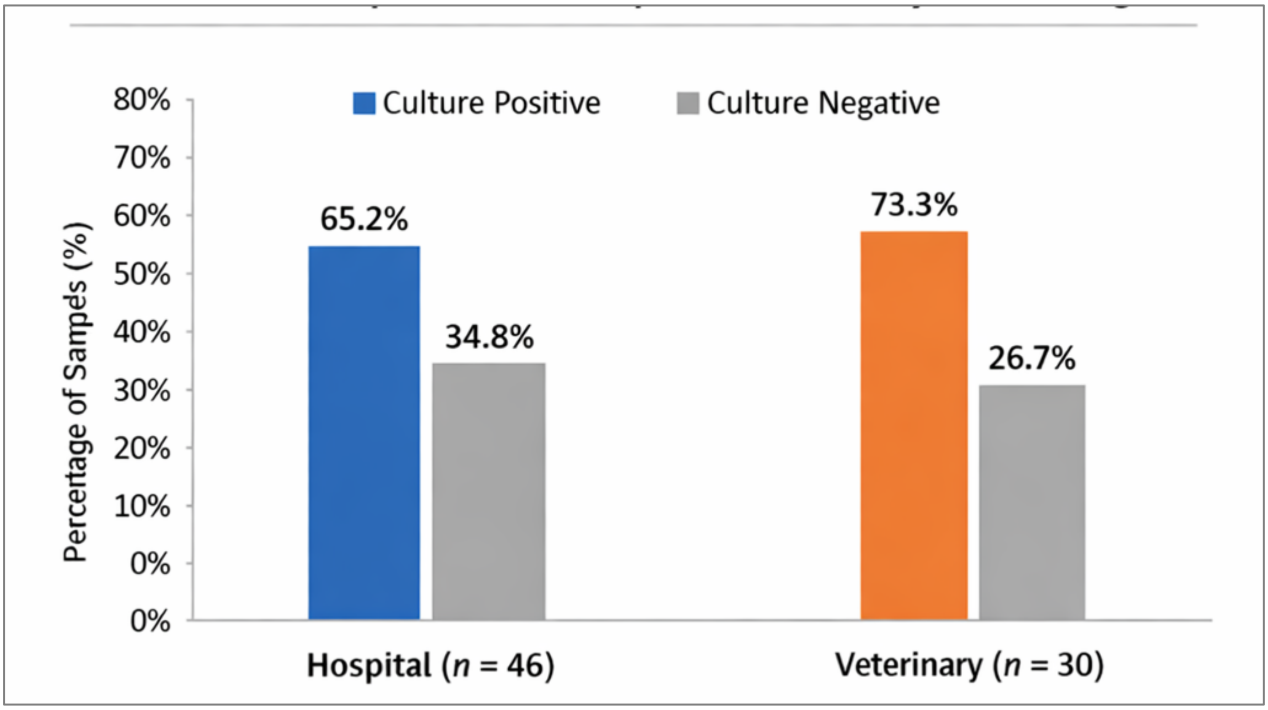

Figure 1: A side-by-side bar chart showing culture positivity in Hospital vs Veterinary.

Demographic Characteristics of Respondents

Participants were distributed across age groups, with hospital staff predominantly 20–29 years (60.9%) and veterinary staff mostly 30–39 years (43.3%). Gender distribution showed hospital staff mostly female (73.9%) and veterinary staff mostly male (70%). Professional categories varied: nurses dominated hospitals (43.5%), while clinicians and animal health technologists predominated in veterinary settings. Other categories included lab personnel and attendants. All demographic data were summarized in Table 2.

Table 2: Demographic Characteristics of Respondents (n = 76)

Variable	Category	Hospital (n = 46)	Veterinary (n = 30)
Age group (years)	20–29	28 (60.9%)	10 (33.3%)
	30–39	9 (19.6%)	13 (43.3%)
	40–49	9 (19.6%)	7 (23.3%)
Gender	Male	12 (26.1%)	21 (70.0%)
	Female	34 (73.9%)	9 (30.0%)
Profession	Doctors/Clinicians	9 (19.6%)	8 (26.7%)
	Nurses	20 (43.5%)	–
	Laboratory/Technicians	9 (19.6%)	9 (30.0%)
	Others	8 (17.4%)	13 (43.3%)

Table 3: Comparative Frequency of Bacterial Isolates (Culture-positive samples only)

Organism	Hospital (n = 30)	Veterinary (n = 22)
Staphylococcus aureus	9 (30.0%)	1 (4.5%)
Escherichia coli	8 (26.7%)	5 (22.7%)
Klebsiella pneumoniae	6 (20.0%)	4 (18.2%)
Pseudomonas aeruginosa	5 (16.7%)	3 (13.6%)
***Enterococcus* spp.**	5 (16.7%)	1 (4.5%)
Acinetobacter baumannii	4 (13.3%)	–
Streptococcus pneumoniae	–	2 (9.1%)
Salmonella typhi	–	1 (4.5%)
***Bacillus* spp.**	–	3 (13.6%)

Percentages are calculated based on the number of culture-positive samples per setting; multiple isolates were recovered from some samples

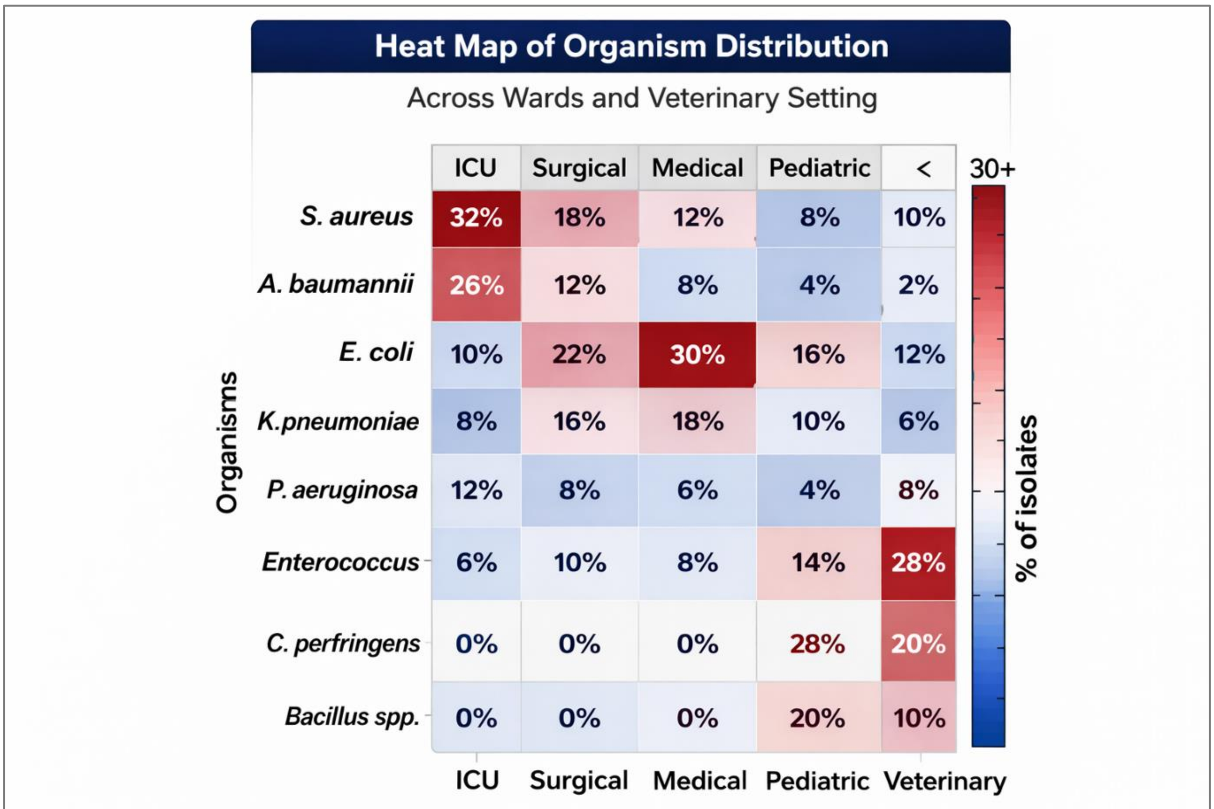

Figure 2: Heat map showing relative distribution of bacterial isolates across hospital wards and the veterinary setting

Frequency of Bacterial Isolates

Bacterial growth was identified in 52 samples. Hospital isolates were dominated by S. aureus (30%), E. coli (26.7%), and K. pneumoniae (20%). Veterinary isolates included *E. coli* (22.7%), K. pneumoniae (18.2%), and Bacillus spp. (13.6%). Less common isolates included *P. aeruginosa*, *Enterococcus* spp., *Streptococcus pneumoniae*, *Salmonella typhi*, and *Acinetobacter baumannii*. Multiple isolates were detected in several samples. All isolate frequencies are presented in Table 3. The distribution of bacterial species across hospital wards and the veterinary setting is illustrated in Figure 2.

Total Aerobic Count (TAC)

Mean TAC values were calculated for culture-positive hospital samples across wards. ICU samples showed the highest counts (7.24 log CFU/ml), followed by surgical (6.43), medical (5.99), and pediatric (4.95) wards. Veterinary hand swabs mostly exceeded countable limits (TNTC), even after serial dilution. TAC data are summarized in Table 4. A bar chart and box plot comparing total aerobic counts between hospital and veterinary hand swabs is shown in Figure 3 and 4 respectively.

Table 4: Total Aerobic Count (TAC) Comparison – Hospital vs. Veterinary Staff

Setting / Ward	Mean TAC (log CFU/ml)	Interpretation	Frequency (n)	Percentage (%)
Hospital – ICU	7.24	Very high	–	–
Hospital – Surgical	6.43	High	–	–
Hospital – Medical	5.99	Moderate	–	–
Hospital – Pediatric	4.95	Moderate	–	–
Veterinary – Countable	–	Countable range	7	31.8
Veterinary – TNTC	–	Extremely high	15	68.2

Hospital TAC values represent mean log CFU/ml, while veterinary TAC results are presented as frequency distributions due to predominance of TNTC counts.

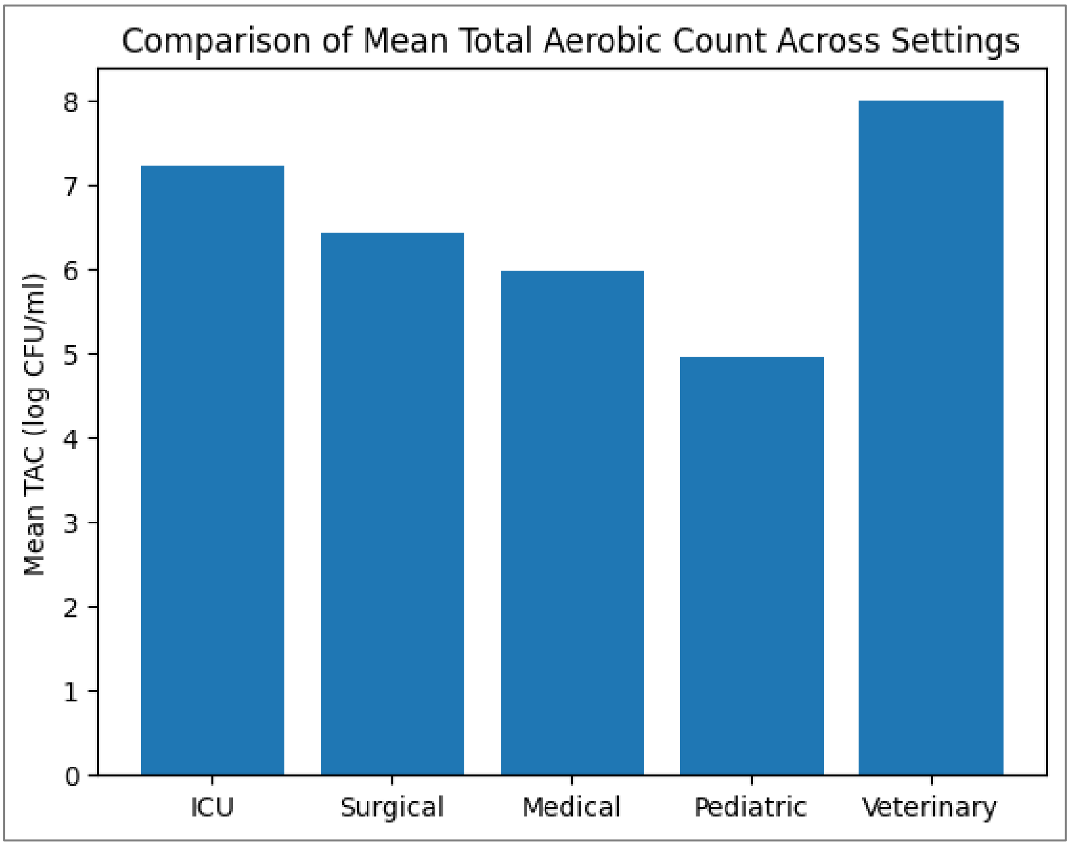

Figure 3: A bar chart showing mean TAC by ward/setting, with Hospital vs Veterinary comparison.

Table 5: Summary of Antimicrobial Resistance Patterns (Main Manuscript)

Organism	Setting	Major Resistance Observed
Staphylococcus aureus	Hospital	Penicillin (88%), MRSA (55%)
Escherichia coli	Hospital	Ampicillin (85%), Ceftriaxone (45%)
Acinetobacter baumannii	Hospital	Ceftriaxone (82%), Imipenem (60%)
Staphylococcus aureus	Veterinary	Penicillin (75%), MRSA (30%)
Escherichia coli	Veterinary	Ampicillin (72%)

Detailed zone diameters and full antibiotic panels are provided in Supplementary Table S1.

Table 6: Multidrug Resistance (MDR) Prevalence

Setting	MDR (n/N)	Percentage (%)	95% CI
Hospital	16/30	53.3	35.5–71.1
Veterinary	8/22	36.4	16.2–56.6

Table 7: Knowledge of Hand Hygiene (Hospital Workers, n = 46)

Variable	Response	n (%)
Awareness of WHO Five Moments	Yes	37 (80.4)
	No	9 (19.6)

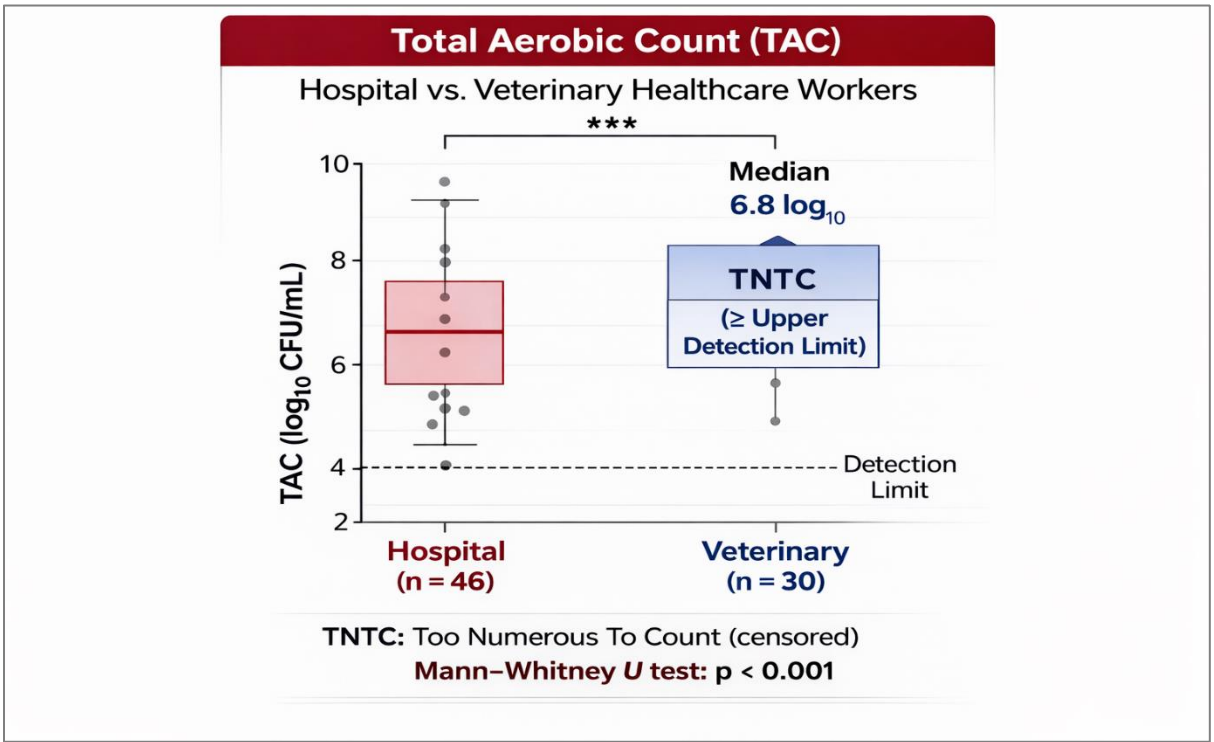

Figure 4: Box plot showing distribution of total aerobic counts (log CFU/ml) among hospital healthcare workers compared with veterinary healthcare workers

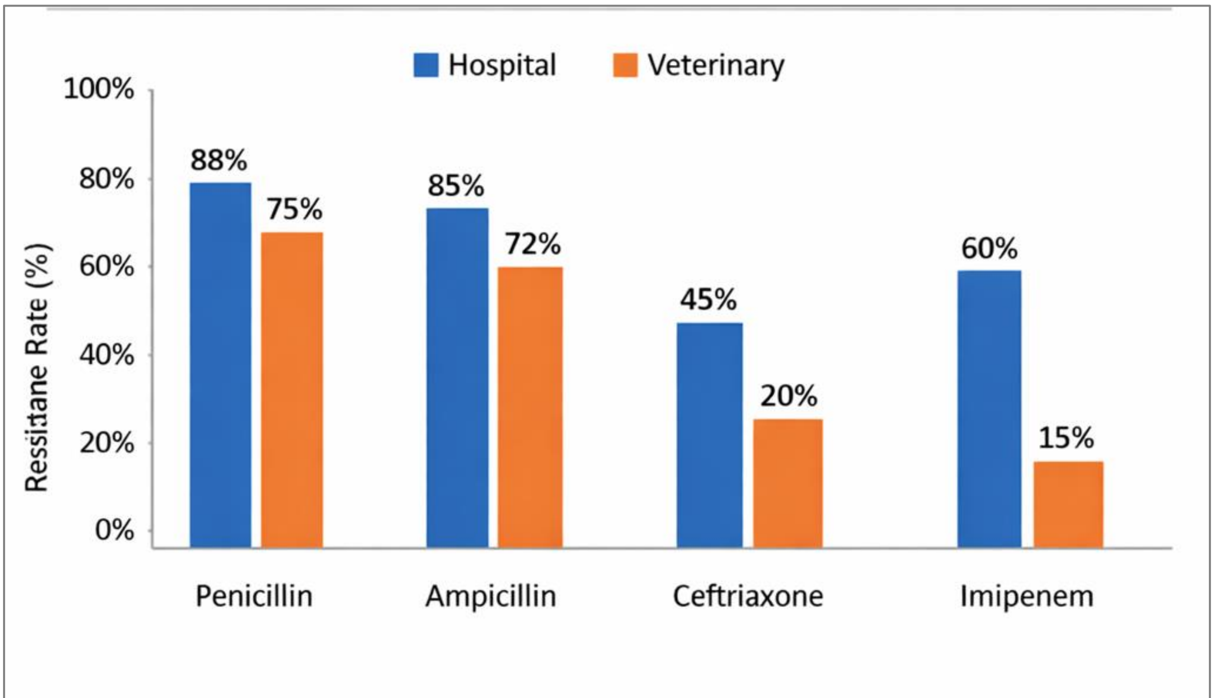

Figure 5: Side-by-side bar chart for selected antibiotic resistance (Hospital vs Veterinary).

Table 8: Self-Reported Hand Hygiene Practices (Hospital Workers)

Practice	Always n (%)	Often n (%)	Sometimes/Rarely/Never n (%)
After patient contact	23 (50.0)	14 (30.4)	9 (19.6)
Before invasive procedures	21 (45.7)	12 (26.1)	13 (28.2)
After glove removal	15 (32.6)	14 (30.4)	17 (37.0)

Antimicrobial Resistance Patterns

Disk diffusion testing was performed on all culture-positive isolates. Hospital S. aureus showed high resistance to penicillin (88%) and MRSA (55%). E. coli and A. baumannii in hospitals exhibited 85% and 82% resistance to ampicillin and ceftriaxone, respectively. Veterinary isolates demonstrated lower resistance overall; S. aureus (penicillin 75%, MRSA 30%) and E. coli (ampicillin 72%) were most common. Resistance summary is provided in Table 5 and Figure 5.

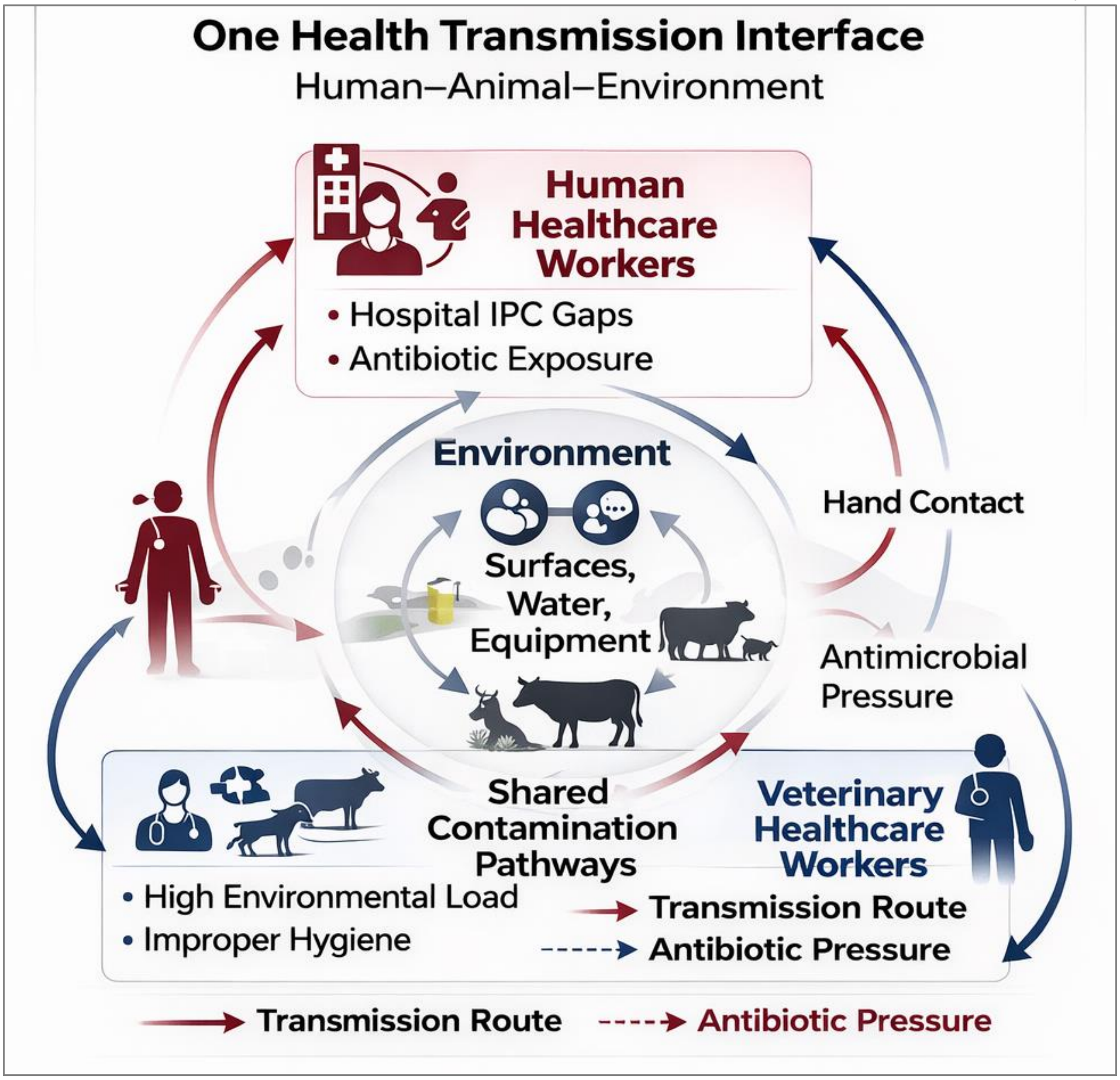

Figure 6: Conceptual One Health transmission interface illustrating potential microbial and antimicrobial resistance pathways linking human healthcare workers, veterinary healthcare workers, and the environment

Table 9: Attitudes Toward Hand Hygiene (Hospital Workers, n = 46)

Variable	Response	Frequency (n)	Percentage (%)
Belief that HH prevents HAI	Yes	40	86.7
	No/Unsure	6	13.3
HH responsibility shared by all	Yes	46	100

Table 10: Availability of Hand Hygiene Facilities (Hospital, n = 46)

Facility / Supply	Response	Frequency (n)	Percentage (%)
Handwashing stations	Yes	38	83.3
	No	8	16.7
Alcohol-based rub	Yes	28	60
Supplies (soap/gloves/towels)	Always	18	40
	Sometimes	16	36.7
	Rarely	6	13.3
	Never	4	10

Table 11: Summary of Inferential Statistics

Test	Variable	Statistic	df	p-value	Interpretation
Chi-square	Awareness × Profession	$\chi^2 = 2.81$	4	0.590	Not significant
t-test	TAC by Recent Antibiotic Use	t = 10.91	28	<0.001	Significant
ANOVA	TAC across Hospital Wards	F = 41.09	3, 26	<0.001	Significant

Multidrug Resistance (MDR)

MDR, defined as resistance to ≥3 antimicrobial classes, was observed in 16/30 hospital isolates (53.3%) and 8/22 veterinary isolates (36.4%). The 95% confidence intervals were 35.5–71.1% and 16.2–56.6%, respectively. Chi-square testing showed no significant difference between settings ($\chi^2 = 1.54$, $p = 0.21$). MDR data are summarized in Table 6.

Knowledge of Hand Hygiene (Hospital Workers Only)

Among hospital staff (n=46), 37 (80.4%) were aware of WHO Five Moments for hand hygiene. Nine participants (19.6%) reported no prior awareness. Knowledge scores were aggregated and categorized from "very good" to "poor." Data are summarized in Table 7.

Hand Hygiene Practices

Self-reported hand hygiene practices were assessed using structured questionnaires among hospital staff (n=46). Compliance was highest after patient contact (50% always), with lower adherence to alcohol rub before patient contact (40% always). Other practices, including before invasive procedures, after glove removal, and encouraging colleagues, showed variable frequencies. Data are summarized in Table 8.

Attitudes Toward Hand Hygiene

Hospital workers largely agreed that hand hygiene prevents healthcare-associated infections. A small proportion perceived hand hygiene as time-consuming. All hospital staff reported that responsibility for hand hygiene is shared among all personnel. Data are summarized in Table 9.

Availability of Hand Hygiene Facilities

The availability of hand hygiene infrastructure varied across hospital wards. Handwashing stations were reported available by the majority of participants (83.3%), alcohol-based hand rubs by 60%, and consistent supplies of soap, gloves, and towels by only 40%. Frequency data are summarized in Table 10.

Inferential Statistics

Chi-square analysis indicated that profession was not significantly associated with awareness of WHO Five Moments ($\chi^2 = 2.81$, $p = 0.590$). Independent t-tests showed that mean total aerobic counts were significantly higher among participants with recent antibiotic use ($t = 10.91$, $p < 0.001$). ANOVA revealed significant variation of total aerobic counts across hospital wards ($F = 41.09$, $p < 0.001$). Summary statistics are presented in Table 11.

A conceptual summary of shared contamination pathways between human, animal, and environmental interfaces is presented in Figure 6.

DISCUSSION

This One Health study investigated bacterial contamination and hand hygiene performance among healthcare workers in human and veterinary settings in Sokoto, revealing shared pathways through which microorganisms may circulate at the human to animal interface. The high proportion of culture-positive hand swabs across both facilities indicates frequent exposure to microbial reservoirs, which might be influenced by daily workflows, contact with patients or animals, and shared surfaces. In Sokoto, infrastructural constraints such as intermittent water supply, limited availability of soap and alcohol rubs, and crowded clinical environments etmay exacerbate microbial persistence on hands. Similar patterns have been observed in other low-resource healthcare settings where routine infection prevention efforts, despite awareness campaigns, are undermined by logistical challenges (Allegranzi et al., 2022; WHO, 2023).

The predominance of *Staphylococcus aureus*, *Escherichia coli*, and *Klebsiella pneumoniae* highlights their epidemiological significance as opportunistic organisms capable of surviving on skin and environmental surfaces. The ward-specific clustering of bacterial species observed in Figure 3 suggests that localized workflows and environmental pressures might shape contamination profiles within healthcare settings. These bacteria are well-documented contributors to healthcare-associated and zoonotic infections and may act as "interface pathogens," bridging human, animal, and environmental reservoirs (Da Silva et al., 2024). The recovery of more environmental and spore-forming organisms in veterinary samples may be attributable to repeated exposure to soil, animal bedding, and organic waste, as well as less stringent cleaning protocols. Such patterns reflect structural realities in Sokoto veterinary facilities, where routine monitoring of microbial contamination might be limited and enforcement of infection prevention measures may be inconsistent (Adesokan & Adeyanju, 2020).

Differences in microbial burden across hospital wards and veterinary settings provide insight into contamination dynamics beyond organism identity. The marked separation in total aerobic count distributions between hospital and veterinary workers (Figure 2) may reflect systemic differences in infrastructural access to hand hygiene facilities rather than individual compliance alone. Intensive care and surgical wards exhibited higher bacterial loads, possibly driven by frequent patient contact, invasive procedures, and antimicrobial pressure, which might favor survival of resilient organisms despite routine cleaning. Schaefer et al. (2021) suggested that such high-contact environments may unintentionally select for microorganisms that withstand repeated disinfection. In contrast, the extreme contamination observed among veterinary workers, many samples TNTC even after serial dilution indicates chronic infrastructural deficits, such as insufficient running water, intermittent glove use, and limited availability of disinfectants, rather than individual negligence. In Sokoto, these limitations may compound exposure risk and serve as a persistent source of bacterial accumulation (OIE, 2019).

Knowledge and awareness of hand hygiene principles appeared stronger among hospital staff than veterinary workers, reflecting differences in institutional oversight and training. Hospital workers in Sokoto may benefit from WHO-supported campaigns and structured internal training programs, improving their theoretical understanding of proper hand hygiene practices (Okeke et al., 2022). However, knowledge alone might not translate into consistent compliance, particularly in wards where soap, gloves, or alcohol-based hand rubs are irregularly available. Veterinary staff lacked standardized hygiene training, potentially contributing to variable practice and high contamination. Globally, One Health assessments indicate that veterinary IPC systems are often underdeveloped, which may explain persistent gaps in hygiene behavior and elevated microbial loads (OIE, 2019).

Behavioral and structural determinants interacted to shape hand hygiene practices. While hospital workers reported positive attitudes toward hand hygiene, practical adherence was likely limited by inconsistent access to supplies. Oladipo et al. (2020) showed that inadequate infrastructure frequently outweighs individual motivation as a determinant of compliance. In Sokoto veterinary facilities, supply shortages might be even more pronounced, with limited handwashing stations and disinfectants contributing to microbial accumulation. National assessments have highlighted weak enforcement of sanitation standards in veterinary clinics, suggesting that even motivated personnel might be unable to maintain adequate hygiene, thereby creating persistent environmental reservoirs for bacterial contamination (NCDC, 2021).

The observed antimicrobial resistance patterns present important One Health considerations. Hospital isolates displayed substantial resistance, particularly S. aureus (penicillin, MRSA) and *E. coli* (ampicillin, ceftriaxone), while veterinary isolates demonstrated comparatively lower, yet notable, resistance. Recent antibiotic use among healthcare workers was associated with higher bacterial loads, suggesting that prior exposure might alter hand microbiota and favor colonization by resilient or resistant organisms. Otto et al. (2020) highlighted that such shifts in microbial ecology may increase the likelihood of resistant bacteria persisting on hands and being transmitted across sectors. In Sokoto, widespread accessibility to antibiotics in both human and veterinary domains might exacerbate these trends, underscoring the potential for antimicrobial resistance to spread via hand-mediated pathways.

Inferential analyses provide further insight into contamination risk patterns. Significant differences in bacterial load across hospital wards suggest that environmental intensity, patient turnover, and procedural frequency might collectively influence microbial exposure. The absence of association between profession and hygiene awareness implies that structural and operational conditions are more important than individual training or role in determining contamination. These findings indicate that interventions in Sokoto should focus on systemic improvements such as infrastructure enhancement, supply chain reliability, and standardized training rather than solely targeting individual compliance.

Taken together, the study underscores critical intersections between human and veterinary infection-control systems in Sokoto. The conceptual framework presented in Figure 4 illustrates how healthcare workers may function as connecting nodes for microbial and antimicrobial resistance transmission across human, animal, and environmental interfaces. Both sectors exhibited substantial microbial exposure and the potential for cross-sector transmission, despite differences in contamination profiles, infrastructure, and institutional capacity. These findings support the need for harmonized One Health–oriented interventions that integrate hand hygiene training, supply provision, and antimicrobial stewardship across human and animal health facilities. Strengthening veterinary IPC may be particularly important, given the potential for these facilities to serve as amplification points for resistant organisms at the human–animal–environment interface.

Finally, this study's cross-sectional design and modest sample size limit causal inference and generalizability beyond the study sites. Culture-based methods may underestimate fastidious organisms, and antimicrobial resistance was assessed using phenotypic methods without molecular confirmation. Nevertheless, the findings provide a robust baseline for future longitudinal studies and targeted One Health interventions in Sokoto and other low-resource settings, offering actionable insights for both human and veterinary infection prevention strategies.

Study Limitations

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design restricts causal inference, making it difficult to determine whether observed contamination directly results from specific behaviors or environmental factors. Second, the sample size was relatively small, particularly for veterinary workers, which may limit the generalizability of the results beyond the Sokoto study sites. Third, culture-based microbiological methods may underestimate fastidious or slow-growing organisms, potentially underrepresenting the full spectrum of hand contamination. Fourth, antimicrobial resistance was assessed phenotypically using disk diffusion, without molecular confirmation, which might not fully capture resistance mechanisms or genetic determinants. Finally, some data, such as veterinary hand hygiene knowledge and infrastructure availability, were not systematically assessed, which may introduce bias or incomplete representation of risk factors. Despite these limitations, the study provides important baseline evidence for future longitudinal, intervention-focused One Health research in similar low-resource settings.

Additionally, multivariable logistic regression analysis was not performed due to the modest sample size and limited number of outcome events, which may restrict the ability to identify independent predictors of contamination.

CONCLUSION

This One Health study highlights substantial bacterial contamination among healthcare workers in both human and veterinary settings in Sokoto. Overall, 68.4% of hand-swab samples were culture-positive, with hospital samples showing mean total aerobic counts ranging from 4.95 log CFU/ml in pediatric wards to 7.24 log CFU/ml in the ICU, while 68.2% of veterinary samples exceeded countable limits (TNTC), indicating extremely high microbial exposure. Staphylococcus aureus, Escherichia coli, and Klebsiella pneumoniae were the most frequently recovered organisms, and multidrug resistance was observed in 53.3% of hospital isolates and 36.4% of veterinary isolates, emphasizing the potential for cross-sector antimicrobial resistance transmission. Knowledge and adherence to hand hygiene practices were higher among hospital workers, reflecting structured training and available infrastructure, whereas veterinary workers demonstrated lower awareness and extremely high bacterial loads, likely driven by systemic limitations in hygiene facilities. These findings underscore the critical need for integrated One Health interventions that strengthen hand hygiene infrastructure, training, and compliance across both human and animal health sectors in Sokoto. This study is limited by its cross-sectional design, small sample size, and reliance on culture-based and phenotypic antimicrobial resistance testing, which may underestimate fastidious organisms and molecular resistance mechanisms. Despite these constraints, the results provide quantitative baseline evidence to guide targeted infection prevention and antimicrobial stewardship strategies in low-resource, human–animal interface settings.

RECOMMENDATIONS

Based on the findings of this One Health study, it is recommended that both human and veterinary healthcare facilities strengthen their hand hygiene systems through targeted training, consistent supply of essential materials, and implementation of standardized infection-prevention protocols. Hospital settings should prioritize measures that bridge the gap between knowledge and actual compliance, including periodic monitoring, feedback mechanisms, and reinforcement of WHO hand hygiene guidelines. Veterinary facilities require urgent infrastructural upgrades, especially access to running water, soap, disinfectants, and functional hand-washing stations, to reduce the extremely high microbial loads observed. Cross-sector collaboration is also essential, and joint human-veterinary IPC programs should be instituted to harmonize practices, share resources, and reduce the risk of cross-transmission of pathogens and antimicrobial-resistant organisms. Strengthening these systems holistically will not only improve worker safety but also reduce zoonotic spread, environmental contamination, and the burden of healthcare-associated infections across both sectors.

AUTHORSHIP DECLARATION

All authors approved the final version of the manuscript and agreed to its submission to UMYU Scientifica.

SUPPLEMENTARY FILE

Available on the online version of the article

REFERENCES

Adamu, U., Mohammed, H. A., Yusha 'u, M., & Salisu, B. (2018). Antibacterial Potentials and Toxicity Study of Cassia Occidentalis Leaf Extracts Against Clinical Isolates of Salmonella Sp. *Science World Journal*, *13*(1), 77–81. [Crossref]

Adamu, U., Yusha, M., Salisu, B., & Hussain, A. M. (2022). Phytochemical screening , antibacterial potentials and gas chromatography-mass spectrometry analysis (GC-MS) of Citrus sinensis leaves extracts. *Microbes and Infectious Diseases*, *3*(1), 192–198. [Crossref]

Adesokan, H. K., & Adeyanju, G. T. (2020). Knowledge and practices of infection prevention and control among veterinary healthcare workers in Nigeria. *Veterinary Medicine and Science, 6*(4), 567–576. [Crossref]

Ajadi, A. E., Bale, S. I., Sorunke, T. A., Onifade, S. A., Oyawoye, T., & Babasola, K. M. (2024). Serological Evidence of Epstein-Barr Virus Capsid Antigen (EB-CA) Among Pregnant Women from Cottage Hospital, Ilorin. *UMYU Scientifica*, *3*(2), 94–101. [Crossref]

Allegranzi, B., & Pittet, D. (2011). Role of hand hygiene in healthcare-associated infection prevention. *Infection Control & Hospital Epidemiology, 31*(1), 1–5. [Crossref]

Allegranzi, B., Kilpatrick, C., Storr, J., Kelley, E., Park, B. J., & WHO Global IPC Unit. (2022). Global progress in hand hygiene and infection prevention: A review of implementation challenges. *The Lancet Infectious Diseases, 22*(6), e191–e205. [Crossref]

Bello, S., Gide Muhammad, B., Rufai Usman, A., Gambo Lawal, M., & Abubakar, H. (2024). Determination of Trace Elements Content of a Popular Traditional Herbal Medicine Used for Internal Hemorrhoids Treatment in Katsina State, Nigeria. *UMYU Scientifica*, *3*(3), 232–238. [Crossref]

Boyce, J. M., & Pittet, D. (2002). Guideline for hand hygiene in health-care settings. *MMWR Recommendations and Reports, 51*(RR-16), 1–44. [Crossref]

Cheesbrough, M. (2010). *District laboratory practice in tropical countries* (2nd ed.). Cambridge University Press.

Da Silva, J. M., Menezes, J., Fernandes, L., Marques, C., Costa, S. S., Timofte, D., ... & Pomba, C. (2024). Dynamics of blaOXA-23 gene transmission in Acinetobacter spp. from contaminated veterinary environmental surfaces: an emerging One Health threat?. *Journal of Hospital Infection*, *146*, 116-124. [Crossref]

Destoumieux-Garzón, D., Mavingui, P., Boetsch, G., Boissier, J., Darriet, F., Duboz, P., … Voituron, Y. (2018). The One Health concept: 10 years old and a long road ahead. *Frontiers in Veterinary Science, 5*, 14. [Crossref]

Erasmus, V., Daha, T. J., Brug, H., Richardus, J. H., Behrendt, M. D., Vos, M. C., & van Beeck, E. F. (2010). Systematic review of studies on compliance with hand hygiene guidelines in hospital care. *Infection Control & Hospital Epidemiology, 31*(3), 283–294. [Crossref]

Grace, D. (2015). *Review of evidence on antimicrobial resistance and animal agriculture in developing countries.* International Livestock Research Institute (ILRI). [Crossref]

Halliday, J. E. B., Allan, K. J., Ekwem, D., Cleaveland, S., & Kazwala, R. (2012). One Health: The interconnectedness of humans, animals and the environment in infectious disease transmission. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 106*(1), 14–21. [Crossref]

Irek, E. O., Ogunsola, F. T., & Aboderin, A. O. (2022). Hand hygiene compliance in Nigerian healthcare facilities: A national review. *Journal of Infection Prevention, 23*(5), 202–210. [Crossref]

Kramer, A., Schwebke, I., & Kampf, G. (2006). How long do nosocomial pathogens persist on surfaces? A systematic review. *BMC Infectious Diseases, 6*, 130. [Crossref]

Mathai, E., Allegranzi, B., Kilpatrick, C., & Pittet, D. (2011). Prevention and control of health care–associated infections through improved hand hygiene. *Indian Journal of Medical Microbiology, 29*(2), 102–106. [Crossref]

Mohammed, A. H., Na 'inna, S. Z., Yusha 'u, M., Salisu, B., Adamu, U., & Kabir, Z. M. (2017). Antibacterial, Cytotoxicity and GC-MS Analysis of Psidium Guajava Extracts. *Bayero Journal of Pure and Applied Sciences*, *10*(1), 163–169. [Crossref]

Mohammed, H. A., Na 'inna, S. Z., Yusha 'u, M., Salisu, B., Adamu, U., & Garba, S. A. (2016a). In vitro Assessment of Antibacterial Activity of Citrus aurantifolia Extracts. *UMYU Journal of Microbiology Research (UJMR)*, *1*(1), 1–5. [Link]

Mohammed, H. A., Na 'inna, S. Z., Yusha 'u, M., Salisu, B., Adamu, U., & Garba, S. A. (2016b). Phytochemical Screening and Antibacterial Activity of Mangifera indica Extracts. *UMYU Journal of Microbiology Research (UJMR)*, *1*(1), 23–28. [Link]

Mohammed, Na 'inna, S. Z., Yusha 'u, M., Salisu, B., Adamu, U., & Garba, S. A. (2017). In vitro Antibacterial Activity of Psidium guajava Leaves Extracts against Clinical Isolates of Salmonella specie. *UMYU Journal of Microbiology Research (UJMR)*, *2*(1), 1–5. [Link]

NCDC. (2021). *National infection prevention and control guidelines for veterinary and animal health facilities in Nigeria.* Nigeria Centre for Disease Control. [Link]

Nejad, S. B., Allegranzi, B., Syed, S. B., Ellis, B., & Pittet, D. (2011). Health-care-associated infection in Africa: A systematic review. *Bulletin of the World Health Organization, 89*(10), 757–765. [Crossref]

OIE – World Organisation for Animal Health. (2019). *Terrestrial Animal Health Code: Infection prevention and control in veterinary settings.* [Link]

Oke, O. A., Bello, A., & Adeyanju, A. T. (2020). Hand hygiene practices among health workers in Nigeria: A multicenter analysis. *African Journal of Infection Control, 13*(2), 1–7. [Crossref]

Odoyo, E., Wanyoike, M., & Mulei, C. (2020). Bacterial contamination of hands and equipment in healthcare and animal-care settings: A cross-sectional assessment. *African Journal of Microbiology Research, 14*(3), 123–131. [Crossref]

Okeke, I. N., Aboderin, A. O., & Byarugaba, D. (2022). Strengthening hand hygiene and antimicrobial stewardship in West Africa: Progress and continuing gaps. *Journal of Infection Prevention, 23*(1), 12–20. [Crossref]

Oladipo, E. K., Onyedibe, K. I., & Afolabi, O. T. (2020). Barriers to hand hygiene compliance in Nigerian hospitals: A multicenter evaluation. *International Journal of Infection Control, 16*(1), 1–10. [Crossref]

Oloruntele, O. I., Adeoye, S. O., Jaji, B. A., Ibrahim, M. M., & Hamza, M. I. (2025). Assessment of the Physico-Chemical Characteristics, Phytochemicals, Biological Activities, and Soap-Making Process Using the Pulp and Seed Oils of Avocados (Persea americana). *UMYU Scientifica*, *4*(1), 452–460. [Crossref]

Otter, J. A., Yezli, S., Salkeld, J. A. G., & French, G. L. (2013). Evidence that contaminated surfaces contribute to the transmission of hospital pathogens and an overview of strategies to address contaminated surfaces. *American Journal of Infection Control, 41*(5), S6–S11. [Crossref]

Otto, M., Kebira, A., & Golan, Y. (2020). Impact of antibiotic exposure on hand microbiota and bacterial carriage in healthcare workers. *Journal of Hospital Infection, 104*(2), 234–241. [Crossref]

Peterside, N., & Chukwu, C. O. (2021). Hand contamination patterns and bacterial isolates among healthcare providers in Southern Nigeria. *Nigerian Journal of Clinical Practice, 24*(7), 987–995. [Crossref]

Robinson, T. P., Bu, D. P., Carrique-Mas, J., Fèvre, E. M., Gilbert, M., Grace, D., & Woolhouse, M. E. J. (2016). Antibiotic resistance is the quintessential One Health issue. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 110*(7), 377–380. [Crossref]

Salisu, B. D., Magaji, A. M., & Abdulkadir, B. (2017). Phytochemical Determination and In Vitro Antimicrobial Activity of Crude Ethanolic Extract of Stem Bark of Boswellia dalzielii. *International Journal of Science and Research (IJSR)*, *6*(12), 1484–1492. [Crossref]

Salisu, B. D., Magashi, A. M., Mohammed, H. A., & Usman, A. (2017). Determination of Phytochemicals and Antimicrobial Activity of Aqueous Stem Bark Extract of Boswellia dalzielii against Some Common Pathogenic

Microorganisms. *UMYU Journal of Microbiology Research (UJMR)*, *2*(1), 238–246. [Crossref]

Salisu, Dandashire, B., Magashi, A. M., Abdulkadir, B., Abbas, M. A., Dauda Goni, M., & Yakubu, A. (2019). Toxicological studies and bioactivity-guided identification of antimicrobially active compounds from crude aqueous stem bark extract of Boswellia dalzielii. *Journal of Advanced Veterinary and Animal Research Research*, *6*(2), 183–192. [Crossref]

Schaefer, M., Hübner, N. O., & Kramer, A. (2021). ICU-related microbial contamination and its relation to workload and patient exposure. *Journal of Critical Care Medicine, 56*, 42–49. [Crossref]

Ukwaja, V. C., Salisu, N., Aliyu, M., & Mohammed, N. (2024). Prevalence, Molecular Characterization and Antibiogram Pattern of Livestock Associated Methicillin Resistant Staphylococcus aureus in Livebird Markets Gusau, Zamfara State, Nigeria. *UMYU Scientifica*, *3*(4), 148–161. [Crossref]

Umar, M. A., Ahmed, A. Y., & Ibrahim, K. (2021). Prevalence of *Staphylococcus aureus*colonization on hands of healthcare workers in tertiary hospitals in Nigeria. *African Health Sciences, 21*(1), 344–352. [Crossref]

Weese, J. S., & Olsen, A. C. (2010). Infection control and biosecurity in veterinary hospitals. *Veterinary Clinics of North America: Small Animal Practice, 40*(3), 409–418. [Crossref]

WHO. (2009). *WHO Guidelines on Hand Hygiene in Health Care*. World Health Organization. [Link]

WHO. (2023). *Guidelines on hand hygiene in health care: A summary of essential practices.* World Health Organization. [Link]

Wright, J. G., Jung, S., Holman, R. C., & Marano, N. (2018). Infection prevention among veterinary personnel in the United States. *Zoonoses and Public Health, 65*(1), 80–88. [Crossref]